INFRASTRUCTURE CHOICES IN EDUCATION IN SOUTH AFRICA: LOCATION, BUILD OR REPAIR

By

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An essay submitted to the Department of Economics

in partial fulfillment of the requirements for

the degree of Master of Arts

Queen's University

Kingston, Ontario, Canada

January 2010

To My Parents and My Teachers

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Abstract

The purpose of this study is to develop a model to arrive at a joint optimizing strategy for the use of a given capital budget for the construction of new school buildings and for the renovation of the already existing schools. This model will provide a tool for ranking construction projects so as to have the maximum positive impact on the education system. A cost-effectiveness framework is used as the main analytical tool in developing this model. A key factor of the model is that it provides the optimal mix of renovation versus new construction that should be undertaken under a fixed budget constraint. The model is applied to a sample data set from the education sector of Limpopo Province, South Africa to quantify the benefits of using the model. It utilizes a very basic set of information that is available in all school districts across the province. Application of this model for the selection of infrastructure investments (either building or repair) in Limpopo yields estimates of the amount of efficiency improvement that are very substantial. This approach to prioritization of individual expenditures on infrastructure in the area of education could be particularly beneficial in the case of countries that are faced with an excessive backlog of demand for school buildings.

JEL Codes: D61, I28, H52, H75

Keywords: education, cost-effectiveness, school location, school construction, school repair, South Africa

1. Introduction

Economists have examined the impact of education on economic growth for the past couple of decades. In 1991, through a cross-sectional study of 98 countries, Barro found a positive relationship between education and economic growth. A study by Mankiw, Romer and Weil (1992) showed that incorporating education, through accumulation of human and physical capital, in the growth model developed by Solow (1956), can provide an excellent explanation of the cross-country data. Such research raised the attention of economists towards investment in education, particularly for developing countries who seek a successful growth strategy. Becker (1995) suggested that most developing countries should provide basic education (i.e., elementary and secondary) for the majority of their people to alleviate poverty.

Investment in education in developing countries has been a goal of many international organizations such as UNICEF, the World Bank and USAID. For instance, the universal education was adopted as one of the eight Millennium Development Goals of the United Nations by world leaders in September 2000 (United Nation, 2000). The importance of such investments stem from the fact that about 90% of the world's children live in low and middle income countries (World Bank, 2008). Developing countries together spend about $260 billion each year on education, and there is ample evidence that these funds are spent inefficiently (Glewwe, 2002; Levin, 2001). Using these funds efficiently will allow developing countries to increase the level of education of their nations that would raise the level of wages and their living standards.

One of the main problems of the education sector of many developing countries is the lack of school buildings and other infrastructure. The number of classrooms is generally inadequate for the large population of students, and often the classrooms are in very poor condition. Over time, without renovation, many will become unusable. Lack of school buildings can result in double shifts or very large class sizes. In Vietnam, in 1998, primary, and secondary schools, on average had 1.9, and 1.7 shifts, resulting in the average school days of about three hours for primary schools and three and half for secondary schools (Glewwe, 2004). In India in 1987, more than 8 percent of schools did not have any building. In some districts in the Indian State of Tamil Nadu, the average number of learners in a classroom in primary schools was about 78 students (Glewwe, 2006). In South Africa, in 2004, the Department of Education in Limpopo Province, South Africa, reported a shortage of about 13,000 classrooms (Jenkins and Klevchuk, 2004). In many developing countries the situation becomes progressively worse every year with the current economic crisis and rapidly growing populations.

To alleviate such problems, some developing countries such as South Africa are heavily investing in school construction and maintenance. As funding available for such public sector investments or the capacity to erect such structures is often limited, it is important to have a system and a criterion to allocate the budget efficiently. This study provides a model for allocating budget resources to education infrastructure in countries or provinces facing a significant shortage of school buildings. The objective is to find the most efficient strategy for selecting the location for the construction and/or renovation of educational infrastructure. This model is applied to the school infrastructure program in the Province of Limpopo, South Africa to illustrate how the benefits of using the model can be quantified.

This paper is organized as follows. Section 2 presents a brief description to cost-effectiveness analysis, followed by introducing a measure of effectiveness for infrastructure investments in education. Section 3, illustrates the process of applying the suggested model to Limpopo. Discussions about the advantages of using the model are presented in section 4 and this is followed by the conclusion section.

2. Methods

2.1. Cost-Effectiveness Analysis

Cost-effectiveness analysis is generally used as an alternative to cost benefit analysis (Boardman, Greenberg, Vining, and Weimer, 2001). In particular, cost-effectiveness analysis is very useful where that the analyst is reluctant to measure the effects of a project in monetary terms or where such measurement is not possible. For instance, when the main objective of the project is to save lives of people and the analyst is not willing to use a shadow price for the value of a life saved. It is also useful when the analyst is dealing with intermediate goods that do not have a clear linkage to preferences. For example, the contribution of different kinds of weapons to overall defense of the country is often not clear. In such cases, it is not possible to conduct a cost benefit analysis but the cost-effectiveness analysis may provide helpful information about the relative efficiency of different weapons.

In a cost-effectiveness analysis, an analyst compares the alternative projects by the incremental cost-effectiveness ratio of the projects. For example, if there are two alternative policies labeled *i* and *j*. The incremental cost-effectiveness ratio of the alternative *i* relative to the alternative *j,* is estimated as shown by equation (1) where *C* stands for the cost and *E* stands for the effectiveness.

$$CE_{ij} = \frac{C_i - C_j}{E_i - E_j} \tag{1}$$

2.2. Defining the Measure of Effectiveness

The first step of a cost-effectiveness analysis is to find a measure for effectiveness of alternative projects. In most studies, this measure is either self-evident or defined in the literature. For instance, to compare the cost-effectiveness of HIV prevention projects, the measure of effectiveness is the number of HIV infections averted by the projects. To carry out a cost-effectiveness analysis for investments in infrastructure in education, however, a measure of effectiveness of the infrastructure investments must be first defined for alternative projects.

The infrastructure investments in this study are either building new class-blocks or renovating existing classrooms in desperate need of repair. Therefore, for the cost-effectiveness analysis, it is required to have a measure for effectiveness of construction and renovation projects. Repairing a classroom that would be unusable in a few years, however, would have a similar effect as building a new classroom in a few years. For example, assume that a classroom is expected to be unusable in two years. Repairing the classroom makes it usable after Year 2 for a period of time. On the other hand, building a new classroom in Year 2 also provides additional class-space from Year 2; therefore, building a new classroom in two years results in similar effects on the supply of education services as repairing the old classroom. The only difference would be in the number of years that the classrooms will be usable. Therefore, finding a numerical measure for the effectiveness of adding class-space is sufficient for the cost-effectiveness analysis of both construction and renovation projects.

The effect of class size on the quality of education has been examined by many researchers and widely discussed in the literature. Through a meta-analysis of 80 studies on the class-size and students' achievement, Glass and Smith (1979) showed that clear and strong negative relationship exists between the class-size and educational achievement. This relationship is stronger where the average number of learners per classroom is higher.

Adding class-space to a school district lowers the learner to classroom ratio, or LCR, and enhances the learning of all learners in the school district. [1] In this study, the change of LCR with respect to an increase in the number of available classrooms is used for deriving a numerical measure of effectiveness, or units of education quality enhancement (EQE). The changes in LCR associated with adding a classroom to a school district can be estimated as the derivative of LCR with respect to the number of available classrooms.

[1] School district represents the catchments area of one or two schools in a district. However, in the available data from Limpopo, each school district represents a school.

Equation (2) displays this calculation where *L* denotes the number of learners and *C* denotes the number of available classrooms.

$$\left|\frac{\partial LCR}{\partial C}\right| = \left|\frac{\partial}{\partial C}\left(\frac{L}{C}\right)\right| = \frac{L}{C^2} \tag{2}$$

To calculate the effects of adding a classroom on the enhancement of learning for all students in the school district, equation (2) should be multiplied by the number of learners in the school district. The total effectiveness, denoted as *E*, is calculated as shown by equation (3).[2]

$$E = \frac{L}{C^2} \times L = \frac{L^2}{C^2} \tag{3}$$

An assumption is made that one unit reduction of LCR creates the same amount of additional EQE units where the LCR is greater than the standard number of learners in a classroom, and creates no EQE unit where the LCR is lower than the standard.[3] The application of the above method for measuring the effectiveness of increasing the number of available classrooms is illustrated in three possible scenarios: 1) construction scenario, 2) renovation scenario, and 3) construction-and-renovation scenario. The costs of infrastructure investments are accounted from the perspective of the department of education. This perspective is adopted because no information is available about any cost other than the cost of construction and renovation of school buildings.

[2] This is an estimate for measuring the effectiveness of adding one classroom to a school district. The formulas for finding the exact amount of effectiveness for infrastructure investments are explained in the next parts of this section.

[3] The standard number of learners in a classroom differs from one place to another. In Limpopo Province, South Africa this number is 40.

2.2.1. Construction Scenario

This scenario demonstrates a method of determining an efficient budget allocation strategy dedicated to the construction of new classrooms. Typically classrooms are built in units of a class-block where each class-block consists of a few classrooms. In this scenario, the effectiveness is measured by the amount of EQE units derived from adding a class-block. Assuming each class-block contains K classrooms, one should consider the changes in the LCR associated with increasing K classrooms to find the EQE units obtained from building a class-block in a school district. This calculation is shown by equation (4).

$$E = \left(\frac{L}{C} - \frac{L}{C+K}\right) \times L = \frac{KL^2}{C(C+K)} \tag{4}$$

Productivity of infrastructure investments, however, depends on some other factors such as location and type of school (e.g., primary, secondary). To account for such differences among school districts, adjustments are needed for the effectiveness derived from equation (4). In many countries, the economic rate of return is believed to be higher for primary level education than for the secondary level. The difference of economic return can be incorporated in the model by increasing the amount of EQE units obtained from infrastructure investments in primary schools by P percent.[4] The factor P is set equal to

[4] In the countries where the economic return of investment in secondary school is higher than primary school, the factor P will become negative.

the proportional additional return obtained from investing in primary schools rather than in secondary schools.[5]

In addition, investments in education in many countries are believed to have a differential rate of return in rural areas as compared to urban areas, and therefore the effectiveness obtained from adding a classroom in rural areas is greater. This differential can be expressed by a factor *R* for the rural areas versus a base value of zero for urban areas. For example, if it is believed that the rate of return of a typical school investment (all other variables in the model being the same) is 20 percent higher in rural areas than urban areas then *R* is set equal to 0.2. Such factors, as well as any further required adjustments, are included in an adjustment factor (*AF*) for estimating the effectiveness of infrastructure investments. This factor should be set for each school district in the analysis.

$$\begin{aligned} E &= \frac{KL^2}{C(C+K)} \times AF \\ AF &= (1+P+R+\cdots) \end{aligned} \tag{5}$$

The effectiveness obtained from infrastructure investments that is shown in equation (5) has the same value in terms of EQE units in all school districts regardless of their location or education level. To consider the entire impact of building a class-block on the enhancement of the education achievement, the effectiveness of building a class-block should be calculated over the entire lifetime of the class-block. The effectiveness may change from year to year due to changes in the number of available classrooms and the

[5] The school districts are specified separately for primary and secondary education, based on the physical location of the available primary or secondary schools.

number of learners in the school district. The number of available classrooms in the future depends on the number of classrooms currently available and their condition. The condition of a classroom determines the number of years the classroom is expected to be usable. The amount of future EQE units created by the addition of a class-block may also be affected by the growth in the number of potential students in the district. Therefore, to obtain the EQE units associated with each year, the number of students and available classrooms in that year should be first estimated.

$$
\begin{aligned}
E_1 &= \frac{KL_1{}^2}{C_1(C_1+K)} \times AF \\
E_2 &= \frac{KL_2{}^2}{C_2(C_2+K)} \times AF \\
&\vdots \\
E_n &= \frac{KL_n{}^2}{C_n(C_n+K)} \times AF
\end{aligned}
\tag{6}
$$

Equation (6) demonstrates the effectiveness of building a class-block associated with Year 1 to Year n. To account for the value of time, the future stream of EQE units must be discounted back to the present time. There is no need for discounting the cost of building a new class-block, since the construction projects are expected to be completed in one year. However, the question of what is the appropriate discount rate to use is often raised. In this study, the discount rate is the economic opportunity cost of funds which is proposed by Harberger (1971) as well as Sandmo and Dreze (1971). A study by Burgess (2008) has compared the economic opportunity cost of funds with the social rate of time preference and the marginal cost of funds to be used as a discount rate. Burgess (2008) has shown that under a wide range of circumstances the economic opportunity cost of funds is the most appropriate discount rate. The calculation of the present value of the future stream of effectiveness, or PVE, is shown by the equation (7) where *r* stands for the discount rate and n stands for the number of years to be considered in the analysis.[6]

$$PVE = \frac{E_1}{(1+r)} + \frac{E_2}{(1+r)^2} + \cdots + \frac{E_n}{(1+r)^n} \tag{7}$$

The incremental cost-effectiveness ratio is calculated for each school district by dividing the given cost of construction of a new class-block by the PVE of building a new class-block in the district. This ratio compares the incremental cost and effectiveness of building a new class-block to a scenario without any infrastructure project. The both cost and effectiveness are zero for the scenario without any infrastructure project. Therefore, the incremental cost-effectiveness ratio can be derived from dividing the cost and effectiveness of building a class-block.

The school district with the lowest incremental cost-effectiveness ratio is the best place to receive the first investment since EQE units are gained at the lowest price. This school district is chosen to be the first location to build a new class-block. To find the next place for building a class-block, the incremental cost-effectiveness ratio must be first updated for the chosen school district. The PVE is recalculated for that school district taking into consideration that the school district will have *K* more available classrooms from the next year. After updating the incremental cost-effectiveness ratios, the school district with the lowest incremental cost-effectiveness ratio is selected to be the second location where a

[6] The length of the period for the analysis can be set equal to the life of a new classroom. However, depending on the available information, one may choose another value.

new class-block is to be built. In the same way, the selection is continued until the cumulative cost in a given year of construction becomes equal to the available budget. The final list of selected schools illustrates the most efficient strategy for the location of construction investments.[7]

2.2.2. Renovation Scenario

In this scenario the problem is determining which schools should be renovated in order to realize the greatest enhancement of the education system. For this analysis it is assumed that the number of classrooms in need of repair, their renovation cost, and the number of years they are expected to be useful are known for each school.

To find the effectiveness of the renovation of an old school, the same method is used as in the previous scenario. For renovation, however, the number of classrooms needing repair is different among schools. For a school that has *D* classrooms in desperate need of repair the effectiveness of renovation is calculated according to changes in LCR of the school district with respect to the addition of *D* classrooms. Equation (8) shows the amount of EQE units obtained from repairing the school. This formula is derived from equation (4) by substituting *D* for *K.*

$$EQE = \frac{DL^2}{C(C+D)} \tag{8}$$

[7] A school district might be selected for several times. The number of times that the school district is selected should be used as the total number of class-blocks to be built in that school district.

In the same manner as before, the measure of effectiveness should be adjusted for the differences in the economic return of investment in rural or urban areas and primary or secondary education.

$$E = \frac{DL^2}{C(C+D)} \times AF \qquad (9)$$
$$AF = (1 + P + R + \cdots)$$

The renovation of a school will increase the number of classrooms starting from the time that the old classrooms are expected to be unusable. Therefore, the effectiveness of the renovation should be considered from the time that the classrooms are expected to be unusable. For instance, if the classrooms will become unusable in *m* years, then the effectiveness should be calculated for each year starting from Year *m* to Year *n*.[8] Similar to the previous scenario, the PVE is calculated from the sum of the present value of the future stream of the effectiveness created by the renovation of the school. This calculation is shown by the equation (10).

$$PVE = \frac{E_m}{(1+r)^m} + \frac{E_{m+1}}{(1+r)^{m+1}} + \cdots + \frac{E_n}{(1+r)^n} \qquad (10)$$

As the cost and the PVE are both zero for the without renovation scenario, the incremental cost-effectiveness ratio is estimated by dividing the renovation cost of school by the PVE of the renovation of school. Based on their incremental cost-effectiveness ratio, the schools are ranked and the one with the lowest incremental cost-effectiveness

[8]As with the previous scenario, *n* stands for the length of the analysis. Also for simplicity, it is assumed that the renovation of a school will lengthen the useful life of its old classrooms and make it equivalent to that of a new classroom.

ratio is chosen as the first place to be renovated. The chosen school is erased from the list of possible renovation projects, and the PVE is updated for the school district in which the chosen school is located. The renovation of the chosen school will increase the number of available classrooms in the school district from the time that the old classrooms are expected to be unusable. The renovation of the school will lower the LCR of the school district in the future; therefore, the PVE and the incremental cost-effectiveness ratio of the renovation of other schools in that school district should be updated. Based on the new ratios, the school with the lowest incremental cost-effectiveness ratio is chosen as the second place to be renovated. This selection procedure continues until the cumulative cost of renovation of the chosen schools becomes equal to the available budget. The final list of chosen schools illustrates the most efficient strategy for the location of renovation projects.

2.2.3. Construction-and-Renovation Scenario

In this scenario, the allocation of budget for both construction and renovation projects is carried out jointly. In other words, construction of new class-blocks and renovation of the old schools are ranked in a same list. It is important to note that the effectiveness of building a new class-block depends on the future condition of the old schools in the district. For example, assuming that two school districts have same number of learners and classrooms but one district has some schools in desperate need of repair, and the other one does not. The PVE of building a new class-block would be greater for the school district that has the old school. This difference in the PVE comes from the number of available classrooms in the future which is smaller in the school district with old schools.

To develop the without project scenario, the future condition of the old schools, the number of learners and available classrooms in the future are estimated for each school district. This scenario is simulated assuming that no construction or renovation project is being carried out. Same as in the previous scenarios, the PVE of the construction of new class-blocks and the renovation of old schools are calculated for each school district. The incremental cost-effectiveness ratios are estimated using the given costs and the PVE of each of the infrastructure investments. In the same procedure as the previous scenarios, the infrastructure investment (construction or renovation) with the lowest incremental cost-effectiveness ratio is ranked as the first investment in the final prioritized list of infrastructure projects.

The PVE are then updated for the infrastructure investments in the school district that the chosen investment is located. Based on the updated PVE, the incremental cost-effectiveness ratios are recalculated for the renovation of old schools and construction of a new class-block in the school district. All possible infrastructure investments are ranked again based on their incremental cost-effectiveness ratio. The investment with the lowest ratio is chosen as the second place in the final prioritized list of infrastructure projects. In the same fashion, the selection and recalculation of the incremental cost-effectiveness ratios are carried out until the cumulative cost of construction and renovation projects becomes equal to the available budget. The final list of the chosen investments displays the most efficient strategy to allocate the available funds among the investments in the different school districts.

3. Case Study

This section presents the application of the suggested model to a concrete situation in Limpopo Province, South Africa. The purpose of this analysis is to determine and quantify the advantages of using the model in a practical context.

3.1. Background

As compared with most developing countries the education sector in South Africa receives a large share of the total government expenditure. In 2006, the total funds allocated to education in South Africa were 5.4% of GDP, or 17.6% of the total government expenditure (World Bank, 2008). However, more infrastructure is required to address the unresolved shortage left by the apartheid education policy. The current government is intent on resolving the imbalances in education. The greatest challenges lie in the poorer, rural provinces where many schools lack the basic utilities such as electricity, telecommunication, water and sanitation. (Education in South Africa, 2006)

The Department of Education in Limpopo is characterized by shortages of classrooms and related infrastructure. In 2004, the classrooms backlogs were about 13,000 in Limpopo. Since 1995, substantial funds have been allocated to infrastructure investments in the education. Due to political pressures that have been enhanced by the absence of any formal project evaluation, however, a large share of those investments has been spent in school districts that were not in the greatest need of additional school buildings (Jenkins and Klevchuk, 2004).

3.2. Method

Using the suggested model in section 2, prioritization of infrastructure investments in education in Limpopo is carried out in the following three scenarios: 1) construction projects, 2) renovation projects, and 3) construction-and-renovation projects.

3.2.1. Data and Assumptions

The data used here are collected by the Department of Education via regional education boards located in Limpopo. This data reflect the situation of 4,942 schools in Limpopo in 2004. In this dataset, each school represents a school district.[9] A sample of 494 schools is used to perform the prioritization analysis. Among the data available for each school, the following parameters have been selected to be used in the analysis:

- *Emis number*: A unique nine-digit number assigned to each school.
- *Lowest grade*: The lowest grade taught in the school.
- *Highest grade*: The highest grade taught in the school.
- *Enrolment*: Number of students enrolled in the school.
- *Perm classrooms*: Number of permanent classrooms in the school.
- *Prefabs*: Number of prefabricated classrooms in the school.

[9] Since the information for each school represents the situation of a school district, there is no relationship between infrastructure investments in one school and the LCR of another school. Therefore, in the analyses of this section, the incremental cost-effectiveness ratios are calculated for the schools.

- *Classroom condition*: A number from zero to six reflecting the condition of the classrooms where zero and six show the worst and the best conditions, respectively.

The lowest and highest grades determine whether the school is a primary or secondary school. Grades lower or equal to seven are considered primary, and those higher than 8 are considered secondary. The total number of classrooms in a school is obtained from adding together the permanent and prefabricated classrooms of the school. For the renovation budget allocation analysis, however, more information is required. While the condition of the school is known, the number of classrooms within the schools requiring repair is not known nor is the cost of repairing each of the old classrooms present in the data set received from the Department of Education[10]. To prepare proper estimates for such information, some assumptions are made based on discussion with the representative of the African Development Bank, economists, engineers and people from the Department of Public Works involved in the construction project. These assumptions are as follows:

Schools with a classroom condition lower or equal to two are in desperate need of renovation and will be unusable in the future without renovation. Schools with a classroom condition higher than two are expected to be usable for the next 20 years.

[10] In this paper reasonable assumptions are made for this missing information in terms of a distribution of likely classrooms requiring repair and the costs of such repairs. However, in operationalizing the model as a planning tool this information is relatively easy to obtain from the work of the survey engineers in the Provincial Department of Public Works. They carry out a periodic survey of the state of the buildings in the province as part of their efforts to maintain a record of the public sector assets in the Province. The survey engineers could specify the actual number of classrooms requiring repair and also estimate the cost of such repairs as they are specialists in this area.

Schools with a classroom condition equal to zero and one are expected to lose 75% and 50% of their classrooms in one year, respectively. Schools with a classroom condition equal to two are expected to lose 50% of their classrooms in four years.

The renovation costs of the classrooms are assumed to be normally distributed with the same standard deviation but a different mean associated with the classroom condition. The standard deviation is set equal to 0.07.[11] For the schools with a classroom condition of zero, the average renovation cost of a classroom is assumed to be equal to the cost of construction of a new classroom. Since classrooms are going to be added by a unit of one class-block including four classrooms, cost of building a new classroom is considered to be one fourth of the cost of building a class-block. Cost of building a new class-block was R 420,000 in 2004. Therefore, the cost of building a classroom is set to R 105,000.[12] The average renovation cost of a classroom is assumed to be 75% and 50% of the cost of construction a new classroom for the schools with a classroom condition of one and two, respectively.

3.2.2. Construction Scenario

The objective of this analysis is to determine the best locations to build the new class-blocks in Limpopo. The available budget for the infrastructure investments at the Department of Education in Limpopo was about R 250,000,000 in 2003-2004. Since the analysis is carried out on a 10% sample, it is assumed that the budget available for the

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[11] This value for the standard deviation is chosen since it provides reasonable estimates for the actual renovation cost of the schools.

[12] Since the data is for 2004, the analysis is carried out in 2004 prices. The present value of the effectiveness of infrastructure investments is also calculated with considering 2004 as the base year.

analysis is about R 25,000,000. The first step of the analysis is to calculate the effectiveness of building a new class-block. It is assumed that it takes one year for a new class-block to become ready to use, and the class-block will be usable for about 20 years. As an example, the calculation of the EQE units obtained from building a new class-block is shown for Pienaarsrivier Primary School that has 567 learners and one classroom with a classroom condition of three.

$$E_1 = \frac{KL_1^{\ 2}}{C_1(C_1 + K)} \times AF = \frac{KL_1^{\ 2}}{C_1(C_1 + K)}(1 + P) = \frac{4 \times 567^2}{1 \times (1 + 4)}(1 + 0.25) = 321{,}489 \text{ EQE units}$$

The adjustment factor, which is (1+*P*) in the above example, represents the difference between the economic return of investment in primary and in secondary schools.[13] The economic returns of investments in education have been estimated for several countries by George Psacharopoulos in 1994. The economic return of investment in primary and secondary schools were estimated as 22.1% and 17.7%, respectively. Based on these rates of return, the parameter *P* is estimated as 25%.[14] Since the classroom condition of Pienaarsrivier Primary School is greater than two the classrooms are supposed to be useful for the next 20 years. Therefore in the status quo situation the number of available classrooms remains constant. The number of learners is also assumed to be constant; therefore the EQE units obtained from building a new class-block would be equal over the next 20 years. To find the PVE of building a new class-block for this school the stream of created EQE units should be discounted back to the present. The discount rate

[13] Since in the available dataset there is no information about rural and urban areas, the economic returns of infrastructure investment in education system in urban and rural areas are set equal for schools in the analysis.
[14] The economic return of investments is 25% higher in primary schools than secondary schools.

is the economic opportunity cost of funds that is estimated as 11% for South Africa by Kuo, Jenkins and Mphahlele in 2003. The PVE for Pienaarsrivier Primary School is calculated as follows:

$$PVE = \frac{E_1}{(1+r)} + \frac{E_2}{(1+r)^2} + \cdots + \frac{E_{20}}{(1+r)^{20}} = E_1\left(\frac{1}{(1+r)} + \frac{1}{(1+r)^2} + \cdots + \frac{1}{(1+r)^{20}}\right)$$

$$= E_1 \frac{1}{r}\left(1 - \frac{1}{(1+r)^{20}}\right) = 321{,}489 \times \frac{1}{0.11} \times \left(1 - \frac{1}{(1+0.11)^{20}}\right) = 2{,}560{,}122 \text{ EQE units}$$

The incremental cost-effectiveness ratio of the construction of a new class-block in Pienaarsrivier Primary School is derived from dividing the cost of building a class-block (R 420,000) by the PVE of building a class-block (2,560,122 EQE units). This ratio is 0.164 for the Pienaarsrivier Primary School. In the same way, the incremental cost-effectiveness ratio of building a new class-block is calculated for other schools in Limpopo. The construction investments are ranked from low to high, based on their incremental cost-effectiveness ratio. The ranking for the top 20 schools is illustrated by table I, where ICER stands for the incremental cost-effectiveness ratio.

Table I. The top 20 schools with the lowest incremental cost-effectiveness ratios

SCHOOL NAME	Enrolment	No. of Classrooms in Year 0	Classroom condition	AF	PVE (EQE units)	ICER of Building a class-block	School Rank
LEGADIMANE PRIMARY	685	1	1	1.25	3,736,593	0.112	1
PIENAARSRIVIER	567	1	3	1.25	2,560,122	0.164	2
MANTSHA PRIMARY	876	9	0	1.25	2,546,195	0.165	3
MUCHUCHI PRIMARY	531	1	3	1.25	2,245,348	0.187	4
BADIMONG PRIMARY	1028	5	2	1.25	1,675,761	0.251	5
MAROTOBANE PRIMARY	439	1	2	1.25	1,534,701	0.274	6
THOMAS NTSHAVHENI	396	2	2	1.25	1,025,236	0.410	7
NAKGWADI SECONDARY	780	12	0	1	922,836	0.455	8
SEGOPOTJE SECONDARY	347	5	0	1	767,085	0.548	9
MPAPALATI PRIMARY	772	16	0	1.25	741,565	0.566	10
MASHAHA SECONDARY	333	1	4	1	706,436	0.595	11
ROOTSE PRIMARY	450	3	1	1.25	671,906	0.625	12
MOKWASELE PRIMARY	847	10	1	1.25	634,774	0.662	13
MADIKOTI PUTSOA	704	15	0	1.25	616,680	0.681	14
KULANI PRIMARY SCHOOL	275	4	0	1.25	602,227	0.697	15
NKOTOBONA HIGH	474	3	1	1	596,390	0.704	16
MOOKAMEDI SECONDARY	280	5	0	1	499,460	0.841	17
PAULOS PRIMARY	852	11	1	1.25	481,718	0.872	18
SEFUFULE PRIMARY	372	4	1	1.25	459,165	0.915	19
LEFAKGOMO SECONDARY	901	12	1	1	430,976	0.975	20

It is important to note that this ranking does not show the best strategy for the budget allocation. Only the first school can be certainly chosen as the best place to receive funding. To determine the next place, one should first recalculate the incremental cost-effectiveness ratio of the chosen school assuming that the school will have four more classrooms from Year 1. The Legadimane Primary School with the lowest incremental cost-effectiveness ratio, estimated as 0.112, will be chosen as the first place for the construction of a new class-block. With four more classrooms, the incremental cost-effectiveness of building a class-block in the Legadimane Primary School would be 1.012, which would be ranked 23rd.

Based on the updated incremental cost-effectiveness ratio, the school with the lowest incremental cost-effectiveness ratio will be selected as the second place in the final prioritized list of construction projects. The selection procedure continues until the cumulative cost of construction becomes equal to the available budge. The final prioritized list of construction investments determines the most efficient sequence of the school to receive funding in order to realize the greatest enhancement in the education system. Table II illustrates the top 20 construction projects of this list.

Table II. The most efficient locations for building the first 20 class-blocks

School Name	Enrolment	No. of Classrooms Year 0	Classroom condition	AF	PVE (EQE units)	ICER of Adding a class-block	Accumulated cost (R)
LEGADIMANE PRIMARY	685	1	1	1.25	3,736,593	0.1124	420,000
PIENAARSRIVIER PRIMARY	567	1	3	1.25	2,560,122	0.1641	840,000
MANTSHA PRIMARY	876	9	0	1.25	2,546,195	0.1650	1,260,000
MUCHUCHI PRIMARY	531	1	3	1.25	2,245,348	0.1871	1,680,000
BADIMONG PRIMARY	1028	5	2	1.25	1,675,761	0.2506	2,100,000
MAROTOBANE PRIMARY	439	1	2	1.25	1,534,701	0.2737	2,520,000
THOMAS NTSHAVHENI	396	2	2	1.25	1,025,236	0.4097	2,940,000
NAKGWADI SECONDARY	780	12	0	1	922,836	0.4551	3,360,000
SEGOPOTJE SECONDARY	347	5	0	1	767,085	0.5475	3,780,000
BADIMONG PRIMARY	**1028**	**5**	**2**	**1.25**	**758,478**	**0.5537**	**4,200,000**
MPAPALATI PRIMARY	772	16	0	1.25	741,565	0.5664	4,620,000
MASHAHA SECONDARY	333	1	4	1	706,436	0.5945	5,040,000
ROOTSE PRIMARY	450	3	1	1.25	671,906	0.6251	5,460,000
MOKWASELE PRIMARY	847	10	1	1.25	634,774	0.6617	5,880,000
MADIKOTI PUTSOA	704	15	0	1.25	616,680	0.6811	6,300,000
KULANI PRIMARY SCHOOL	275	4	0	1.25	602,227	0.6974	6,720,000
NKOTOBONA HIGH	474	3	1	1	596,390	0.7042	7,140,000
MANTSHA PRIMARY	**876**	**9**	**0**	**1.25**	**509,239**	**0.8248**	**7,560,000**
MOOKAMEDI SECONDARY	280	5	0	1	499,460	0.8409	7,980,000
PAULOS PRIMARY	852	11	1	1.25	481,718	0.8719	8,400,000

As it is shown in table II, the Badimong Primary School and the Mantsha Primary School are both chosen two times. It means that if the available budget is limited to the construction cost of 20 class-blocks, the most efficient strategy is to build two class-blocks in the Badimong Primary School, two class-blocks in the Mantsha Primary School, and one class-block in each of the other 16 schools of the table II.

3.2.3. Renovation Scenario

In this scenario, the objective is to select those renovation projects that result in the greatest enhancement in education system, assuming that an amount of R 25,000,000 is dedicated to renovation projects. First step is to determine the situation of the schools without any infrastructure investments in the next 20 years. Since the number of learners is assumed to be constant, the main factor of the analysis would be the number of usable classrooms in each year. Schools that are considered in this analysis are those that have a classroom condition lower than 3.

For example, Badimong Primary School with 1,028 students has only five classrooms with a classroom condition of two. As mentioned before, it is assumed that schools with a classroom condition of two are expected to lose 50% of their classrooms in four years. Badimong Primary School has five classrooms and 50% of its classrooms would be two and half classrooms. Since having two and half classrooms is not a sensible estimation, this number is rounded and used as the number of available classrooms. The number of classrooms that are in desperate need of repair comes from the difference of the number of total classrooms in Year 0 and the rounded number of available classrooms in each year. For example, for Badimong Primary School, three classrooms will be available after Year 4 and two classrooms are in desperate need of renovation. The EQE units obtained from repairing the Badimong Primary School comes from an addition of two classrooms from Year 1. This effectiveness is calculated by using the equation (9) and setting *D* equal to two.

$$E_4 = \frac{DL_4^{\ 2}}{C_4(C_4+D)} \times AF = \frac{DL_4^{\ 2}}{C_4(C_4+D)} \times (1+P) = \frac{2\times 1028^2}{3\times(3+2)}(1+.25) = 176{,}130 \text{ EQE units}$$

Same as in the previous scenario, the difference of the economic return of the primary and secondary schools is adjusted for Badimong Primary School by the adjustment factor. As the number of available learners and classrooms are not expected to vary after Year 4, the amount of EQE units obtained from renovation is the same for every year from Year 4 to Year 20.[15] By using the equation (10), the PVE of repairing the Badimong Primary School is estimated as follows:

$$PVE = \frac{E_m}{(1+r)^m} + \frac{E_{m+1}}{(1+r)^{m+1}} + \cdots + \frac{E_n}{(1+r)^n} = E_4\left(\frac{1}{(1+r)^4} + \frac{1}{(1+r)^5} + \cdots + \frac{1}{(1+r)^{20}}\right)$$
$$= \frac{E_4}{(1+r)^3}\left(\frac{1}{r} - \frac{1}{r(1+r)^{17}}\right) = \frac{176{,}130.7}{1.11^3}\left(\frac{1}{0.11} - \frac{1}{0.11\times 1.11^{17}}\right) = 972{,}173 \text{ EQE units}$$

The average cost of renovation of a classroom with a classroom condition of two is R 52,500 which is 50% of the cost of building a new classroom. As mentioned before, the renovation costs of classrooms are assumed to be distributed by a normal distribution around the average cost with a standard deviation of 0.07. By using Microsoft Excel, the cost of renovation of Badimong Primary School is estimated as R 120,198. The

[15] Since each school in the Limpopo dataset represents a school district, after renovation of a school the number of available classrooms in the school district will remain constant. However, in a more general situation a school district may contain more than one school. Consequently, the number of available classrooms may vary in the future, and the effectiveness of renovation should be calculated separately for each year.

incremental cost-effectiveness ratio for the renovation of Badimong Primary School is 0.124 that is calculated by dividing the PVE of repairing the school by its renovation cost.

Using the same method, the incremental cost-effectiveness ratios are calculated for other schools in Limpopo. Schools are ranked according to their incremental cost-effectiveness ratio from low to high. The most efficient budget allocation for renovation is to choose the schools from this list until the accumulated cost becomes equal to the available budget.[16] The list of the top 20 renovation investments are illustrated by table III.

Table III. The top 20 chosen renovation projects

School Name	Enrolment	Total Calassroom Year 0	Classroom condition	AF	Renovation cost of the School	ICER of repairing the school	Accumulated cost
THOMAS NTSHAVHENI	396	2	2	1.25	50,964	0.094	50,964
BADIMONG PRIMARY	1028	5	2	1.25	120,198	0.124	171,162
ROOTSE PRIMARY	450	3	1	1.25	74,135	0.221	245,297
NKOTOBONA HIGH	474	3	1	1	70,440	0.236	315,737
MANTSHA PRIMARY	876	9	0	1.25	739,636	0.249	1,055,373
METSI A- PHEPHA	375	3	2	1.25	50,571	0.313	1,105,945
SEFUFULE PRIMARY	372	4	1	1.25	156,454	0.454	1,262,399
TSHILILO SECONDARY	347	3	1	1	75,461	0.472	1,337,859
MOKWASELE PRIMARY	847	10	1	1.25	342,282	0.479	1,680,141
MAPHOTLE PRIMARY	376	4	2	1.25	120,404	0.494	1,800,545
SEJADIPUDI PRIMARY	362	4	2	1.25	116,089	0.514	1,916,635
KULANI PRIMARY SCHOOL	275	4	0	1.25	314,953	0.558	2,231,588
LIBSON FARM PRIMARY	225	3	0	1.25	196,467	0.585	2,428,055
SEGOPOTJE SECONDARY	347	5	0	1	470,833	0.614	2,898,888
HAM PRIMARY	249	3	1	1.25	71,428	0.694	2,970,316
MATANGARI PRIMARY	699	10	2	1.25	241,411	0.716	3,211,727
PAULOS PRIMARY	852	11	1	1.25	402,169	0.735	3,613,896
MOTSHEUDI SECONDARY	1013	12	2	1	351,508	0.745	3,965,404
MOOKAMEDI SECONDARY	280	5	0	1	378,052	0.757	4,343,456
LETUPU SECONDARY	313	4	1	1	149,539	0.767	4,492,994

[16] In the general model, finding the renovation budget allocation strategy is not so straightforward. Since in the Limpopo case each school represents a school district, renovation of a school does not alter the incremental cost-effectiveness ratio of other schools. Therefore, recalculation of the incremental cost-effectiveness ratios is not required.

3.2.4. Construction-and-Renovation Scenario

In this section, the construction and renovation projects are ranked simultaneously in order to find the most efficient strategy for spending R 25,000,000 dedicated to building and repairing the schools. The potential investments are repairing the schools in desperate need of repair and building a new class-block for every school in Limpopo. In this scenario, the first step is to determine the most efficient investment for the schools in desperate need of repair. In other words, one should determine that if building a new class-block has lower incremental cost-effectiveness ratio or repairing the school. In practice the renovation cost of a school might be higher than the cost of building new prefabricated class-blocks. In this study, by assuming that the renovation costs are normally distributed, the possibility of undergoing higher renovation cost has been simulated in the analysis.

As an example the determination of the most efficient investment in Kulani Primary School is explained here. The Kulani Primary School has 275 students with four classrooms with a classroom condition of zero. It is expected that 75% of the classrooms become unusable in Year 1. The renovation cost of the school is estimated as R 300,124. Using the same method as in the previous scenarios, the incremental cost-effectiveness ratios of renovation of the school and building a new class-block are estimated as, 0.532 and 0.697, respectively. The most efficient investment for the Kulani Primary School is the renovation of the school.

The incremental cost-effectiveness ratios are estimated for the renovation and construction projects of all schools in the analysis. Schools are ranked based on their incremental cost-effectiveness ratio. Schools in desperate need of repair that have a ratio for renovation and a ratio for construction are ranked based on the minimum of the ratios that represents the most efficient investment for the school. Among all schools in Limpopo, the Thomas Ntshavheni Primary School has the lowest incremental cost-effectiveness ratio, which is 0.101 for the renovation of the school. This school is selected as the first place to receive the funds.

To find the next place for the budget allocation, the ranking list should be updated assuming that the Thomas Ntshavheni Primary School is not in need of renovation anymore. This assumption means that the Thomas Ntshavheni Primary School can use its classrooms for the entire period of the analysis. Based on this assumption the PVE of building a new class-block in the Thomas Ntshavheni Primary School falls from 1,025,236 to 520,324 EQE units. Consequently, the incremental cost-effectiveness ratio for this school rises from 0.410 to 0.807. The schools are ranked again based on their incremental cost-effectiveness ratio. The Thomas Ntshavheni Primary School is ranked 31st in the new ranking based on its updated incremental cost-effectiveness ratio. In the new ranking, building a new class-block in the Legadimane Primary School has the lowest incremental cost-effectiveness ratio; therefore, construction of a new class-block in this school is chosen as the second investment to receive funding. In the same fashion, the selection is continued till the accumulated cost of infrastructure projects becomes equal to the available budget. Table IV illustrate the list of top 20 infrastructure investments of this scenario. Note that the incremental cost-effectiveness ratio of renovation is not applicable (NA) for the schools without any classroom in desperate need of repair.[17]

Table IV. The top 20 chosen construction and renovation project

School Name	Enrolment	Total Calassroom Year 0	Classroom condition	AF	ICER of building a class-block	ICER of repairing the school	Build or Repair
THOMAS NTSHAVHENI	396	2	2	1.25	0.410	0.101	Repair
LEGADIMANE PRIMARY	685	1	1	1.25	0.112	NA	Build
BADIMONG PRIMARY	1028	5	2	1.25	0.251	0.139	Repair
PIENAARSRIVIER	567	1	3	1.25	0.164	NA	Build
MANTSHA PRIMARY	876	9	0	1.25	0.165	0.228	Build
MUCHUCHI PRIMARY	531	1	3	1.25	0.187	NA	Build
MAROTOBANE PRIMARY	439	1	2	1.25	0.274	NA	Build
ROOTSE PRIMARY	450	3	1	1.25	0.625	0.331	Repair
NKOTOBONA HIGH	474	3	1	1	0.704	0.337	Repair
MAPHOTLE PRIMARY	376	4	2	1.25	1.108	0.428	Repair
BADIMONG PRIMARY	1028	5	6	1.25	0.449	NA	Build
NAKGWADI SECONDARY	780	12	0	1	0.455	0.736	Build
METSI A- PHEPHA	375	3	2	1.25	1.036	0.473	Repair
SEJADIPUDI PRIMARY	362	4	2	1.25	1.195	0.489	Repair
SEGOPOTJE SECONDARY	347	5	0	1	0.548	0.495	Repair
SEFUFULE PRIMARY	372	4	1	1.25	0.915	0.500	Repair
KULANI PRIMARY	275	4	0	1.25	0.697	0.532	Repair
MPAPALATI PRIMARY	772	16	0	1.25	0.566	1.195	Build
MOKWASELE PRIMARY	847	10	1	1.25	0.662	0.587	Repair
MASHAHA SECONDARY	333	1	4	1	0.595	NA	Build

4. Discussion

To illustrate the advantages of using the suggested model, the results in terms of the present value of the units of effectiveness produced by a given budget allocation using the model are compared to a budget allocation that does not use such an analysis or criterion.

[17] Some schools in table IV have one classroom with a classroom condition of one or two. Since they only have one classroom, the rounded number of available classroom of those schools will remain one in the future. Therefore, no renovation project is assigned to those schools.

To describe the present rule for the budget allocation that currently exists without using the results of this analysis, it is assumed that the budget is randomly allocated to the schools where the learner-to-classroom ratio of the schools are higher than the standard, which is 40 in Limpopo. During this random selection, whenever the LCR of a school falls below 40, that school is erased from the list of possible investments. A random selection may not necessarily reflect the current system for budget allocation. In the past schools were often built in locations close to other villages where new schools have been recently built. Although these schools could be used by more than one village, because of the need for local politicians to be seen delivering at least as good a set of educational services as their competing politicians were delivering nearby, the system for school selection is yielding a pattern of resource allocation that is likely to be worse than a random selection rule (Jenkins and Klevchuk, 2004). In practice, funding might be given to school districts with an LCR lower than 40, which is worse than the random selection rule used here. In this paper, the randomized budget allocation provides a base case for the situation of not using an analysis for quantitatively estimating the advantage of using the suggested system for ranking areas for construction and repair of schools in a real world situation.

The randomized budget allocation is carried out for an amount of R 25,000,000 for the three scenarios similar to the previous section. The results of the randomized budget allocation are displayed and compared with the model-based budget allocation in figure I to III.

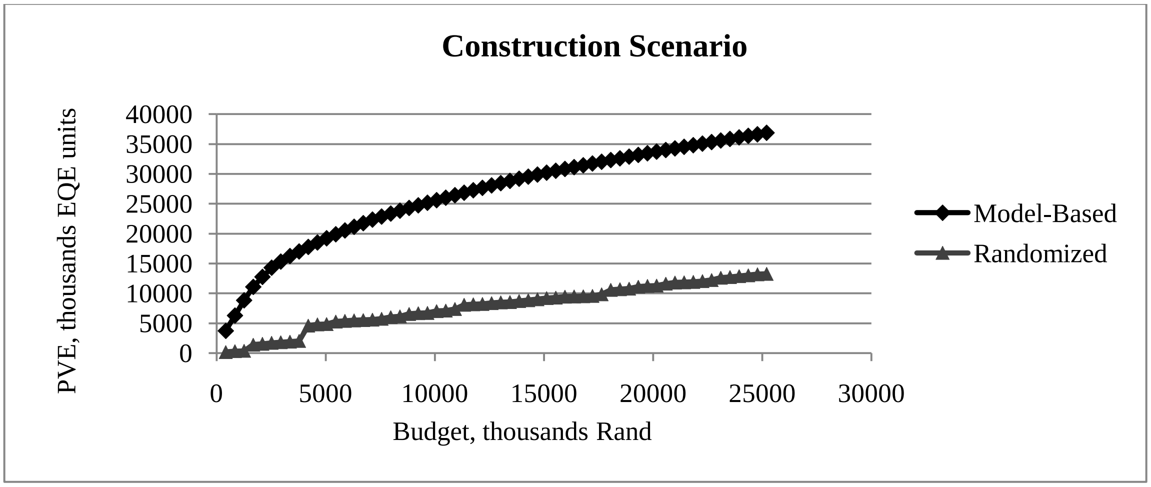

Figure I. Results of the model-based and the randomized budget allocation for the construction scenario

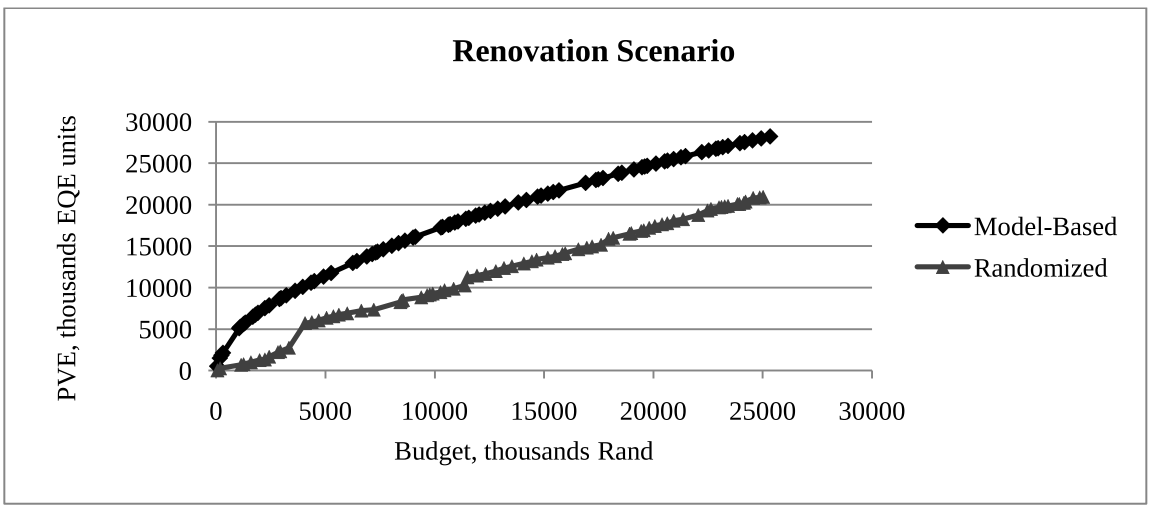

Figure II. Results of the model-based and the randomized budget allocation for the renovation scenario

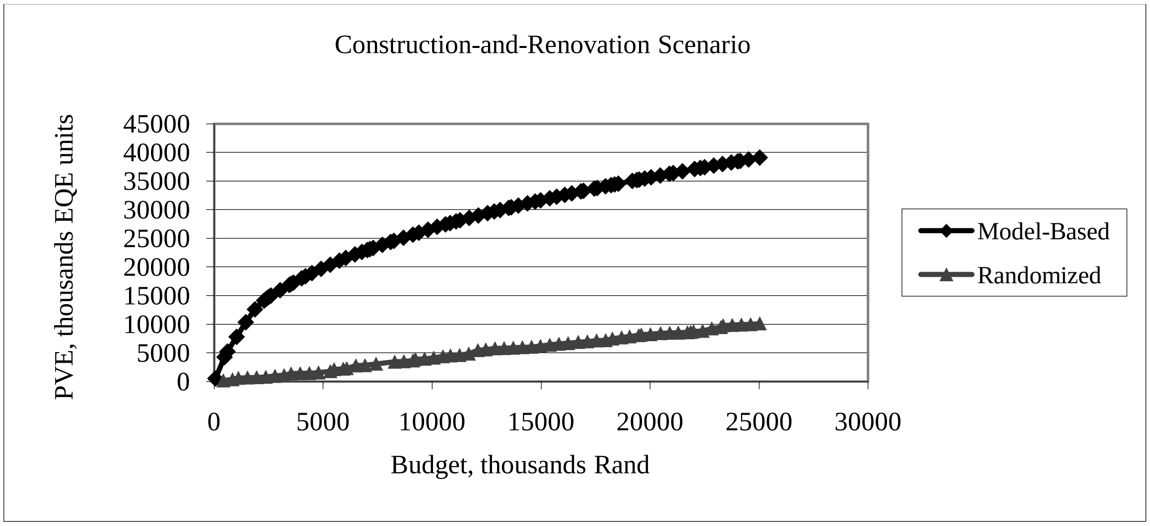

Figure III. Results of the model-based and the randomized budget allocation for the construction-and-renovation scenario

Except for the renovation scenario, the effectiveness obtained from the model-based budget allocation is very much higher than the effectiveness of the randomized budget allocation. For the construction, renovation, and construction-and-renovation scenarios, the EQE units obtained from the model-based scenarios are about 177%, 34%, and 287% greater than that of the randomized budget allocation. For instance, if the budget is allocated randomly to construction of new class-blocks then by using the suggested model the effectiveness of construction projects will increase by 177% in terms of EQE units. The reason that the results of the randomized budget allocation in the renovation scenario are not very different from the model-based budget allocation is that the cost of repairing all schools is about R 50,000,000 which is only two times bigger than the available budget. If the available budget was R 50,000,000 instead of R 25,000,000, there would not be any difference between a model-based and a randomized budget allocation.

In addition, using a model-based budget allocation can result in an ample savings of funding. For instance, in the construction scenario, spending about R 2,500,000 based on the selected schools of the model-based analysis creates the same amount of EQE units as spending R 25,000,000 randomly. In other words, the result of a randomized budget allocation in terms of EQE units are achievable only by spending 10% of the budget in an efficient way resulting in a savings of R 22,500,000. In the construction-and-renovation scenario, this savings is R 23,500,000 which is about 94% of the available budget. Such huge savings indicate the great necessity of a systematic budget allocation in education among the developing countries that their budget is mostly spent based as a response to political pressures rather than following a systematic analysis that will yield real value in terms of services received by their constituents.

A question that is often raised by the decision makers for infrastructure investments in education is how to optimally balance the budget expenditures between construction and renovation projects. The results of the model-based budget allocation show that the greatest enhancement in education system is achievable by using the model in the construction-and-renovation scenario. Allocating separate budget for construction and renovation, does not generally lead to the greatest enhancement in the education system. Without a complete analysis, it is almost impossible to exactly determine the best budget-mix for construction and renovation projects. As an example, assume a scenario that 5% of the R 25,000,000 budget is dedicated to renovation projects and the rest is dedicated to construction projects. The budget allocation for this scenario is carried out by both model-based and randomized selection method. The results of these two analyses are compared to the model-based construction-and-renovation scenario.

The infrastructure investments chosen by the model in this scenario result in 93% of the EQE units that is achievable through the model-based construction-and-renovation scenario where there is no constraint for spending the budget among construction or renovation projects. A randomized budget allocation for this scenario results in about 33% of EQE units that is achievable through model-based construction-and-renovation scenario. From the other hand, the results of the model-based and randomized budget allocation for this scenario in terms of EQE units are achievable with the model-based construction-and-renovation scenario through spending 85% and 8% of the budget, respectively.

The results of the model-based construction-and-renovation scenario suggest that about 62% of the R 25,000,000 budget should be spent on the renovation projects to obtain the greatest enhancement in education system. Figure IV illustrates the optimal budget-mix between construction and renovation projects for allocating a budget up to R 35,000,000. It is important to note that these results for the optimal budget-mix are heavily dependent on the assumptions for the situation and renovation costs of old schools. The optimal budget-mix might be very different for an education system with different situation and renovation costs. The suggested model in construction-and-renovation scenario, however, always results in the optimal budget-mix for any education system.

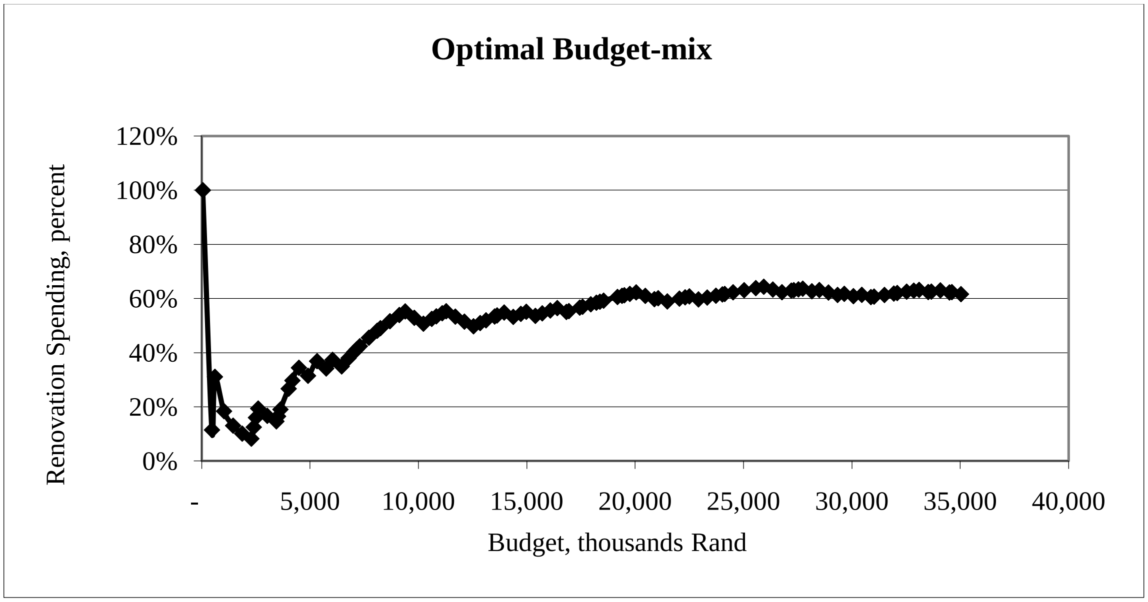

Figure IV. Optimal share of budget to be allocated to renovation projects

5. Conclusion

Around the world the decisions concerning the location of school buildings have been the focus of much political lobbying and controversy. As a result, many of the locational decisions for school buildings have produced an inefficient allocation of investments for this sector. While the criteria used in this study to rank investment opportunities may be still imperfect, it reflects a major improvement over current practice for many countries.

The cost-effectiveness model was designed under the condition to use only the information that is readily available in the Limpopo Province, South Africa. The information comes from the annual survey of public sector assets carried out by the Department of Education in the provincial governments. More sophisticated education information systems will no doubt enable a more accurate analysis of investment alternatives to be undertaken. However, such information systems are costly to design, implement, and maintain. Furthermore, it may take a decade before being fully comprehensive and liable. Given the information available in many less developed countries, the model presented here could be an appropriate first step in the design of a more rational system of setting locational priorities for investments in school buildings.

The model was applied to a set of data from Limpopo, and the results were compared with a randomized budget allocation among the schools in need of funding. This comparison indicates that using the model can result in an enormous savings and a more efficient education system. Since the model is capable to compare the effectiveness of construction projects with renovation projects, it determines the optimal mix of renovation versus new construction for a given budget. The optimal budget-mix for Limpopo highlighted the importance of the repair decisions regarding the existing structures as a potentially efficient alternative to the construction of new ones. The underfunding of repair is a chronic characteristic of the public sector budget of most developing countries and this paper seeks to put a spotlight on this issue.

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