Estimating Economic Effectiveness of Economic Infrastructure: A Methodological Exploration

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Abstract

Purpose: Economic Infrastructure is a prerequisite for economic development. To this end, it is necessary to reveal the theoretical background for estimating the effectiveness of economic infrastructure and establish the methodology for estimating the effectiveness. Until now, there have been a number of qualitative and quantitative studies that investigate the effect of infrastructure on the economy. However, we can hardly say that there is an agreed upon methodology for estimating such effectiveness. The aim of this paper is to solve methodological problems arising in estimating the effectiveness of infrastructure in terms of economic, physical-value, and spatio-temporal aspects.

Methods: The first section of the paper discusses theoretical problems for estimating the effectiveness of economic infrastructure. For this, we analyze the preceding studies on economic infrastructure as an economic concept, and on this basis, systemize its specific features and roles in a new way. The second section illustrates the main indicators and methodology for estimating the effectiveness of economic infrastructure. In this section, we apply various indicators related to physical and value aspects to suggest the methodology for estimating the space-time effectiveness of economic infrastructure.

Results: Based on the drawbacks of the previous approaches, this paper finds the rationality to estimate the economic effectiveness of economic infrastructure using the benefit to cost approach rather than the functional approach.

Implications: This study can be of significance to the policymakers or investors in decision-making related to infrastructural investment. They can calculate the economic effectiveness using the proposed methodology, upon which they can select optimal infrastructural projects for the short term or long term.

Keywords: Economic Infrastructure (EI), Economic Effectiveness (EE), Infrastructure, Net Income, Output Value, Capital Investment, Economic Development

1. Introduction

In order to make effective use of the existing level of economic condition and to develop an economy on a stable foundation, it is important to improve Economic Infrastructure (EI) and other basic facilities in advance. Until now, various international organizations and many researchers have made a number of studies on infrastructure. For example, the World Bank (1994) discussed the role of infrastructure in promoting economic development for different countries. Many scholars studied the impact of infrastructure on economic growth (For example, Aschauer, 1989; Munnell, 1990; Finn, 1993; Canning, 1999; Wylie, 1996; Zhang and Fan, 2004; Kamps, 2006; Straub et al. 2008; and Pereira and Andraz; 2007). The findings are useful to suggest a methodology for estimating the Economic Effectiveness (EE) of infrastructure. But there are some limitations in revealing the role of EI in detail and establishing the methodology for estimating its Economic Effectiveness (EE). In other words, researchers have focused on the contribution of infrastructure to economic development, but they have not considered the economic benefits due to the creation and operation of infrastructure, thus the effect of infrastructure. From this, two research problems are raised; (a) how are the benefits due to the creation and operation of EI expressed in economic development?, and (b) how is Economic Effectiveness (EE) of Economic Infrastructure (EI) calculated? In order to measure the EE of the infrastructure, it is necessary to establish a statistical estimation methodology in a proper way. It requires clarification of theoretical problems related to estimation methodology, set relevant indicators and evaluate on a scientific principle. This paper is aimed to elucidate the features and role of EI and solve theoretical problems on the estimation of EI's EE on the basis of already-published research findings and theoretical background. This paper is organized as follows. The first section analyzes the preceding research successes on EI and reveals its features. The second section discusses the concept of efficiency and EE of EI. The third section suggests the methodology for estimating EE of EI.

2. General Understanding of EI

2.1. Pre-study of EI

Analyzing the preceding research successes on EI is a prerequisite for elucidating the nature and role of EI as an economic concept. Until now, there have been some studies of the nature and classification of infrastructure and the correlations between its internal sectors. First of all, the nature and classification of infrastructure have been studied. Tinbergen (1962) introduced the distinction between infrastructure (for example, roads and education) and superstructure (manufacturing, agricultural and mining activities) without neither a precise definition nor any theoretical references of these terms. Material infrastructure, for example, has the function of rendering possible avenues for the development of economic activities. It puts into action the potentialities of economic units for the benefits of the society (Buhr, 2003). Infrastructure is a heterogeneous term, including physical structures of various types used by many industries as inputs to the production of goods and services (Chan et al. 2009). And it encompasses "social infrastructure" (such as schools and hospitals) and "economic infrastructure" (such as network utilities). They are the essential ingredients for the success of a modern economy (Stewart, 2010). Torrisi (2009) classified infrastructure into personal and institutional**;** material and immaterial; economic and social; core and not-core; basic and complimentary, as well as, network, nucleus and territory infrastructures. Kumari and Sharma (2015) explained the term 'infrastructure' in detail, including the types of infrastructure such as physical/economic infrastructure and social infrastructure. Some researchers studied the interactions between individual elements of infrastructure. Illustrating the interconnection among infrastructural elements, Edgar et al. (2017) assessed that the disruption of one infrastructural element affects other elements and thus, it can lead to cascading failures in others. Clifford (2015) developed an infrastructure impact analysis tool that integrates and automates the interactions of existing infrastructure simulation tools, which will anticipate escalating outcomes. Quelhas et al. (2007) used a linear model as the foundation for developing a generalized network flow model of the United States' integrated energy system involving electricity, gas, coal, and petroleum. The findings of the preceding studies serve as an important theoretical basis for describing EI as an economic concept, its features, and its contribution to economic development. Here in this study, we have adopted the definition and classification of Kumari and Sharma (2015).

2.2. Specific Features of Economic Infrastructure (EI)

What is important in understanding EI is to realize its concept and specific features correctly. The production process of material wealth requires the development of sectors of directly creating the physical material wealth on one hand and the further strengthening of reproductive ties among those sectors on the other. In fact, the reproductive process is the continuous process of production, distribution, exchange, and consumption of the products. The continuity and sequence of the reproductive process are ensured by the close interactions of all the phases of reproduction, and these interactions are supported by the role of elements linking those phases. According to research orientation, these elements can be studied as individuals or as an integral whole termed infrastructure.

When it comes to infrastructure, it can be said, in general, to be a concept indicating the elements which underlie a certain object. There are two sectors in economic construction; one refers to the sectors creating the physical material wealth and the other sectors ensuring the activities of those sectors creating the physical material wealth. They have their own intrinsic features and economic content, and play the role of ensuring the normal activities of the former sectors. In socio-economic development, infrastructure can be defined as the whole of basic facilities and units which are commonly used in reproductive phases and diverse economic activities.

Infrastructure has some features. First, infrastructure mainly forms a certain network in an organizational and technological aspect. Infrastructure is the whole of basic facilities and units ensuring the economic ties among sectors, regions, and enterprises and thus, these facilities and units form a network to serve the economic activities. Examples are road network, railway network, communication network, power network, irrigation network and the like. Due to these

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features of infrastructure, researchers discussed the infrastructure network and its impact on the economy (For example, Fernald, 1999; Ouyang, 2014) and analyzed the correlation between infrastructural elements within node-link environments (For example, Zavala and Chang, 2016). The better-organized and the more developed the infrastructural network is, the better the economy functions, the more perfectly the reproduction of material wealth and people's consumption life are ensured, and the closer the tie among sectors or regions becomes.

Second, infrastructure is used for people's productive and consumptive activities at the same time. Infrastructural facilities are not always used only for productive activities. For example, a road network serves for freight and passenger transports, and a power network is used by productive organs and enterprises, as well as by people and nonproductive organs. For this reason, it is difficult to practically distinguish between the productive and nonproductive uses of infrastructure, and thus, it is done conditionally for theoretical analysis. In some cases, therefore, we divide infrastructure into EI and social infrastructure. The former contributes to economic development and the latter to people's social life. For this reason, it is said that infrastructure is the ultimate enabler and serves the basis for economic and social development (Faul Foxlee and Stan Stavros, 2016a).

Third, infrastructure doesn't create a physical product. Infrastructure does not include the facilities which directly create physical products; it is mainly what contributes to ensuring and completing social production to realize final consumption. Thus, the result of the operation of infrastructure can't be accumulated as in the case of industrial or agricultural products; it assumes service character in all respects.

Fourth, infrastructure, in view of its use, is the facilities that are commonly used by all sectors of a national economy. All facilities belonging to infrastructure are commonly used by units and people using them. In other words, infrastructural facilities do not belong to a user, but to all the users. Such an understanding of specific features of EI is a prerequisite for systemizing its role played in economic construction.

2.3. Role of EI

To reveal the role of EI correctly is an important condition enabling us to set indicators for estimating the effectiveness on the basis of its role. Conceptually, infrastructure may affect aggregate output in two main ways; (a) directly, considering the sector contribution to GDP (Gross Domestic Products) formation and as an additional input in the production process of other sectors; and (b) indirectly, raising total factor productivity by reducing transaction and other costs, thus allowing a more efficient use of conventional productive inputs. Infrastructure can be considered as a complementary factor for economic growth (Novella Bottini et al. 2016a). Infrastructure is the ultimate enabler, underpinning the economic and social development; infrastructure enables the efficient movement of people and goods (transport); it enables the knowledge economy (telecommunications); it enables the proliferation of energy and water (power and utilities); it enables the social ecosystem for a healthier and more educated society (health, education, justice, etc.) (Novella Bottini et al. 2016b).

The benefit to cost analysis adopted typically on transport projects focuses largely on the value of any investment to transport users – primarily measured indirect benefits such as improved journey time, less congestion, improved safety and a reduction in environmental externalities (Faul Foxlee and Stan Stavros 2016b). As the factors to improve the impact of infrastructure on the economy, there could be spare capacity, greater flexibility, interconnection and complementaries, and so on, which affect in different ways (Novella Bottini et al. 2016c). Better quantity and quality of infrastructure can directly raise the productivity of human and physical capital and hence growth (Estache and Garsous 2012a).

Some scholars analyzed the academic debates on impacts of infrastructure on the economy and stated the significances of understanding why there have still been many debates with regard to impact level of infrastructure on GDP level and its longer-term impact on the growth potential of the economy. As those academic debates, they suggested the questions such as "How much infrastructure matters to growth?", "Which infrastructure matters to growth when?" and so on, and demonstrated the factors affecting the suggested questions (Estache and Garsous 2012b). Other researchers, treating the infrastructure as the general public capital, said that public capital has a positive impact on economic growth, and compared and analyzed the relation between the increase in the stock of public capital and the increase in GDP (Romp and De Haan, 2007; Bom and Lighthart, 2009).

In some studies, the impact of the individual elements of infrastructure on the economy was illustrated. For example, some researchers demonstrated the positive impact of energy infrastructure on output/growth (Dethier et al. 2008; Garsous, 2012) and other researchers tried to analyze the impact of water and sanitation on the economy in various aspects (Binswanger et al. 1992; Estache et al. 2005). In addition, researchers analyzed the positive impact of telecommunication infrastructure on economic growth (For example, Zhan-Wei Qiang and Pitt, 2004; Chakraborty and Nandi, 2011) and investigated the impact of transport infrastructure on economy in various aspects (For example, Buys et al. 2006; Estache and Fay, 2010; Wilson et al. 2003).

Based on previous studies we can identify a number of EI's roles. The first significant role of EI is found to have its contribution to labor productivity. The important mission of EI is to ensure economic ties among regions, sectors, and enterprises in a circulation sphere and so, its development actively contributes to enhancing labor productivity. Firstly, the development of EI makes it possible to provide factories and enterprises with the necessary amount of raw and other materials, fuel, and power in time; it enables them to reduce time lost due to the shortage of raw and other materials, fuel, and power, thus increasing output per hour. Secondly, the creation and operation of a reasonable infrastructural network corresponding to the distribution of productive force make it possible to further strengthen the specialization and cooperation of production in individual enterprises as well as on nationwide scale and thus, enhance labor productivity further. Thirdly, the construction of computer networks and other IT-based communication networks in keeping with the era of the knowledge economy and the reliance on them enable to convert production and business activities into information processes and actively push forward the scientific views and rationality, thereby enhancing labor productivity.

The next significant role of EI is expressed in accelerating social reproduction and ensuring the effectiveness of investment. When it comes to social reproduction, production regulates consumption, which in turn reacts to production. The medium connecting production with consumption is distribution and exchange. EI plays the role of linking production to consumption in social reproduction. Therefore, giving priority to the development of EI makes it possible to reduce the stay time of material wealth in circulation, thus increasing production and enhancing the EE on nationwide scale. The acceleration of social reproduction is found in the acceleration of not only the reproductive phases themselves but economic ties between regions or sectors. When producers are geographically separated from consumers and the sources of raw material, fuel, and power are dispersed, a better infrastructural network can activate the economic ties among regions or sectors, thus diminishing the production period and enhancing its economic effectiveness.

The development of EI contributes to avoiding the hoarding of investment to enhance the effectiveness of capital construction further. The failure to ensure the smooth and in-time supply of raw and other materials, fuel, and power to new factories and enterprises gives rise to the hoarding of the invested money. The construction of new factories and enterprises accompanied with perfect preparation of infrastructure ensures their simultaneous operation and normalization, with the reduced period of investment redemption and its further enhanced effectiveness. And constructing infrastructure in advance shortens the construction period. As compared with industrial and agricultural products, in general, construction is large in scale and requires a long period. For this reason, the construction of a building necessitates many laborers, materials and equipment, and the larger the construction scale is, the more important this is. Only when the construction of infrastructure precedes other construction work, can it be possible to ensure the concentration of labor, materials, and equipment. And it is also possible to proclaim the completion of construction work as soon as it is finished. Such an understanding of the role of EI serves as another theoretical basis in solving problems for estimating the effectiveness of EI.

3. Theoretical Problems for Estimating the EE of EI

3.1. Pre-study of Effectiveness and the Methodology for its Estimation

When solving the theoretical problems arising in estimating EE of EI, it is necessary to understand what effectiveness means. Many researchers have made a lot of a study of effectiveness before. Typical among them are the studies related to the essences of efficiency and EE, their categories, efficiency indicators, its analysis methods and so on. First of all, there were many studies on the concepts of efficiency and EE. In general, the representation of the efficiency characterizes the development of systems, processes, and events. Quantitatively, the efficiency is expressed by the ratio between the results obtained in the production process, and the costs of social labor, associated with the achievement of these results. Therefore, the meaning of increasing efficiency in production is a more rapid growth of the result (effect) as compared to the cost (Petrosyan et al. 2016a). Studying the production process efficiency, many researchers discussed the concepts of efficiency and EE in a more detailed way. Generally, efficiency can be defined as a measurement (usually expressed as a percentage) of the actual output to the standard output expected. Efficiency measures how well something is performing relative to existing standards (Koliński and Śliwczyński 2016a).

In the economic aspect, efficiency is the result of the company's activity, which is a proportion of the achieved effect on borne spending (Koliński and Śliwczyński 2016b). Koliński et al. (2014) classified production efficiency into economic efficiency and operating efficiency. According to his discussion, while the typical example of economic efficiency is the efficiency of the organization, that of operating efficiency is the efficiency of the workstation, and the efficiency of the process goes into both economic efficiency and operating efficiency. Koliński et al. (2016c) also defined different efficiencies in the aspect of managing production after analyzing the data of APICS (2004). According to his definition, efficiencies can be classified into allocative efficiency, efficiency variance, line efficiency, manufacturing cycle efficiency, materials efficiency, operating efficiency, performance efficiency productivity, worker efficiency, labor efficiency, and labor efficiency variance. Treating productivity and efficiency without discrimination, Daraip and Simar (2007) distinguished between partial productivity, when it concerned a sole production factor, and a total factor (or global) productivity when referred to all (every) factors, and made mention of scale, allocative and structural efficiency.

APICS (2004) describes efficiency as follows; 1) actual units produced to the standard rate of production expected in a time period, 2) standard hours produced to actual hours worked (taking longer means less efficiency), and 3) actual volume of output in value to a standard volume in a time period in value. David (2007) classified different efficiency ratios into five groups; liquidity, leverage, activity, profit, and growth. Various international organizations defined the efficiency of resources and established indicators of characterizing it. For example, according to the United Nations Environment Programme (UNEP), resource efficiency is about ensuring that natural resources are produced, processed, and consumed in a more sustainable way, reducing the environmental impact from the consumption and production of products over their full life cycles (UNEP, 2012). The European Commission is using resource productivity as its lead indicator. This is calculated by dividing GDP by domestic material consumption (DMC), which provides a figure in euros/tonne (European Commission, 2011). This indicates when less material is being used to provide the same economic output.

Next, researchers discussed methods of improving efficiency in various aspects. Introducing different concepts of production, Koliński (2013a) described the efficiency-improving methods according to them. According to his description, production can be classified into lean and agile production and according to them, methods of improving efficiency of actions can include those such as; 1) lowering spending and keeping the level of effects at the same time, 2) lowering spending and raising the level of effects at the same time, 3) keeping the level of spending and raising the level of effects at the same time, and 4) raising the level of spending and raising drastically the level of effects at the same time. On the other hand, discussing efficiency like productivity, some authors described methods of increasing productivity. Those are as follows; 1) improve effectiveness with better decisions, 2) improve efficiency using fewer inputs to achieve the same outputs, 3) improve performance in some other way such as higher quality, fewer accidents, less disruption, and 4) improve morale to give more co-operation and incentives (Waters, 2002). Next, researchers discussed the significance of efficiency or EE analysis. For example, Petrosyan et al. (2016b) say as follows: "An analysis of the overall effectiveness of economic activity is the prerogative of the senior management and linked to the definition of the product price, lot size of purchases of raw materials and supplies products, equipment replacement or technologies." They described the main objectives of efficiency analysis as follows; assessment of the economic situation, detection factors and causes of the state of progress, preparation and justification to management decisions, identification and mobilization of reserves.

Next, researchers discussed the efficiency indicators and their analytic method. First of all, various kinds of indicators of effectiveness were set in relation to the definition and classification of efficiency. A typical one is an indicator expressed as the correlation between input and output. This indicator can be expressed in physical and monetary aspects and it can be considered as a positive or reciprocal number. For example, Nábrádi et al (2007) systemized the indicators of efficiency. He divided the most basic indicators among them into physical and economic efficiency indicators and defined them. According to him, physical efficiency means that in input-output relations both input and output are measures expressed in the physical dimension, and if any of the elements (input-output) are expressed in money value, economic or business efficiency is mentioned. And he discussed the general formula of efficiency as follows: Efficiency = Output/Input, or Efficiency = Input/Output, or Efficiency = Output/Output, or Efficiency = Input/Input.

Koliński (2013a) also discussed various methods of improving efficiency and suggested the indicator of efficiency as output/input relation. As seen above, many researchers made a great advance in studying efficiency. These studies make possible to estimate the EI's EE in similar to EE of production and business. However, as seen earlier, it can be said that there are some limitations in revealing the theoretical problems for estimating EI's EE. In other words, the concept of EE in production and business is not similar to the one of EE regarding EI. Therefore, based on the previous studies of efficiency, this paper suggests the indicators and methods for estimating EI's EE in theoretical aspects.

3.2. Principle for Estimating EI's EE

To clarify the principle for estimating EE of EI is a prerequisite for setting the indicators for estimating EE of EI and producing estimation methodology. The first principle is that all the effects generated in various aspects due to creation and operation of a given infrastructure must be captured physically. It is because the infrastructure affects not one economic sector but several sectors at the same time. Physical effects obtained by the creation and use of some infrastructure should be evaluated by considering all the advantages from it, whether those advantages are directly or indirectly offered to economic sectors. Such estimation of the effectiveness of EI enables to easily and intuitively understand the economic effects produced by creating and operating individual infrastructures, and it can serve as a basis to evaluate the effectiveness in value and spatio-temporal aspects.

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The second principle is that EE of EI must be evaluated in the value aspect and in spatio-temporal aspect. In other words, EE of EI must be evaluated by considering all the effects obtained directly or indirectly in individual economic sectors, as well as on the nation-wide scale. That is why EI affects equally not only on any one of the economic sectors but on all sectors. This means that the investment in construction and reconstruction of infrastructure is calculated, considering the economic successes themselves obtained from the realization of the investment, as well as the successes made in all factories, enterprises, and sectors using the productive services of the infrastructure. Taking a newly-built roadway, for example, its economic effects should be calculated, considering the transport expense saved due to construction of this new road, as well as the decreased loss, the saved amount and newly created net income in all factories and enterprises using those road. These principles are the theoretical basis in setting the indicators for estimating EI's EE.

3.3. Indicators and Methodology for Estimating EI's EE

The right estimation of EI's EE depends on scientifically setting indicators. Effectiveness, in general, is the concept of characterizing the interrelation between input and output. Examples are output per unit of human and material inputs in the production process, output per unit of capital investment in construction work and the like. Similarly, EE of infrastructure can also be characterized by the output per unit of infrastructure. For this reason, EE of EI can be evaluated by the ratio of input-output. In this sense, the indicator characterizing the effectiveness of infrastructure which is revealed with interrelation between input and output may have the same mathematical algorithm as in the case of the indicator characterizing the effectiveness of production and construction. But they differ from each other in their economic contents. The creation and use of the EI are aimed to ensure the normal reproductive ties among enterprises, sectors, and regions. In other words, it is necessary to evaluate how much the establishment and use of infrastructure have increased production and how much new products have been created throughout the whole society. It is needless to say that it is possible to evaluate the effectiveness within the frame of the infrastructure itself.

In this case, it is necessary to analyze all the components of infrastructure in correlation with each other, because they operate in close relations. When it comes to the connection between transport and material supply, the rapid growth of transport reduces the demand for warehouse that are one of important facilities for material supply, with other factors held constant. On the contrary, imperfect productive communications or warehousing raises stricter requirements for transport.

Such correlation among components of infrastructure makes it possible to evaluate EE of EI itself as follows; when the increased expenditure for one of the components strengthens the productive performance of the infrastructure, EE can be evaluated by how much the demand for other components is reduced, that is, how much the expenditure for them is reduced. This estimation method is of significance in taking measures for the balanced development of internal infrastructural facilities of an economy in the correlation between the demand for EI and the demand for the human and material resources for its creation. However, only when EE

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of EI is evaluated from the point of view of how much it contributes to the economic development of a country, can it be said that the estimation fully conforms to its mission. Such an understanding of EI's EE requires that between the EE indicator expressed as a correlation between input and output, the output indicator, that is, the advantage should be set correctly. In this case, the input may refer to the total amount spent on EI.

First, the effectiveness of EI can be evaluated by using the indicator of output value per dollar spent on infrastructure. Considering the mission of EI and specific features of EE, the output, that is, the output value shown as a numerator should be calculated not as the value of productive services representing the performance of EI itself but as the output value of the economic sectors creating material wealth in physical form. The economic sector creating material wealth in physical form means one of sectors producing the tangibles such as industry, agriculture, and construction.

This is shown in the following formula:

$$output\ value\ per\ dollar\ of\ EI = \frac{output\ value\ of\ sectors\ creating\ material\ wealth\ in\ physical\ from}{total\ amount\ of\ EI\ value}$$

The total amount of EI value shown as the denominator is calculated as a full-value, scale indicator. This indicator gives an understanding of how the existing EI contributes to the production of material wealth. But, when the indicator is calculated for a year, as well as dynamically, the impact of EI on production can be more clearly understood.

Second, EE of EI can be evaluated by using the indicator of output value per investment in EI. It can be said, however, that the estimation of EE through the indicator of output value per investment has some limitations in that the indicator reflects the cost of products. Instead, the indicator of net income per investment is more reasonable to use, because it gives the possibility of calculating EE of infrastructural investment comprehensively on a national scale. The indicator of net income per investment in the creation of EI can be calculated according to individual enterprises creating material wealth in a physical form, or according to economic sectors or the whole national economy. This is shown in the following formula.

$$E_i = \frac{M}{K_i} \quad M = M_i + \sum_{j=1}^{n} \Delta M_{ij} \qquad \Delta M_{ij} = a_{ij} \Delta Q_{ij} \qquad (1)$$

where

E_i - effectiveness of *i*th infrastructural expenditure (capital investment)

K_i - *i*th infrastructural expenditure (capital investment)

M - the total amount of net income (or benefit) created in the limit of economic sectors or on the scale of a national economy, due to the construction of *i*th infrastructure

M_i- effects (net income or savings) created directly by the construction of *i*th infrastructure

a_{ij} - coefficient of net income (or benefit) per output value of *j*th product produced additionally by means of the effects created directly due to the construction of *i*th infrastructure a_{ij}<1 (*j* =1, 2, …, *n*)

ΔM_{ij} - net income (or benefit) created additionally due to the construction of *i*th infrastructure in *j*th sector

ΔQ_{ij} - annual increase of jth product produced additionally by means of the effect of ith infrastructure

Here, the amount of net income can be calculated by means of benefit, that is, output value minus cost. In other words, we can call such a method as the benefit-cost ratio approach. For example, in the case of transport infrastructure, we can divide the benefits according to individual elements of transport infrastructure into the following types (See **Table 1**).

Table 1. Types of benefits according to individual elements of transport infrastructure

Transport infrastructure	Types of benefit	
Road	Vehicle operating cost savings	Difference of vehicle operating cost between with and without road
	Time cost savings	Value of work time saved usually based on the relevant hourly wage rate, and reduction in working capital as a result of the earlier delivery of goods
	Accident cost savings	Avoided medical expenses; avoided damage to vehicles, properties, and road structure; avoided income loss due to injuries; and avoided deaths
	Reduction in environmental impacts	Avoided health expenditure and loss of productive time due to a reduction in air pollution, in carbon dioxide (CO_2) emissions
	Additional benefit	Benefit due to generation of new traffic
Rail	Reductions in user costs	Reductions in user costs for existing passengers, freight shipments, and operators.
	Cost savings	More efficient use of fuel and materials; reduction in the crew, passenger, and cargo time; more efficient utilization of rolling stock; reduction in working capital
	Benefit due to a reduction in accidents and in pollution and CO_2 emissions	
	Additional benefit	Benefit due to generation of new traffic
Airport	Cost savings	Cost reductions for existing users (passengers, cargoes, and operators)
	Additional benefit	Benefit due to generation of new traffic
Port	Cost savings	Where they ease congestion, reduce ship waiting time, or lower anchorage and berth and cargo-handling cost for existing traffic, cost savings per unit of cargo and/or passenger
	Additional benefit	Benefit due to generation of new traffic

Source: Own elaboration

The above estimation of the effectiveness of EI does not consider its temporal aspect. The estimation of the effectiveness of EI can be said to be perfect when it considers its temporal aspect. EI has its own service life and so, its EE can be analyzed and estimated dynamically at a certain point in time. In other words, the lifecycle-cost analyzing method must be used to evaluate EE of EI, considering the cost and the benefit obtained in its service life. In this case, the indicator of net income per investment in infrastructure is affected by its service period up to the point of time when its components are considered or by its service life when it has served its time. Therefore, the dynamic format of the net income indicator is the following.

$$M^T = M_i t + \sum_{j=1}^{n} \Delta M_{ij}^{t} \qquad (2)$$

where

M^T - total amount of net income (or benefit) up to the point of time of estimation

t - life-cycle or service life of infrastructural components (or establishments) up to the point of time of analysis and estimation

The dynamic analysis and estimation of EE require the consideration of the investment in the creation of infrastructure, as well as the expenditure for its operation. In this case, the value given as denominator should be the converted expenditure value that includes both the capital investment in the construction of infrastructure and the expenditure for its operation. Estimation of effectiveness of EI can be conducted in various forms during the life-cycle. In the first years of life, effectiveness can be evaluated by compensation period of investment, and then in the period until the end of life after the compensation period of investment – by benefit per operating expenditure. Such process can be showed using the following figure (**Fig. 1**).

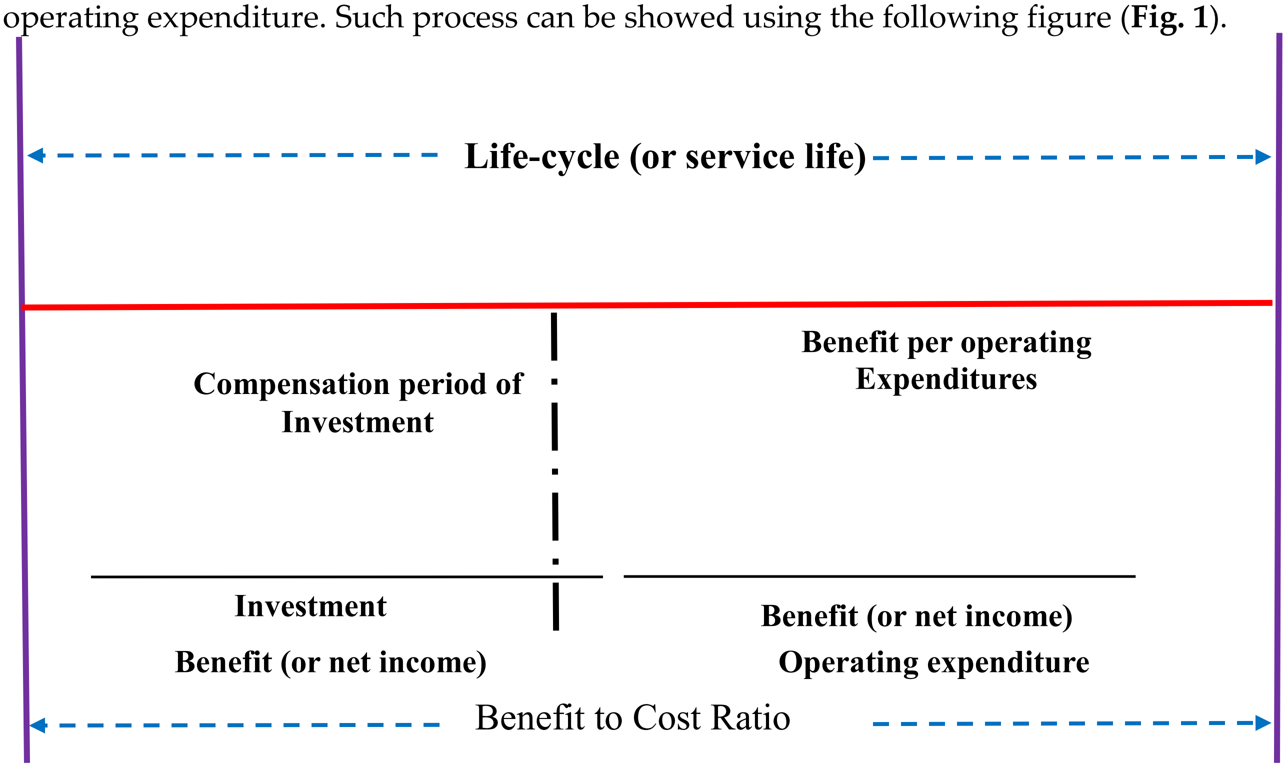

Fig. 1: **Method of estimating the effectiveness of EI during the Life-cycle**
Source: Own study

The estimation of EI's EE should consider its social effects. Infrastructure by its nature affects not only the economy but the environment. These effects may be positive or negative. But whether those effects are positive or negative, they must be evaluated qualitatively and quantitatively. Only then, can it be said that EE of EI is evaluated comprehensively. In other words, if the creation and operation of a given infrastructure affect the environment positively, the gain must be added to its economic effects; if negatively, the economic effects should be reduced as much as the loss. Taking the construction of a power plant, for example, the negative influence is given to the environment by a thermal power plant gives but positive one by a solar thermal power station. If the creation and operation of infrastructure affect the environment negatively, the cost to compensate for the negative influence must be added to lifecycle cost; if positively, the obtained gain must be added to the benefit. As seen above, EE of EI can be evaluated comprehensively on the scale of a national economy; it can also be evaluated through a concrete analysis of in what processes individual infrastructural facilities bring about economic effects to the sectors creating material wealth in a physical form. This way of estimating the effectiveness of EI enables to deeply understand the role of infrastructure in developing a national economy and ensuring economic ties among enterprises, sectors, and regions and take measures to further develop the infrastructure in accordance with its mission.

4. Conclusion

In order to evaluate the EE of EI, it is necessary to clarify theoretical problems. Those problems may include the specific features of EI, its role in economic construction, the principle, indicators and methodology for the estimation of EI's EE. Infrastructure has some features. They are found in that EI (1) forms a certain network in an organizational and technological aspect, (2) performs both productive and nonproductive functions, (3) doesn't create products in a physical form, and (4) are commonly used in all sectors of a national economy.

EI plays a significant role in economic construction. The role finds itself in the fact that EI (1) actively contributes to enhancing labor productivity on a nationwide scale, (2) accelerates social reproduction and ensures the effectiveness of investment. Such an understanding of the features and role of EI is the theoretical basis for estimating EE of EI. Our suggestions regarding the methodology for estimating the EE of EI are outlined as follows.

First, the effectiveness of EI can be evaluated in a physical form. In this case, the effects of individual components constituting an infrastructure can physically be summed up in various aspects. Next, the effectiveness of EI can be evaluated in value. In this case, the effectiveness can be evaluated by calculating the output value per unit of infrastructure value; it can also be estimated by calculating the effectiveness of expenditures for infrastructure through the calculation of the effects obtained directly and indirectly by its creation and operation. Indicators showing those direct or indirect effects can be output value, net income and the like. This shows that the EE of EI can be evaluated by the ratio of input-output, as well as the benefit-cost ratio. The abovementioned estimation of EE of EI makes it possible to deeply understand the role of infrastructure in ensuring the development of the national economy and the economic ties among enterprises, sectors, and regions and to take measures for developing EI further in accordance with its mission.

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5. Limitation and Further Research

Based on the findings in the previous studies of infrastructure and its effectiveness, the paper has systemized the features and roles of the infrastructure and suggested theoretical problems arising in estimating its effectiveness in physical, value and spatio-temporal aspects. Of course, other various problems can be raised.

First, the estimation of EE of EI should consider the changing net present value. Net present value is the present value of the cost which may be incurred in the future; it may be changed due to various factors. In this case, net income, that is, the benefit can be changed, thus affecting the estimation of EE. Second, EE of EI should be evaluated, considering the correlation among the internal sectors within a given infrastructure itself. The methodology mentioned in the paper presupposes the fact that all internal sectors constituting a given infrastructure have a positive influence on the economy and its intensity is the same in a certain period of time of estimation. In practice, however, the influence given to the economy by the individual components of infrastructure may be different and is not in the same intensity in a given period of time. And any one of the infrastructural components, although perfected in a region, cannot completely offset the negative influence produced by the imperfection of the other component. Therefore, these and other problems should be studied in the future,

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