Send Orders for Reprints to reprints@benthamscience.ae

BENTHAM OPEN

CrossMark

The Open Transportation Journal

Content list available at: www.benthamopen.com/TOTJ/

DOI: 10.2174/1874447801711010044

REVIEW ARTICLE

A Crossing-Line Between Transportation Evaluation and Natural Capital Assessment: Perspectives on Ecological Economics and Project Evaluation

Hye Kyung Lee[1] and Hwan Yong Kim[2,*]

[1]*School of Architecture and Architectural Engineering, Han-Yang University, Sangrok-Gu, Ansan, South Korea*
[2]*Division of Architecture and Urban Design, College of Urban Sciences, Incheon National University, Incheon, South Korea*

Received: October 26, 2016 Revised: February 16, 2017 Accepted: April 03, 2017

Abstract:

Introduction:

Ranging from everyday choices to political arrangements, making the most efficient and effective outcome of the given circumstances is a critical part of decision-making process. Accordingly, achieving a balanced and sophisticated perspective in decision-making process is a hard task. However, there are possible ways to direct this issue, at least to some conceptual extent, and this article identifies possible considerations for more sustainable infrastructure planning decisions.

Methods:

This study presents a thorough review on project evaluation and transport externalities, especially in terms of ecological valuations. After that, a case study on a high-speed rail in the state of Texas, USA is examined to elaborate suggested solutions in sustainable transportation decision-making.

Results:

To appropriately reflect the changes in ecological features induced by a transportation project, location specific or project-based measurements are critical parts. There are certain ways to capture the monetary values of ecological features. Using the suggested methods, two high-speed rail alternatives are compared, and the one with more ecological preservation is considered could save the difference identified in construction in less than 15 years with the savings in monetary values of ecological features.

Conclusion:

Because environmental impact is often regarded in a separate study measuring the degree, not the economic values associated with it, precise meaning of ecological externalities is hard to understand. However, many scholars in both transportation and ecology disciplines emphasize the need for more inclusive considerations on opportunity costs of natural environments, and recently technological advances made this issue become more plausible. Based on Texas case, calculating monetary values of ecology could provide a different future about transportation investments, and for that reason, we should think more thoroughly on externalities.

Keywords: Transportation project evaluation, Environmental externalities, Ecosystem valuation, Environmental impact assessment, Benefit-cost analysis, Natural capital.

1. INTRODUCTION

Optimizing investment decisions is an important task for many professionals. Ranging from everyday choices to

* Address correspondence to this author at the Division of Architecture and Urban Design, Incheon National University, 119 Academy-ro, Yeonsu-gu, Incheon, South Korea 22012, Fax: 82-32-835-0776; Tel: 82-32-835-8473; E-mails: hwan.kim@inu.ac.kr, double.hs@gmail.com

political arrangements, achieving the most efficient and effective outcome from given circumstances is a critical part of decision-making process. This is particularly true for infrastructure investment decisions because building a new facility requires a significant amount of time and cost. A transportation project especially demands a holistic view based on their longstanding and great degree of impact on society. However, this does not mean we only need to focus on the economies of scale and ignore other aspects of the built environment. For example, considering more environmental features, such as endangered species or vegetation cover in railroad or highway construction may require greater cost at the beginning, but may allow us to preserve our natural environment more ecologically and sustainably in the long run. In this extent, as a part of the general planning process, infrastructure planning requires more thoughtful decision-making procedure for better resource management.

Then, how can we achieve a balanced perspective in decision-making? In addition, what aspects should be considered when making more sustainable decisions in transportation investments? These questions are hard to answer definitely, as they all could become very complex if an attempt is made to precisely model or quantitatively measure. However, there are possible ways to direct the questions, at least to some theoretical extent, and this article is to identify possible considerations for more sustainable infrastructure planning decisions, especially in terms of transportation investments.

The article first identifies issues in transportation externality studies with a review on benefit cost analysis, total cost analysis, and multi-criteria analysis. After that a theoretical consideration on ecosystem valuation is provided to emphasize the importance of including economic values of environments in a project evaluation. Finally, a case study is suggested to provide a possibility to include ecological evaluation in a transport project and discuss what it means to the final outcome in a project appraisal process.

2. MATERIALS AND METHODS

2.1. Transportation Externalities

Transportation project evaluation refers to a set of actions for assessing alternatives in a transportation project [1, 2]. There are about 6 components in project evaluation: 1) demand forecast; 2) value of time; 3) safety; 4) environmental impacts; 5) efficiency; and 6) economic impact [3, 4]. Despite the fact that some countries, such as Japan, Germany, and France calculate monetary values of environmental features consumed by a transportation project, the U.S. and U.K. calculate environmental resources *via* a point system, not necessarily as features of financial significance [4, 5].

The U.S' missing practice on environmental valuation in terms of monetary terms could be found in some other works as well. Lee [6] argues that the evaluation process can be separated into three segments: 1) alternative generation; 2) impact estimate; and 3) evaluation and selection. During the impact estimate, the U.S. practices often left out considerations in environmental costs. There are mandatory procedures for some fixed costs, such as loss of habitat, wetlands, and parks, because federal law imposed the constraint of no net loss [6, 7]. Nonetheless, the current practice still lacks a means to precisely capture the economic costs of environmental features consumed by a specific project.

To overcome the lack of more thorough considerations during the evaluation process, a number of efforts have been made. Researchers started focusing on environmental externalities in transportation projects [3, 8 - 14], and most of them calculate externalities in congestion, noise, and air pollution. For example, Lu and Morrell [14] examined different sized airports and included noise and emission costs to benefit-cost analysis (BCA). The result indicates that approximately 450,000 airplane movements per year create marginal economic benefits in regards to environmental costs. In other words, if an airport creates more than 450,000 movements per year, then the associated external costs are greater than the economic benefits.

The only shortcoming of this type of approach is that environmental externalities are generally limited to a number of aspects, all of which are not precisely environmental, but rather socio-environmental. As a result, true consumptions on ecological attributes are not thoroughly considered. This is acceptable, as ecological features do not have a standard, standalone market to appraise their values. However, transportation projects last longer and possess a greater impact, and thus need to be regarded in a more multifaceted way. Estimating the amount of specific ecological features consumed by a transportation project would be a hard task, but can be plausible with some precautionary considerations. According to previous studies, the resulting damages on ecology depend heavily on the technology used and the location of the transport activity [9, 14 - 16]. The application of environmental externalities reveals a great variation depending on the transport mode, the technology used, and the location of the transport task. In other words, transport externalities are especially site-specific and depend on the nature of the project. Therefore, externalities should be estimated on a case-by-case basis and the inclusion of specific measures will indeed improve the final investment decisions.

The needs for more location-specific externalities are also found in other articles. Quinet [17] urges that location-specific measures are necessary to reply to the questions on geographic aggregations. It means that we need to measure transportation impacts on the environment with a “bottom-up” approach, cumulatively measuring the impacts from a small to larger scale, not in an aggregated scale. In cases where data availability is lacking, however, this can be hard to achieve. The shortcoming of using aggregate-level analyses is that we cannot distinguish with any degree of precision between local situations or the types of transportation used [11, 18]. Hence, recent studies emphasize the need for more project-based or site-specific measures in transportation externality studies. Although measuring the economic values of environmental features is a difficult task, there are ways to capture the benefits, at least to a theoretical extent.

2.2. Measuring Externalities – EIA, BCA, TCA, and MCDA

To answer the issues generated in the previous section, this section introduces possible remedies with well-known limitations that have been used by many previous studies. Environmental impact analysis (EIA) is one of the prevalent forms to capture the environmental externalities as well as ecological consumptions. Even though EIA in general does not require monetary estimates, externalities are frequently captured during the process. EIA is calculated using a weighting standard, and there are 5 categories: 1) travel impacts; 2) air quality; 3) noise; 4) ecological impacts; and 5) socioeconomic impacts [10, 19]. Using the pre-established formulas, each category’s impact scores are estimated. Consequently, the most suitable alternative is selected, or mitigation measures are examined if there is no other way to change the project. The only problem with the traditional EIA is that it is very hard to understand the exact damages in financial terms as it utilizes a point system, also known as the degree of impact [12]. This is particularly true for the changes in ecology, as ecological impacts are hard to understand with just the degree. Ecological impacts, especially the ones induced by infrastructure facilities, are cumulative and long lasting in nature; shortsighted views and subjective terms are not suitable in the long run.

In addition to the EIA, BCA is one of the most widely utilized methods in project evaluation. Accordingly, articles in transportation project evaluation, especially the ones focusing on externalities frequently utilize BCA as their main method. However, researchers have continuously reported the limitations in traditional BCA, particularly within the domain of the environmental costs [16, 18, 20 - 22], and have identified two limitations. First, BCA requires second-best conclusions for more comprehensive environmental costs evaluation. Otherwise, there are no proper comparisons available and the solution becomes the only practical and possible option in terms of economic costs. Second, choosing the right discount rate and project duration are keys to the final outcome. Environmental deduction should be discounted at a low or even zero rates because they involve intergenerational equity and may become practically insignificant [20, 21, 23 - 25].

BCA has been used less by transportation decision-makers in the U.S. for several reasons. Many factors other than economic efficiency are important to the decision-makers, but are difficult to enumerate in monetary terms and may even be non-quantifiable [18, 24, 26]. This is particularly true for ecological valuation, as a market to assess economic tradeoffs for ecological features does not exist in reality. Further, the term “benefits” is relatively subjective, requiring scrutiny in defining the scope in a project. The Total Cost Analysis (TCA) is sometimes more implementable because it is easily understood by the public and political decision-makers. Advantage of using TCA is that there is no suggestion that all “benefits” have been considered; decision-makers are free to use their own value judgments to tradeoff total cost against non-monetizable impacts, such as social, environmental and economic. In addition to the TCA, multi-criteria decision analysis (MCDA) is considered a good alternative. A common argument in the use of traditional BCA is its unambiguous quantitative number it produces. MCDA, on the other hand, uses techniques that are theoretically and practically impossible to reflect the desirability of transport infrastructure projects as just one number [27 - 29]. Therefore, implementing user judgments or weights is a necessary step to make the evaluation process reliable and to produce a more flexible and comprehensible result.

Some elements in BCA, especially in ecological aspects, require data that are not always available or immediate at hand. This leads to situations in which applicants are freed from the obligation to complete that part of the evaluation [18, 20, 30]. This is partly true that not all the criteria are the same, nor need to be treated equally important. To this extent, using MCDA over BCA seems appropriate. It is especially common methods of valuing environmental impacts in BCAs that cannot possibly result in a true picture of the real values people attach to goods, such as nature, landscapes or a clean environment [27, 28, 31]. For that reason, ecological effects, for instance, have been expressed in very limited monetary terms in the BCAs [7, 20]. Therefore, precisely capturing the amount of consumptions on ecological attributes is a hard task to achieve depending on data availability as well as limited valuation methods. As noted, since environmental externalities are inclined to measure the socio-environmental values, ecological valuations should be regarded in a different way that economic consumptions need to be dealt in more comprehensive and analytical settings.

These issues have become plausible to resolve, as technology has progressed up to a point where location-specific estimates are now possible. Implementation of geographic information systems (GIS) or utilization of satellite images enables researchers to pinpoint the changes in specific environmental features induced by man-made structures. Incorporating such techniques will reduce the exposed limitations as more location-specific measures are incorporated and could be able to specifically quantify the amount of attributes replaced or eliminated permanently. In addition, using a combination of supplementary methods, such as the TCA and detailed ecosystem valuation may improve the well-known limitations in BCA and EIA to a greater degree. This perspective also corresponds with the U.S. transportation practice, where cost-effectiveness evaluation is mainly used. More availability in data will eventually enhance the specificity of the outcome and increase reliability. In this extent, the question arises on the use of environmental valuation methods. Specifically, the way how the ecological features are measured will largely drive the entire evaluation process regardless the types of evaluation methods.

2.3. Ecosystem Valuation

Costanza and Daly [32] wrote about the idea of natural capital and its relationship to overall sustainability. The study provides an in-depth background of natural capital and its implications. According to the authors, the term natural capital is based on a more functional definition of capital as “a stock that yields a flow of valuable goods or services into the future (p. 38)” [32]. The authors divide natural capital into two types. The first type is renewable or active natural capital, while the second is nonrenewable or inactive natural capital. Renewable natural capital is active and self-maintaining using solar energy. Ecosystems are renewable natural capital. They can be harvested to yield ecosystem goods, such as wood but they also yield a flow of ecosystem services like erosion control and recreation when left in place [32]. Nonrenewable natural capital is more passive. Fossil fuel and mineral deposits are the best examples. In the past, only manufactured stocks were considered as capital because natural capital was considered abundant enough to support mankind's activities. However, we are in a new era and natural capital has become a limited source. Human economic activities can significantly reduce the capacity of natural capital to yield the flow of ecosystem goods and services upon which the productivity of human-made capital depends [32 - 34]. This is important as the classical economic theory assumes that human-made capital is a near-perfect substitute for natural resources. It is arguable that for any given product embodying any given level of technical knowledge, human-made capital and natural capital are, in general, complements, not substitutes [33].

There are two additional points that are highly important in this regard. First, the authors clarified that ecosystem services provide an important portion of the total contribution to human welfare on this planet. We must begin to give the natural capital stock that produces these services adequate weight in the decision-making process, otherwise current and continued future human welfare may drastically suffer [34, 35]. Further, the use of this process is for project appraisal, where ecosystem services lost must be weighed against the benefits of a specific project. Because ecosystem services are largely outside the market and uncertain, they are too often ignored or undervalued, leading to the error of constructing projects whose social costs far outweigh their benefits [34, 35].

Recent articles present a conceptual framework and typology for describing, classifying and valuing ecosystem goods and services [36, 37]. There are four functions of ecosystem: 1) regulation; 2) habitat; 3) production; and 4) information. In addition, an ecosystem has three particular values: 1) ecological; 2) socio-cultural; and 3) economic [37, 38]. Values are estimated according to either direct or indirect market values, and *via* different estimation techniques. Indirect valuation can be done with 5 methods: 1) avoided cost; 2) replacement cost; 3) factor income; 4) travel cost; and 5) hedonic pricing. On the other hand, direct valuation utilizes revealed preferences. An ecosystem’s first function, regulation functions are mainly valued through indirect market valuation techniques such as, avoided cost and replacement cost. An ecosystem’s second function, habitat function is usually measured with direct valuation. Similarly, production functions are measured through direct market pricing and factor income methods. Information functions are mainly measured through contingent valuation (cultural and spiritual information), hedonic pricing (aesthetic information), and market pricing (recreation, tourism and science) [18, 36, 39].

3. RESULTS

Incorporating Ecosystem Valuation in Infrastructure Projects: A High-Speed Rail Case

As can be seen, natural capital can barely be replaced by man-made capital and thus, its supply is strictly limited. Therefore, valuing ecosystem services and understanding their values to human life will be an important task. Like Costanza and Daly described, it is imperative that developing societies confronting the limited supply of natural resources, consider the values of natural capitals [32]. Otherwise, all investment decisions will be based upon direct market values and we can only expect physical growth, not the qualitative developments [32, 34]. As Wilson *etal*. [38] described, it is obvious that when the economic values of non-market goods and services are left out of decisions, resulting policy tends to overestimate the role of the market values and bias decision-making in favor of immediate development and resource extraction. In addition, economists have tended to concentrate on those ecosystems where their values have direct effects to individuals or society, and this is particularly true in most of developing countries [39]. In contrast, ecological models have tended to concentrate on aspects of ecosystems that are important to ecosystem functions but that are not directly valued by people [3, 5, 18].

A good application of using ecological costs in a project may be high-speed rail (HSR). Because of its longer-lasting impact on the society, HSR and railways at large should be carefully planned from its beginning. To do so, a number of methodologies could be adopted, and GIS provides a new opportunity for route optimization. Fig. (**1**) illustrates possible HSR routes between Austin and Houston airports in the state of Texas, U.S.A. Route 1 is designed with more emphasis on built environment variables, such as land use, roads, housings, and population when route 2 is optimized for environmental variables, such as hydrology, floodplain, wetlands, and vegetation covers. It means the first route is more closely related to man-made variables, whereas the second one gave more consideration on environmental features. Using cost surface and shortest route functions in ArcGIS, each path is optimized with the given variables. More detailed modeling information can be found in the previous literature [5, 40, 41].

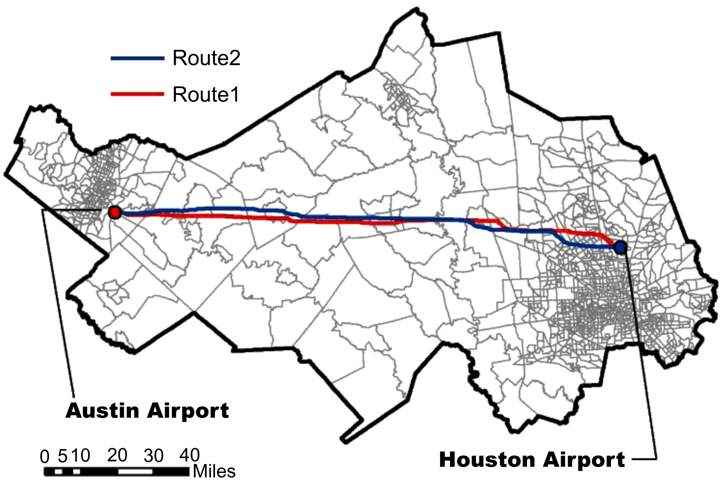

Fig. (1). HSR routes between Austin and Houston airports.

Construction and operation costs are estimated using previous study results that are mostly based on per length information. South Korean and Japanese HSR cost estimates are implemented to precisely capture the associated costs. The average construction cost per mile with two countries' estimates is $ 26 million and the average operation cost is about $1.8 million. Both countries use construction and operation costs per distance, meaning that the total costs for the two categories vary largely with length. Ecological costs are calculated by using the method, value transfer with the study results from Constanza [34] and other associated literature [40, 41]. Using previous 131 cases and 51 relevant articles, each land cover's monetizable elements are identified. After that, transferrable ecological values are set to maximum, minimum, median, and average values. The consumer price index (CPI) is used to set each value to the same dollar-year. Finally, the environmental consumption in terms of acreage is calculated for each route and multiplied to the adjusted ecological values. Using GIS land cover dataset, it is possible to pinpoint how much natural land covers are converted to impervious surfaces (rail tracks).

Table (**1**) summarizes the results. As can be seen, the construction cost difference between the two alternatives is about $3.3 million, and this is due to the reason that route 2 passes through urban cores, requiring more costs for land acquisition.

Table 1. Expected total costs of each alternative (million $ / year).

Cost Elements	Route 1 (233.6 km)	Route 2 (233.6 km)
Construction Costs	$6,247.9M	$6,251.5M
Operation Costs	$422.1M	$422.1M
Ecological Costs	$5.3M	$5.1M
Total Costs	$6,675M	$6,679M
Difference	-	+$3.3M

$ 3.3 million may be a big difference. However, considering the fact that an HSR lasts for over 20 to 30 years, this initial investments should not become a game-changer in decision-making process. Rather, we should think more on timespan of the facility and savings that we could expect from reduced ecological consumption. As seen in Table (**1**), route 2 saves about $ 0.2 million for its consideration on environmental features during the planning stage. If this difference is calculated in a 20-year timespan, then the total cost shows a different result. Fig. (**2**) illustrates costs change in 30 years. In the 14th operation year, route 2 surpasses the total costs of route 1 because of the savings in ecological costs. It means if we regard the environmental changes as one of economic features in our transportation investments, the entire decision-making process should change and adjust to adopt ecological costs as one of cost attributes.

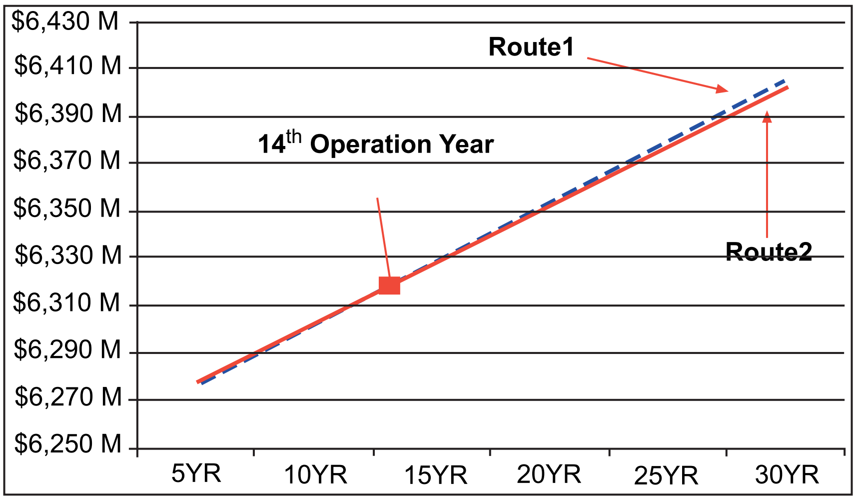

Fig. (2). Cost shift in a 30-year timeframe.

CONCLUSION

This article is intended to give an overview on the transportation project evaluation process, and to examine the improvements that could be made upon. As mentioned, because environmental impact of a transportation project is often regarded in a separate study measuring the degree of impact, not the economic values associated with it, precise meanings of ecological externalities for a particular project is hard to understand. In addition, many of externalities studies focus on limited values, such as noise, congestion, or pollution and thus, they have strong tendency to neglect the true consumption on ecological features.

To outline possible remedies to the problems identified above, a thorough review on project evaluation and transport externalities literature is provided. Furthermore, to answer the missing part in incorporating ecological consumption in transportation evaluation, an HSR case was given to identify a possibility to include ecological costs in a decision-making process. It is clear that many scholars in both transportation and ecology disciplines articulate the need for more inclusive and comprehensive measures in project evaluation. To appropriately reflect the changes in ecology induced by a transportation project, location specific or project-based measurements are critical parts. There are certain ways to capture the economical values of ecological features, and some of them are very plausible to be included.

Technological advances made the project evaluation process become more inclusive. As a result, calculating both environmental externalities and ecological consumption became more than possible to elaborate during project evaluation process. If we are to use the technologies where more sophistication and precision is available, shouldn't we, as experts, be using them to model or interpret the costs that are beyond the formal market theory? Also, if a transportation corridor shows the ecological values lower than another alternative, although the total length and construction costs may be higher, shouldn't we choose a route that is environmentally beneficial and economically sound, even if it detours slight? This is an important point because we are dealing with a subject that generally lasts longer and will certainly impact our future generations to a greater degree.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

Declared none.

REFERENCES

[1] J. Mei, and L. Wen, "The application of fuzzy comprehensive evaluation method in the selection of enterprise transportation services", *Adv. Manag. Sci.,* vol. 3, no. 3, pp. 25-31, 2014.

[2] C.K. Sinha, and S. Labi, "Impacts on wetlands and other ecosystems", In: *Transportation decision making: Principles of project evaluation and programming.,* John Wiley & Sons Inc: Hoboken, New Jersey, 2007, pp. 313-336.
[http://dx.doi.org/10.1002/9780470168073.ch12]

[3] M. Belhaj, and E. Fridell, *External costs in the transport sector: A literature review,* The Swedish Environmental Research Institute: Stockholm, Sweden, 2010.

[4] Y. Hayashi, and H. Morisugi, "International comparison of background concept and methodology of transportation project appraisal", *Transp. Policy,* vol. 7, pp. 73-88, 2000.
[http://dx.doi.org/10.1016/S0967-070X(00)00015-9]

[5] H. Kim, "Ecological valuation in a transportation project: Value transfer and spatial decision support systems", *Int. J. Environ. Sci. Technol.,* vol. 11, no. 8, pp. 2281-2290, 2014.
[http://dx.doi.org/10.1007/s13762-014-0615-y]

[6] D.B. Lee, "Methods for evaluation of transportation projects in the USA", *Transp. Policy,* vol. 7, pp. 41-50, 2000.
[http://dx.doi.org/10.1016/S0967-070X(00)00011-1]

[7] J.A. Annema, C. Koopmans, and B. Van Wee, "Evaluating transport infrastructure investments: The Dutch experience with a standardized approach", *Transp. Rev.,* vol. 27, no. 2, pp. 125-150, 2007.
[http://dx.doi.org/10.1080/01441640600843237]

[8] W. Adamowicz, "Valuation of environmental externalities", In: D.A. Hensher, and K.J. Button, Eds., *Handbook of transport and the environment.,* Elsevier Ltd.: Oxford, UK, 2003, pp. 375-389.
[http://dx.doi.org/10.1108/9781786359513-020]

[9] A. Bento, D. Kaffine, K. Roth, and M. Zaragoza-Watkins, "The effects of regulation in the presence of multiple unpriced externalities: Evidence from the transportation sector", *Am. Econ. J. Econ. Policy,* vol. 6, no. 3, pp. 1-29, 2014.
[http://dx.doi.org/10.1257/pol.6.3.1]

[10] D.K. Brucker, C. Macharis, and A. Verbeke, "Multi-criteria analysis in transport project evaluation: An institutional approach", *European Transport.,* vol. 47, pp. 3-24, 2011.

[11] M. Chester, and A. Horvath, "Life-cycle assessment of high-speed rail: The case of California", *Environ. Res. Lett.,* vol. 5, p. 014003, 2010.
[http://dx.doi.org/10.1088/1748-9326/5/1/014003]

[12] E. Demir, Y. Huang, S. Scholts, and T. Van Woensel, "A selected review on the negative externalities of the freight transportation: Modeling and pricing", *Transp. Res., Part E Logist. Trans. Rev.,* vol. 77, pp. 95-114, 2015.
[http://dx.doi.org/10.1016/j.tre.2015.02.020]

[13] M. Janic, "High-speed rail and air passenger transport: A comparison of the operational environmental performance", *Journal of Rail and Rapid Transit.,* vol. 217, no. 4, pp. 259-269, 2003.
[http://dx.doi.org/10.1243/095440903322712865]

[14] C. Lu, and P. Morrell, "Determination and applications of environmental costs at different sized airports: Aircraft noise and engine emissions", *Transportation,* vol. 33, pp. 45-61, 2006.
[http://dx.doi.org/10.1007/s11116-005-2300-y]

[15] G. Vossiniotis, and D. Assimacopoulos, "The marginal environmental costs of transport in Greece", *Glob. NEST J.,* vol. 1, no. 2, pp. 77-89, 1999.

[16] X. Wang, and L. Sanders, "Energy consumption and carbon footprint of high-speed rail projects: Using CAHSR and FHSR as examples",

Journal of Rail and Rapid Transit., vol. 0, pp. 1-10, 2011.

[17] E. Quinet, "Evaluation of environmental impacts", In: D.A. Hensher, and K.J. Button, Eds., *Handbook of transport and the environment.,* Elsevier Ltd.: Oxford, UK, 2003, pp. 357-373.
[http://dx.doi.org/10.1108/9781786359513-019]

[18] M.L. Plummer, "Assessing benefit transfer for the valuation of ecosystem services", *Front. Ecol. Environ,* vol. 7, no. 1, pp. 38-45, 2009.
[http://dx.doi.org/10.1890/080091]

[19] S.L. Dhingra, K.V. Rao, and V.M. Tom, "Environmental impact assessment for sustainable transport", In: D.A. Hensher, and K.J. Button, Eds., *Handbook of transport and the environment.,* Elsevier Ltd.: Oxford, UK, 2003, pp. 309-329.

[20] W.M. De Jong, "Cost-effective use of evaluation models: An empirical 17cross-national investigation", *Int. J. Technol. Manag.,* vol. 19, no. 3, pp. 368-383, 2000.
[http://dx.doi.org/10.1504/IJTM.2000.002821]

[21] P. Nijkamp, B. Ubbels, and E. Verhoef, "Transport investment appraisals and the environment", In: D.A. Hensher, and K.J. Button, Eds., *Handbook of transport and the environment.,* Elsevier Ltd.: Oxford, UK, 2003, pp. 333-355.
[http://dx.doi.org/10.1108/9781786359513-018]

[22] L. Tyrväinen, "Economic valuation of urban forest benefits in Finland", *J. Environ. Manage.,* vol. 62, no. 1, pp. 75-92, 2001.
[http://dx.doi.org/10.1006/jema.2001.0421] [PMID: 11400466]

[23] E. Beukers, L. Bertolini, and M. Te Brömmelstroet, "Why Cost Benefit Analysis is perceived as a problematic tool for assessment of transport plans: A process perspective", *Transp. Res. Part A Policy Pract.,* vol. 46, no. 1, pp. 68-78, 2012.
[http://dx.doi.org/10.1016/j.tra.2011.09.004]

[24] P. DeCorla-Souza, D.B. Lee, M. Sullivan, and D. Timothy, "A framework for benefit-cost evaluation of a typical highway concession proposal", *Transportation Research Board 94th Annual Meeting.,* 2015

[25] M. Greenstone, E. Kopits, and A. Wolverton, "Developing a social cost of carbon for US regulatory analysis: A methodology and interpretation", *Rev. Environ. Econ. Policy,* vol. 7, no. 1, pp. 23-46, 2013.
[http://dx.doi.org/10.1093/reep/res015]

[26] P. Decorla-Souza, J. Everett, B. Gardner, and M. Culp, "Total cost analysis: An alternative to benefit-cost analysis in evaluating transportation alternatives", *Trans.,* vol. 24, no. 2, pp. 107-123, 1997.
[http://dx.doi.org/10.1023/A:1004949400677]

[27] B. Feizizadeh, and T. Blaschke, "GIS-multicriteria decision analysis for landslide susceptibility mapping: Comparing three methods for the Urmia lake basin, Iran", *Nat. Hazards,* vol. 65, no. 3, pp. 2105-2128, 2013.
[http://dx.doi.org/10.1007/s11069-012-0463-3]

[28] B. Feizizadeh, P. Jankowski, and T. Blaschke, "A GIS based spatially-explicit sensitivity and uncertainty analysis approach for multi-criteria decision analysis", *Comput. Geosci.,* vol. 64, pp. 81-95, 2014.
[http://dx.doi.org/10.1016/j.cageo.2013.11.009] [PMID: 25843987]

[29] P.K. Paul, and J. Ganguly, "Green computing: The emerging tool of interdisciplinary environmental sciences-problems and prospects in Indian scenario", *Int. J. Phar. Bio. Res.,* vol. 5, no. 04, pp. 210-214, 2013.

[30] J. Malczewski, "GIS-based multicriteria decision analysis: A survey of the literature", *Int. J. Geogr. Inf. Sci.,* vol. 20, no. 7, pp. 703-726, 2006.
[http://dx.doi.org/10.1080/13658810600661508]

[31] K. Lidouh, "On the motivation behind MCDA and GIS integration", *Int. J. Mul. Dec. Mak.,* vol. 73-74, no. 3(2-3), pp. 101-113, 2013.
[http://dx.doi.org/10.1504/IJMCDM.2013.053727]

[32] R. Costanza, and H.E. Daly, "Natural capital and sustainable development", *Conserv. Biol.,* vol. 6, no. 1, pp. 37-46, 1992.
[http://dx.doi.org/10.1046/j.1523-1739.1992.610037.x]

[33] R. Costanza, "Social goals and the valuation of ecosystem services", *Ecosystems (N. Y.),* vol. 3, no. 1, pp. 4-10, 2000.
[http://dx.doi.org/10.1007/s100210000002]

[34] R. Costanza, R. d'Arge, R. Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, V.R. O'Neill, J. Paruelo, G.R. Raskin, P. Sutton, and M. Belt, "The value of the world's ecosystem services and natural capital", *Nature,* vol. 387, pp. 253-260, 1997.
[http://dx.doi.org/10.1038/387253a0]

[35] G. Bingham, R. Bishop, M. Brody, D. Bromley, E.T. Clark, W. Cooper, R. Costanza, T. Hale, G. Hayden, and S. Kellert, "Issues in ecosystem valuation: improving information for decision making", *Ecol. Econ.,* vol. 14, no. 2, pp. 73-90, 1995.
[http://dx.doi.org/10.1016/0921-8009(95)00021-Z]

[36] S.R. Groot, A.M. Wilson, and M.J. Boumans, "A typology for the classification, description, and valuation of ecosystem functions, goods, and services", *Ecol. Econ.,* vol. 41, pp. 393-408, 2002.
[http://dx.doi.org/10.1016/S0921-8009(02)00089-7]

[37] M. Zhao, R.J. Johnston, and E.T. Schultz, "What to value and how? Ecological indicator choices in stated preference valuation", *Environ. Resour. Econ.,* vol. 56, no. 1, pp. 3-25, 2013.
[http://dx.doi.org/10.1007/s10640-013-9636-0]

[38] M.A. Wilson, and J.P. Hoehn, "Valuing environmental goods and services using benefit transfer: The state-of-the art and science", *Ecol. Econ.,* vol. 60, no. 2, pp. 335-342, 2006.
[http://dx.doi.org/10.1016/j.ecolecon.2006.08.015]

[39] Herrera Environmental Consultants Inc., Northern Economics Inc. and Spatial Informatics Group LLC. Ecological Economic Evaluation, Department of Natural Resources and Parks, Maury Island, King County, Washington. Seattle, WA., 2004, p. 61.

[40] H. Kim, D.F. Wunneburger, E.M. Bright, J. Huang, C. Morgan, and M. Neuman, *Texas urban triangle: Pilot study to implement a spatial decision support system for sustainable mobility.,* Transportation Institute: College Station, Texas, TX, 2011, p. 42.

[41] H. Kim, D.F. Wunneburger, and M. Neuman, "Optimizing a high-speed rail route using sustainability indicators and a raster-based GIS modeling process", *Technical Paper Unpublished,* 2011.