Prioritization of Infrastructure Projects: A Decision Support Framework

Darwin Marcelo, Cledan Mandri-Perrott, Schuyler House, Jordan Schwartz
World Bank PPP Group

27 August 2015[1]

Key words: prioritization, infrastructure, decision support, multi-criteria analysis, CBA, PCA

Abstract

Governments worldwide must inevitably establish priorities and decide how to allocate limited resources for public investment. This challenge is particularly pronounced in the case of infrastructure development, where huge financing gaps have been projected for the following decades. As such, governments are faced with both systematically prioritizing and selecting proposed infrastructure projects and expanding their budget space via alternative sources of finance. Scholarly prescriptions for infrastructure decision support are not always reconcilable with actual practice, given varying degrees of technical analytical capacity and data quality at the government level. The challenge, then, is to identify alternative tools for use in different contexts, in ways that are most likely to be helpful to policy makers and governments to support investment decisions. Such decision frameworks must, however, meet tests of effectiveness, efficiency, and public legitimacy in project prioritization and, as appropriate, ensure long term asset sustainability and, where applicable, bankability for private investment.

This paper responds to the first demand, namely prioritizing infrastructure projects through systematic, evidence-based analysis. Our basic premise is the recognition that most infrastructure policy-making contexts demand a reconciliation of highly technical and objective economic policy analysis on the one hand, and more political and practice-based inputs, on the other, all within the resource means of governments. We start with a review of common approaches and current practices in infrastructure prioritization. Next, we introduce a multi-criteria decision support tool, the Infrastructure Prioritization Framework (IPF), for governments to assess the relative importance of projects based on social-environmental and financial-economic and indices. The tool is structured to take advantage of available data; accommodate variant criteria and objectives; attend to social and environmental factors; and provide an intuitive platform and graphical interface for displaying results. The resulting analysis is considered against the sector budget and/or national fiscal constraints. A key strength of IPF

1. This paper is still subject to World Bank Group internal review.

is that it may be flexibly applied. The framework can incorporate elements from other common methods, such as expert judgment and cost-benefit analysis. Thereafter, we present lessons and findings from two pilot applications of IPF in Vietnam and Panama. We show how IPF is ultimately meant for use as an input to infrastructure decision-making rather than a definitive ranking that leaves no room for discussion.

Introduction

Infrastructure services, widely deemed critical to economic development, trade connectivity, social welfare, and public health, are underprovided in many regions and are typically featured in national development plans. While national and sub-national agencies and constituencies may identify and propose a wide array of required infrastructure projects, governments usually have insufficient financial resources to implement the full suite of proposals. As such, planners are faced with difficult decisions about which projects to select for implementation within the confines of available funding and or fiscal space.

Global estimates of infrastructure investments required to support economic growth and human development lie in the range of US$65-70 trillion by 2030 (OECD, 2006), while the estimated pool of available funds is limited to approximately US$45 trillion (B20, 2014). Leading up to 2020, an estimated US$1-1.5 trillion will be required each year to meet growth targets in emerging and developing economies (World Bank). These needs are particularly intensified for developing regions, as the changing landscape of investment and international aid over the past fifteen years has also reduced the availability of donor funds and shifted the locus of infrastructure decision-making from donors to home governments.

The clear gap in infrastructure funding means that governments will inevitably be faced with paring down the portfolios of planned infrastructure projects, expanding the pool of resources to fund infrastructure, or both. This implies grappling with challenging decisions regarding the relative exigency, efficiency, and effectiveness of investments in the short and medium-terms, and actively pursuing alternative sources of finance. These demands require improved decision-support tools, analyses, and information in order to support and justify decisions. Further, there is a need for improved information to appropriately manage risk and attract private investment.

Making and supporting these decisions in a manner that is sufficiently rigorous and legitimate, yet practically applicable and affordable, relies on a fundamental level of information quality and availability and a clear set of criteria upon which to base choices. Finding this balance also requires an analytical framework that is sophisticated enough to accommodate multiple considerations yet parsimonious enough to remain administratively feasible and affordable.

Decision processes surrounding infrastructure investments are numerous and are usually done at different levels of government across multiple time periods, with linked sub-processes at the pre-decisional, decisional, and implementation stages. The components of broader decision frameworks, which cover the full collection of processes from problem identification to implementation, may vary according to differing political and administrative processes, rules, and institutional structures. Common to broader decision frameworks, however, is the comparison of alternative investments, wherein decision support tools may be applied.

Existing planning literature attends to the relative strengths of decision support tools such as cost-benefit analysis (CBA) and multi-criteria decision analysis (MCDA), which remain prominent to investment and infrastructure policy decision-making. Nevertheless, systematic infrastructure prioritization is largely ad hoc, politically determined, or contingent on negotiated, and / or subjective assessments. This suggests that the practical aspects of decision support are as important as technical sophistication. Robust and objective methodologies can help alleviate pervasive problems such as poor or reactive planning, regressive investments, over-commitment, information asymmetries, corruption, and high degrees of political interference. Furthermore, there is growing emphasis on the importance of social and environmental factors and non-economic policy objectives to supplement traditional economic and financial considerations. Infrastructure decisions must account for collective societal goals and local context as important determinants, while structuring those considerations to minimize particularism in infrastructure policy.

In response to these observed needs, the World Bank developed an innovative and adaptable Infrastructure Prioritization Framework (IPF) to support governments in prioritizing infrastructure investments. This paper builds upon the early conceptualization and first application of the approach, which laid the groundwork for the IPF (Mandri-Perrott, Marcelo, and Haddon 2014).

Whilst a number of available tools may be considered to support investment decisions, this tool is differentiated in four ways. First, it systematically incorporates national policy goals, social and environmental sustainability considerations, and long-term development aims alongside financial and economic indicators. Second, it is predicated on parsimony and pragmatism. Third, as project scores are plotted on a two-dimensional matrix that also references available funding, it provides decision-makers with an intuitive, graphical interface upon which to compare alternative investments and investment scenarios. And fourth, it opens space for policy debate to shape the configuration of the framework and influence the selection of infrastructure projects without affecting the robustness of the tool.

In summary, under intensifying budget pressure and the drive for efficiency, governments need to better justify and legitimize infrastructure investment decisions through systematic, evidence-based analysis. Whereas the requirements of some decision support methods are technically cumbersome or so costly as to become prohibitive for wide application, this Infrastructure Prioritization Framework (IPF) provides a middle ground, balancing the requirements of precision and pragmatism.

This paper discusses the IPF and its relevance to broader investment decision frameworks as well as its relationship to other decision support methodologies, including CBA and MCDM. The tool's technical aspects are discussed, along with initial lessons gleaned from pilot applications in Vietnam and Panama. The paper concludes with recommendations related to refining the tool for general use and further exploring its applicability to identifying opportunities for private investment.

Qualifying Prioritization

Recent attention to infrastructure investment prioritization is grounded on government-side demands for evidence, comprehensiveness, value, and legitimacy in infrastructure decision-making. The **rationale** as to *why* there is demand for systematic infrastructure prioritization. Our decision support framework is also shaped by a set of desired characteristics for a policy-oriented decision process, which we describe as **principles** of prioritization. These describe the aspirations for *how* prioritization should be carried out. In this section, we discuss demand for and merits of prioritization, reflecting on attention to and debates over evidence-based infrastructure decision-making. We follow with a brief discussion of the principles of prioritization as they apply to a decision framework such as the proposed IPF.

In late 2014, the Group of Twenty (G20) Development Working Group (DWG) requested that MDBs take steps to ensure that project preparation facilities (PPFs) collaborate to support governments in infrastructure prioritization. Their draft 'MDB's Common Approach to Prioritizing Infrastructure with their Partner Countries' promotes a harmonized approach to project preparation, including use of standardized environmental and social safeguards policies as well as common approaches to assessing potential projects, including application of ex-ante cost-benefit analysis and assessments of project executability, development effectiveness, and greenhouse emissions (G20 DWG, MDB's Common Approach to Prioritizing Infrastructure with their Partner Countries, 2015).

Prioritization is further validated as a proposed precursor to identifying opportunities for private sector investment. The 2014 World Economic Forum (WEF) Investment Blueprint proposes that, "a strategic vision for infrastructure should be the first step for a government to maximize investor financing in infrastructure. This vision should describe the government's medium to long-term infrastructure goals, along with the underlying economic and social rationale, and enable the prioritization of a pipeline of projects in the shorter term... It ensures that a government makes the most of existing infrastructure, and that new infrastructure addresses clearly defined needs and is appropriately prioritized" (WEF, 2014 p. 19). An earlier WEF report, 'Strategic Infrastructure: Steps to Prioritise and Deliver Infrastructure Efficiently and Effectively' (2012), proposes that governments must understand the infrastructure deficiencies; formulate a long-term vision and medium-term goals; and decide which potential solutions create the greatest impact in terms of economic growth, while considering social and environmental issues.

The points attend to a major difficulty associated with infrastructure prioritization: shortfalls in the assessment of current infrastructure deficiencies and needs. The list of projects presented for consideration and selection do not necessarily emerge from comprehensive policy analysis or extensive planning, which could otherwise afford policy-makers useful guidance on which projects to select (or which sectors to focus on, in particular) based on the prioritization of policy problems. Rather, projects are often proposed in a somewhat ad hoc manner, requiring simultaneous consideration of policy goals (i.e., problem analysis) and the merits of projects as they relate to addressing those goals.

The prioritization framework is not intended to altogether replace traditional planning or policy analysis, which remain critical to identifying policy problems, assessing issues' relative importance or urgency, and selecting amongst alternative solutions for attending to them. These remain important pre-prioritization activities. Rather, the framework helps government prioritize projects within a sector from amongst a proposed set based on existing problem assessment, policy analysis, or pre-feasibility study.

Rationale for Prioritization: Demands for a Systematic Multi-criteria Approach

The desirability of alternative prioritization approaches is predicated on an ability to meet demands for evidence, comprehensiveness, value, efficiency, and immediacy. Essentially, a prioritization initiative asks, "What projects are most important in the short- and medium-terms?" The determination of importance, however, is locally differentiated, value-laden, and reliant on preferences. Further, selection depends on a government's particular policy goals and the severity of problems it is challenged to solve.

An important underpinning for prioritization is appropriate ***evidence*** to increase rational policy decision-making. The rise of evidence-based policy analysis (EPBA) can be traced to the UK government of the 1990s, which rigorously pursued approaches to policy analysis in cross-departmental teams working on complex issues. It is no surprise, then, that the UK also institutionalized 'Value for Money' analysis – a common, albeit heterogeneous, approach to infrastructure investment decision-making today. EBPA is believed to be important in answering key questions like: What options will 'deliver the goods'? How can programs provide greater 'value for money'? How can program managers achieve 'outcomes'? and, 'What works?' (Davies, Nutley and Smith 2000; Reid 2003).

Expanding beyond purely technical research and analysis (i.e., 'science'), a line of thought that has recently gained traction suggests that two other types of evidence are particularly relevant to modern policy making: practice (professional program management experience) and political judgment (Head, 2010). Scientific knowledge is garnered from systematic analysis of the causal relationships that explain conditions and trends. Practical implementation knowledge, on the other hand, is derived from the 'practical wisdom' of professionals in their communities of practice. And political knowledge relates to making contextual judgments about "the possible and the desirable" (Head 2010, p. 80). An increased appreciation of the multiple *bases of knowledge,* then, is the next iteration of EBPA.

An appreciation of the 'multiple lenses' or facets of evidence links easily to the second rationale of prioritization, ***comprehensiveness***. Comprehensiveness implies making decisions based on (a) consideration of a sufficiently extensive set of projects, and (b) a sufficiently wide set of criteria. While the criteria need not be exhaustive, it should nevertheless account for the key facets of infrastructure policy goal attainment. Direct attendance to the multiple goals that are embedded in any given policy or strategy (e.g., fiscal prudence, equity, sector-specific gains, etc.) supports the use of multiple criteria. Furthermore, comprehensiveness is a response to common criticisms that infrastructure investment decision-making is ad hoc, politically driven, or characterized by 'cherry-picking', 'easy wins', or 'creaming' rather than thoughtful, holistic analysis.

Decisions about infrastructure investment are inherently integrated with considerations of ***effectiveness*** and ***value***, the third and fourth logical pillars of prioritization. The selection and structuring of a prioritization methodology are intertwined with decisions about how to define effectiveness in infrastructure policy, particularly via the selection of criteria. The logic of effectiveness refers to the use of a methodology to most effectively attain a set of policy goals related to infrastructure development, which may include economic growth, sectorial goals, environmental sustainability, or human development. And the logic of value speaks to the core underpinning of many established prioritization methods – that of creating public value at the least cost to individuals in a polity.

The fifth logic of prioritization is ***legitimacy***. Prioritization is undertaken to afford public legitimacy to government infrastructure decisions and the organizations imposing them, particularly in democratic contexts, where public assent matters most. Legitimacy is typically founded on both inputs and outputs. Input legitimacy refers to the processes whereby public decisions are made and is a matter of design. To be legitimate with respect to input and design, the process of infrastructure selection should be transparent, fair, consensual and objective. As such, it relates to the logic of evidence. Output legitimacy, on the other hand, is determined by outcomes, and is a matter of an institution earning its relevance based on performance. As such, it is directly aligned with the logics of effectiveness and value.

While not the primary focus of this paper, a final parameter of interest, important to closing the infrastructure gap, is ***opportunity.*** This refers to opening new opportunities for funding infrastructure investments. As options for infrastructure finance expand beyond public resources and traditional bank lending (for example the use of capital markets), more attention is focused on creating conditions that increase the likelihood of institutional investment and direct private sector participation, for example, via Public Private Partnerships. The assemblage of well-planned project pipelines, which are prioritized in a legitimate and transparent fashion, will control political risks and improve project bankability.

Principles of Prioritization: Guiding the Process of Prioritization

In addition to the drivers of systematic prioritization, we have identified four primary decision support principles that suggest how prioritization should be done. These are accuracy, practicality, political feasibility, and suitability. The first, ***accuracy***, demands that methods of prioritization be sufficiently precise to afford meaningful comparisons amongst projects. This does not require extreme exactitude but suggests that thresholds of 'correctness' are required to ensure that the logic of evidence is attained and reliable.

The second two conditions – practicality and political feasibility – are quite clear-cut and underpinned by the common thread of feasibility. The first, ***practicality***, attends to the administrative feasibility of the prioritization process and deals with the institutional capacity, the cost and time limits of decision-making imposed on analysts, consultants, and decision-makers, and the availability and quality of information upon which decisions must be based. This, whilst seemingly trivial, is an important point, since many governments forego, rush through, or roughly approximate structured planning processes due to cost, staffing, or knowledge deficits. A critical facet of this principle is ***parsimony***; the use a minimum amount of relevant information.

The second principle, ***political feasibility***, accepts that prioritization cannot be so devoid of latitude that it is rendered completely inflexible or unresponsive to political factors. In other words, there is a balance to be struck between technical objectivity and political representation and accountability.

Lastly, the principle of ***suitability*** demands that the criteria selected for decision-making be appropriate to judge the relative desirability of projects. The suitability of decision criteria is dependent on policy goals, general norms of governance, and the availability of information associated with a potential criterion. There are several examples of infrastructure development principles that may be helpful to guide the appropriate selection of decision criteria. These are summarized in Appendix 1.

In summary, most infrastructure policy-making contexts demand a reconciliation of highly technical and objective economic policy analysis on the one hand, and more political and practice-based inputs, on the other, all within the resource means of governments.

Infrastructure Investment Decision Support Approaches

Scholarly prescriptions for and experiments with infrastructure decision support are not always reconcilable with actual practice. Academic works typically focus on highly precise, sophisticated approaches to decision analysis, wherein information availability is high and analytical resources plenty. In practice, there are varying degrees of technical analytical capacity and data quality, as well as different degrees of technical analyses by policy makers. The challenge, then, is to identify alternative tools for use in different contexts, in ways that are most likely to be helpful to policy makers and governments to support their investment decisions. In this section, we discuss the prevailing approach to infrastructure decision support –cost benefit analysis– as well as multi-criteria decision methods.

Cost-Benefit Analysis and Value for Money

Perhaps the most familiar and widely accepted method of project comparison in infrastructure is Cost-Benefit Analysis (CBA). The practical development of Cost-Benefit Analysis started in the 1930s in the United States, largely for public investment planning at the federal level, and has remained a staple of policy analysis since (Zerbe & Bellas, 2006). This is largely because CBA, whilst complex with respect to inputs, is a fairly straightforward concept, allowing comparison of projects based on a single metric, monetized value.

CBA essentially totals all costs and benefits of a project over its lifetime and discounts future flows to calculate present values. The (discounted) present values of costs and benefits are compared, either by use of net present value (ranking projects by highest NPV) or the benefit-to-cost ratio (BCR) (used to reflect efficient use of inputs for outputs). A fundamental principle and key strength of CBA is that it allows decision makers to intuitively compare diverse alternatives based on a single indicator, the project's net value (Thomopoulos, Grant-Muller, & Tight, 2009).

CBA can be applied in traditional financial terms to assess alternative projects for a company, but may also be extended for public expenditure analysis by considering the full suite of (monetary and non-monetary) costs and benefits to all of society. In Societal Cost-Benefit Analysis (SCBA), prioritization is based on selecting projects that maximize the net present values for society overall, without regard to the particular 'winners' and 'losers' of alternative projects.

These assessments require the quantification and monetization of *all* positive and negative effects (costs and benefits), which demands full, or near-full information about projects. But many costs and benefits are difficult to monetize. For example, valuing lives saved, added convenience, or averted pollution requires making many assumptions. A common criticism of SCBA is that social and environmental costs are often underestimated, relegating key social and environmental issues to positions of lesser importance, particularly if their monetized impacts are relatively low compared to other economic considerations. Further, CBA-based assessments of societal value do not typically consider distributional effects or issues of equity and social justice, which is a particular concern when investments are intended to close development gaps.

Beyond these debates, there is a set of practical and technical issues related to the mechanics of CBA. First, addressing intangible factors and strategic concerns is difficult with CBA. Common procedures to establish monetized values for some non-marketed factors (e.g., stated preference or hedonic pricing approaches) are not necessarily applied to all non-priced impacts (e.g., social cohesion) (Dodgson, UK, 2009). These problems expose a potential for optimism bias or cost underestimation (Cantarelli, Flyvbjerg, Molin, & Van Wee, 2010; Thomopoulos et al., 2009), and represent information gaps that can be detrimental to the analysis. A second issue relates to the selection of an appropriate discount rate. Many analyses assume a standard rate to be applied to a country and sector, which undoubtedly alleviates the burden of determination. However, it is also known that even slight alterations in such rate of return can have a significant effect on calculated benefit–cost ratios and net present values (Thomopoulos et al., 2009; Van Delft & Nijkamp, 1977).

Thus, while the optimizing principle underpinning CBA is elegant and useful for evaluating alternative projects' contributions to overall social welfare, it demands complete information about all possible alternatives and their relative tradeoffs and all constraints affecting the decision-making process (Van Delft & Nijkamp, 1977). This model does not hold where information gaps are significant.

Practically speaking, the relevant data for CBA may be unavailable, too expensive, or too difficult to collect or calculate on a regular basis, given a government's financial and technical resources for project preparation. Richardson (2000) for example, raises concerns about what he considers a dearth of 'practical intelligence in CBA, which translates to the loss of important iterative considerations that emerge via deliberation.

Notwithstanding these concerns, CBA remains an enormously useful base of evidence in situations where governments have the resources to successfully perform CBA, and where information availability is high. Further, Zerbe and Bellas

(2006) defend CBA by suggesting that critics fail to (1) offer viable substitutes, except for vague references to politics; (2) address whether CBA is useful or how it might be improved; or (3) test criticisms empirically.

Other attempts are made to extract particular costs and benefits that are linked to key priority goals from the overall CBA in order to focus more specifically on partial impacts. For example, Berechman and Paaswell (2005) utilize a modified CBA to assess New York City transport projects, separating out the estimations of transportation benefits and costs from overall economic development benefits and costs. The approach was employed to deal with the fact that economic costs and benefits were much higher than transportation-specific costs and benefits (e.g., time saved) so as to render the latter completely insignificant to the overall assessment, despite the importance of transport-specific goals to policy makers.

'Value for Money' (VfM) refers to a broad range of approaches used for project appraisal, many of which wholly or partially employ CBA. VfM analyses may be qualitative or quantitative, but generally compare projected project outcomes with the resources employed to attain them. In this way, VfM is useful as an assessment of the relative efficiency of alternative means of reaching the same ends. That said, VfM analyses are widely disparate with respect to the inputs used and level of quantification. Some are inclusive of full CBA or cost-effectiveness analysis[2] as key inputs, whereas others may qualitatively discuss the differences between alternatives at the same cost, or the differences in base costs for alternative approaches to addressing the same policy problem.

Multi-Criteria Decision Analysis

Another set of approaches that has gained traction in recent years is the multi-criteria analysis. Multi-criteria decision approaches/methods (MCDA/M) aim to formalize the inclusion of non-monetary and/or qualitative factors into decision analysis. In some cases, simple multi-criteria methods may be useful alternatives to CBA when information problems are common or analytical resources limited. In others, MCDMs are used to extend CBA. This turn in infrastructure development and planning is a response to concerns about over-specialization, the potential to demote critical social and environmental factors in CBA, the need to reconcile multiple infrastructure-related policy goals, and practical limitations on information.

Planning has traditionally been concerned with facet planning, focusing limitedly on sets of socio-economic merits of alternatives without taking into account wider societal interests or coordination with other planning issues (van Delft & Nijkamp, 1997). The past ten years have witnessed a shift to multi-criteria analyses and multi-objective decision models to rectify these concerns, as well as to directly make use of political knowledge and judgment and bring non-financial concerns to the forefront of decision-making.

On the practical side, increased use of MCDA reflects attempts to work around time restrictions; the availability and quality of data to support analysis; the analytical skills of those providing analysis; and organizational requirements

2. Cost effectiveness analysis relates to evaluating alternative operational means of attaining the same goals, but is less applicable to differentiating between the relative attractiveness of different types of projects.

(DCLG, 2009). This brings up an important point, namely that the appropriateness of alternative decision approaches depends on the decision situation at hand.

Multi-criteria methods may be most appropriate when either non-monetized costs or benefits are key decision factors, when information is incomplete, or when institutional capacity is limited. If, on the other hand, information is fully available and the policy goal at hand is maximization of societal benefit (in monetizable terms), then optimizing models are useful. For the principle of optimization to be the basis of a decision, however, it must be assumed that all measures of performance related to the objectives of a proposal can be expressed in a common scale of measurement, as in CBA (Rogers & Duffy, 2012).

In cases where information is incomplete or non-reducible to a common metric, or where multiple policy goals are at stake, Beinat and Nijkamp suggest that the "compromise principle" is more appropriate than the optimizing principle. This presumes a variety of decision criteria and states that solutions must reflect a compromise between multiple priorities, while discrepancies between outcomes and goals are traded off by use of preference weights (Beinat & Nijkamp, 1998).

This has been particularly true in decision support for transport infrastructure (Tsamboulas, 2007), where multi-criteria analyses seek acceptable compromise solutions between diverse objectives of various stakeholders. As Tsamboulas argues, infrastructure projects often have a host of different objectives and come along with complex issues arising from the project, which "question the appropriateness of the one-dimensional evaluation methods" (p. 22).

MCDA Methods

A number of MCDA methods are used in infrastructure decision-making (though none as extensively as CBA). Among the most commonly used are factor rating methods; multi-objective mathematical models; Analytic Hierarchy Process (AHP) (Saaty 1980); vectorial methods such as REGIME (Hinloopen et al. 1983, Nijkamp et al. 1993) and the ELECTRE family of methods (Roy 1985, Schaerlig 1985, Szidarovsky 1986); and multi-attribute utility theory (MAUT) methods (Churchman, et al. 1957, Beuthe 1996, Schaerlig 1985).

In terms of intuition and transparency, additive models, which sum criteria with assigned weights, are favorable since they are "able to cope with almost any problem" (Tsamboulas, 2007) and are easy to understand. While some additive MCDAs are contingent on wholly quantitative and statistical inputs, others, such as the Analytic Hierarchy Process (AHP) and MACBETH, focus explicitly on expert value judgment to assign values, to some variables and criteria weights.

De Montis, et al., extensively compare alternative decision methods for application to sustainable development, contrasting the approaches across three major categories (De Montis, De Toro, Droste-Franke, Omann, & Stagl, 2004):

(1) Operational components: Criteria traits (interdependence, completeness), weights (transparency of process, type, meaning), and solution-finding procedures;

(2) Applicability in the user context: Project constraints (cost, time) and structure of the problem-solving process (participation, problem structuring, tool for learning, transparency, mode of communication); and

(3) Applicability for problem structure: Indicator characteristics (geographical scale, micro-macro link, method combinations), data solution (types of possible data, risks / uncertainties, data processing requirements).

They find that, in selecting amongst methods, important considerations include the ability to deal with complex situations (criteria, different scales and aspects, type of data, uncertainties); possibility to involve more than one decision-maker (stakeholder participation, communication, and transparency); and engagement of stakeholders in order to increase knowledge and change opinions on problem structuring and alternatives to addressing problems. All of the MCDAs demonstrated the ability to deal with complex situations, though each had highly specific yet minor methodological weaknesses. But different methods were markedly better or worse with respect to aiding learning, allowing participation, and being intuitively understandable to users.

Criteria Selection and Weighting in MCDA

Two critical issues in the application of MCDM, specifically in additive models, are the selection of criteria by which alternatives will be assessed, and the weighting of criteria themselves. The simplest mode of weighting is equality, wherein all criteria are equally considered. For example, the Cities Development Initiative for Asia equally weights (.20) project purpose, public response, environmental impact, socio-economic impact, and feasibility of implementation in its toolkit for assessing public projects (CDIA, 2010).

An alternative method is negotiated expert guidance, wherein a panel of decision-makers decides weights based on experience and their basket of interests. A formalized, facilitated method of expert-based criteria weighting is the Analytic Hierarchy Process (AHP), developed by Saaty (1980). It is principally a method designed to convert subjective assessments of the relative importance of weights, and has therefore potential use in dealing with issues of equity. The key input for AHP is the decision makers' responses to a series of pairwise comparisons of various alternative options. Responses may be either in a verbal or in a numerical format and, in either case, are coded on a nine-point intensity scale for analysis. Responses can be used to derive both weights for criteria and performance scores for alternatives. AHP is used extensively in South Korea for infrastructure planning.

But AHP has also had its detractors (French, 1988; Goodwin & Wright, 1998). For example, the 1–9 scale used may be 'user friendly', but not all pairwise comparisons may be consistent, as there is no capability for comparisons requiring a scale with more options. Also, there is a methodological problem of "rank reversal", which occurs when an additional new option becomes available that results in the reversal of the initial alternatives' ranking. There have been attempts to overcome this with various improvements whilst retaining the underlying strengths of the approach (e.g. Wang & Elhag, 2006), but the rank reversal is a discomfiting phenomenon. Nevertheless, well-known adaptations with corresponding software applications include REMBRANDT (Lootsma, 1992), MACBETH (Bana e Costa & Vansnick, 1997), Expert Choice (Jayaswal, Patton, & Forman, 2007) or HIPRE (Hamalainen & Lauri, 1995).

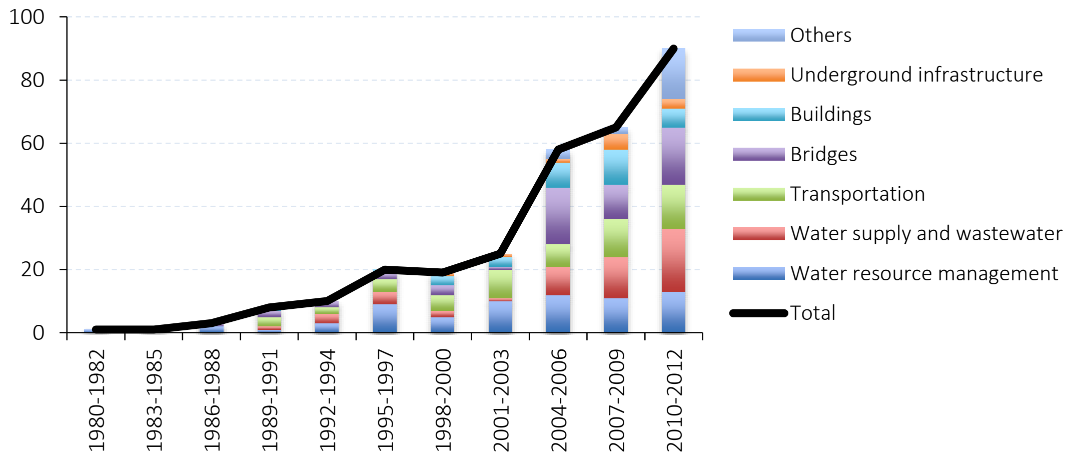
Before expositing the IPF's mode of criteria weighting, we first briefly review decision-support methods currently in use.

Current Practices in Infrastructure Prioritization: Approaches in Use

With respect to prioritizing and ranking infrastructure projects, the most widespread applications of multi-criteria methods have been in the transport and water sectors. A wide number of methods and their combinations, including CBA, AHP, MAUT, PROMETHEE, TOPSIS, and ELECTRE have been used in comparing road and bridge projects, water resource management options, and water supply systems. MCDM has also been used to make decisions regarding urban development and power.

Through an extensive review of journal articles focused on MDCM and infrastructure decision-making between 1980 and 2012, Kabir, Sadiq, and Tesfamariam find that both infrastructure management studies and the application of multi-criteria approaches to infrastructure decision-making are on the rise. The number of infrastructure management studies has risen from single digits in the 1980s to hundreds towards the end of the 2000s (Kabir, Sadiq, & Tesfamariam, 2014). Whilst these are not necessarily directly correlated to MCDM methods in use, they indicate a sharp upswing in interest in MCDA for infrastructure. Of these 300 studies, however, only a subset of approximately 40 expressly applied MCDA to choose amongst alternative strategies for infrastructure maintenance and development (e.g., site selection, project architectures alternatives, technology selection), but with more limited scopes than sector-wide project privatization. Only 14 attended broadly to ranking projects (as opposed to selecting amongst mutually exclusive alternatives), and only ten ranked projects across a sector. This suggests that the space for developing sectorial infrastructure prioritization strategies remains wide open.

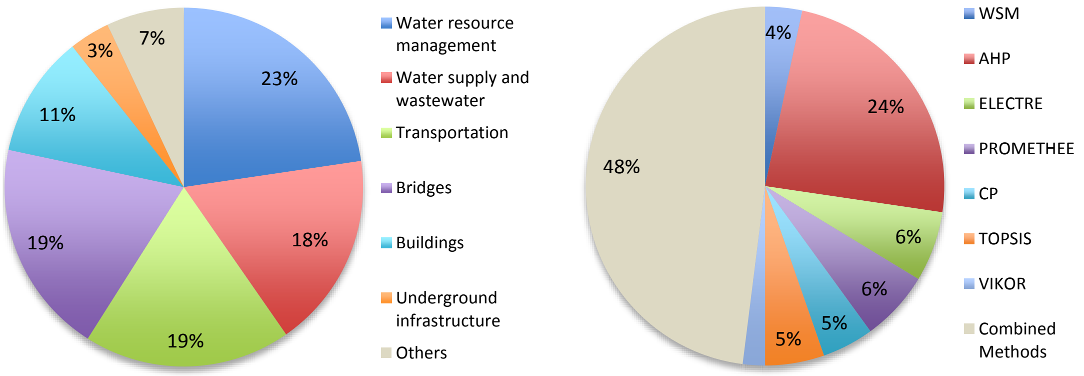
Figure 1. Number of studies published related to MCDM in infrastructure management, 1980-2012 (Kabir, et al, 2014)



Source: Authors' figure, drawn from (Kabir, et al, 2014) data

The highest applications of MDCM are in the water and transport sectors, which combined, account for over 70% of the 330 papers discovered in the authors' extensive literature review (Figure 1). Further, AHP represents the most common approach to factor weighting.

Figure 2. Distribution of articles published based on MCDM applied to infrastructure management, by sector (a) and method (b) (Kabir et al, 2014)



Source: Authors' figure, drawn from (Kabir, et al, 2014) data

The review undertaken also found a large number of studies (48%) wherein multiple MCDA methods were applied comparatively, or to a lesser extent, combined, suggesting a high degree of experimentation to find methods that both support attendance to wider sets of criteria, whilst also accounting for practical aspects of data availability, time, cost, and complexity.

Very few have systematically combined MCDA with CBA, with examples primarily limited to the transport sector (Barfod, Salling, & Leleur, 2011; Salling, Leleur, & Jensen, 2007). The COSIMA software and decision model developed by Salling, et al (2007), for example, extends conventional CBA by including "missing" decision criteria that address issues that are difficult to assess by conventional CBA but are nevertheless valuable to decision support. The resultant expression of "total value" based on both parts is conceptually powerful, but the analysis required to come to the value is complex.

Select Government Approaches to Prioritization

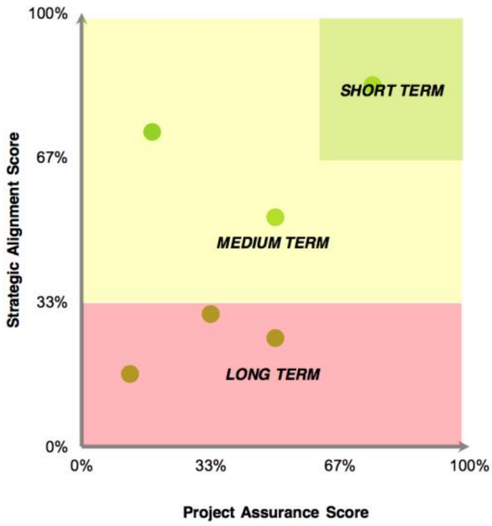
Cost-benefit analysis is used widely across the US, New Zealand, UK, Australia, Singapore, Chile, and a number of other countries to assess and prioritize alternative infrastructure projects. The UK and New Zealand's guidelines on application of CBA are widely cited and used for application across the world. The UK, Australia, and many US states have also recently published notes, guidelines, and papers on the application of multi-criteria analysis, expanding the 'Value for Money' discourse to suggest more structured ways to employ MCDA.

Infrastructure Australia, a federal statutory board established under the Department Infrastructure and Transport, is tasked with planning and coordination cross-state road and public transport projects. In order to prioritize proposed projects, the agency applies a two-state process of project "profiling" and "appraisal." Profiling, as a first filter, qualitatively assesses the compatibility of proposed initiatives to strategic infrastructure priorities (i.e., key issues and problems) along a scale of "highly beneficial" to "highly detrimental" with respect to stated policy goals. Thereafter, CBA is employed as the primary tool for project appraisal, including estimates of Wider Economic Benefits (WEBs), such as those related to agglomeration. Advice on calculating WEB is based on the UK government's Transport Analysis Guidance (2014). Following CBA, the process requires that assessors qualitatively discuss benefits and costs that generally cannot be monetized (e.g., visual / landscape, social cohesion, heritage or cultural impacts) and thereafter classify each non-monetized item along a spectrum from "highly beneficial" to "highly detrimental." These two inputs are used to inform selection, which is based on expert review and consensus of a panel of eleven members.

Australia's **State of New South Wales** has developed a Major Projects Assurance Framework inclusive of an additive multi-criteria model. The framework assesses proposed projects at several stages of project planning and prioritizes projects according to assessed performance along two dimensions. Performance with respect to strategic objectives is measured by alignment with NSW's investment themes, value for money, the project's ability to afford citizens "a better life" (by reducing cost of living and improving livability), and economic efficiency. Performance with respect to the 'Infrastructure NSW Project Assurance' objective is based on sufficiency of the analysis, cost-benefit analysis, professional assessments of the suitability of project management, and risk assessment. CBA is augmented by professional review and qualitative inputs.

Qualitative assessments are numerically scored on a scale from 3 (strongly positive) to -3 (strongly negative) and added using a system of weights decided by a panel of professionals within Infrastructure NSW. Similar to the proposed IPF, projects are plotted onto a two-dimensional plane, with axes defined by the Strategic Objective and Project Assurance Objective scores. Projects are classified as short-, medium-, and long-term, depending on their collective scores (Figure 3).

Figure 3. Infrastructure NSW conceptual project mapping



Source: Government of New South Wales (2014)

Additive models based on expert- or agency-decided criteria weights have also been applied across Europe to transport projects, as well as to prioritize infrastructure projects in developing countries.

The **UK National Investment Plan**, managed by the Treasury's infrastructure unit, specifies an Infrastructure Top 40 list of projects marked for priority government support and investment. These projects are grouped by sector, but not listed in order of importance. Projects are chosen by the following criteria:

(1) Strategic importance (SI): significant contribution towards an objective;

(2) Capital value (CV): significant capital value;

(3) Regional priority (RP): high strategic importance or capital value in a region;

(4) Demonstrator (D): innovative or novel and could improve future delivery;

(5) Unlocking investment (UI): enables significant private sector investment (HM Treasury, 2014).

South Korea, on the other hand, employs AHP extensively to prioritize a large number of projects across sectors, under an extensive evaluation framework, which determines weights via the AHP structured expert pairwise technique. AHP has also been used to rank projects sub-sectorially (primarily in transport) in the US, Indonesia, China, Turkey, India, and Palestine, but is not (to our knowledge) used as a national prioritization framework outside of Korea.

The Infrastructure Prioritization Framework

The Infrastructure Prioritization Framework (IPF) is a quantitative approach that synthetizes financial, economic, social, and environmental indicators and considers these alongside the public budget constraint. The results are displayed in a graphical interface to provide infrastructure investment decision-makers and planners with a simplified picture of projects' comparative performance against two dimensions. These dimensions synthetize underling key indicators and guide options for selecting particular projects under the budget constraint.

Recognition of three critical empirical issues motivated the construction and ongoing development of this framework. First, there are significant challenges facing many governments in infrastructure planning, wherein large numbers of infrastructure projects are identified in National and Sector Development Plans, which are to be implemented with scarce public resources, limited institutional capacity, and cost and time constraints. Second, there is a need to meaningfully address environmental and social factors in infrastructure development, which are often difficult to monetize. Third, there is a desire to balance analytical efficiency, derived from standardization, with policy and political responsiveness.

To the last point, the IPF recognizes that the selection of infrastructure projects on objective economic grounds cannot be dissociated from the politics of project selection. Particular projects may be chiefly valued by governments and other stakeholders due to key policy goals which are non-economic in nature, or due to considerations that objective indicators cannot measure, such as upholding election promises, promoting social cohesion, or honoring culture. As such, this support framework explicitly accommodates policy and political responsiveness in two ways: through the selection of criteria for assessment, and by leaving a degree of freedom in decision-making through provision of two references for judgment (i.e., two indices). In other words, the tool provides decision–makers with the means to select projects that provide society, at the very least, with either high economic benefits or environmental and social gains. While an optimal combination of all features is naturally desirable, the decision support framework does not preclude projects that are not strongest on both aspects.

In addition to building in space for consultation and professional and political judgment, the following design ideals were incorporated, based on a survey of international best practice:

(1) The strategic relevance of a project must be determined at the sector level as well as within the appropriate tier of government;

(2) Project appraisal should be based on quantitative measures, to the greatest extent possible, in order to limit subjectivity;

(3) Standard indicators of social value and financial return should drive project appraisal;

(4) Inertial funding trends should be overcome to allocate resources to projects that provide the largest gains to society; and

(5) The final output should be transparent, allowing for a clear audit trail for each evaluation project.

A key strength of IPF is that it may be flexibly applied. The framework can incorporate elements from other common methods, such as expert judgment and cost-benefit analysis. Expert judgment and deliberation come into play via the selection and definition of criteria, as well as in the selection of projects within the budget constraint. IPF can also take advantage of CBA components that are relatively easily quantified, measured, and monetized (e.g., net present values of marketed costs and revenues). When the resources, capacity, and information are sufficient to perform CBA in the usual manner, IPF can also employ the outputs of full CBA analyses (e.g., benefit-cost ratios, ERR, NPV) as inputs to a multi-criteria model. IPF's most important value-adds to CBA are in (a) directly treating non-marketed impacts in 'natural' units, as opposed to monetized amounts, and (b) relieving some of the burden of determining and justifying the assumptions required to monetize all benefits and costs.

Technical Features

Five key technical features characterize the IPF. First, the IPF is designed to account for the inherent multidimensionality in infrastructure planning processes. Two composite indices allow for the comparison of projects against others within a sector. The key output is a graphical display of projects' performance along two axes, defined by financial-economic and social-environmental composite index scores.

Second, the public budget for infrastructure projects is considered as a fixed amount and superimposed upon the financial-economic and social-environmental axes on the plane. As a result, the budget constraint sets quadrants on the plane (see Figure 5). Future developments of the IPF may relax this assumption to account for private participation through PPPs and other private financing schemes making the budget constraint variable.

Third, governments determine the specific indicators or 'criteria' comprising each composite index through a consultative process. Indicators may include such financial-economic indicators as rates of return, multiplier effects, and net present values, and social-environmental indicators like number of targeted beneficiaries, carbon footprint, and jobs created. These criteria need to account for the multiple development goals at the relevant national and sector levels.

Fourth, IPF uses statistical methods to make qualitative data usable and aggregate indicators into composite indices[3]. In practice, information may be quantitatively or qualitatively recorded, depending on the attribute to be measured. Qualitative data is more common when assessing social-related phenomena and has an important informative value in infrastructure projects. To make use of this information, a method to convert qualitative information into numerical data is applied.

Last, when multiple variables must be simultaneously considered to assess a large number of observations (infrastructure projects in this case), information and process requirements can become burdensome and costly. To address this problem, indicators are combined into two performance indices: social-environmental and financial-economic. While multiple methods may be used to combine indicators, a common information reduction method, Principal Component Analysis (PCA), is applied. Details are provided in the next section.

Constructing the IPF Indices

The IPF combines financial-economic factors with social-environmental outcomes in quantitative analysis to generate a graphical matrix output that plots each project's performance against the two indices, along with the budget constraint. The selection of variables seeks to preserve the principle of parsimony. Accordingly, this methodology relies on and requires a minimum level of relevant information to assess the various outcomes associated with infrastructure investments. The selection of variables may differ amongst application contexts, based on government policy goals (e.g., particular sectorial, social, and environmental aims) and stakeholder consultation. For explanatory purposes, however, we will discuss the IPF index construction as performed in the pilot test for Vietnam[4].

The indices combined information for two variable classes: social-environmental and financial-economic, with five variables each. Whilst this translates to a comparison across ten variables, the information was condensed via statistical means into two composite indicators, the Social and Environmental Index (SEI) and the Financial and Economic Index (FEI), each built on quantitative and transformed[5] qualitative variables combined via an additive model.

To condense disparate data types and scales of measurement into indices, three data transformations are required. One must (a) transform qualitative data and ordinal quantitative data into usable scalar data, wherein the intervals between

3. A composite value or index value is a single numerical figure that combines information from several underlying variables. The strength of this approach is that a decision–maker can efficiently consider complex phenomena like economic performance, sustainability, or competitiveness in a single variable (Freudenberg, 2003, Nardo, et al., 2005). A selection of widely cited indices is listed in Annex 1.
4. The work in Vietnam is described in detail in Mandri-Perrott, Marcelo, and Haddon 2014. At the request of Vietnam's Ministry of Planning and Investment (MPI), the World Bank piloted the IPF to prioritize and select public infrastructure investments. One of the objectives of the IPF in this case was to provide the Government of Vietnam (GoV) with the means to operationalize the guidelines and requirements of the Public Investment Law (PIML) in an open and transparent manner. The Pilot Test covered over projects in three sectors: transport, irrigation and urban.
5. To generate a valid numerical expression for the composite indices, it is required that qualitative information is transformed into quantitative variables.

values reflect degrees of difference; (b) standardize criteria measurements to a common scale; and (c) establish weights for each criterion in the additive model.

The transformation of categorical and ordinal qualitative and quantitative data into usable numerical data may be done using the Alternating Least Squares Optimal Scaling (ALSOS) algorithm, a widely accepted transformation approach. Within a quantified categorical variable, the numbers assigned by the ALSOS algorithm to each category reflect the distance *between* categories, thus revealing the implicit metric of the variable (Young, et al., 1976)[6].

Once qualitative information is transformed and standardized to isolate the various units of measure, it can be synthetized using standard statistical methods. In the case of Vietnam, Principal Component Analysis (PCA) was used to determine the weights of each variable in the index's additive function. One of the main characteristics of PCA is the ability to calculate coefficients based solely on the statistical relationship between variables. This is particularly useful when there is a preference to objectively assign weights.

Essentially, PCA is an information reduction procedure that seeks redundancies within a set of variables. These redundancies can be expressed as linear combinations or 'principal components' of the variables comprising the set. Each principal component is a weighted average of the original indicators or component variables. The coefficients, or weights, associated with variables in each principal component are those that maximize the variance of each.

The first principal component corresponds to the linear combination of variables that retains the maximum information of the original data set (Pearson, 1901). The notation for the first principal component y is:

$$(1) \qquad y_i = w_1 x_{1i} + w_{2i} x_{2i} + \cdots + w_n x_{ni}$$

Where i denotes each observation and w_n denotes the weight for the n^{th} variable x.

In the context of the IPF, the first principal components of the social-environmental and financial-economic variable sets become the composite indices. The coefficients w_n of each 'first principal component' are taken as the weights associated with each variable x.

Social and Environmental Index (SEI)

Infrastructure projects are meant to improve quality of life. A number of direct social and environmental benefits are associated with their implementation, including improved access to public services and job and income opportunities created during the construction and execution of investments. These benefits come at a cost, however. Engineering works frequently require clearing forested areas, polluting and endangering natural environments, and sometimes construction works involve the resettlement of families or communities. The IPF directly considers relevant social and environmental benefits and costs via the social and environmental index (SEI), whose sub-components will be dependent on the evaluating government's selected criteria.

6. Statistical software such as SPSS and SAS include routines to easily perform transformations of qualitative variables into numerical variables for PCA. The same packages can be used to perform PCA.

In Vietnam, the SEI consisted of five indicators: Direct Jobs Created (DJ); Number of Direct Beneficiaries (NB); People Affected by Repurposing of Land Use (PA); Cultural and Environmental Risks (CER), and Pollution, in terms of CO_2 equivalent emissions (CO2). The data required to compute each variable were primarily sourced from existing project feasibility studies. Additional variables on projected indirect effects were estimated using data routinely gathered by the National Statistic Office of Vietnam (Marcelo, Mandri-Perrott, & Haddon, 2015)[7]. PCA was used to synthetize social and environmental variables into a composite index. Since many social and environmental data were recorded as qualitative ordinal variables, they were transformed using the ALSOS[8] methodology. Further, all quantitative and quantified qualitative variables were standardized to have zero mean and unit variance.

Finally, PCA was used to generate an index function from the first principal component, with the coefficients used as the weights for each standardized variable. The resultant SEI function was expressed as follows:

$$SEI = \beta_{11}ZDJ + \beta_{12}ZNB + \beta_{13}ZPA + \beta_{14}ZQCER + \beta_{15}ZCO2 \quad (2)$$

The linear combination of the standardized variables *ZDJ*, *ZNB*, *ZPA*, *ZQCER* and *ZCO2* is known as the first principal component and is equivalent to the SEI additive function. In other words, the SEI is the linear combination of variables that retains the highest possible variability of the original data. The coefficients $\beta_{11}, \dots, \beta_{15}$ can be interpreted as the relative weights of SEI variables.

The Financial and Economic Index (FEI)

The same procedure was used to construct the FEI, only with different variables. Financial profitability and economic value are probably the most common investment decision considerations. That said, public investment decisions must also consider externalities and indirect economic effects, such as multiplier and network effects on other industries and economic sectors.

The Financial and Economic Index (FEI) seeks to condense the minimum amount of relevant information required to appropriately represent the financial and economic effects derived from infrastructure investments. In the case of Vietnam, the FEI consisted of five indicators: Financial Internal Rate of Return (IRR), Multiplier Effects (ME), Priority Economic Zones (PEZ), Implementation Risks (IR), and Complementarity/Competition effects (CC).

As with the SEI, data required to compute each variable for the FEI was drawn from Feasibility Studies (FSs). Additional data on indirect effects generated could be calculated using data routinely collected by the National Statistic Office.

A FEI was calculated using PCA, as follows:

$$FEI = \delta_{11}ZIRR + \delta_{12}ZME + \delta_{13}ZQPEZ + \delta_{14}ZQIR + \delta_{15}ZQCC \quad (3)$$

7. The information collected was used to populate a Microsoft Excel form, which in turn populated a database with embedded macros, programmed to transform the data using transformation functions and weights required to calculate the total SEI score for a project.
8. For example, cultural heritage loss and environmental risks were qualitatively classified from "high" to "low". To apply PCA, the variable was transformed to a quantitative value.

where the suffix Z again denotes standardization, the suffix Q indicates quantification of a qualitative variable, and the coefficients $\delta_{11},\ldots,\ \delta_{15}$ maximize the variance of the first principal component.

Comparing Projects by SEI and FEI

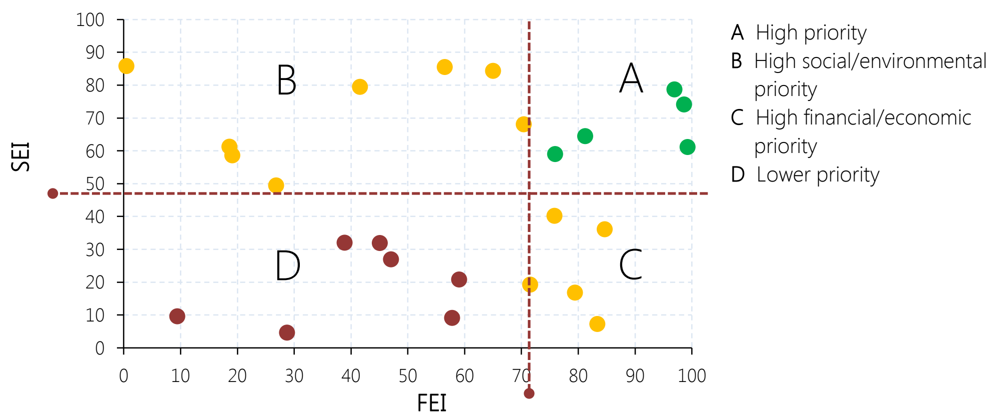
Construction of the SEI and the FEI composite indicators allows the ranking of projects within a sector, according to projected performance along each dimension. But a good infrastructure investment, in terms of financial and economic performance, may simultaneously be a poor choice from a social and environmental perspective, and vice versa. Thus, policymakers should not make definitive investment decisions based on only one dimension. In fact, neither should decisions be made on both without the inclusion of a critical additional information piece – the public budget constraint.

Projects are first plotted on a two-dimensional Cartesian plane, with axes defined by the SEI and FEI scores. In Figure 4, each point represents a proposed infrastructure project, within one sector. The location of a project in the plane is determined by coordinates (x,y), defined by the (*FEI, SEI*) pair.

After projects are plotted, the budget constraint is considered and superimposed upon the plane, for both dimensions and perpendicular to each. To locate the point of intersection where the budget constraint crosses each axes, priority is assigned to each project using a hierarchical descending score (along each dimension), until the budget limit is met. At the point where the budget is exhausted (represented as the last project to be funded, based on prioritization along one index/axis only), the budget constraint is imposed onto the plane. Since this is done along each axis (rather than delineating a singular threshold), the budget constraint results in quadrants being formed on the plane. In Figure 5, the dotted lines represent the annual budget constraint for the sector at hand.

Projects that fall inside the budget constraint along each axis represent the 'Investment Possibilities' set within each dimension. For example, from a FEI point of view (X axis), the location of the budget constraint line indicates the threshold where public resources would be fully exhausted. In the example of Vietnam, resources would be sufficient to finance only those projects with a FEI above 70. From a SEI perspective, on the other hand, resources would be enough to finance only those projects with a score above 46.

Figure 4. Vietnam Prioritization Matrix Frame



Quadrant A contains high–priority infrastructure projects that simultaneously score high on the SEI and FEI (green points, Figure 4). These projects are highly recommended for implementation. On the other hand, projects falling into quadrant D (red points) may be classified as lower–priority, since they score relatively low on both the SEI and FEI (red dots, Figure 5).

Projects in quadrants B and C have two common features. First, they score relatively high on either the SEI or FEI, but not both. Second, all of projects in either quadrant B or C, or a combined array of select projects within each, could be implemented with public funds. If the SEI is definitively privileged over the FEI, all projects in quadrant B could be selected for funding. Conversely, if the FEI is unequivocally more important to a government, all of the projects in quadrant C could be implemented. Alternatively, some portion of quadrant B and quadrant C projects could be funded, where both the FEI and SEI are deemed important. Quadrant B and C projects may be given a medium priority level.

Identification of these medium-priority projects leaves space for expert review, flexibility, and informed political debate. That project must be selected from amongst these, the negotiated process of ordering projects within Quadrants B and C allows IPF to capture important information from the professional and political bases of knowledge amongst decision-makers. In other words, the framework informs decisions regarding projects in the medium-priority set, but leaves room for structured professional and political judgment.

Lessons from Vietnam and Panama Pilots

The IPF has been piloted in Vietnam and Panama, with positive responses from policy makers in both countries (Mandri-Perrott, Marcelo, and Haddon, 2014; Marcelo, et al, 2015). The experiences brought to light a number of issues for further refinements to the framework, which are discussed in this section. Both governments were amenable to pilot the IPF given their respective strategic planning cycles, infrastructure needs, fiscal plans, and legislative and governmental support for employing a prioritization methodology. While the two projects are an important start, more work is needed to explore implications of regional disparities in the context of application and data availability, and in developing specific links to project financing and PPP identification.

Vietnam Experience

In Vietnam, two factors made prioritization a natural pursuit for the Ministry of Planning and Investment. First, the 2014 Public Investment Law referred specifically to implementing a classification and selection system for proposed infrastructure, to incorporate assessments of financial efficiency and effectiveness alongside social and environmental sustainability. Second, the pilot test aligned with the Government's strategic planning cycle. The pilot covered 30 randomly selected projects in three sectors: transport, irrigation, and urban. An important pre-condition was that projects should have already undergone a preliminary feasibility study (FS) (Mandri-Perrott, Marcelo, and Haddon 2015).

Following an initial exploratory and consultation period, the IPF was employed for ex ante project evaluation in three sectors: transport, irrigation, and urban, in a two-stage approach. Since the Ministry of Planning and Investment (MPI) did not have sufficient funding to support a full set of feasibility studies for the approximately 3000 proposed projects, an initial qualitative project validation and classification filter was applied to identify a subset of projects for which feasibility studies could be funded[9]. Following the first filter, about 268 projects were selected for feasibility study grants. Of these, thirty projects were randomly selected to run the pilot: ten each from transport, irrigation, and urban sectors. The calculation of the SEI and FEI and the plotting of the projects against the budget constraint followed the steps described above.

The primary lessons drawn from experiences in Vietnam are summarized here. First, there are important pre-analysis steps required to ensure sufficiently comparable data. One of the challenges of the pilot was that some data, even from within Feasibility Studies, was either opaquely determined (e.g., IRR) or had limited comparability across projects (Mandri-Perrott, Marcelo, and Haddon 2015). Ensuring that data are similarly defined and measured is essential to any comparison method including PCA, as variations in measurements due to definitional differences can lead to criteria weighting biases as well as mis-measurement of any one project's performance against the criterion at hand. Feasibility studies should follow clear rules, guidelines, and standards to ensure quality and comparability of data.

Second, special attention must be given to the metrics used to measure variables, especially when PCA is used to assign weights to produce composite indices. For example, the concept of poverty may be expressed by the population of poor residents or the poverty ratio. The appropriate metric will depending on the correlations with other variables.

Third, pre-filters or additional variables may be required when there are inherent biases in the set of projects proposed or where the Government aims to break regressive patterns. For example, in Vietnam, it was observed that projects in poorer regions tended to score lower on some variable inputs to the FEI or SEI. This observation justified use of an initial filter to reflect policy goals (Mandri-Perrott, Marcelo, and Haddon 2015).

Fourth, in order to improve robustness of results and foster concurrent application with other analytical tools (including CBA and expert assessment), where appropriate and feasible, users must have sufficient capacities to understand the mechanics and implications of key decisions regarding its use. These include the selection of criteria, definition of indicators, and relationships to other decision support methods. As such, capacity building remains an essential component of the application of the IPF and its adoption. An important fact is that the IPF will still require a degree of decision-making regarding its calibration that in itself implies a minimum level of technical capacity.

Further, to extoll the benefits of responsiveness inherent to the tool, the proposed methodology should not be a one–off exercise. Rather, it should be utilized as a

9. The first filter reduced the set of projects under consideration by assessing whether they met tests of (a) legal and procedural validity; (b) strategic validity (alignment with development goals); and (c) financial validity (capital value within available resources). Projects that passed all three tests were thereafter classified geographically to identify those projects located in either (a) priority development areas due to poverty levels or key economic development initiatives or (b) environmentally protected regions. Naturally, the former were assigned higher classification scores, whereas the latter were penalized. The MPI or sector agency will allocate funding for FSs to projects in the highest importance groups and then proceed through the remaining groups until the FSs funding is exhausted.

progressive approach, intended to 'live and grow' with the country's infrastructure needs and policy objectives. As such, the prioritization program should involve continuous refinement of the decision-support tool, based on informed deliberation regarding criteria selection and any pre-decisions of a policy nature (Mandri-Perrott, Marcelo, and Haddon 2015).

Fifth, governments must be aware of potential sequencing conflicts related to the timing of project selection processes in different ministries and line agencies. One strategy to mitigate this is for central government to oversee and provide guidance for systematizing project selection and coordinating sectorial prioritization activities.

Last, planning offices and decision makers must be familiarized with the multi-criteria approach to build credibility of the decision support tool itself, requiring consultation and clear explanation of the technical inputs and model structure. While some fluency with established quantification methods like CBA is observed, there is a certain degree of risk aversion associated with applying new methods. Building acceptance of the decision support tool itself is critical to legitimizing the analysis (Mandri-Perrott, Marcelo, and Haddon 2015).

Panama: Transport and Water

In Panama, the conflation of the current economic outlook and three institutional supports spurred the IPF pilot. GDP growth and economic buoyancy in 2014 motivated an ambitious public investment program, accompanied by a high number of infrastructure project proposals to the Ministry of Economics and Finance. Nevertheless, the proposed set of projects exceeded the available funding space and allowable deficit ceiling, demanding selection of some projects and postponement of others. The application of a prioritization methodology was endorsed in the Government Strategic Plan 2015-2019 and a draft amendment to the 2008 Social Fiscal Responsibility Law, which stated that a system of prioritization strategies was needed for infrastructure development in the future. Similarly, the public investment law contained implementation notes to employ a prioritization strategy tied to the five-year investment plan 2015. The 2015 World Bank Country Partnership Framework (CPF) also called for application of a prioritization tool. These factors confirmed demand for prioritization of investments in infrastructure planning.

The IPF was applied to a selection of 35 proposed projects in water supply and sanitation and 19 in transport. These projects were identified in consultation with the Ministry of Economics and Finance. The pilot offered a key opportunity to replicate and refine the existing framework, in that it entailed decision analysis based on limited financial-economic data, particularly for a portion of the water projects. In this way, it replicated a common input problem for infrastructure decision-making, namely restrictions on data.

Planners from several agencies, in consultation with the Ministry of Economy and Finance and a team from the World Bank, agreed on a set of component SEI and FEI variables. The SEI variables initially selected included the number of beneficiaries (BEN), direct jobs created during implementation (EMP), the population of poor serviced by the project (POOR), social and environmental risks

(SER), and the carbon footprint (CO2). The final analysis used only the first three, due to data problems and lack of specificity in the risk variable.[10]

The FEI was originally expected to include the internal rate of return (IRR) and/or economic rate of return (ERR) of projects, depending on data availability. However, given that many of these investments were proposed for projects with no direct monetary benefits and largely indirect economic effects (i.e. mainly projects with a large public good component[11]), the calculation of IRR would have produced unrealistic or incalculable results. The alternative would have been to account for all indirect positive effects and estimate benefits. This would have required data on monetized benefits for such effects, which was not available. For these reasons, benefit-cost ratios (BCRs) were used. The BCRs also allowed for the analysts to control for project size and avoid penalizing projects with higher costs but potentially higher benefits[12].

The results from the transport projects assessed are presented in Figure 5.

Figure 5. SEI and FEI, Transport Projects, Panama Pilot 2015

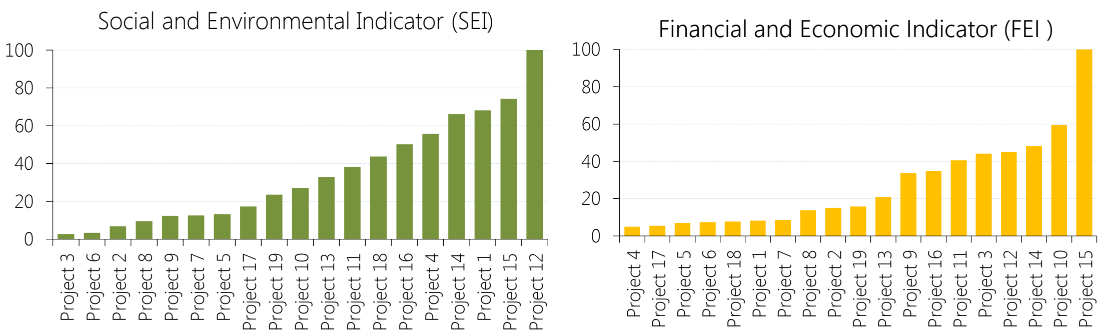
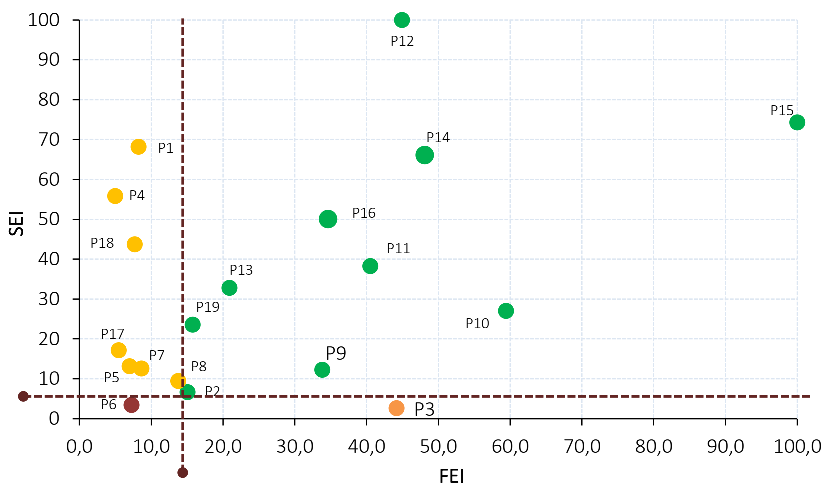


Figure 6 shows the results of plotting each project's SEI and FEI scores.

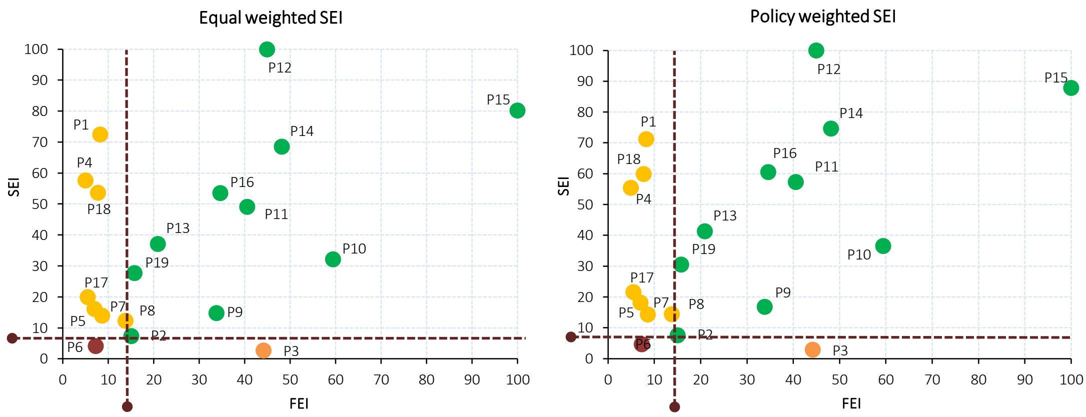
Figure 6. SEI and FEI plot for selected transport projects, Panama 2015



10. See Marcelo, Mandri-Perrott, and House, 2015 for a description of these challenges.
11. An example of this sort of project would be investments in wastewater treatment facilities, where tariffs are often insufficient to cover the full costs of the assets and its sustained operation and maintenance.
12. More details on the calculation of composite indices and results of the pilot in Panama are available in Marcelo, Mandri-Perrott, & House, 2015.

The pilot offered a number of key lessons. The first and most significant was that composite indices are far more sensitive to indicator values than weights. This highlight the comparative advantage of using PCA. A sensitivity analysis was performed to compare PCA indices against composite indices using subjectively established weights. Two subjective weighting schemes (equal weighting and hypothetical policy-determined) were tested to calculate alternative SEI composite indices. Figure 7 shows that the ranking of projects changed only minimally when using policy-determined or equal weights (Marcelo, Mandri-Perrott, & House, 2015). In practice, the use of subjective weighting can give rise to a number of problems ranging from purely technical (i.e., rank reversal in AHP) to political (i.e., lack of transparency and discretion in selection of infrastructure-projects).

Figure 7. Comparison of Transport SEI and FEI scores, equal versus policy weighting



Another form of sensitivity analysis was performed by comparing project prioritization outcomes for water and sanitation combined, with prioritization outcomes for analysis organized by subsector (i.e., water and sanitation projects considered separately). While rankings did not change within each subsector, a set of sanitation projects formerly relegated to a lower priority were naturally designated 'high priority' when budget was set aside for sanitation.

The second lesson is that special consideration should be given to the selection and definition of metrics to deal with regressive biases. This applies to any comparative approach. As in Vietnam, Panama showed a potential for an inherent bias towards infrastructure projects in wealthier or urban regions. If development plans were aimed at improving rural areas, however, this could create adverse results. This can be overcome by careful indicator specification.

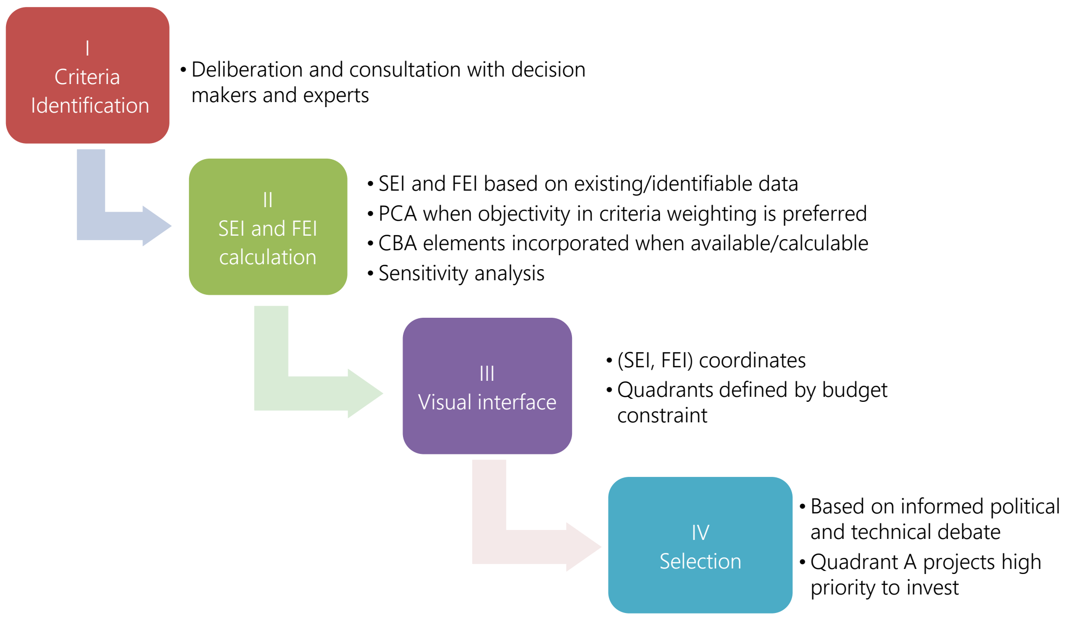
The third lesson relates to the appropriate use of financial and economic indicators in conditions of low information. We recognize the value of incorporating CBA elements on the financial and economic side of the IPF. To integrate these elements to the framework when information is extremely limited, additional criteria is required. For example, if only project cost is known, additional variables must be considered to build the FEI. This practical constraint highlights the importance of improving information systems at the project level to effectively implement any kind of prioritization tool.

A final lesson is that the IPF can take into account both efficiency and efficacy considerations. This is shaped by the construction of variables. For example, one could use the absolute number of beneficiaries as an input to the SEI to consider policy effectiveness when service expansion is a priority. On the other hand, 'beneficiaries per dollar spent' may be more appropriate if the goal is fiscal efficiency. In the case of Panama, where development of water services in rural areas was an important policy goal, the decision was made *not* to control indicators by project size in order to protect against the possibility of privileging urban projects with greater economies of scale (Marcelo, Mandri-Perrott, & House, 2015).

Towards a Framework for Infrastructure Investment Decisions

This paper presents the IPF as a comprehensive multi-criteria tool for infrastructure prioritization. Whilst the framework's legitimizing strength is in its quantitative objectivity, it also makes room for deliberation and consultation. It is meant for use as an input to infrastructure decision-making rather than a definitive ranking that leaves no room for discussion. Moreover, elements from other existing approaches such as CBA can be integrated as additional criteria into the IPF. The graphical interface is helpful to inform discussions about the relative importance of financial-economic and social-environmental factors, as well to explore of the potential effects of reallocating funds between sectorial budgets.

Figure 8. Sequence of the IPF



While not the specific purview of this paper, it is of interest to reflect on the potential use of the IPF in broader infrastructure decision processes. In this section, we discuss aspects of its use, relationships to other components of infrastructure policymaking, and next steps in developing it as a generalizable prioritization approach.

First, there is an important relationship between IPF and problem analysis. The departure point of prioritization exercises will undoubtedly differ across contexts. In some cases, governments will have extensively assessed infrastructure deficiencies and identified key infrastructure objectives to be met by particular projects. In these cases, the strategic objectives may be incorporated as sub-criteria in the IPF. On the other hand, when sequencing is undertaken based only on proposals, but without policy *problem* analysis, the IPF can only rely on a more general set of FEI and SEI sub-criteria, such as those used in Vietnam and Panama. The full menu of possible configurative links between agenda setting, infrastructure policy formulation, and decision-making (the locus of IPF) has not yet been fully explored.

There are also interesting paths to explore with respect to the concurrent application of IPF with other infrastructure decision support tools like CBA, Value for Money analysis, and PPP-specific tools like the EIU's Infrascope tool. There are undoubtedly some input complementarities linking prioritization with identification of suitable candidate projects for PPP, which have yet to be catalogued and developed.

With respect to the IPF, specifically, we have identified a set of key focal points and questions for future research. These issues include the following:

(1) Sectorial Rebalancing: How can decision-makers best use the IPF to explore possibilities of rebalancing sectorial budgets? Where good PPP candidates are identified within the high- or medium-priority project sets, the budget constraint may be extended in that particular sector, or funds may be reallocated to other sectors with higher shortfalls, or high-SEI scored projects with insufficient funding.

(2) Robustness and Sensitivity Analysis: How do the results determined by IPF compare to results derivative of purely subjectively weighted models? How can sensitivity analysis be incorporated to improve IPF?

(3) Participation and Consultation: Which stakeholders should be included in the application of IPF?

(4) Private Participation: How does the IPF relate to the identification of public-private partnerships or other private financing opportunities? How will IPF results change with variable budget constraints resulting from private participation?

Lastly, there is a need to deal with prioritization, not only as a question of *what* to do, but also a question of *when* to invest. The IPF may be used to rule some projects out altogether, but may also be extended to assess of the relative immediacy of proposed projects and timing of investments over long impact horizons. In their assessment of the infrastructure needs in South Asia, Andres, et al suggest that prioritization criteria "must be able to answers questions about short-term needs versus longer-term development needs, especially in developing countries… Given substantial lock-ins associated with infrastructure investments, should a country continue attempting to fill current gaps or direct investments to infrastructures that are likely large bottlenecks in the medium term?" (Andres, Biller, & Dappe, 2014). Whilst the IPF, as a flexible framework, is sufficiently malleable to address these extended needs and future questions, the answers to these remaining questions will only be realized through continued experimentation in different contexts. Refining this framework is a worthwhile pursuit to ensure its appropriate application and usefulness to infrastructure decision-makers and investors.

Annex 1. Examples of globally recognized indices

Area / Sector	Composite Indicator
Economy	Composite of Leading Indicators (OECD) OECD International Regulation Database (OECD) Economic Sentiment Indicator (EC) Internal Market Index (EC) Business Climate Indicator (EC)
Environment	Environmental Sustainability Index (World Economic Forum) Wellbeing Index (Prescott–Allen) Sustainable Development Index (UN) Synthetic Environmental Indices (Isla M) Eco–Indicator 99 (Pre Consultants) Concern about Environmental Problems (Parker) Index of Environmental Friendliness (Puolamaa) Environmental Policy Performance Index (Adriaanse)
Globalization	Global Competitiveness Report (World Economic Forum) Transnationality Index (UNCTAD) Globalization Index (AT Kearny) Globalization Index (World Markets Research Centre)
Society	Human Development Index (UN) Corruption Perceptions Index (Transparency International) Overall Health Attainment (WHO) National Healthcare Systems Performance (King's Fund) Relative Intensity of Regional Problems
Innovation and Technology	Summary Innovation Index (EC) Networked Readiness Index (CiD) National Innovation Capacity Index (Porter and Stern) Investment in Knowledge–Based Economy (EC) Performance in Knowledge–Based Economy (EC) Technology Achievement Index (UN) General Indicator of Science and Technology (NISTEP) Success of Software Process Improvement (Emam)

References

Andres, L., Biller, D., & Dappe, M. H. (2014). Infrastructure Gap in South Asia: Infrastructure Needs, Prioritization, and Financing. *World Bank Policy Research Working Paper*(7032).

Barfod, M. B., Salling, K. B., & Leleur, S. (2011). Composite decision support by combining cost-benefit and multi-criteria decision analysis. *Decision Support Systems, 51*(1), 167-175.

Beinat, E., & Nijkamp, P. (1998). *Multicriteria analysis for land-use management* (Vol. 9): Springer Science & Business Media.

Brown, H. (2014). *Next generation infrastructure*: Springer.

Cantarelli, C. C., Flyvbjerg, B., Molin, E. J., & Van Wee, B. (2010). Cost overruns in large-scale transportation infrastructure projects: explanations and their theoretical embeddedness. *European Journal of Transport Infrastructure Research, 10*(1), 5-18.

CDIA. (2010). City Infrastructure Investment Programming Prioritisation Toolkit: User Manual: From Wish List to Short List: Prioritising Urban Infrastructure Projects for Local Development. Manila, Philippines: Cities Development Initiative for Asia.

DCLG. (2009). Multi-criteria Analysis: A Manual (pp. 165). London: London Department for Communities and Local Governance.

De Montis, A., De Toro, P., Droste-Franke, B., Omann, I., & Stagl, S. (2004). Assessing the quality of different MCDA methods. *Alternatives for environmental valuation*, 99-184.

Head, B. W. (2010). Reconsidering evidence-based policy: Key issues and challenges. *Policy and Society, 29*(2), 77-94.

HM Treasury. (2014). UK National Infrastructure Plan 2014.

Kabir, G., Sadiq, R., & Tesfamariam, S. (2014). A review of multi-criteria decision-making methods for infrastructure management. *Structure and Infrastructure Engineering, 10*(9), 1176-1210.

Khisty, C. J. (1996). Operationalizing concepts of equity for public project investments. *Transportation Research Record: Journal of the Transportation Research Board, 1559*(1), 94-99.

Manaugh, K. (2013). *Incorporating issues of social justice and equity into transportation planning and policy.* McGill University.

Mandri-Perrott, C., Marcelo, D., & Haddon, J. (2014). A Methodology to Prioritize and Select Infrastructure Investments. Report to the Vietnam Ministry of Planning and Investment. The World Bank.

Marcelo, D., Mandri-Perrott, C., House, S. (2015). Prioritizing Infrastructure Investments in Panama: Pilot Application of the World Bank Infrastructure Prioritization Framework. Report to the Panama Ministry of Economy and Finance. The World Bank.

Martens, K. (2009). *Equity Concerns and Cost-Benefit Analysis: Opening the Black Box.* Paper presented at the Transportation Research Board 88th Annual Meeting.

Rogers, M., & Duffy, A. (2012). *Engineering project appraisal*: John Wiley & Sons.

Salling, K. B., Leleur, S., & Jensen, A. V. (2007). Modelling decision support and uncertainty for large transport infrastructure projects: The CLG-DSS model of the Øresund Fixed Link. *Decision Support Systems, 43*(4), 1539-1547.

Thomopoulos, N., Grant-Muller, S., & Tight, M. (2009). Incorporating equity considerations in transport infrastructure evaluation: Current practice and a proposed methodology. *Evaluation and program planning, 32*(4), 351-359.

Tsamboulas, D. (2007). A tool for prioritizing multinational transport infrastructure investments. *Transport Policy, 14*(1), 11-26.

Van Delft, A., & Nijkamp, P. (1977). *Multi-criteria analysis and regional decision-making* (Vol. 8): Springer Science & Business Media.

Zerbe, R. O., & Bellas, A. S. (2006). *A primer for benefit-cost analysis*: Edward Elgar Publishing.