Economic Commission for Africa (ECA)
Southern Africa Office (SRO-SA)

# Cost-Benefit Analysis for Regional Infrastructure in Water and Power Sectors in Southern Africa

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Southern Africa Office (SRO-SA)

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# Acronyms

| | |
|---|---|
| APR | Accounting Price Ratio |
| AEGM | Ad-hoc Experts Group Meeting |
| B – C | Benefits less Costs |
| BTL | Build-Transfer-Lease |
| BOOT | Build-Own-Operate |
| BOT | Build- Operate -Transfer |
| CBA | Cost-benefit analysis |
| CEA | Cost -Effective Analysis |
| CF | Conversion Factor |
| COMESA | Common Market for Eastern and Southern Africa |
| DRC | Democratic Republic of Congo |
| DSM | Diagnostic Statistical Manual |
| EIA | Environmental Impact Assessment |
| EIB | Export Import Bank |
| ELF | Environmental Landscape Feature |
| ENPV | Economic Net Present Value |
| ERR | Economic Rate of Return |
| ESKOM | Electricity Supply Commission |
| FNPV | Financial Net Present Value |
| FOB | Free on Board |
| FTA | Free Trade Area |
| GDP | Gross Domestic Product |
| ICPs | International Cooperating Partners |
| IEG | Independent Evaluation Group |
| IWRM | Integrated Water Resources Management |
| JV | Joint Venture |
| LHWP | Lesotho Highlands Water Project |
| LROT | Lease - Rehabilitate - Operate – Transfer |
| MCA | Multi-Criteria Analysis |

| | |
|---|---|
| MDG | Millennium Development Goals |
| NEF | Noise Exposure Forecast |
| NEPAD | New Partnership for Africa's Development |
| PPAs | Power Purchase Agreements |
| PPPs | Public - Private - Partnerships |
| QALY | Quality Adjusted Life Year |
| RBO | River Basin Organization |
| RERA | Regional Electricity Regulators Association |
| RISDP | Regional Indicative Strategic Development Plan |
| RSAP | Regional Strategy Action Plan |
| SADC | Southern African Development Community |
| SAPP | Southern Africa Power Pool |
| SDR | Social Discount Rate |
| SIO | Semi – Input - Output |
| UNDESA | United Nations Department of Economic and Social Affairs |
| UNECA | United Nations Economic Commission for Africa |
| VAT | Value Added Tax |
| WA | Wheeling Agreements |
| WB | World Bank |
| WTA | Willingness to Accept |
| WTP | Willingness to Pay |
| ZESCO | Zambia Electricity Supply Corporation |
| ZIZABONA | Zimbabwe-Zambia - Botswana - Namibia |

# Foreword

This report documents synthesis of background submissions incorporating enrichment from discussions amongst experts of the Southern Africa Subregion at the Ad-Hoc Experts Group Meeting held in Lilongwe, Malawi, in March 2010. The topic of the report, coming from ECA-SADC Muti-Year Programme, is very important because all the countries in the subregion in particular, and in Africa in general, are committed to regional infrastructure as an important precondition for economic development

Several years back, economists developed methods for appraising investment projects financed from public budgets, one of which is the use of 'social cost-benefit analysis': a test that weighs the costs and benefits of a public project in terms of its contribution to national (social) welfare. If the social benefit of the project exceeded its social costs, the recommendation was that the government should undertake the project. Although there are important differences in the various methods for evaluating the costs and benefits, they have at least three elements in common:

First, they emphasize that inputs and outputs of a project should not necessarily be valued at current market prices because the market price may not reflect the social opportunity cost of the resource, i.e., its cost in forgone benefits to society. For example, if a project hires an unemployed worker, even though his wage is a cost to the project, it does not represent the social cost, which would be the supply price of labour (the price at which a person would be willing to work). When there is unemployment this usually means a wage that is below the prevailing wage. Thus, rather than use market wages as the cost of labour, the evaluation is instructed to use a set of "shadow prices" that reflects the social opportunity cost of the inputs and outputs of the project.

Second, policymakers are encouraged to evaluate every component of a project relative to a counterfactual, i.e., what would have happened without the project? The labour example also illustrate this principle: because the worker was unemployed, no national output is forgone when he is drawn into the project.

Third, the methodology dictates that because the benefits and costs of the project occur at different points in time, they should be combined in some summary statistic, such as the net present value or internal rate-of-return of the project.

Nowadays, however, assessment would have to acknowledge that the practical application of these principles has been limited and that governments use the techniques only rarely. There are many reasons for this decline in the use of social cost-benefit analysis, two of which include new concerns such as poverty, gender, environment and sustainability, and the complexity of the methodology. Furthermore, the traditional approach also often fails to address the fundamental questions of concern to policymakers of today, including question of achieving equity and fairness in the allocation of resources. This question is of general interest to both national and regional policymakers alike.

The world has evolved substantially due to water, food, energy, climate, economic growth and human security challenges, as well as globalization that the world economy faces. Governments are now reconsidering the role of the State. Instead of asking if the project generates a positive net social benefit, governments and agencies are asking if there is a rationale for public provision of that good or service, particularly within the context of regional cooperation among neighbouring countries with respect to provision of public goods, including infrastructure (dams, water supplies, irrigation, power, etc.).

In this regard, the standard approaches to project analysis are revealed in-sufficiently suited to answering the latter question. Two striking examples of regional cooperation projects in the SADC subregion, namely Shire-Zambezi Waterway (SZW) and Western Power Corridor (WESTCOR) Projects readily come to mind. Despite their adoption as priority projects by both SADC and COMESA, cooperation amongst member countries could not be readily achieved for lack of framework agreement on sharing joint costs and benefits in equitable and cooperation-stabilizing ways, which principles and guidelines are included in this report. The use of formal cost-benefit analysis, equitable sharing and other concepts and techniques in this report are relevant and, indeed, vital if resources are to be judiciously allocated.

It is hoped that the report will indicate to the SADC Secretariat, River Basin Organizations (RBOs), government executives, Southern Africa Power Pool (SAPP), private actors and consultants working on regional infrastructure projects on shared watercourses and in the power sector, the value of economic analysis, and that it will also serve to guide economists on the application of the complicated methodology to real-world problem.

Sizo MHLANGA (Mr)
Officer-In-Charge

# Acknowledgement

This study was accomplished under the overall supervision of Ms. Jennifer Kargbo, Director of the Subregional Office of ECA for Southern Africa (ECA-SRO-SA) and guidance of Mr. Dhliwayo Minorweyi, Senior Economic Affairs Officer responsible for Infrastructure in the Office.

The study team comprised two consultants, namely Mr. Daniel B. Ndlela from ZIMCONSULT who produced a report on Cost-benefit analysis (CBA) and Mr. Lawrence Msaba of Southern African Power Pool (SAPP) who produced another report on issues and challenges associated with the SAPP. The team was complemented by Mr. Johnson A. Oguntola, Senior Regional Adviser (Integrated Water Resources Management (IWRM), whose initial report focused on CBA as a methodology for the *ex ante* appraisal of water resources projects and on other related concepts, including equitable sharing of costs and benefits of regional water, energy and other associated infrastructure projects.

The consolidation of the three original reports was achieved by the Senior Regional Adviser (IWRM), overseen by Mr. Emile Ahohe as Officer-in-charge (OIC), Subregional Office for Southern Africa (SRO-SA).

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# Executive Summary

This report presents the output of an analytical study of Cost-benefit analysis (CBA) and key issues and challenges of regional infrastructure development in the Southern African subregion. The report aims to inform decision makers and guide investment in regional infrastructure projects in the SADC region and offer general policy advice. The report is divided into six chapters: introduction, conventional cost-benefit analysis methodology and applications, relevant concepts for regional cooperation on joint infrastructure in trans-boundary river basins, economy of scale in the SADC power sector, issues and challenges in developing regional energy and water infrastructure and a general conclusion.

The introductory chapter I gives an overview and general background to the report, introduces the concept of cost-benefit analysis and sharing of common costs and benefits to promote regional cooperation and makes a case for infrastructure for competitiveness and for 'pull and push' factors in regional economy. The chapter gives the main objective as having a reference document for the subregional public and private actors in the water and power sectors. It cautions that CBA is not an easy task but possible and desirable for the subregion for future allocations of water and power resources as a framework. It cites the lumpy nature of investments, high transaction costs and externalities, to buttress the assertion.

Chapter II postulates that the basic tenet of CBA is the calculation of monetary values for the appraisal of net effect of economic benefits and costs. Although guidelines exist for carrying out CBA, the chapter argues that actual implementation is never an easy process. While the basic principles and structure of project appraisal are spelt out in the Report as Annex A, a caveat is added that it is vital for the reader to have a good grasp of the economic analysis anchored on procedures forming basis for CBA methodology. These include: (a) determination of costs and benefits; (b) conversion of market prices to accounting prices also known as shadow prices; (c) monetization or quantifying non-market impacts e.g. externalities; (d) inclusion of any indirect effects not already captured by shadow prices; (e) social discounting of costs and benefits with a real social discount rate; and (f) calculation of economic performance indicators, i.e. economic net present value (ENPV), economic rate of return (ERR) and the benefit-cost (B/C) ratio.

The chapter counsels that when converting market prices to shadow prices, it is important to carefully assess and consider how the social costs are affected by departure of observed prices from the following reference values:

- marginal costs for internationally non-tradable goods, such as local transport services;
- border prices for internationally tradable goods, such as agricultural crops or some energy services or manufactured goods.

For every traded item, border prices are easily available: they are international prices, Cost Insurance and Freight (CIF) for imports and Free on Board (FOB) for exports, expressed in the same currency. For non-traded items: the standard conversion factor is used for minor non-traded items or the items without a specific conversion factor, while for major non-traded items sector-specific conversion factors are used based on long run marginal cost or willingness-to-pay.

The chapter surmises that ENPV is the most important and reliable social CBA indicator and should be used as the main reference economic performance signal for project appraisal. The Economic Rate of Return (ERR) and Cost -Benefit Ratios are also meaningful. The evaluation criteria stipulates that every project with an ERR lower than the social discount rate or a negative ENPV should be rejected. A project with a negative economic return uses too much of socially valuable resources to achieve too modest benefits for all citizens.

The chapter recommends that application of the CBA framework to Regional Water and Energy Infrastructure should be done in two stages, starting with project definition and estimating costs and benefits of the project:

A precise definition of the project to be undertaken is important in order to set parameters for analysis. A project application may consist of several interrelated but relatively self-standing components. The components are separable and can be treated as independent projects if benefits and costs of each component are independent. Appraising such a project involves consideration of each component independently and assessment of possible combinations of components. Indirect costs and benefits need to be carefully evaluated as far as possible and be factored into the project analysis.

Total costs of a project comprise investment costs and operating costs. Costs should be expressed in terms of relevant opportunity costs (the expense of the next best economic activity that must be forgone if the project concerned is to be allocated resources). The economic costs of raw materials should be evaluated by considering the loss that their diversion from the best alternative use will cause to society. Sunk costs should be omitted. The cost of the measures necessary to neutralize possible negative externalities must be included in the economic analysis. The cost of other negative externalities must also be factored in for CBA.

Benefits should be valued unless it is clearly not practical to do so. Real or estimated market prices constitute the first point of reference for the value of benefits. Where market distortions exist, prices will not reflect the social opportunity cost of inputs or outputs and hence the prices will need to be converted into accounting prices using appropriate conversion factors provided by the planning authorities. The monetary value of benefits must be quantified, first, as the revenue from the sale of energy (at appropriate shadow prices). The latter can be substituted, if possible, by estimating the willingness to pay (WTP) for energy, for example, by quantifying the marginal costs the user would incur to acquire energy (e.g. installing and using private generators).

Chapter III of the report, given the finite nature of water resources, the presence of large transaction costs and externalities, which make it impossible to separate decisions on water use from decisions on property rights and the issue of CBA applications in water infrastructure projects, was discussed from a wider perspective. The source document or international instrument for water resources management, namely the 1997 UN Convention on the Non-Navigational Uses of International Watercourses, was copiously cited to demonstrate that in addition to the economic efficiency achieved with the classical CBA methodology in chapter II, there are other associated and broader tools of analysis for achieving not only economic efficiency, but also equitable use, as well as encouraging conservation and protection of the water resource.

The application of CBA methodology to water resources management in the light of the UN Convention was seen in two different perspectives: for the evaluation of economic feasibility of individual projects (be it in a non-cooperative game or in a manner designed to achieve Pareto efficiency) and for cost and benefit allocations to multipurpose objectives (especially to multiple beneficiaries, either on a single project or several projects within the same river basin).

The chapter analyses the UN Water Convention to highlight the importance of promoting optimality, efficiency, equity and fairness (and thus cooperation) in the development of the water resources either for a single project or for entire river basin development. It discusses the river basin as unit of planning and development and underscored the importance of River Basin Organizations (RBOs) as necessary mechanisms for the sustainable planning, development and management of trans-boundary river basins. RBOs promote consensus on data and information, policy integration, inter-operability standards and quantitative overall and distributive costs and benefits of various development scenarios for analysis and studies of project feasibility evaluation and sharing of benefits and costs. Discussions on the river basin as a planning unit also touched on the ecosystem approach, integrated water resources management (IWRM), sustainable development concept and governance for sustainable development.

Factors militating against regional cooperation along international watercourses are highlighted to include valuation in terms of costs and benefits of a riparian State, riparian discount rate of natural resource use, sense of shared identity with other riparian countries, concerns for issue linkages, national image and sovereignty and number of players and their capabilities, among others.

The chapter discusses issues relating to designing incentives and principles, including Pareto optimality, individual and group rationality, invariance to utility scale, additivity, monotonicity (or fairness) and explored opportunities offered by cost savings from economies of scale achieved through aggregating group or national needs and joint implementation of water infrastructure projects by groups of countries. Economies of scale was traced to various sources that include the geometrical and physical consequences of reconfiguration, cost of embodying capital services in capital goods and more intensive use of indivisible inputs.

The chapter examines at length issues concerning sharing of common costs and benefits of multi-purpose reservoirs among its beneficiaries and how to solve such problems in an efficient, optimal, just, equitable, fair, reasonable and sustainable way. Effective distribution rule, normative theories of justice, envy-free distribution, distributive judgments and interpersonal comparisons, priority principle, consistency principle, games of fair division, equity and efficiency, all of which are embedded in the concept of cost and benefit sharing, were highlighted. The chapter also discusses other incentives for cooperation, including managing water as a local common good, establishing common interests, devising incentives to advance common interests, formal and informal incentives for cooperative behaviours and harnessing economies of scale.

The chapter recommends that in addition to well-known components of costs of joint multi-purpose water infrastructure projects, the value of water resources project sites supplied by countries should be regarded as a proper component of the total costs of joint projects creditable as a real cost contributed by participating countries. It discusses the principles of equity and fairness in water rights distribution as well as typical solution concepts that embed economic efficiency, optimality, equity, fairness, sustainability and stability of cooperation. Important concepts, including CBA, Shapley value, nucleolus and the core, featured among other mathematical concepts highlighted in Annex D. The chapter also recommends a general principle for measuring cost and value of water. Finally, it includes a survey of water management problems and shared watercourses to which the principles outlined in the report have been or could be applied.

Chapter IV discusses economy of scale in the SADC power sector and chapter V discusses issues and challenges facing the energy sector to include (i) dilapidated power generation and transmission equipment; (ii) slow pace of implementation of power projects chiefly due to the inadequate project packaging capacity among member States and relevant institutions to match bankable projects with appropriate financing; (iii) over-dependence on ESKOM of South Africa to sign Power Purchase Agreements to secure project funding; (iv) single buyer model that discourages other creditworthy customers from participating in PPAs; and (vi) complex project financing deals driven by lenders.

The regional challenges in the development of the SADC power infrastructure include (i) lack of an enabling environment for other players to participate; (ii) differences in policies and legislation in various countries causing delays in concluding Power Purchase Agreements (PPAs) & Wheeling Agreements (WAs); (iii) need for government support for PPAs and/or wheeling agreements to underpin investment projects; (iv) project Coordination Aspects including the need for a dedicated Project Coordinator, and the need for Project Development Agreements (IGMOU and IUMOU); (v) impact of government internal costs on the cost of the project: Fees for EIA report reviews and approvals, VAT duties and taxes; and (vi) non-cost reflective tariffs.

Chapter V also discusses the water sector's main challenges, including (i) huge disparities between available water infrastructure and potential for development; (ii) lack of capacity to develop, implement, operate and maintain infrastructure systems; (iii) inadequately prepared projects in terms of bankability and project details; (iv) lack of funding for both project development and implementation; and (v) the need to balance the development drive with adequate environment, social and economic benefits.

Other challenges to the development of water infrastructure include (i) delays in concluding some of the agreements governing shared water courses; (ii) unwillingness of countries to cooperate on joint infrastructure projects; (iii) reduction in political will and support; (iv) climate change; and (v) the current global financial crisis.

Chapter VI, the general concluding chapter, highlights some of the issues and challenges that are associated with developing regional water and energy infrastructure which range from the physical state of infrastructure, financial requirements, to political willingness and institutional capabilities. The report also brings to the fore, the important roles of gender and environment as cross cutting issues.

# Chapter I – Introduction

## 1.1 Overview and general background of report

This report on Cost-benefit analysis (CBA) for appraisal of feasibility and for fostering cooperation projects in Southern Africa is a guide on how the region could harmonize its conduct of cost-benefit analysis of joint projects to promote regional cooperation in water and power infrastructure projects. It is built upon the conventional practice of CBA and the principles of sustainability, equitable sharing and obligations for cooperation among countries sharing an international watercourse as enunciated in the Revised SADC Protocol on Water (2000) derived from the 1997 UN Watercourse Convention, or among countries sharing a regional power pool facility.

The report is intended to serve as a reference for the SADC secretariat, SADC River Basin Organizations (RBOs), secretariat of Southern Africa Power Pool (SAPP), government executives, water and power utilities, private sector actors and consultants working on regional infrastructure projects on shared watercourses and in the power sector in Southern Africa. The intention is to acquaint them with international norms to discourage implementation of infrastructure projects that penalize external parties and to encourage coalitions of private actors joining efforts to implement medium- to large -scale multipurpose infrastructure projects.

The term "infrastructure" usually refers to the added-value of a nation-State (or region) relative to the raw natural capital of its ecological zones and includes dams, roads, ports, canals, sewers and border posts. Infrastructure in general terms is immobile (locality-dependent) and has a long expected service life. While CBA is not an easy task, it is both possible and desirable if the subregion is in the future to allocate its water and energy resources – human, financial and material – on as objective a basis as possible. In other words, it would be in the interest of the subregion to develop a sound economic framework for estimating the costs and values (benefits) of infrastructure projects.

One of the challenges especially in the case of water is the lumpy nature of infrastructure investments coupled with associated high transaction costs and externalities to third parties. Effective infrastructure project implementation hinges on international norms and sound practices acquired through training and practical experience but may be guided by operational manuals targeted at leaders and technical personnel who are able to achieve shared objectives. The actors are constantly changing, but a concise, common guideline is needed by all.

This report is intended therefore to supply that essential guideline, based on the demand formulated in the 2007-2009 ECA-SADC Multi-Year Programme of Activities. It was compiled from analytical studies conducted by two consultants and one member of ECA staff, with consultations among experts of SADC member States held during an Ad-Hoc Experts Group Meeting (AEGM) in Lilongwe, Malawi, in March 2010.

The study was undertaken in two phases: the first phase involved presentation of an outline framework for assessing costs and benefits as well as issues and challenges of regional infrastructure projects on energy and water brought forward by the sector experts at the AEGM. The second phase involved the writing of three individual reports: a main report on cost -benefit analysis framework and two supporting in-depth reports on the energy and water sectors to augment the main report. The recommendations and issues raised at the AEGM were taken into account in finalizing the three initial reports consolidated into this single document

## 1.2 Sharing of common costs and benefits promotes regional cooperation

Cost-benefit analysis is an economic evaluation tool to promote scientific choice of infrastructure, but can also be used as a tool for joint infrastructure cost- and benefit- sharing with a view to promoting optimality, efficiency, equity and fairness (and thus cooperation) in the allocation of the water resource either for a single project or for entire basin development. Relevant water infrastructure and operations may include dam reservoirs, conveyance canals, irrigation projects, power plants and power lines, desalination plants, water and waste-water treatment plants, groundwater or pipeline pumping stations, artificial recharge basins and other groundwater banking infrastructure.

In addition to having a strong river basin regulatory institution, regional cooperation is another necessary mechanism for the sustainable planning, development and management of trans-boundary river basins replete with positive and negative externalities, contested property rights and substantial gains from cooperation. Without cooperation, such international public goods become sources of international tensions as each country or water user maximizes its own benefits from the use of the resource without paying attention to the impact on other countries, over-exploitation, lower water levels or pollution. Moreover, cooperation among countries sharing an international watercourse may be necessary to achieve the desired optimality, economic efficiency, equity and fairness in the development of the international watercourse as recommended by the 1997 UN Convention.

However, achieving regional cooperation in sharing water resources across national borders remains a major challenge. Regional institutions such as the African Union Commission (AUC), the Economic Commission for Africa (UNECA), SADC, COMESA and other Regional Economic Communities (RECs) can help by putting relevant issues on the table and by promoting the establishment of strong and credible River Basin Organizations (RBOs) and Power Pools entrusted with conducting economic analysis and other similar studies to deal with issues concerning project feasibility, evaluation and sharing of benefits and costs as necessary incentives for fostering agreements among riparian or cooperating countries. The RBOs and Power Pools can also promote policy integration, inter-operability standards, consensus on data and information as well as quantitative overall and distributive costs and benefits of various development scenarios.

The incentive offered to induce cooperation among countries sharing international watercourses or Power Pools is inherent in the principles outlined in this paper to guide cooperative joint ventures, including discussions on issues relating to designing incentives and such principles as Pareto optimality, individual and group rationality, invariance to utility scale, additivity, monotonicity (fairness) and, most importantly, in exploring the opportunities offered by cost savings from economies of scale achieved through aggregation of group or national needs and joint implementation of water infrastructure projects by groups of countries. Economic theory informs that when the rate of output and capital are altered by reconfiguration rather than replication, the three dimensional world where we live always produces a complex set of reactions, some tending to reduce the unit cost of output and others tending to increase it. Other reactions also alter the performance of the capital good in ways that are only indirectly reflected in the relevant service flow.

Increasing returns to some characteristics of specific technologies are often balanced by decreasing returns to other characteristics of the main technology or in complementary technologies. The optimal size of productive unit is therefore the one at which the economies in some aspects of the technology just balance the diseconomies in other aspects. The smallest workable size is seldom the most efficient. As size increases most characteristics encounter favourable scale effects. However, many characteristics encounter decreasing returns which eventually dominate so that further increases in capacity result in higher rising costs per unit of capacity delivered. Furthermore, the steady high volume of throughput, needed to achieve and maintain potential economies of scale and scope could rarely be attained as long as the flow of goods depended on the local markets. All these issues underscore the need for regional cooperation.

A widespread problem occurring in the cost-benefit analyses of public works projects designed to serve different constituencies, such as a multi-purpose reservoir, is how to share common costs and benefits among its beneficiaries. The goal of this kind of cost-benefit analysis is how to devise criteria and methods for solving such problems in an efficient, optimal, just, equitable, fair, reasonable and sustainable way. It is this broad spectrum of cost-benefit analysis considerations that is explored in this Report to underscore the need for regional cooperation among countries that share international watercourses for the implementation of regional infrastructure and for compliance with the provisions of the 1997 UN Convention on the Non-Navigational Uses of International watercourses.

## 1.3 Case for infrastructure for competitiveness and as 'pull and push' factors in regional economy

This report comes against the background that to be "a competitive and effective player in international relations and the world economy", the subregion must place infrastructure as the 'pull and push' factor in driving investment in the regional economy. A general undersupply of infrastructure services can be a major binding constraint on the progress of economic activity.

In most parts of the African region, severe bottlenecks in road transportation, ports, energy and water have not only increased the cost of doing business, but have most certainly held growth back. Infrastructure development has been included in most if not all the treaties of the RBOs and the African Regional Economic Communities (RECs). This unquestionably provides the best framework for aligning sectoral policies as large infrastructure projects are intrinsically costly and risky for individual countries to undertake. Regional pooling of resources becomes a more sustainable approach to achieving infrastructure development.

The general agreement that investment in the economy in general and private investment in particular is being held back by lack of sufficient and reliable infrastructure services cannot be over -emphasized. The inadequacies of infrastructure networks are threats to national competitiveness and hamper the achievement of the economic potential of SADC's FTA and COMESA's custom union. Greater efforts should be made to increase subregional economic activity and to generate regional sources of capital so as not to jeopardize future growth opportunities and competitiveness.

There is a perception that the benefits of large regional infrastructure projects tend to disproportionately accrue to larger, compared to the smaller and low -income member States of a REC or RBO. The challenge to build an understanding of rationality in investing in such regional infrastructure is to convince member States that their contribution will have a positive impact on the national growth of all the countries that have proportionally taken a stake in these projects in line with their priorities. The difficulty in demonstrating the existence of benefits stems from the fact that, whereas the costs of regional infrastructure development are usually well defined, the benefits accruing to each party often are not. Demonstrating how each country in the regional supply chain would gain from regional infrastructure development is paramount in order to achieve regional cooperation in the financing of regional infrastructure.

Any appeal for infrastructure investment and development should also be matched by calls for sharpening the tools and methods of Cost-benefit analysis (CBA). This will assist in making informed policy decisions at the country and subregional levels. These methods provide perceptible awareness and define ways of improving the existing projects and programmes towards more efficiency, cost -effectiveness and sustainability. While the fundamental approach to CBA is similar, its application will differ between infrastructure sub-sectors and within countries. Some of the main differences include the types of impacts that are included as implicit and explicit costs and benefits within appraisals, the extent to which impacts are expressed in monetary terms and differences in the discount rate between countries and sectors.

# Chapter II – Conventional cost-benefit analysis methodology and application to water and energy sectors

## 2.1 Cost-benefit analysis (CBA) as a tool for project evaluation

CBA is a process used to appraise or assess a project or a proposal. It involves weighing the total costs (implicit and explicit) against the total benefits of one or more actions. The analysis finds, quantifies, and adds all the positive factors (the benefits), then identifies, quantifies and subtracts all the negatives (the costs). The difference between the two indicates whether the planned action has a net benefit and therefore advisable or should be set aside or discarded. The approach is explicitly designed to inform the decisionmakers through optimizing the social and environmental impacts. Applied to regional infrastructure, CBA can evaluate the desirability of regional projects. The aim is to gauge the benefit and cost of the infrastructure development relative to the status quo. The costs and benefits of an intervention are evaluated in terms of the public's willingness to pay for them (benefits) or willingness to pay to avoid them (costs).

A thorough and complete CBA is an indispensable tool in evaluating any seriously considered projects, including regional infrastructure projects. For large projects, the indirect economic effects should be taken into account explicitly, as the reasons for such projects usually involve strategic considerations. The application of CBA is not always appropriate for small infrastructure projects, however, an analytical framework considering opportunity costs of public funds, shadow prices for social benefits and forecasts of main variables on a time horizon of 10-20 years is always helpful (Alessandro Valenza and Silvia Vignetti, 2006).

The main task of CBA is the calculation of monetary values for the appraisal of net effect of social benefits and costs. Even though there are guidelines for carrying out CBA, the actual implementation is never an easy process. In assessing the costs and benefits of infrastructural projects, it is important to include all the possible benefits of flexible investment strategies. Moreover, uncertainties should be taken into account by adding a (project-specific) risk premium to the discount rate.

There are hardly any empirical studies that have focused on regional integration of infrastructure in Africa. The reasons could be due to data constraints and numerous components of welfare changes arising from the projects. For example, regional data do not usually allow analysts to make reliable estimates of the overall impact of individual projects on intra-regional trade or trade with other countries outside the region; indirect employment effects are difficult to quantify; and competitiveness may depend on foreign trade conditions, exchange rates and changes in relative prices (European Commission, 2008).

## 2.2 Methodology

The basic principles and structure of project appraisal consists of (i) definition of a project in the socio-economic context, (ii) project identification, (iii) feasibility and option analysis, (iv) financial analysis, (v) economic analysis and (vi) risk assessment. These steps are further outlined in Annex A. CBA is aimed at understanding the social, economic and institutional context in which the projects are implemented. Credible forecasts of B-C (benefits less costs) often relies on the accuracy in the assessment of the macro-economic and social conditions of the region.

CBA methodology comprises the following procedures:

i. Determination of costs and benefits;
ii. Conversion of market prices to accounting prices/ shadow prices;
iii. Monetization or quantifying non-market impacts (e.g. externalities);
iv. Inclusion of any indirect effects (when relevant and also not already captured by shadow prices);
v. Social discounting (costs and benefits are discounted with a real social discount rate); and
vi. Calculation of economic performance indicators i.e. economic net present value (ENPV), economic rate of return (ERR) and the benefit-cost (B/C) ratio.

### 2.2.1 Converting market prices to accounting prices (Shadow Prices)

The social opportunity cost of a good is better reflected by its accounting price. The most commonly used method of calculating shadow prices or accounting prices is the LMST method[1] (code named after Little, Mirrlees, Squire and Tak). The LMST approach divides goods into two broad categories:

- Tradable goods (consumption goods and productive factors that are exported or imported which have effect on a nation's balance of payments).
- Non-tradable goods (includes all other consumption goods and productive factors such as local labour, electricity and services).

The LMST methodology uses international prices to shadow-price project inputs and outputs that are classified as tradable. The underlying assumption is that world prices more accurately reflect the opportunities available to a country though they may not be totally free of distortions.  For every traded item, border prices are easily available, as international prices, cost insurance freight (CIF) for imports and free on board (FOB) for exports, expressed in the same currency.

1 The U.N. Industrial Development Organization and I.M.D. Little and J. A. Mirrlees initially developed the basic methods.  Lyn Squire and Herman van der Tak, employees of the World Bank, then synthesized the ideas.  The resulting approach (the LMST accounting price method) continues to enjoy wide acceptance, see Anvari Morteza, http://www.anvari.net/20_CBA/boardman_im_ch16doc

The shadow pricing involves multiplying each market price by an accounting price ratio (APR), where:

$APR_i$ = (accounting price of good i) ÷ (market price of good i)

$APR_i$ = (shadow price of good i) ÷ (market price of good i)

Shadow price of good i = $APR_i$ × market price of good i

Instead of computing a ratio for each component a standard conversion factor (CF) is used. CFs can be obtained from previous studies of the economy – for example, through "semi-input-output analysis (SIO)[2]."

Using SIO, an aggregate CF known as the standard conversion factor (SCF) can be obtained. The SCF is the ratio of the value of all production at accounting prices to the value of all production at market prices (i.e. it is a weighted average of CFs for all productive sectors, where weights are the contribution each sector makes to total national output). The SCF is used for minor non-traded items or the items without a specific conversion factor, while for major non-traded items sector-specific conversion factors are used, based on long run marginal cost or willingness-to-pay.

$$\mathbf{SCF = (M + X)/[(M + T_m - S_m) + (X - T_x + S_x)],}$$

Where: M is the total value of imports in CIF border prices, X is the total value of exports in FOB border prices, Tm is the total tariff on imports, Tx is the total taxes on exports, Sm is the total subsidies on imports and Sx is the total subsidies on exports.

SCF calculations may be more complex, because of non-tariff barriers and other sources of international trade distortions such as special regulations for the service sector as well as different tax patterns across countries and sectors. Ideally the calculation of some key national CBA parameters should be done by member States planning offices because of its macroeconomic nature and not on project by project basis (European Commission, 2008).

The cost insurance freight (CIF) price is the cost of an import plus insurance and freight expenses to the port of destination. CIF price is also referred to as a border price given that it corresponds to the foreign currency needed to pay for it at the border. When valuing an import price of a good, costs (*such as transport costs*) are added to the CIF price by using their respective shadow prices. However, tariffs are excluded. Since official exchange rates in developing countries often do not reflect the actual value of currency, shadow exchange rates can be used. Official exchange rates can nonetheless be appropriately used to value imports, if applied consistently.

2 The SIO analysis uses national input-output tables, national census data, household expenditure surveys and other national data (on tariffs, quotas and subsidies) to estimate CFs - Anvari Morteza: http://www.anvari.net/20_CBA/boardman_im_ch16doc

The free on board (FOB) price is the price of an export at the port of origin before insurance and freight charges are added. The FOB price includes the cost of producing the good, export taxes and the cost of transportation to the point of origin. The shadow price of an export is valued on the basis of contribution of each unit to the nation's foreign exchange.

Non-tradable inputs for a project, such as electricity, are diverted from other uses, as opportunity cost. For CBA purposes, this opportunity cost has to be measurable at the same standard with traded goods, hence the cost of the good can be broken into its traded, non-traded, and labour components. Each non-traded component can then be further broken down. By multiplying each of the components and sub-components by its APR, the opportunity cost of supplying a non-traded good to a project can be evaluated in terms of traded goods.

When the supply of an input is fixed (e.g. due to an import quota), then a project will increase the market price of the input, thereby reducing the consumption of it by current consumers. In such a case, the opportunity cost of using the input in the project is the consumption forgone by consumers.

Wages may be distorted due to various factors like imperfect labour markets, macroeconomic imbalances revealed by high and persistent unemployment, dualism and segmentation of labour conditions (e.g. when there is an extensive informal or illegal economy). Therefore, there is need to correct observed wages using conversion factors to compute shadow wages and the opportunity cost of labour.

If a conversion factor is available, the shadow wage can be obtained by multiplying the CF for skilled workers by the project wage. If a CF for skilled workers is unavailable, then a sector specific CF or the SCF can be used.

The opportunity cost of labour value depends on the various types or ranges of employment: (i) full employment, (ii) mild unemployment, (iii) dualistic labour market and (iv) strong involuntary unemployment. In situations where there is limited employment data, high unemployment levels and no unemployment benefits the CF for labour cost can be calculated as follows:

$$\mathbf{SWR = W(1-u)(1-t)}$$

Where SWR = shadow wage rate, **W** is the market wage, **u** is the regional unemployment rate, **t** is the rate of social security payments and relevant taxes. The conversion factor CF is (1-u)(1-t)

The formula table for calculating SWR for different types of employment is included in Annex B.

### 2.2.2 Monetization of non -market impacts and valuing costs and benefits where there is no market value

Where no market prices exist, the market may be simulated by estimating 'willingness to pay' (WTP) and willingness to accept (WTA) as the projects outcome methods. WTP and WTA are determined by inferring a price from observing consumer behaviour through use of questionnaires.

Where WTA and WTP fail to provide values, for example evaluating potential health benefits and environmental and social benefits, an alternative approach - the 'revealed preference' method - is used. Revealed preference techniques involve inferring an implicit price revealed indirectly by examining consumers' behaviour in a similar or related market. Hedonic pricing as an example of this approach may be used (H.M. Treasury, 2003)[3].

**Table 2.1: Examples of non-market impact valuation**

| Sector | Non-Market Impact | Impact assessment |
|---|---|---|
| Transport | Savings in travel and waiting time | The value of working time savings is the opportunity cost of the time to the employer, equal to the marginal cost of labour. |
| Healthcare | Life expectancy/ quality of life<br>- Prevention of fatalities/injuries | - Quality-adjusted life year (QALY) is the most commonly used measure of health benefit. Tools such as the EuroQol instrument allow for estimation of the number of QALYs gained by the recipients of the project.<br>- The WTP for a reduction in the risk of death or serious injury. |
| Environment | - Landscape<br>- Noise | -The Environmental Landscape Feature (ELF) model constitutes a first attempt at a benefits transfer tool for appraising environmental policies. The model provides estimates of the WTP for some features (e.g. heather moorland, rough grazing, field margins and hedgerows) on an area basis and estimates of their diminishing marginal utility.<br>- Noise is measured in Noise Exposure Forecast (NEFs); one NEF is equal to a mean exposure over time to one decibel of noise. The sensitivity of real estate prices to changes in noise level is measured by the noise depreciation |

*Source:* HM Treasury Green Book (2003)

3 A model identifying price factors according to the premise that price is determined both by internal and external characteristics of the good being sold. The model is often used in Housing and Transport projects.

### 2.2.3 Social Discounting

Social discount rate (SDR) is used for discounting in the economic analysis. It reflects the view on how future social benefits and costs should be valued when compared with present ones. Theoretically, a social discount rate determined country by country should better reflect this view. There are three alternatives for SDR (Florio M & Vignetti, 2003):

i. Using the real financial rate of return, supposing that the marginal public investment should have the same return as the private one;
ii. Using a formula based on the long -term growth rate of the economy; and
iii. Using a standard conventional cut-off rate (World Bank and European Bank for Research and Development use a quite high real required rate of return of 10 per cent).

It must be noted that it is more difficult to fix a standard benchmark for social discount rate across the subregion.

### 2.2.4 Inclusion of indirect effects

Indirect effects are defined as quantity or price changes occurring in secondary markets. It is therefore important to distinguish between efficient and distorted secondary markets in order to understand whether or not to include indirect effects in CBA. A distorted secondary market is one in which prices do not equal social marginal opportunity costs due to the existence of taxes, subsidies, monopoly power and externalities. Indirect effects occurring in efficient secondary markets should not be included in the evaluation of the project's costs and benefits whenever an appropriate shadow price has been given in the primary markets, the main reason being that they are already captured by shadow prices. Hence, adding these effects to the costs and benefits measured in primary markets results in double-counting.

With regard to fiscal corrections the general rules are as follows (European Commission 2008):

- Prices of inputs and outputs to be considered for CBA should be net of VAT and of other indirect taxes;
- Prices of inputs, including labour, to be considered in the CBA should be gross of direct taxes;
- Subsidies granted by a public entity to the project promoter are pure transfer payments and should be omitted from revenues under economic analysis (i.e. CF=0).

However, there are instances in which the indirect taxes (or subsidies) are enforced as a correction for externalities, for example, taxes on carbon dioxide emissions to discourage negative environmental externalities. In such a case it is justifiable to include these taxes (subsidies) in project costs (benefits), though care should be taken to avoid double counting.

## 2.2.5 Calculation of economic performance indicators

After the correction of price (or wage) distortions and the choice of an appropriate social discount rate, the project's economic performance can be calculated using the following indicators[4]:

- Economic Net Present Value (ENPV) - the difference between the discounted total social benefits and costs;

$$ENPV = \sum_{t=0}^{n} a_t s_t = \frac{So}{(1+i)^0} + ENPV = \sum_{t=0}^{n} a_t s_t = \frac{So}{(1+i)^0} + \frac{S1}{(1+i)^1} \frac{S1}{(1+i)^1} + \dots + \frac{Sn}{(1+i)^n} \frac{Sn}{(1+i)^n}$$

*St* = balance of cash flows at time t, *ai* = discount factor, n=number of years, t= time

- Economic Internal Rate of Return (ERR) - the rate that produces a zero value for the ENPV;

$$ENPV ENPV = \sum s_t \sum s_t / (1 + ERR)^t (1 + ERR)^t = 0$$

- Benefit -Cost ratio, i.e. the ratio between discounted economic benefits and costs.

$$B/C B/C = PV(B)/PV(C) PV(B)/PV(C)$$

PV = present value, B= total benefits, C=total costs

The ENPV is the most important and reliable social CBA indicator and should be used as the main reference economic performance signal for project appraisal. The ERR and B/C though meaningful, are independent of the project size and may involve problems. There may be cases where the ERR may be multiple or not defined, while the B/C ratio may be affected by considering a given flow as either a benefit or a cost reduction. Nevertheless, the use of the benefit-cost ratio is appropriate, for example, under capital budget constraints. The evaluation criteria is that, every project with an ERR lower than the social discount rate or a negative ENPV should be rejected. A project with a negative economic return, uses too much of socially valuable resources to achieve very modest benefits for all citizens.

## 2.2.6 Sensitivity analysis

This is used to test the vulnerability of options to unavoidable future uncertainties. Spurious accuracy should be avoided, and it is essential to consider how conclusions may change, given the likely range of values that key variables may take. Therefore, the need for sensitivity analysis should always be considered and, in practice, dispensed with only

4 Ibid

in exceptional cases.  The calculation of switching values shows by how much a variable would have to fall (if it is a benefit) or rise (if it is a cost) to make it not worth undertaking an option. This should be considered a crucial input into the decision as to whether a proposal should proceed or not. It therefore needs to be a prominent part of an appraisal[5].

Variables that are likely to be both inherently uncertain and fundamental to an appraisal include growth of real wages, forecast revenues, demand, prices and assumptions about the transfer of risks.

## 2.3 Shortcoming of the CBA approach

CBA is an applied social science that heavily relies on approximations, working hypotheses and shortcuts because of lack of data or constraints on the resources of evaluators. Its subjective nature therefore requires that evaluators do their job in the most independent and honest environment so as to bring about best possible analysis.

## 2.4 Applications of the CBA framework to regional infrastructure projects

Box 1 below summarizes the steps and sequence of tasks involved in the application of the CBA framework to regional infrastructure projects.

### Box 1: CBA Framework

Step 1: Setting the stage
- Specify the project to be undertaken.
- Identify any constraints that must be satisfied and any other factors to consider in the analysis (e.g. the effects of a project proposal on small businesses and the socially disadvantaged).

Step 2: Determine the scope of the analysis
- Determine the stakeholders to be considered.

Step 3: Assess the costs and benefits
- Direct costs – the costs of implementing and maintaining the project
- Quantity and quality of the goods to be supplied.
- Efficiency of competition.

Step 4: Output
- Provide a baseline statement of the problem that the project is designed to address.
- Present the main option(s) considered.
- Provide an appraisal setting out the costs and benefits of those options, quantifying them or (if quantification is not possible) being explicit about the trade-offs involved. The appraisal should also set out key assumptions on which the analysis is based.

5 HM Treasury (2003)

### 2.4.1 Project definition

A precise definition of a regional project to be undertaken is imperative in order to set parameters for analysis. A project application may consist of several inter-related but relatively self-standing components, for example, a multipurpose project comprising hydro-electric power, irrigation water and recreational facilities. When benefits and costs of each component are independent, then the components are separable and can be treated as independent projects. Assessing such a project will involve, firstly, the consideration of each component independently and, secondly, the assessment of possible combinations of components (European Commission, 2008).

Having a well defined project therefore helps to ensure that direct and indirect benefits and costs are specified accurately, within long-term system planning.

#### Estimating costs

Total costs of a project are made up of investment costs and operating costs. Costs should be expressed in terms of relevant opportunity costs, which reflect the expense of the next best economic activity that must be forgone if the project concerned is to be allocated resources. It is important to explore all possible opportunities that may exist.

Sunk costs - costs of goods and services that have already been incurred and are irrevocable therefore should be disregarded in an appraisal. Relevant costs are those about which decisions can still be made. However, this includes the opportunity costs of continuing to tie up resources that have already been paid for. Depreciation and capital charges should not be included in an appraisal of whether or not to purchase the asset that would give rise to them[6]. Depreciation is an accounting device used to spread the expenditure on a capital asset over its lifetime. Capital charges reflect the opportunity cost of funds tied up in capital assets, once those assets have been purchased.

Even where an appraisal covers the full expected period of use of an asset, the asset may still have some residual value in an alternative use within an organization, in a second-hand market, or as scrap. These values should be included and tested for sensitivity, as it may be difficult to estimate the future residual value at the present time. It can be useful to distinguish between fixed, variable, semi-variable and step costs:

- Fixed costs remain constant over wide ranges of activity for a specified time period;
- Variable costs vary according to the volume of activity;
- Semi-variable costs include both a fixed and a variable component e.g. maintenance costs that may vary in proportion to activity;
- Semi-fixed or step costs are fixed for a given level of activity but they eventually increase by a given amount at some critical point.

6 These maybe important for resource budgeting purposes; HM Green Book (2003)

### Estimating the value of benefits

The general rule is that benefits should be valued unless it is clearly not practicable to do so. Real or estimated market prices provide the first point of reference for the value of benefits. Where market distortions exist, prices will not reflect the social opportunity cost of inputs or outputs hence the prices will need to be converted into accounting/shadow prices using appropriate conversion factors[7]. For example in the case of a market dominated by monopoly suppliers, or significantly distorted by taxes or subsidies, prices will not reflect the opportunity costs and therefore will need to be converted.

## 2.4.2 CBA framework applied to national or regional Energy sector

### Valuation of benefits

The monetary value of benefits must be quantified, first, as the revenue from the sale of energy (at appropriate shadow prices). The latter can be substituted, if possible, by estimating the willingness-to -pay (WTP) for energy, for example, by quantifying the marginal costs the users would incur to acquire energy (e.g. installing and using private generators).

The above -mentioned estimated accounting/shadow price does not include additional socio-economic benefits deriving from the implementation of projects that use renewable energy. Renewable energy benefits such as reduction in greenhouse gases that affect the climate and the production of polluting gases, liquids and solids of various kinds which adversely affect the environment and human health, need to be valued. Such benefits can be valued by use of a standard shadow price, e.g. for the carbon dioxide emissions avoided (*the shadow price should be attributed to the quantities of energy, produced or saved*). Alternatively, the financial value of the incentives for the production of energy from renewable sources can be used as a proxy of the WTP of the whole society for the environmental benefits from the renewable sources. The shadow price can be applied to the amount of the saved energy (or consumption avoided) in the energy saving projects as well.

The value attributed to a greater or lesser dependence on energy from abroad should also be estimated. The evaluation should be conducted by applying appropriate shadow prices to the substituted imported energy.

### Valuation of Costs

There is need to identify the opportunity cost of the various project inputs. The economic costs of raw materials should be evaluated by considering the loss to society of their diversion from the best alternative use. Costs of goods and services that have already been incurred and are irrevocable must be ignored as they are 'sunk costs'. Only costs about which decisions can still be made should be factored in and this includes the opportunity costs of continuing to tie up resources that have already been paid for.

The cost of the measures necessary to neutralize possible negative effects on air, water and land, both due to the construction and operation of the plant must be included in the

7 In most instances this is provided by the planning authorities

economic analysis. The cost of other negative externalities that cannot be avoided, such as loss of land and spoiling of scenery, should also be included.

### CBA Framework applied to hydropower projects

The concepts outlined above are generally applicable in both large national and regional projects, as shown in Table 2.2 below.

## Table 2.2: Examples of benefits and costs associated with installing a new Hydropower Generating Plant

| Beneficiary | Direct Benefits | Indirect Benefits |
| --- | --- | --- |
| Consumers | Reduced tariffs, due to lower operating costs as a result of economies of scale,<br>Increased employment levels in all involved member States during the construction phase and also maintenance phase,<br>Improved supply conditions (World Bank, 2009), including better reliability and security of supply due to access to imports during emergency situations (Eberhard,2003, SEE Case Study),[1]<br>Improved access, reliability and quality of service, while allowing lower tariffs. Lower electricity rates, achieved through regional electricity cooperation and integration, will foster increased regional growth. Enhanced rural electrification programmes as local needs of individuals, families, communities and businesses will be better met through the increased availability of electricity. | Time saving for the individuals previously not having access to electricity;<br>**Water for recreational use:** water from reservoir can be used to develop public recreational facilities like water parks for water sports and gardens.<br>Flood control and prevention:- dams help prevent floods in the areas adjoining the large rivers. |
| Industrial/ Firms/ Investors | Increased revenues as more consumers access electricity- e.g. through rural electrification.<br>Reduced or postponed costs, which include short-term energy and operation costs (World Bank, 2009) as well as long-term investment costs through improved reserve margin and avoided investment in peak capacity (RECI, Module 1).<br>Economies of scale as larger-scale plants are enabled by larger markets (Eberhard, 2003). Lower production costs and/or lower investments in generation, achieved through the interconnection of electric power systems, should have an impact on rates to the customers' advantage.<br>Fostering further development of country-level electricity markets where integration allows sufficient scale to support increased competitive participation (UN-DESA, 2005, SIEPAC Case Study). The extent of competitive market development that can be supported will depend on the degree of market power. | Damming for hydropower provides **irrigation water for farming t**hus ensuring agriculture outputs throughout the year even in the areas where there is scanty or no rainfall.<br>Developing countries overcome costs and national limits in technical expertise by sharing skills.<br>Enhancing the capacity of these countries to credibly commit to a stable regulatory policy can ultimately facilitate infrastructure investment. |

| Beneficiary | Direct Benefits | Indirect Benefits |
|---|---|---|
| Government | Reduced fiscal strain due to reduced costs and where private sector investment is enabled (Eberhard, 2003, Argentina-Brazil Case Study). Increased revenues from such activities as exporting electricity and wheeling | Political benefits as a result of increased interdependence and integration among neighbours, and closer ties fostered by the experience of cooperating to develop the integration (Eberhard 2003; UN-DESA 2005, SEE Case Study. Strengthening the legal capacity and experience in countries participating in the process of creating legal structures to support electricity integration. This process can also establish a precedent for trade in other energy forms or products (UN-DESA, 2005). |
| Environmental | Reduced environmental impact (including avoided air and water pollution and displacing biomass which is often associated with deforestation; UN-DESA) and contribution to sustainable development resulting from more efficient energy use (Eberhard, 2003) | |
| COSTS | | |
| Consumers/ Individuals | **Large -scale human displacements as communities in the affected areas are forced to relocate.** | |
| Industrial/Firms/ Investors | **High initial capital cost or investment**. Hydroelectricity plants take ample time to construct as they involve lots of designing, planning and testing. Dam construction requires: Lots of steel, iron and cement which make the hydroelectric power plants very expensive. | |
| Government | Fiscal strain due to high set up costs associated with installing a new generating plant. | |
| Environment | **Disruption of the ecosystem;** river damming can disturb the animal and vegetation life which can lead to their destruction and possible extinction. Loss of land. | |

A specific example of benefits and costs associated with a regional hydro-power project in the Southern Africa subregion - the Western Power Corridor Project (Westcor), is summarized in Box 2 below:

### Box 2: Westcor Cost-Benefit Analysis

The benefits would have been:

- Estimated revenues annually from sales US $US2 Billion
- Job creation in the five countries during and after construction works.
- Income to WESTCOR SADC
- Reduction in carbon emission
- Economic growth due to increased availability of electricity supply
- Reduced power deficit leading to economic growth
- Minimization of carbon emissions
- Increased access to electricity for the people of Southern Africa
- Minimum environmental and social impact
- Positive contribution to renewable and sustainable energy and addresses action on minimizing climate change
- Long-term benefits outweigh cost of project.

Costs

- Total cost of the project $US8 Billion, including transmission lines
- Loan and debt repayment within 10 years
- Resources (Water + Land Usage +Taxes) and concession payment to D R Congo estimated at $US500 Million per annum

## 2.4.3 CBA Framework applied to provision of water services

Because water services is a broad subject, the benefits and economic costs of projects in the water resources sector have to be identified on a case-by-case basis as they are strongly related to the type of investment and services offered.

### Valuation of benefits and costs:

#### (a) Trans-boundary river basin projects

The primary basis for determining the benefits from the development of a trans-boundary river basin is the expected contribution of the planned development programme. This is estimated by the incremental benefits to the system expected to result from the planned project. Benefits resulting from any of several segments of a planned programme would be common to the system and hence not creditable to a specific segment merely because of its priority in scheduled development.

The value of the site and water resources contributions may be measured by their opportunity cost (the expected productivity in available independent alternatives that are foregone as a result of the joint project). This would be the value of the net benefits expected to accrue within the country from the most advantageous independent alternative likely to be developed in the absence of the joint project. The foregone benefits would be the net of required development costs and their value adjusted for time and certainty of occurrence on the basis of standards comparable to those used for the joint project. The costs of a joint development project would thus include two components:

i. the outlays necessary for establishing and operating the project; and
ii. opportunity costs reflected in the net benefits foregone from available independent alternatives.

The project benefits would need to be sufficient to cover both components of costs, with any excess indicative of the mutual advantage of joint development. A more in -depth analysis of trans-boundary river basin including, cost- and benefit-sharing, is presented in chapter III below.

### (b) Projects aimed at increasing the quantity and or reliability of water supply

The main social benefit in the economic analysis may be evaluated according to estimates of expected demand for water resources that the project will satisfy. The benefit is equal to the water demand satisfied by the project and not satisfied in the do-nothing alternative, suitably valued (European Commission, 2008). Water service provision is a classic case of natural monopoly with local authorities dominating; hence the market prices generally suffer considerable distortions.

The shadow price for water can be estimated on the basis of the user's willingness-to-pay for the service. This WTP can be estimated empirically by applying the market prices of alternative services (such as water tank trucks, bottled drinking water, distribution of drinks and purification by means of technological devices installed by the users).

Alternatively, a conversion factor (CF) may be applied to the revenues deriving from the water service, achieved or improved by the project. The CF is based on a planning parameter that can be defined, e.g. by calculating the mean value between the WTP and the long -term marginal cost of the service, and adjusting the result in order to take the distributive effects into account. This method must be used with caution, and only in cases where it is difficult to determine the WTP directly.

### (c) Water projects aimed at preventing leakages

The main benefit of the interventions aimed at limiting water leaks is the reduced volume of water used for supplying the networks compared to an equal or greater quantity of distributed water. Examples are projects for network rehabilitation or, more in general, of 'water asset management'. As in the previous case (a), the benefit is given by the water preserved for other uses, to be quantified as indicated above.

### (d) Projects aimed at improving the quality of water

For any intervention, that is intended to guarantee the availability of drinking water resources in areas with sanitary problems, and where water sources are polluted, the benefit may be directly estimated by valuing the deaths and illnesses that can be avoided by means of an efficient water supply service. To make an economic valuation, it is necessary to refer on one hand (illnesses) to the total cost of hospital or out-patient treatments and to the income loss due to possible absence from work, and on the other hand (deaths) to the statistical life value quantified on the basis of the average income and residual life expectancy or with other methods.

### (e) Sewer and depurator projects

The social benefits of sewer and depurator projects may be evaluated on the basis of the potential demand for sewage that will be fulfilled by the investment and estimated according to an adequate accounting price. Alternatively, if possible, direct valuation may be applied to benefits such as:

- The value of the illnesses and deaths avoided as a result of an efficient drains service; and
- The value derived from preserving or improving the quality of the water bodies or the lands in which the waste water discharges and the related environment.

### (f) Mixed drains projects

For mixed drains projects, the benefit is the damage avoided to land, real estate and other structures due to potential flooding or unregulated rainwater, valorized on the basis of the costs for recovery and maintenance (avoided costs). Taxes and subsidies should be treated as transfers within society and should therefore be excluded from the estimation of economic costs. However, in the water service projects, as in other sectors in which a strong connection with the natural environment exists, it is important to distinguish between general taxes and environmental taxes and subsidies:

- general taxes need to be deducted from economic costs;
- environmental taxes and subsidies may represent internalized environmental costs or benefits and, as such, should not be deducted from economic costs or revenues (but attention should be paid in such a case to avoid double-counting of externalities).

## CBA Framework applied to the Lesotho Highlands Water Project (LHWP)

The Lesotho Highlands Water Project (LHWP) is a good example of a successful regional water project with hydropower generation component. The aim of the project was to provide the South African province of Gauteng with the lowest cost alternative supply of water and at the same time supply electricity and revenue to Lesotho. Box 2 above summarizes the LHWP objectives, benefits and costs as well as lessons learnt from project.

## 2.5 Developing effective policies, financing mechanisms and institutions for harnessing benefits of regional infrastructure

### 2.5.1 Policy Challenges in the power sector

The World Bank (2009) report states that the depth and extent of Africa's power crisis and associated costs require renewed efforts to tackle the policy and institutional challenges needed to improve performance and financing. The report identified the following as key challenges:

- Strengthening sector planning;
- Recommitting to the reform of State-Owned Enterprises;
- Increasing cost recovery;
- Speeding up electrification;
- Expanding regional trade in power; and
- Closing the financing gap.

The report suggests that the interdependent challenges highlighted above could be tackled simultaneously, as efforts to boost generation through regional power trade may stumble if the utilities remain inefficient and insolvent. Expanding electricity distribution systems without addressing power generation shortages and improving transmission capacity would clearly be futile. In addition, focusing exclusively on utility reform would be fruitless without a start on substantial, long -gestation investments in both generation and access to improve the quality of service and make the utilities viable.

### 2.5.2 Financing Infrastructure in Southern Africa

The financial challenges in regional infrastructure development derive from lack of coherent policy framework for infrastructure development and financing socially desirable but non-bankable projects. Inadequate infrastructure due to inadequate funding gives rise to high transaction costs.

The financial viability of existing utilities is a key foundation of healthy power and water sectors. If the utilities become financially viable they will be more operationally effective as they are able to finance timely maintenance activities. They also become more creditworthy and thus may begin to secure their own access to domestic or international capital markets. Such a goal can only be achieved through tariffs that are high enough to cover operating costs and to contribute as much as possible to covering capital costs as well.

The global financial crisis and huge government debts constitute other factors affecting finance for infrastructure projects in the region.

## Ways of Financing Africa's Infrastructure

The traditional mechanisms of financing Africa's Infrastructure have been through international and regional funding agencies such as the World Bank, European Union/EIB Infrastructure Trust Fund, African Development Bank and NEPAD Projects, China and other bilateral agreements.

Infrastructure development has been solely the responsibility of the Government but in recent years the private sector is increasingly getting involved, mainly through Private Public Partnerships (PPPs). Sources of funds have now been diversified to include financial institutions, export credit agencies, official development assistance and development finance institutions. The sources of funds for infrastructure development tend to depend on the extent and nature, scope and scale of a particular project.

The power sector constitutes Africa's largest infrastructure needs. Whether measured in generating capacity, electricity consumption, or security of supply, Africa's power infrastructure delivers only a fraction of the service found elsewhere in the developing world (World Bank, 2009).

Regional trade is the most cost-effective way to expand Africa's power generation since it allows countries to pool the most attractive primary energy resources across national boundaries. According to the World Bank Infrastructure Report 2009, regional trade shaves around $US0.01 per kilowatt-hour off the marginal cost of power generation in each of the power pools (and as much as $US0.02 to $US0.04 per kilowatt hour for some countries), leading to savings of about $US2 billion a year in the costs of developing and operating the power system.

In order for Africa to meet the estimated $US92 billion investment in infrastructure for the next 10 years, UNECA[8] suggest the following financing initiatives:

- African Governments to continue playing an important role in infrastructure development;
- Donor community to increase funding for infrastructure development. However, it is important that there be coordination of projects among donors;
- Using Africa's Pension funds to finance infrastructure;
- Infrastructure indexed bonds as a potential means of financing Africa's infrastructure;
- Using the Global Financial Markets to finance infrastructure;
- Special Government credits to private investors in infrastructure development;
- Establishing regional infrastructure banks;
- African countries devoting a fixed percentage of their GDP to infrastructure development; and
- Levying special taxes to support infrastructure development.

8 AEGM presentation on Financing Africa's Infrastructure by Mr. Joseph Attah-Mensah of ECA's Regional Integration, Infrastructure and Trade Division, March 2010.

Instead of heavily relying on the above traditional financing mechanisms, an alternative approach would be to allow a limited number of energy intensive users, such as large mining companies, to sign and buy directly from cross-border projects by way of PPAs to make the projects funded**.**

A sustainable flow of capital from international markets to develop infrastructure in Africa is impeded by issues relating to policies, institutions and regulation. It is important that African Governments should set up an African Investment Guarantee Agency to provide risk-mitigation instruments (including guarantees and political risk insurance).

## Private sector participation

Private sector engagement in SADC countries is at various levels of development ranging from strong public-private sector partnerships, on one hand, to a cautious relationship between the State and Business. In the latter case, the private sector is generally handed down the policies and at best engaged at the programming stage. In member countries where the Public Sector sees it as mandatory to consult the Private Sector on policy, legislation and programmes that affect business, markets tend to be better regulated and developed and business environments are more attractive to both internal and external investors (*SADC RISDP, 2008*).

Where Governments of member States consider infrastructure investment to be strategic, equity has been bought directly or indirectly within the project and provided guarantees in order to reduce risk. They have also teamed up with the private sector within the Build-Operate and Transfer (BOT) framework to encourage PPPs (SADC Infrastructure Development Status Report, 2009). Other PPP options include Build-Own-Operate-Transfer (BOOT), Lease-Rehabilitate-Operate-Transfer (LROT), Build-Transfer-Lease (BTL) and Joint Ventures (JVs).

Governments have been the main actors of economic activities in Africa. However, in recent years, Africa's private sector has been growing partly due to globalisation and the inefficiency of State -owned companies to manage infrastructure. In sub-Saharan Africa, the share of private investment in total investment stood at 70 per cent in the 2000s, up from 51 per cent in the 1970s. Although the performance of the private sector in the 1990s and mid -2000s has been very positive, there is still need for increased private sector participation in the provision of infrastructure on the continent.

There has been exceptional growth in private sector infrastructure financing in recent years[9]:

- Consortiums with defined equity structure in the investment (Maputo Corridor and New Limpopo Bridge) Public Private Partnerships – Governments have identified infrastructure as strategic and bought equity

9 Mxolisi Notshulwana (DBSA) March 2010: Policy and Financial Implications of Infrastructure of Regional Development, UNECA Workshop, Lilongwe, Malawi.

directly or indirectly within projects and provide guarantees in order to reduce risk.

- DBSA through partnership and mobilization of its resources contributes to this financing framework by combining financial support with development knowledge. DBSA has financed over 60 per cent of the public power utilities operating in the Southern African subregion and the commitment beyond financing is illustrated by the longstanding relationship with Zambia Electricity Supply Corporation (ZESCO). DBSA's cumulative commitments in SADC exceed $US 1.2 billion and comprise medium and long-term finance (public and private) in a range of currencies.
- DBSA's participation in large, complex projects such as Mozal Smelter, the N4 Toll Road between Witbank and Maputo, the Marromeu Sugar project and Lesotho Highlands Water project have resulted in strengthening of relationships with commercial and development finance institutions (DFIs). Removing constraint to enterprise development, development of capital markets and extension of credit lines to intermediaries, are some of the activities that DBSA is engaged in on infrastructure funding.

The limited financial resource of African Governments is one of the reasons for their inability to provide adequate infrastructure. Furthermore, infrastructure competes with other sectors for government financing. Governments have a tendency of heavily subsidizing infrastructure services, which are priced below costs, putting tremendous strain on their budgets. Key policy issues that need to be addressed are summarized in Box 3 below:

### Box 3: Key Policy Issues on Financing

- African Governments should set up an African Investment Guarantee Agency to provide risk-mitigation instruments (including guarantees and political risk insurance).
- Strengthening of capital markets in member States is crucial for participation of the private sector in the development of infrastructure.
- Governments should continue to be major players in the financing, development and delivery of infrastructure services.
- Debt clearing strategies should be in place to improve creditworthiness of Governments, crucial in facilitating access to global and domestic capital markets, and to bring in private equity investments to a range of public-private partnerships.
- Institutional reforms should be pursued to provide transparency, good corporate governance, good regulatory framework and an enabling environment for private and public enterprises to thrive.
- Strong institutional framework for protecting creditors' rights, effective covenants and sound legal systems are important for achieving substantial investments in infrastructure.
- Stable macro-economic policies are essential for infrastructure investment promotion.
- Development of cross -border financing.
- Financing issues need to be resolved before project inception to avoid discontinuity.

### 2.5.3 Gender Mainstreaming

The SADC secretariat has made giant strides in embracing gender equality in most of its programmes, including infrastructure. Progress has been made with respect to gender mainstreaming in infrastructure programmes and projects as, among others, they relate to the following[10]:

- Ensuring that infrastructure provision addresses gender equality in terms of equal rights, responsibilities and opportunities of women and men in all infrastructure projects and programmes in both urban and rural settings. This means that women and men are not discriminated against in access to opportunities;
- Training of women in careers involving infrastructure to enable them to attain decision -making positions in the sector which has hitherto been the preserve of men;
- Promotion of economic empowerment of women and men through promotion of community based projects in the areas of tourism, communication and transport.

It is, however, important that gender mainstreaming be seriously implemented at the national level. Member States are urged to mainstream gender in infrastructure decision -making and develop appropriate indicators to measure it. Member States should ensure that water infrastructure provisions address the needs of rural women - as they are mostly affected by the water infrastructure deficiencies - by including Gender Experts in water infrastructure decision -making. Ultimately, this will reduce the burden of collecting water and promote community based social development (MDG3).

### 2.5.4 Facilitating the process of Regional Integration

The World Bank Independent Evaluation Group, (IEG, 2007) identifies three unique dimensions of regional programmes to be:

- The design and implementation of regional programmes must account for relations between countries and political economy within countries;
- Regional programmes require division of labour between regional and national institutions which need to be agreed and structured; and
- Regional programmes involve objectives on two levels, regional and national, that have to be harmonized and sequenced.

The IEG also notes that successful regional initiatives hinge on the following factors (World Bank, 2007):

- Strong country commitment to regional cooperation;
- The scope of objectives has to match national and regional capacities;

10 SADC Report (2009) op.cit

- Clear delineation and coordination of the roles of national and regional institutions;
- Accountable governance arrangements; and
- Planning for sustainability of programme outcomes.

Political commitment is a primary requirement for a successful regional integration process. Achieving this cooperation requires evaluation of the costs, benefits and risks (winners and losers at the country and within-country level) and recognition of how benefits and costs will be shared.

Coordination is necessary to overcome market failures and address the political concerns. Coordination is needed both during the process of developing the regional integration arrangement and thereafter in the phase of operating the regional power system. Country -level roles must be clearly defined and understood.

Sequencing is characterized by four overlapping phases, the order of which is not necessarily binding save for reaching of agreements being a foundational requirement for a successful project implementation:

- Demonstrating project feasibility, reaching agreement among participating countries and arranging financing;
- Developing the institutional infrastructure;
- Developing the physical infrastructure; and
- Preparing the operating phase.

Institutional reform measures hold the key to improving utility performance. Countries that have advanced the institutional reform agenda for the power sector show substantially lower hidden costs than those that have not, as do countries with more developed power regulatory frameworks and better governance of their State-owned utilities[11].

The UNDESA (2005) report suggests that economic and financial structures need to be in place before physical interconnectors proceed. Also, fairness, inclusiveness and transparency are vital to ensure that all groups and stakeholders are represented in the process of developing the integration project.

Political agreements underlie the legal agreements; these should stipulate how benefits, costs and information are to be shared. Also of importance is how the interconnection will be operated and how firms will be selected and paid[12].

## 2.6 Conclusions and recommendations

In conclusion, the chapter puts forward the view that Cost -Benefit Analyis (CBA) is a useful tool in appraising regional water and energy infrastructure projects. It is also very helpful in informing decisionmakers through highlighting the social, economic and en-

11 World Bank Report 2009: Africa's Infrastructure, A Time For Transformation.

12 Ibid

vironmental impacts. Though not explicitly taken care of in the CBA methodology, the impacts of cross cutting issues of gender mainstreaming in the infrastructural development is considered important in both project formulation and implementation. Though the CBA fundamentals are the same, the application to specific sector and sub-sectors vary with the nature of each project. As demonstrated in this chapter, utmost care needs to be taken when evaluating indirect benefits and costs to ensure that there is no double counting of impacts.

The accuracy of CBA results depends on the availability of relevant up -to -date information and an independent and honest environment crucial for project evaluators to bring about best possible analysis since CBA involves processes that are subjective in nature. Record keeping and data compilation are still lagging behind in most SADC countries and need to be addressed.

The most important evaluating tool of CBA is the economic net present value (ENPV). A positive ENPV (*ENPV>0)* shows that a project has a positive impact on society and is worth implementing. However, when ENPV is negative, this shows a project will not be useful to society. The only exceptional cases where a project with a negative ENPV can be carried out would be in projects with significant non-monetary benefits such as cultural values and biodiversity. The ENPV differs from the Financial Net Present Value (FNPV) in that the latter uses distorted market discounted values, whereas the former uses opportunity costs or shadow prices of goods and services which include as much as possible any social and environmental externalities associated with the regional infrastructure project.

While cost-benefit analysis is the most commonly used technique in appraising public investment other methods such as the Cost-Effectiveness Analysis (CEA), Multi-Criteria Analysis (MCA) and Economic -Impact Analysis (EIA) can also be used. These approaches, however, cannot be seen as substitutes for CBA but rather as complements for special reasons or as a rough approximation when actual CBA is impossible. In addition, these alternative methods are often difficult to standardize, making comparison across regions complicated.

The success of any regional infrastructure project hinges on more than a comprehensive CBA model. It rests also on wide ranging factors such as funding availability, managerial capabilities, institutional reforms and political commitments.

Political commitment is a key factor to regional infrastructural development. The extent to which the countries are committed to the projects is directly influenced by the level at which projects are endorsed. Regional projects should be endorsed at Heads of State level rather than at Ministerial level as is the case at present. Political commitment could then endorse a Project Coordinator and government underwriting of the tariff gap could set the appropriate policy to enable regulators to implement "cost pass through".

SADC and COMESA should enhance economic initiatives in infrastructure development. There is need to speed up the establishment of a SADC project preparation unit with the requisite capacity to prepare bankable infrastructure projects and mobilize capital for project implementation. Leading countries in implementing regional infrastructure projects are encouraged to set up Special Purpose Vehicles in order to secure partial risk guarantees.

National plans and budgets should incorporate regional infrastructure projects and resource mobilization should be consistent with the financial strategies of Governments. Funding of infrastructure projects will require coordination and harmonization between traditional and non-traditional development partners to optimize funding. Member States will need to intensify efforts to implement tariff that enables SP to maintain, improve efficiency and sustain level agreements.

The SADC regional water infrastructure projects should be designed on multi-purpose basis with collateral use across various economic sectors. Appropriate governance structures should be established for each region's infrastructure projects. Member States are urged to clearly define the objectives and beneficiaries of the projects. Member States need to identify and address skills gaps. Countries that share trans-boundary river basins should forge cooperation in order to harness the potentials of downstream benefits of upstream investment projects.

Member States should take into account such cross cutting issues as gender mainstreaming and environmental concerns at both the formulation and implementation stages of regional infrastructure projects. This ensures that the projects are relevant to the needs of sustaining the welfare of the communities.

# Chapter III – Relevant concepts for regional cooperation on joint infrastructure in trans-boundary river basins

## 3.1 Cost-benefit analysis in the context of the 1997 UN Convention on the Law of the Non-Navigational Uses of International Watercourses

### 3.1.1 The 1997 UN Convention

The management roles expected from basin-wide regulatory institutions are spelt out in the main (enabling) management instrument that is widely approved at the global level. In its preambles, the UN Convention on the Law of the Non-navigational Uses of International Watercourses adopted by the General Assembly of the United Nations on 21 May 1997 highlighted the importance of international cooperation and good neighbourliness in water resources management.

Designed to regulate practices affecting uses, protection measures, preservation and management of international watercourses, the convention also recognized regional economic integration organizations to which its member States have transferred competence in respect of matters governed by the Convention, and which they have been duly authorized in accordance with relevant internal procedures, to sign, ratify, accept, approve or accede to, as “Watercourse States”. In this regard, the SADC Revised Protocol on Shared Watercourses, adopted in 2000, represented a “clone” of the 1997 UN Convention.

Article 3.4 of the Convention provides: “…..Such an agreement may be entered into with respect to an entire international watercourse or any part thereof or a particular project, programme or use except insofar as the agreement adversely affects, to a significant extent, the use by one or more other watercourse States of the waters of the watercourse, without their express consent”. Article 4.2 further provides: “A watercourse State whose use of an international watercourse may be affected to a significant extent by the implementation of a proposed watercourse agreement that applies only to a part of the watercourse or to a particular project, programme or use is entitled to participate in consultations on such an agreement and, where appropriate, in the negotiation thereof in good faith with a view to becoming a party thereto, to the extent that its use is thereby affected”. Both these provisions further underscore the need for regional cooperation on the international watercourse.

Article 5 of the Convention provides for equitable and reasonable use and participation of watercourse States. Article 5.1 states: “Watercourse States shall in their respective territories utilize an international watercourse in an equitable and reasonable manner. In particular, an international watercourse shall be used and developed by watercourse States with a view to attaining optimal and sustainable utilization thereof and benefits therefrom, taking into account the interests of the watercourse States concerned, consistent with adequate protection of the watercourse".

Article 6.1 provides seven factors relevant to equitable and reasonable use, including: "...(e) existing and potential uses of the watercourse; (f) conservation, protection, development and economy of use of the water resources of the watercourse and the costs of measures taken to that effect; (g) the availability of alternatives, of comparable value, to a particular planned or existing use".

Furthermore, article 25.2 provides that: "Unless otherwise agreed, watercourse States shall participate on an equitable basis in the construction and maintenance or defrayal of the costs of such regulation works as they may have agreed to undertake". And it went on to state in article 25.3 that: "For the purposes of this article, "regulation" means use of hydraulic works or any other continuing measure to alter, vary or otherwise control the flow of the waters of an international watercourse".

These extensive citations of the role of cost-benefit analysis considerations within the context of the UN Watercourse Convention became instructive to underscore the two related but different applications of cost-benefit analysis: for evaluation of individual projects or entire river basin programmes, and for cost- and benefit-sharing. The latter aspect involves the division of project and programme costs and benefits among purposes, interests, groups and individuals. Whereas evaluation is concerned primarily with cost-benefit relationships in production, cost- or benefit-sharing focuses attention on the distribution or incidence aspects of project effects. Furthermore, efficiency in producing services is the overriding consideration in evaluation, while emphasis is on equitable distribution arrangements in cost- or benefit-sharing.

### 3.1.2 Economics of Project Formulation

Another noticeable and important characteristic of the UN Convention is that the optimal, equitable, reasonable, sustainable, beneficial and economic principles extolled are achievable at the national and international levels, and applicable to single as well as to multiple projects. The need for a clear conception of the function of cost-benefit analysis in determining the character and scope of resource development therefore becomes fundamental.

Regan M.M. and E.L. Greenshields (1951) identified two possibilities for the application of cost-benefit analysis to resource development: either the best balance of project features within a single project, or best balance of several constituent projects in a comprehensive programme. They also asserted that the optimum scale of development, as indicated by economic analysis, can only be established by arriving at the proper relationship not only of phases within a project, but also among a number of projects considered as incremental parts of a comprehensive programme.

The application of an incremental approach is essential to the establishment of the optimum scale of development. The approach can enhance the achievement of the goal of maximizing net benefits from a given project or from the investment of the limited amount of funds available for resource developments. Projects so designed would include all features that add benefits in excess of separable costs, with the total benefits of all features greater than total costs.

Furthermore, the degree of intensity of each feature is carried to the point at which marginal benefit-cost relationships are in balance. With the use of sound economic principles brought into project formulation, many questions relating to the financial and economic feasibility of projects would be resolved. If, for example, economic analysis is brought into play to achieve the optimum balance between purposes that are served by multiple-purpose undertakings, then many of the problems of joint cost allocation can be resolved equitably and understandably on the basis of relative net benefits accruing to each purpose. This assumes that uniform basic standards of measuring values would be employed throughout project formulation, in the allocation of joint costs, and in establishing prices or other levies on the consumers of project services.

## 3.2 Cost-benefit analysis in a trans-boundary basin setting

### 3.2.1 Cost-benefit analysis in the Context of Regional Cooperation

#### (i) Cost and Benefit Sharing on an International Watercourse

In national rivers, the objective of cost sharing is that of adjusting for the disassociation of benefits and costs between individuals, groups, areas and the nation. In international rivers, the objective is that of devising additional arrangements to compensate for disassociations that occur between the participating countries (Regan, M.M. (1958).

It may be possible to establish cost-sharing arrangements for joint development when greater net benefits would result, whereby each participating country would share equitably in its advantages. As a minimum, the net benefits accruing to each country under joint development should at least equal those obtainable under available independent alternative programmes. Any gains over such a minimum could be distributed in a way that would allow each country to obtain a comparable advantage.

Adequate consideration of each country's independent alternatives represents a major requirement for establishing an equitable and acceptable basis for sharing financial responsibility. A more comprehensive treatment of project costs would be required than is commonly applied in the analysis of national rivers, where no direct allowance is made for site and water resource values. The net benefits over project costs become attributable to such resources as residual claimants. Allowance for the value of such resources supplied by countries constitutes a proper component of the total costs of a joint project and creditable as a real cost contributed by participants. Under the assumption that the benefits accruing to each should at least be sufficient to cover the costs incurred, the inclusion of alternative opportunity costs would insure each country of being at least as well off under a joint as under independent development.

The value of the site and water resources contributions may be measured by their expected productivity in available independent alternatives that are precluded or foregone as a result of the joint project. More precisely, it represents the value of the net benefits expected to accrue within the country from the most advantageous independent alternative likely to be developed in the absence of the joint project. The foregone benefits would be the net of required development costs and their value adjusted for time and certainty of occurrence on the basis of standards comparable to those used for the joint project.

The alternatives used must be real in the sense that they are likely to be achieved in the absence of the joint project. Also, they should be consistent with the existing state of river-basin development, any governing treaties and acceptable principles of international law. The restraints imposed by the 1997 UN Convention would restrict alternatives to those that did not change the existing regime of a river to the detriment of other countries.

The costs of a joint development project would thus include two components: (1) the outlays necessary for establishing and operating the project; and (2) the opportunity costs reflected in the net benefits foregone from available independent alternatives.

The project benefits would need to be sufficient to cover both components of costs, with any excess indicative of the mutual advantage of joint development. The methods appropriate for computing the benefits of national rivers are generally applicable to international rivers. Some problems of differences in standards might arise, but perhaps much of this could be resolved by applying the standards considered appropriate for the optimum available uses of project services. To the extent that project services were mobile, they would be appraised in terms of their highest available market value.

The primary basis for determining the benefits from the development of a particular site might well be its expected contribution to the planned eventual development programme or system. This would involve an estimate of the incremental benefits to the system expected to result from the addition of a particular project. Benefits resulting from any of several segments of a planned programme would be common to the system and hence not creditable to a specific segment merely because of its priority in scheduled development.

The cost- and benefit-sharing could take any of several forms as shown in Annex D.

### (ii) Factors that influence Regional Cooperation on International Watercourses

International River basins exemplify pervasive collective action problems to which two analytical traditions are normally applied (Halla Qaddumi, 2008): the theory of public goods (and by extension common pool resources[13]) and game theory. Within these, various models have been designed to support the conclusion that under conditions of "anarchy" due to the absence of an overarching mechanism, cooperation between individuals

13 A common pool resource has the same attributes as a pure public good, but its benefits are subtractable or rival (the use of the resource by one individual diminishes the benefits available to others). A public good is defined as a good that is non-rival and that cannot be managed in such a way as to preclude its use by any individual (non-excludability).

or States will be difficult, if not entirely impossible to achieve (Halla Qaddumi, *op cit.*). At the same time, more sophisticated models (i.e. those with longer time horizons), have shown that "under suitable conditions, cooperation can emerge in a world of egoists without central authority" (Axelrod, 1984).

The "suitable conditions" or incentives to cooperate are determined by three main factors: (a) the type of good (i.e. its subtractability) – for example, the expected gains from agreement may be greater with non-renewable resources where degradation is irreversible than with renewable resources where regeneration may be possible; (b) the number of "players" (riparian) – in general, the larger the number of players, the more difficult it is to achieve cooperation outcomes, *ceteris paribus*; (c) the heterogeneity or homogeneity of riparian countries in terms of (i) capabilities, (ii) preferences or interests, and (iii) beliefs or information.

Capabilities refer to the relative power – including economic, political and geographic (e.g. location on a river) – and bargaining strength of the riparian countries. A riparian's preferences or interests determine its valuation, in terms of costs and benefits, of potential strategies and outcomes. Preferences and interests are a function of such factors as the riparian's discount rate of natural resource use (i.e. present value of future payoffs, which essentially weighs the importance of current actions relative to future actions), sense of shared identity with other riparian countries and other considerations, such as a nation's concerns for issue linkage, national image and sovereignty (Le Marquand, 1976). A riparian's beliefs and the information at its disposal, in addition to its processing of this information, will colour its perception of the issue and therefore indirectly affect its interests or preferences.

The number of players and their capabilities, preferences and information affect the costs of transacting, the ability to communicate and the ability to make credible commitments. Changes in any of these variables may alter the incentives of players to cooperate. The key question is how to affect a change in these variables such that (more) cooperative outcomes are achieved.

### (iii) Issues in Designing Incentives for Cooperation

#### *(a) Managing Water as a Local Common Good*

A model for achieving cooperation consists of assimilating the management of a shared watercourse into the management regimes for local common properties. Local common property encompasses a wide range of resources whose shared feature is the need for some form of collective management, and poses interesting problems in such disparate subfields as agricultural economics and the theory of the firm (Seabright, Paul, 1993). The main members of the local community (i.e. countries sharing the resource) are few enough to be known to each other; some of their actions are observable; and consequently they have the ability and sometimes the incentive to build reputation for behaving in certain ways. Another feature of management in this case is the absence of even the potential for intervention by a State that is more powerful than any of the individual countries sharing the resource.

Local common properties include the familiar *dramatis personae* of environmental micro-economics, like grazing lands and inland fisheries; collectively managed irrigation systems such as canals and tanks; underground aquifers and oil reserves; forests and many wildlife habitats. They also include many phenomena that should be analysed in similar terms, such as partnerships and joint-stock companies, collective amenities in apartment buildings and pension funds.

### *(b) Establishing Common Interests*

The main analytic interest raised is one of resolving conflicts over the contribution of different members towards a common management policy. Social choice theory points out that the very existence of an optimal collective management policy cannot be taken for granted, and that mechanisms to decide upon such a policy may be vulnerable to strategic manipulation. Furthermore, the information required for common property management will be reduced if it can be assumed that the management policy for the resource (for example, what its aggregate rate of depletion should be) can be determined separately from the way that policy should be implemented (for example, how the consumption made possible by the agreed-upon depletion rate should be shared out among members). Seabright, P. [*op cit.*] labeled these two aspects of the management problem as the *production plan* and the *implementation plan*.

*A priori*, the separation of the two tasks may only be possible when everyone can agree on what would be the optimal production plan, without knowing anything about the distribution plan, which sounds unlikely. However, according to the Fisher separation theorem, a firm's shareholders will unanimously support attempts by that firm to maximize value as long as the economy has complete risk-sharing opportunities. Consequently, it is possible to determine the firm's optimum production plan (given a price system) without knowing anything about shareholders' preferences or constraints. It follows that, for there to be conflicts of interest between member-beneficiaries of a common property resource over the production plan, production decisions must make a significant difference to at least some members' risk-sharing opportunities, and must do so in different ways for different members.

Solving such conflicts of interest may be very difficult, and the absence of appropriate means of compensation for the missing risk-sharing mechanisms may lead to a breakdown of the management of the common property resource.

### *(c) Devising Incentives to Advance Common Interest*

The central implementation problem for common property resources is that, in the absence of binding agreements to the contrary, consumption of the common resource by one agent will impose negative externalities on others. Since individuals do not take these externalities into account, aggregate consumption of the resource is typically inefficiently high. In a classic article, Garrett Hardin (1968) referred to this outcome as a "tragedy of the commons." Alternatively, the externalities may mainly affect investment, in that resources expended in the enhancement of the common property resource's value may typically confer external benefits on other members, and under-investment will result.

The investment externality characterizes virtually all common property resources, including such non-standard examples as firms: the tendency towards under-investment by shareholders in monitoring a firm's management is a classic example. As a matter of fact, the distinction between consumption and investment externalities is practically useful but not analytically important because the optimal production plan for common property resources will typically involve most if not all members both consuming less of the resource than their private incentives would lead them to do, and investing more of their other resources in the maintenance and enhancement of the common property resource's value.

A number of informal mechanisms are available to induce members of a common property resource to undertake collectively beneficial but individually costly actions: the privatization of property rights; the decentralization of incentives within common ownership and control; and the delegation of management responsibility to an agent so that participants are limited to a monitoring role.

### *(d) Informal Incentives for Cooperative Behaviours*

Game theory has devoted much effort to explaining cooperative behaviour in terms of a more sophisticated understanding on the part of individuals about where their (individual) long-term interests really lie. In particular, individuals face problems of collective action not once but repeatedly. The knowledge that pursuit of their short-term interests can harm their long-term aims by affecting the reaction of others in future interactions may be a powerful inducement to behaviour that displays apparent solidarity with the interests of the group (Seabright, P. op cit.)

The idea that repetition can sustain cooperation is based on the thought that individuals tempted to defect may be dissuaded from doing so from fear of losing the benefits of cooperation in the future. For this dissuasion to be effective, however, three conditions must hold. First, the future must matter enough to outweigh the immediate benefits to any individual of failing to cooperate; that is, other players must have at their disposal retaliatory strategies that "hurt" the deviator sufficiently in future periods, even when future payoffs are discounted.

Secondly, the retaliatory strategies must be credible, i.e. once an individual has defected, it must be in others' interest to put the retaliation into effect. In this regard, retaliation may be credible naturally (what they would anyway do in the circumstances, as when it involves playing a Nash equilibrium of the prisoners' dilemma game). Alternatively, it may be true because of a credible agreement between the affected parties to put the retaliation into effect. In the latter circumstance, retaliation is itself a form of collective action, which must therefore be credible if the original collective action is to be credible. It is in this respect that one can think of the setting up of institutions as a central form of common property resource management.

Thirdly, the benefits of cooperation in the future must themselves be sufficiently probable to act as an incentive to cooperation in the present. Sheer repetition of the game is not enough to ensure this. For example, if the game is to be played a fixed number of times, then both players will know before the last repetition of the game that defection in that last round cannot be punished and that therefore cooperation is unlikely in that round. For future cooperation to be a sufficiently probable incentive, one of a number of conditions must hold: the game may be infinitely repeated, or there may be sufficient uncertainty about how many times it will be repeated.

An alternative solution is “reputation;” even a very small probability that the player is of a type that intrinsically prefers to cooperate acts as an incentive to all types of players to behave cooperatively, so long as the game is sufficiently far from its final period for the loss of a reputation for cooperation to be costly. Another is bounded rationality, where a small probability that the player is of a type to cooperate “irrationally” has much the same effect. Finally, the one-shot game may have multiple Nash equilibriums over which all players have a strict preference ordering. In all cases, the possibility of cooperation depends upon players’ not discounting future payoffs too heavily; if they do not place much value on the future, the gains from short-term self-interested behaviour may be too great for any future inducements to outweigh. They must also be able to observe one another’s behaviour with sufficient reliability to observe whether agreements are being kept.

Whenever the sustainability of cooperation is a marginal matter, the presence or absence of trust will affect the extent to which cooperation succeeds. This presence or absence of trust may itself depend on past traditions and institutions: institutions can channel trust. One possibility for this to happen is simply that certain institutions, by giving people the opportunity to undertake collective action, allow them to establish a reputation for cooperation that will serve them well in the future.

A second possibility appeals to the idea that institutions may allow the establishment of “collective reputation.” Both these suggestions imply that trust is to be understood as a kind of capital good, embodied either in individuals or in the organizations to which they belong, and which acts as a State variable whose value influences the probability of future cooperation independently of the direct payoffs associated with such cooperation. Where it is unclear what kind of behaviour is inconsistent with optimal resource management, institutions may help members to coordinate on relatively simple (and therefore more easily monitored) standards of acceptable behaviour.

***(e) Formal Incentives for Cooperative Behaviour***

Three kinds of formal inducement to cooperative behaviour in the management of common property resources can be distinguished: the privatization of property rights; the decentralization of incentives within common ownership and control; and the delegation of management responsibility to an agent so that participants are limited to a monitoring role.

The case for privatizing property rights in what have hitherto been common property resources rests on the view that having an individual or firm own the resource will lead to the resource being allocated in a more efficient way. Privatization is seen as a response to changing conditions rather than an adverse judgment on the appropriateness of collective management for previous conditions.

However, private property rights itself may fail to solve the problems of externalities that bedevil common property resources. When contractual relations remain in important respects incomplete, private property may also weaken the mechanisms of cooperation that previously existed, either by shifting the bargaining power of the parties so that they no longer share enough interdependence to make cooperation credible, or by weakening the credibility of long-term contracts.

Decentralization of incentives under common management occurs when members of a local common property resource meet and decide on systems of rewards and penalties to implement a production plan. The most frequent means of doing so are production quotas, reinforced by systems of monitoring, with fines, or the threat of exclusion from the common property resource altogether for those who breach the agreement.

However, all forms of collective management involve some asymmetry in the degree of involvement of different parties. At one end of the spectrum is delegating managerial responsibility to an agent entrusted with managing the asset on behalf of others; at the other, full participatory decision-making. In the middle of the range, a smaller group of agents are chosen by the larger group, which simply means that the collective management problem of the original owners of the common property resource is reproduced in miniature among the agents.

The delegation of responsibility to an agent does not, of course, leave the original members with nothing to do (otherwise they might as well just sell the asset); but it does limit their activities to a monitoring rather than a fully participatory role. Some jobs can be easily monitored using almost none of the skill or the effort that is required for the task's performance. Others need much more. Delegation of management responsibility is much more likely where the management of the resource resembles the first kind of task rather than the second, since those who delegate save themselves a substantial amount of work.

The benefits of delegation will depend on the extent to which the conflicts of interest between the agent and the principals who are the members of the common property resource can be minimized through appropriate remuneration procedures. If agents of the State are to be involved in the management of a common resource, they need an incentive to act in the interests of those to whom the resource notionally belongs.

### *(iv) Harnessing Economies of Scale to Foster Regional Cooperation*

*Economy of Scale: an untapped source of incentive for cooperation*

One of the sources of economic incentive for cooperation among riparian countries is economy of scale. The three-dimensional world entails many scale effects, both increasing and diminishing. There are four important sources of scale effects that can arise when output is varied in the long run, including: the geometrical consequences of reconfiguration, the physical consequences of reconfiguration, the cost of embodying capital services in capital goods and the more intensive use of indivisible inputs (Lipsey, R.G. 2000).

*Scale Effects Arising from Geometrical Relations*

The geometrical relation governing any container typically makes the amount of material used, and hence its cost (given constant prices of the materials with which it is made), proportional to *one dimension less than* the service output, giving increasing returns to scale over the whole range of output (at least with respect to the inputs of materials). This holds for more than just storage. Costs of construction also often increase less than in proportion to the increase in the capacity of any container.

For example, the capacity of a closed cubic container of sides denoted as s is $s^3$. The amount of welding required is proportional to the total length of the seams, which is 12s. The amount of material required for construction is $6s^2$. So material required per unit of capacity is 6/s while welding cost is $12/s^2$. Not only are both of these falling as the capital good is reconfigured to increase its capacity; they fall at different rates.

The ubiquitous real world scale effects only show up when some product is reconfigured to make it produce a different rate of service output. This occurs whenever the capital good used to produce the service flows that are required for an altered rate of production of the final good needs to be reconfigured.

*Scale Effects Arising from Physical Laws*

In most cases of long -run reconfiguration, a different design of capital goods is required if a different capacity rate of service flow is required. The physical nature of the world typically implies non-constant returns to outlay: the cost of producing a unit of the capital service varies as the output capacity of the capital good is varied. For example, the geometrical reasoning given above cannot produce a final conclusion about scale effects. It is imaginable that as the capacity of a container is increased, the walls would need to be thickened proportionally, making the volume of material increase linearly with the capacity of the container. From Physics, this is not so in most cases: although some thickening is often required, in many (probably most) cases, the thickening is less than in proportion to the increase in the surface area. In such cases, the volume of material increases less than in proportion to the increase in capacity (although more than in proportion to the increase in surface area).

If all the dimensions of a bridge are altered in the proportion $\lambda$, its structural strength is altered by $1/\lambda$ and its weight is altered by $\lambda^3$ (under the simplifying assumption that it is optimal to use the same types of materials in bridges of all sizes). In other words, bridges and other similar structures, exhibit diminishing returns in the sense that as their size and the amount of materials used in their construction are increased, their strength increases less than in proportion. This is one of the most important sources of diminishing returns to reconfiguration that limits the extent to which other sources of increasing returns can be exploited by building larger versions of some generic capital good.

These examples illustrate that when the rate of output is altered in the long run, and capital good is altered by reconfiguration rather than replication, the nature of the world will almost always produce a complex set of reactions, some tending to reduce the unit cost of output, some tending to increase it. Other reactions will alter the characteristic performance of the capital good in ways that are only indirectly reflected in the relevant service flow.

These examples also show that the one-stage production function stated in terms of input services may display constant returns while the whole production process has increasing returns, because the cost of producing a required capital service flow falls as output increases. This is typically due to technical relations embedded in the nature of the capital goods themselves, which do not display constant returns to inputs when they are reconfigured.

*Scale Effects Arising from the Technology of Producing Capital Goods*

Eaton and Lipsey (1997) explained why roundabout production is chosen even though it requires waiting, by deducing universal scale effects in the technology of producing capital goods on the basis of a very small input of empirical knowledge. They explained that there is a positive cost of waiting (i.e. the interest rate is positive). Furthermore, capital goods are needed to yield given flows of services over time and a decision must be made on the amount of durability to build into these goods. Further still, there is a universal scale effect in embodying services in capital goods: as durability of the capital good is increased, there is some range starting from zero over which the services that it embodies rise faster than the cost of adding to the good's durability.

This scale effect appears to be rooted in the physical nature of durable goods that yield their services over long periods of time.

*Scale Effects Arising from Indivisibilities*

There are three ways in which a capital good can be described: its internal makeup, a blueprint of how to make it; the inputs that go into making the good; and the good's service output. These are respectively called physical, input, and output descriptors. In reality, manufactured capital goods having differentiated parts are not divisible in any of the senses defined above. They cannot be physically subdivided and have the parts perform as did the complete good; neither their physical dimensions nor the list of inputs that go into making them can be scaled up or down without altering their various performance characteristics significantly.

Increasing returns to some characteristics of specific technologies are often balanced by decreasing returns to other characteristics of the main technology or in complementary sub-technologies. The optimal size of productive unit is then the one at which the economies of scale in some aspects of the technology just balance the diseconomies in other aspects. The smallest workable size is seldom the most efficient. As size increases, most characteristics encounter favourable scale effects. However, many characteristics encounter decreasing returns which eventually dominate so that further increases in capacity result in higher rising costs per unit of capacity delivered.

If the unit cost of delivering a capital service is plotted on the Y-axis and the capacity output of the capital good delivering that service on the X-axis, the resulting cost curve is U-shaped. As one moves along it from left to right, the capital good is being reconfigured to deliver increasing amounts of the services per unit of time. The precise shape of the curve, and whether it reaches a minimum at relevant output capacities, depends on technical relations which cannot be discovered without a detailed knowledge of the engineering characteristics of the specific technology in question. *A priori* reasoning cannot tell us about the existence and range of such scale economies and diseconomies.

Furthermore, the steady high volume of throughput (material) needed to achieve and maintain potential economies of scale and scope could rarely be attained as long as the flow of goods depended on local markets.

*Opportunities for Inducing Regional Cooperation through Gains from Economy of Scale*

In addition to the informal and formal incentives previously discussed, the cost savings and extra gains achieved through economies of scale can also provide incentives for cooperation, but the main question is "how to reach a state of cooperation" and "how to cut the cake if it comes to cooperation?" (Stef Tijs, 1981). The success of cooperative ventures often relies on agreements on how to share the costs and or benefits generated. There is no single, all purpose solution to the sharing problem. In satisfying the existing need for suitable mechanisms to distribute cost or reward among the agents involved, organizational constraints and goals, environmental aspects as well as the amount of available information should be taken into account. Joint ventures require an allocation mechanism that is efficient, fair, and provides incentives to (different groups of) agents involved to agree upon.

As discussed in 3.2.1 above, the value of the site and water resources contributions are also cost components for countries supplying them and thus constitute additional incentives for regional cooperation.

## 3.2.2 The River Basin as Unit of Water Resources Development

### (i) River Basin Concept

Only one characteristic distinguishes a river basin from other natural areas of the earth's surface: the waters within the basin tend to flow toward a single outlet and form an interconnected system (drainage). This physical unity forms part of the hydrologic cycle. Climate, geology, topography, soils, flora and fauna all interact with the basin's waters, and if there is a change in any of these factors, either naturally or by human intervention through waterworks and land use, the entire watercourse system reacts through adjustments in water volume, flow rate, discharge, sediment load and quality.

The functional unity of the river basin found expression in human institutions long before it was fully understood (Ludwik A. Teclaff, 1996). Dependence on water control in the fluvial civilizations sometimes translated into cooperation among States, but more often into political consolidation and expansion by a single power throughout a river basin, with special emphasis on securing upstream areas. Frequently, unification prompted the construction of bigger and better irrigation and reclamation works. Conversely, when empires broke up into smaller units, water resources development suffered severe setbacks because the central, basin-wide water administration also collapsed (Ludwik, A. Teclaff, op cit.).

The riparian rights doctrine reflected the interdependence of waters and the unity of the basin by recognizing the community of interests of the landowners bordering on the flowing waters but, like the medieval immemorial usage doctrine, it protected this community of interests by trying to reduce the possibility of change and the scope of new uses. The notion of a community of riparians was soon transferred from local groups to States which began to conclude treaties requiring the consent of the other party or parties on a river for any alteration in the flow of frontier waters. There were other ways, however, in which basin cohesion became manifest.

The fact that the navigable waters of a river basin formed an interconnected system found expression through measures to facilitate navigation. In other areas and in periods in which waterways were the best or only means of communication, a favorable pattern of drainage influenced the emergence of a commercial unity. This happened when an entire basin became the hinterland of a major seaport (e.g. Mississippi basin and New Orleans) or when association of boatmen and ship owners embraced so many tributaries that a virtually basin-wide organization of navigation was achieved. This gave such basins cohesion through water use and even facilitated political unification consolidated in the community of riparian States when treaties affirming the principle of freedom of navigation among such States appeared.

More explicit advocacy of the treatment of a river or a river basin as a unit for the efficient utilization of water came about when rapid advances in technology (especially the invention of reinforced concrete and development of earth-moving equipment) in the latter part of the 19th Century made multipurpose use of streams possible.

The fact that many river basins encompass a great deal of land led quickly to a viewpoint advocating the basin as a distinct economic region in which the integrated development of all resources would be planned and supervised by a body with basin-wide powers. Such an organization was the Tennessee Valley Authority (TVA), a government corporation established in 1933 with powers to plan, construct and operate multipurpose projects for, among other goals, improvement of navigation, flood control, reforestation and proper use of marginal lands, marketing of power, and the agricultural and industrial development of the basin.

Later on, States riparian to some very large rivers in Africa (i.e. Niger River Basin) and South America (i.e. La Plata and Amazon basins) agreed to develop their huge river basins under joint management, transferring the basin-as-economic-region idea to an international plane.

The river basin concept also received the blessing of the United Nations in a number of official pronouncements. In 1956, the Secretary-General declared that river basin development was recognized as an essential feature of economic development. A panel of experts, established to review the economic and social implications of the integrated river basin, reported in 1957 that individual water projects could not usually be undertaken with optimum benefit unless there was at least the broad outline of a plan for the entire drainage area.

The Dublin Statement of 1992 on Water and Sustainable Development proclaimed that the most appropriate geographical entity for planning and management of water resources is the river basin, including surface and groundwater.

### (ii) The Ecosystem Approach, Integrated Management and Sustainable Development

The term "ecosystem" in a context of natural resource management dates back to the Stockholm Conference on the Human Environment of 1972. Conferences and workshops promoted the idea as a basis for coordinated land and water management. In its 1993 guidelines on the Ecosystem Approach in Water Management, the Economic Commission for Europe recommended consideration of the whole catchment area as a natural unit for integrated ecosystems-based water management. It declared that a river basin covering a large territory might be regarded as an ecosystems continuum, representing at any given time a succession of ecosystems types from headwaters to mouth (or delta).

The concept of holistic or integrated management has also come to be associated with sustainable development. The Dublin Statement on Water and Sustainable Development of 1992 says that effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems and also linking land and water uses across the whole of a catchment area or groundwater aquifer. The Statement supports the river basin as a unit for planning, management, protection of ecosystems and resolution of water conflicts.

The United Nations Conference on Environment and Development held at Rio de Janeiro in 1992 described integrated water resources management as based on "water as an integral part of the ecosystem, a natural resource and an economic good, the quantity and quality of which determines its utilization." It stressed that "integrated water resources management should be carried out at the catchment basin or sub-basin level, taking into account existing inter-linkages between surface and ground waters. Furthermore, it outlined four principal objectives to be pursued[14]. Two years later, the United Nations Commission on

14 The first of these objectives is "to promote a dynamic, interactive, iterative and multi-sectoral approach" to management, integrating technological, socioeconomic, environmental and human health considerations. Other objectives address planning, based on community needs, full public participation (including women and indigenous peoples) in policy-making, and strengthening the appropriate institutional, legal and financial mechanisms to "ensure that water policy and its implementation is a catalyst for sustainable social progress and economic growth." On paper this is remarkably like the valley authority approach to creating all-purpose basin units, but without the valley authority and with the addition of environmental and some sociological concerns.

Sustainable Development also recommended integrated management, mobilization and use of water resources in a holistic manner, and urged that special attention should be given to the integrated management and conservation of river and lake basins, nationally, internationally and at all appropriate levels.

In its miscellaneous provisions, the International Law Commission (ILC) defined management as (a) planning the sustainable development of an international watercourse, and (b) otherwise promoting rational and optimal utilization, protection and control of the watercourse. The Commission's earlier draft defined "joint institutional management" as including "planning of sustainable, multi-purpose and integrated development of international watercourse(s) (systems)."

### (iii) Governance for Sustainable Development

The United Nations and associated agencies worried about ecological degradation because of economic growth for some decades before appointing the World Commission on Environment and Development (WCED) to address the issue (Kemp, R, et al, 2005). The Commission's conclusion was that the ecological and social failures had common causes and demanded a common response.

The main dimensions of sustainable development consist of maintaining the integrity of biophysical systems, better services for more people, and freedom from hunger, nuisance and deprivation. To these may be added choice, opportunity and access to decision -making – aspects of equity, within and across generations. Sustainability is about intermediate and long term integration: the pursuit of all the requirements for sustainability at once, seeking mutually supportive benefits (Gibson, 2001).

Because of the interconnections among its factors and purposes, sustainable development is essentially about the effective integration of social, economic, and ecological considerations at all scales from local to global, over the long haul. Compromises and sacrifices are unavoidable. Given the distance between current conventional practice and potentially sustainable behaviour, the objective is to recognize the intertwined importance of social, economic and ecological imperatives and to find ways of contributing to them. The aim is not only fair treatment of each part, but also choices that strengthen the whole in a lasting way.

Most often, three pillars – social, economic and ecological – are identified. Important work has also been done in exploring the concepts of social, ecological and economic capital for sustainability, with particular interest in the existence and limits of potential substitutions. In practical applications, however, the pillar-focused approaches have suffered from insufficient attention to overlaps and interdependencies and a tendency to facilitate continued separation of social, economic and ecological analyses.

Governance (mode of social coordination) is different from *governing;* which is an act, a purposeful effort to steer, guide, control and manage (sectors or facets of) society. Governance is how one gets to act, through what types of interactions (deliberation, negotiation, self-regulation or authoritative choice) and the extent to which actors adhere to collective decisions. It involves the level and scope of political allocation, the dominant orientation of State, and other institutions and their interactions. Governance structures organize negotiation processes, determine objectives, influence motivations, set standards, perform allocation functions, monitor compliance, impose penalties, initiate and/or reduce conflict, and resolve disputes among actors. The effective exercise of power is through a network of interconnected actors, all of whom hold power, through knowledge resources, money and rights granted to them (Kemp, R. et al. 2005).

Better governance is a prerequisite for, and also a product of, steps towards sustainability. According to the European Commission, good governance consists of openness and participation, accountability, effective coherence, efficiency (proportionality) and greater sensitivity to the immediate context that is promised by subsidiarity. Other requirements for sustainability include means of internalizing external costs and ensuring integration of policy considerations, evaluation of options and dealing with trade-offs. Emphasis is on the role of institutions as entities that are largely viewed as being "up there" and, at least currently, insufficiently within the reach of ordinary citizens. As such, this view of governance seems concerned primarily with minimizing bureaucratization and hierarchy.

Governance for sustainability has certain key features and components. For example, Kemp, R. et al. (op. cit.) identified policy integration as an important "interrelations" issue regarding the coordination of government policies and the corresponding and complementary positions and initiatives of other governance actors. The evolution of the modern State has been towards an increasing degree of sectoral specialization to deal with differentiated problems. Specialization has helped develop valuable responses to particular problems, but it has also led to neglect of broader considerations and to partial solutions that are inadequate or damaging from a broader sustainability point of view.

Policy integration is not the consolidation of policies to create a single integrated policy dealing with everything. There remains a need for specialized policies. Effective integration for practical decision-making centres on acceptance of common overall objectives, coordinated elaboration and selection of policy options, and cooperative implementation designed for reasonable consistency and, where possible, positive feedbacks.

Cost and benefit sharing is an exercise in modeling. Thus, the full diversity of interested parties, their purposes, and the goals of allocation (sharing) must be recognized before meaningful solutions can be obtained. Accounting for the combinations of joint costs and revenues (benefits) may prove to be the next major breakthrough in accounting – analogous to the development of input-output and national income accounts – and, as in those cases, the potential usefulness of the theory will stimulate the collection of necessary data to carry out the calculations. This underscores the need for strengthening existing RBOs and establishing new ones where they do not presently exist, for proper river basin governance.

## 3.3 Equity and other concepts for cost and benefit sharing in joint infrastructure projects

### 3.3.1 Principles of Equity and Fairness in Water Rights Distribution

#### (i) Effective Distribution Rule

Among other incentives discussed above, harnessing economy of scale can result in creation of common property which in turn can promote regional cooperation. According to Young, H.P. (1985), an *allocative problem* arises whenever a bundle of resources, rights, burdens, or costs is temporarily held in common by a group of individuals and must be allotted to them individually. An allocation is a decision about who gets a good or who bears a burden, and is usually decided by a group or by institution acting on behalf of the group.

Three different types of decisions are involved in an allocation: the first is the supply decision concerning the total amount of the good to be distributed. The second is the distributive decision concerning the formula or principle by which the good is allotted among the eligible parties. Both decisions are normally made by institutions. The third type of decision is made by individuals in response to these institutional choices (reactive decisions). The combination of all three levels of decision-making yields an *effective* allocation.

Distributive decision focuses on rules of distribution and the principles invoked to justify such rules. An *allocation rule* is a method, process, or formula that allocates any given *supply* of goods among any potential *group* of claimants according to the salient *characteristics* of those claimants.

The allocation rules in practice usually exhibit one of three broad conceptions of equity. *Parity* means that the claimants are treated equally, either because they actually are equal or because there is no clear way to distinguish among them. *Proportionality* acknowledges differences among the claimants and divides the good in proportion to these differences. *Priority* asserts that the person with the greatest claim to the good gets it. Parity, proportionality, and priority also figure prominently in the major theories of distributive justice.

While these conceptions of equity describe the general *structure* of a rule, its *content,* however, derives from specific normative principles. These *normative* principles may be contrasted with the ways that distributive decisions are made in practice. These *empirical rules* of equity, as revealed by the choices that institutions make, are usually more complex and nuanced than any single normative principle. Instead they often represent a balance or compromise between competing principles (Young, H.P, op cit.).

#### (ii) Normative Theories of Justice: Aristotle, Bentham, and Rawls

Three general theories of justice figure prominently in discussions about equity. The oldest and most prominent is Aristotle's *equity principle* which states that goods should be divided in proportion to each claimant's contribution. This idea, however, has two substantial limitations. First, there must be some way to measure the contribution of each claimant on a cardinal scale. Sometimes such a measure is natural; at other times, the measure of contribution is not so clear. Second, for proportionality to be workable, the goods must be divisible. When they are not, one could make them divisible by distributing chances at receiving the good, but then proportionality loses some of its plausibility.

The second theory of justice is the classical utilitarianism which asserts that goods should be distributed so as to maximize the total welfare of the claimants (the *greatest good for the greatest number*). Again, this doctrine also fell into disrepute for two reasons. First, no method is provided for comparing levels of satisfaction among different individuals. In the revealed preference approach to utility, the units in which utility is measured are quite arbitrary; thus, it is meaningless to add and subtract them across individuals. Second, even if we could devise some method for comparing individual utilities, it is not clear that the utilitarian *principle* is ethically sound, since it might require imposing great harm on a few in order to confer a small benefit on the many.

A third approach to social justice that meets the previous objections to some extent is due to John Rawls (1971). The central distributive principle may be simply stated: the least well-off group in society should be made as well off as possible (Young, H.P, op cit.). This is known as the *maximin or difference* principle. It is not a welfarist conception of justice, because "well-off" does not refer to a person's subjective level of satisfaction. It refers rather to the *means* or *instruments* by which satisfaction or happiness can be achieved. Economic income is one such means; others include opportunity, power, and self-respect. Rawls calls these *primary goods*.

The principle refers to the effective distribution of income after economic incentives are taken into account. Thus, Rawls's principle avoids two of the problems inherent in classical utilitarianism. First, it is based, at least in part, on observable characteristics of individuals (such as income) rather than on interpersonal comparisons of welfare. Second, it avoids the ethical problem of benefiting the many at the expense of the few.

Rawls's theory is not without its drawbacks, though. Income is not the only currency in which justice is evaluated: other primary goods (e.g. self-respect) are involved that do not lend themselves readily to objective comparisons. Moreover, even if we could make such comparisons, it is not clear how we should *weight* different primary goods. Second and most important, it is not clear that the maximin principle satisfies the intuitions about justice. Is it just to impose serious inconveniences on almost everyone in society in order to raise the opportunities, the income, or the self-respect of the least fortunate by a miniscule amount? (Young, H.P, op cit.).

### (iii) Envy-free Distribution

The conceptual difficulties posed by the utilitarian and Rawlsian principles led to the adoption of an entirely different approach to distributive justice. A distribution is said to be *envy-free* if no one prefers another's portion to his own. This concept does not require interpersonal comparisons of utility, because each person evaluates every other person's share in terms of his *own* utility function.

Envy-freeness was first proposed in a very strong form by Tinbergen (1953), who argued that an equitable society is one in which no person wants to *change places* with another. "By places we mean their whole situation: especially their occupations and incomes, but also personal conditions such as health, size and health of their families, levels of education, abilities..." Attractive as this concept may be in theory, it is impossible to achieve if people envy the personal characteristics of others which is probably the most common object of envy?

A more pragmatic formulation was subsequently suggested by Foley (1967) which does not require that society *in general* be envy-free; but only requires that no person prefer another's portion *of a particular allocation of goods*. If an estate is being distributed among heirs, for example, the "no envy" criterion says that no heir should prefer another's portion of the property to his own. They might envy each other because of other goods that they own, or because of their different abilities and circumstances of life, but not because someone else received a more desirable portion.

The idea makes sense provided that the parties have equal claims on the goods, and the goods are divisible. An example would be an inheritance in which the heirs are bequeathed equal shares. Of course, if the estate contains only one homogeneous good, such as money, an allocation is envy-free if and only if it is divided equally. Hence there are no novel implications in this case. The principle takes on greater interest when the property consists of different kinds of goods.

Typically, there are many allocations that are both envy-free and efficient, but it is not clear that all of them are equally fair. The Oxford English Dictionary defines fair: equitably, honestly, impartially, justly; according to rule (Young, H.P. op cit.).

One way to resolve this problem of indeterminacy is to resort to an allocation *process* that is perceived to be fair by two parties. Consider the traditional method of divide and choose. By the toss of a fair coin one of them (A) is designated to be divider. Since *B* has the opportunity to select the portion s/he prefers, s/he will certainly not envy *A*'s portion. However, *A* can also protect himself from envy by creating two portions that he values equally. Then no matter which portion *B* selects, *A* will not strictly prefer it to the one left over for him. However, the divider can manipulate the outcome if he knows the chooser's preferences. The resulting allocation is envy-free and efficient, but is it fair? This suggests looking for equity principles that discriminate more finely among envy-free allocations.

### (iv) Distributive Judgments and Interpersonal Comparisons

The appeal of no envy is that it does not require making interpersonal comparisons of utility; thus, it has an operational meaning within the framework of modern utility theory. The weakness of the concept is that it only applies when the parties have equal claims on the good, which is often not the case. Indeed, most fair division problems revolve around the question of how *differences* in claims – due to disparities in merit, desert, contribution, need, and so forth – should be taken into account, in which case the no envy principle is more or less irrelevant.

The problem with no envy is that it dispenses with interpersonal utility comparisons by not making interpersonal comparisons of any kind. However, distributive decisions almost always involve comparisons and value judgments. It is pointless to assume them away; one needs instead to ask *on what basis* they are made. Any theory of equity with explanatory power is going to have to come to terms with the fact that humans make comparative judgments of this sort all the time. Moreover, there is nothing in *utility theory* that says that such comparisons cannot be made; the theory is simply silent on *how* they are made.

### (v) Why Classical Formulas Fail

Equity cannot be reduced to simple, all-embracing solutions such as the difference principle, the greatest good principle, or the proportionality principle. There are three standard methods for transforming an indivisible good into a divisible one: randomization, rotation, and conversion. Under *randomization* each claimant has a probability of getting the good; under *rotation* the claimants take turns at using the good; under *conversion* they exchange the indivisible good for a divisible one and split the proceeds. The relative suitability of these methods depends on the circumstances.

Yet another way of handling indivisibilities is to *compensate* those who do not get the good, or in the case of burden, to compensate those who do. Each of these mechanisms – randomization, rotation, conversion, and compensation – changes the original allocation problem into a new one that involves divisible goods. But none of them goes to the heart of the distributive issue which is: how much is each claimant entitled to? On what theory or principle the shares are determined. This nub of the distributive problem is not resolved by introducing divisible goods.

### (vi) Priority Principle

The evidence suggests, moreover, that indivisible allocations are often handled by confronting the indivisibility directly instead of trying to circumvent it. One of the ways to do this is to apply the *priority* principle: he who has the greatest claim gets the good; the others do not. The basis of priority may be simple. More often, priority is based on a mixture of criteria. Each such criterion captures a notion of equity, but not equity in the Aristotelian sense of proportionality. It is equity based on *priority*. Priority is an ordinal rather than a cardinal principle because it does not say *how much more* deserving one claimant is compared to another; it simply says that one claimant is more deserving than another.

In some situations priority is largely a matter of judgment. In other situations, priority is less a matter of judgment and more a matter of logic. The issue then becomes how to achieve equity *as near as may be*.

### (vii) Consistency Principle

A fruitful approach to this problem is to begin by asking what solution is most equitable when there are just two claimants. This case is usually simple to grasp intuitively. Once a standard of equity has been established for two-claimant situations, a many-claimant problem may be solved according to the following principle: *allocate the good so that every* *two claimants divide the amount allotted to them as they would if they were the only two claimants*. This *consistency principle* turns out to be one of the most powerful unifying ideas in the theory of fair allocation. Any allocative rule that satisfies the consistency principle also satisfies the priority principle and vice versa.

### (viii) When Proportionality Fails for Divisible Goods

When the good is *divisible* and the claimants can be compared by some numerical measure of *entitlement*, classical principles like proportionality work very well. Even in this case, however, proportionality may not necessarily be the most appropriate solution or the only equitable solution. A second difficulty with proportionality (and many other rules) is its failure to take economic incentives (or opportunity costs) into account. Equal division fails for the same reason.

Perhaps the most serious problem with proportionality, however, is that it does not always accord with our *intuitions* about equity. The *progressivity principle* is by no means unique to taxation, but is seen in many other kinds of assessments. The rationale is clear: those who are better off can absorb the loss more easily. These cases illustrate why proportionality (as well as the other classical principles) do not always yield satisfactory answers, even when the goods are perfectly divisible. To explain what equity means in practice, more subtle and nuanced kinds of solutions are required.

### (ix) Games of Fair Division

The allocative decision is not entrusted to an institution in this case, but is negotiated by the claimants directly. Suppose, for example, that a group of countries are negotiating their respective shares in a producers' cartel. The purpose is to limit production and drive up the price so each country naturally wants to claim as large a share of the output as possible. The bargaining chip that each holds is the threat to pull out of the agreement and drive down the price by increasing production unilaterally.

What determines the outcome is the power relation among the claimants: the skill and patience with which they bargain and the credibility of their alternatives. While these factors are important, however, they rarely determine the outcome. If everyone simply demands the maximum amount for himself, there is a good chance that the process will end in stalemate. The key to resolving a distributive bargain is not to make self-serving demands, but to make a proposal that the *others* find plausible and justifiable. This is precisely where equity arguments come in: they *coordinate* the expectations of the bargainers by establishing a plausible basis for the agreement. Equity principles are the *instruments* used to resolve distributive bargains.

The solution is to design a *procedure* for dividing the goods that the claimants believe to be fair. By a "procedure" is meant a game with prescribed rules and moves that results in a specific division.

Fairness involves a balancing of demands, equal treatment, a concern with legitimacy, lack of coercion. It provides a basis for voluntary consent (Young, H.P, 1985). Indeed, it is possible to propose the following empirical test of a "fairness principle": is it sufficiently compelling to cause parties with diverse interests to *voluntarily* agree to its application?

Two approaches to achieving fair allocations may be distinguished. One is strictly normative: all of the objective data are at hand and the problem is to device an appropriate formula for making an allocation based on these data. Such techniques are typically encountered in cost-benefit analysis. The second approach is to design a procedure – e.g. a court trial, an arbitration rule, an auction, or a competitive market – that seems fair and impartial *a priori*, and by its functioning produces an allocation (which might or might not seem fair *a posteriori*). In both cases, game theory plays an important role: cooperative game theory in the design of normative formulas, and non-cooperative game theory in the design of procedures.

### (x) Equity and Efficiency

Suppose that the claimants have well-defined shares in the common property (not necessarily equal shares), and different preferences for the goods it contains. A *competitive allocation* is one for which there exists a set of *prices*, such that every claimant likes his portion best among all the portions that he can afford to buy given the value of his share at these prices. Such an allocation can be discovered through a market-like mechanism that does not require the claimants to know anything about one another's utilities. Moreover, the resulting allocation can be justified on grounds of equity. *It is the only efficient and consistent way of reallocating the property that leaves everyone at least as well off as she/he was initially*.

This result provides both a theoretical and practical answer to the question of how to allocate divisible goods both fairly and efficiently without making inordinate demands on the players' information. In problems of local justice, equity and efficiency often complement each other. Principles of equity are the instruments by which societies resolve distributive problems when efficiency by itself yields indeterminate results. The definitions provided in Box 4 below provide further insights.

### Box 4. Cost and benefit sharing: some definitions

Cost and benefit sharing may be viewed within the broader framework of economic welfare by posing the question: under what circumstances is the decentralized sharing of costs and benefits within watercourses or within public enterprises and firms “consistent” with an allocation (sharing) that is fair for society as a whole? In other words, what characterizes societal allocations that have the property that they seem fair when viewed by any subgroup of society (assuming the others’ allocations are fixed)? This “consistency” or “stability” principle (together with several regularity properties) implies that the allocation must maximize some additively separable social welfare function on the space of feasible alternatives. In other words, in order for an allocation to be locally stable, it must meet some global optimization criterion. Commonly advocated social welfare functions of this type include classical utilitarianism, the Nash social welfare function and a refinement (due to Sen) of Rawls’s maximin criterion (Young, H.P, 1985).

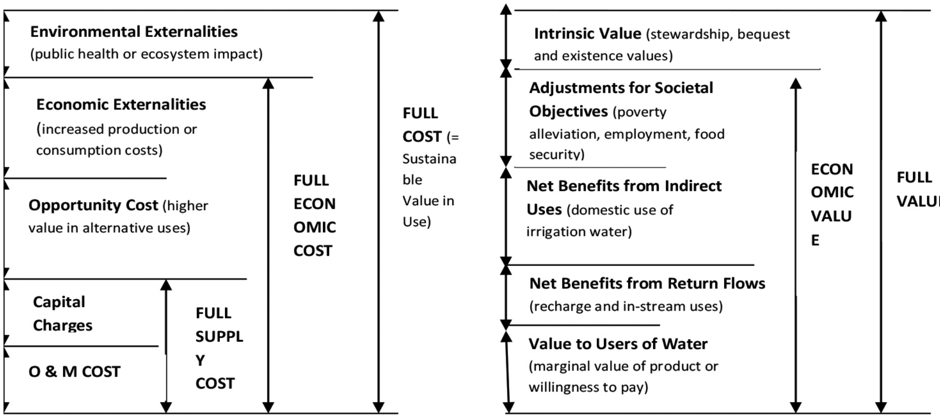
Fair means, firstly, “attractive in appearance: pleasing to view”. Significantly, a secondary meaning is “pleasing to hear: inspiring hope or confidence often delusively … specious”. It is closely connected to such ideas as just, equitable, impartial, unbiased and objective. “Fair … implies a disposition in a person or group to achieve a fitting and right balance of claims or considerations that is free from undue favoritism even to oneself … Just stresses, more than fair, a disposition to conform with, or conformity with the standard of what is right, true, or lawful, despite strong, especially personal, influences tending to subvert that conformity” (Webster, 1981)

## 3.3.2. Typical Solution Concepts Embedding Optimality, Economic Efficiency, Equity, Fairness, National and Group Rationality, Sustainability and Stability of Cooperation

The function of economic analysis in designing single projects or basin programmes is a crucial issue. Establishment of appropriate benefit and cost concepts, as well as those of project formulation and design, is only the initial phase of economic analysis. In order to apply such concepts in defining the optimum scale of development, succeeding phases require methods and procedures for measuring effects in comparable terms. Project effects arise in diverse physical forms, at differing times and for varying periods. In some circumstances the certainty of their occurrence is doubtful. Systematic treatment should be applied to such types of diverse effects as secondary benefits, inundation impacts and intangibles.

Figure 1 below depicts the principles for estimating the cost and value of water infrastructure and services.

### Figure 3.1: General Principles for Cost and Value of Water (Rogers, et al. 1997)




There is no shortage of plausible methods for cost allocation. The essence of the problem, however, lies not in defining methods, but in formulating principles and standards that should govern allocations, and then determining which methods satisfy them.

Minimal data of the problem are the total costs to be allocated and the objects to which costs are to be assigned. In specifying the latter it is necessary to ascertain when two cost objects are comparable, i.e. would be assigned equal costs in the absence of other information. The cost objects could be multipurpose uses of reservoirs or countries participating in a joint project on an international watercourse.

The second aspect of the problem consists in estimating the cost associated with each subset of cost objects. The specification of these costs for all subsets defines a *cost game* on the cost objects which are called "players." Computing a cost for each of $2^n$ subsets of n cost objects is daunting if n is larger than 4 or 5. In practice the structure of the problem often allows simplifications. For example, airport-type cost games, in which costs depend only on certain critical thresholds, are manageable even for very large n. Other situations may allow the grouping of players and allocating costs hierarchically, first among groups and then within each group.

A third aspect of the problem is the anticipated ***benefit*** from the project. Economic efficiency suggests that the optimal set of the cost objects is the one that yields the greatest benefits net of costs. In principle, the allocation of benefits can be carried out using the same methods that apply to the allocation of costs. If demands are not known, however, serious difficulties arise in trying to design a cost allocation scheme that implements an efficient decision. One reasonable approach is to employ a competitive bidding scheme that generates an efficient decision and at least *covers* all costs.

Four general principles stand out as important criteria for judging cost allocation methods (Young, H.P, 1985). These are: monotonicity, additivity, consistency and staying in the core. Monotonicity axioms describe notions of fairness and induce incentives to cooperate. Furthermore, a value is additive if in a game that is the sum of two games, the value of each player equals the sum of his values in the two component games. Consistency and staying in the core seem most compelling for one-shot investment problems, or in public utility pricing where cross-subsidization is a major issue. In this case, the nucleolus seems to be the best choice; although another core solution – the per capita nucleolus – has the advantage of being monotonic in the aggregate, which the nucleolus is not.

An impossibility theorem states that *no* core solution method is fully monotonic, and only the Shapley value is monotonic in the strongest sense. The Shapley value can also be characterized as the unique method that is additive and allocates no costs to "dummy" players. On the other hand, the Shapley value is not necessarily in the core. The Shapley value seems well suited to situations in which costs are allocated in parts, or are reallocated periodically, but it is not satisfactory when core solutions are required.

In brief, there is no all-embracing solution to the cost allocation problem. Which method suits best depends on the context, the computational resources and the amount of cost and benefit information available [Young, H.P, op cit.] The mathematical formulas for all the various concepts are included in Annex D.

## 3.4 Glimpses of water management problems and shared water courses to which outlined principles have been or could be applied

### 3.4.1 Outside of the African Continent

Deciding on the right solution concept in issues concerning fostering regional cooperation requires a thorough examination of the foundations of the solution concept in order to see how they fit reality. The decision, however, may also depend on the coalition function chosen to model the situation. It is not sufficient to recommend a certain solution on the ground that game theory has defined it. There is also the need to justify why the particular solution is appropriate to the specific issue. Many sharing problems arising from practice in the past were important in the development of cooperative game theory, either as supporters of already known theory or as inspiration source for new directions. Some of the commonly cited examples are typified by the following:

#### (i) The Tennessee Valley Problem

One of the most exciting examples of joint cost allocation is the multipurpose reservoir, where a dam on a river is planned to serve several different regional interests, such as flood control, hydro-electric power, navigation, irrigation and municipal supply. The dam can be built to different heights, depending on which purposes are to be included. The cost function associated with such a problem typically exhibits decreasing marginal costs per cubic meter of water impounded up to some critical height of the dam, after which increasing marginal costs set in due to technological limitations. The water resource planning problem is how to apportion the costs among the different purposes.

This problem has a rich history dating back to the creation of the Tennessee Valley Authority (TVA) in the 1930s. Certain cost allocation formulas suggested for the TVA system are still in use today (in modified form) by water resources agencies, including the Bureau of Reclamation in the United States Department of the Interior (Young, H.P, 1985).

The TVA Act of 1933 as analyzed by Ransmeier (1942) stipulated that the costs of TVA projects be specifically allocated among the purposes involved, the principal ones being navigation, flood control and power. Ransmeier suggested several criteria for judging cost allocation methods: The method should have a reasonable logical basis … It should not result in charging any objective with a greater investment than would suffice for its development at an alternate single purpose site. Finally, it should not charge any two or more objectives with a greater investment than would suffice for alternate dual or multiple purpose development.

The TVA asserted that its allocation of joint costs was not based on any one mathematical formula, but as Ransmeier (1942) observes, "there is little to recommend the pure judgment method for allocation. In many regards it resembles what Professor Lewis has called the `trance method` of utility valuation." Nevertheless, according to Ransmeier, the TVA did in fact use a method and merely "rounded off" the resulting allocations in the light of judgment. This method, called the "alternative justifiable expenditure method", is a variant of an earlier proposal called the "alternative cost avoided method", due to Martin Glaeser. It has become, after further refinements, the principal textbook method used by civil engineers to allocate the costs of multipurpose reservoirs, and is known as the "separable costs remaining benefits method" (SCRB).

The Tennessee Valley Problem also included the use of rules related to the $\tau$-value of the related game. This problem was faced when solving the question about (the price of) electricity power in the TVA programme. The Authority had to prepare allocations of the costs of the Wilson Dam and of additional reservoir projects which might be implemented among five objectives, namely navigation, flood control, development of power, national defense and fertilizer production.

## 3.4.2 In Africa

### (i) Introduction

Apart from applying economic analysis basin-wide to evaluate existing water resources developments for optimality, equity and fairness of projects costs and benefits distribution, many existing or pipeline projects can serve as candidate cases for promoting regional cooperation (hence regional integration) by using some of the principles outlined in this chapter. These include the following:

### (ii) Regional Cooperation and Benefit sharing in the Senegal River Basin

The four riparian countries of the Senegal River Basin, namely Guinea, Mali, Mauritania and Senegal, established the Senegal River Basin Organization (OMVS) in 1972 for river basin planning and project execution in order to address energy shortages and growing water constraints hampering countries' economic performance. The hydropower and irrigation potentials of the basin were estimated at 1200 MW and 320,000 ha respectively. OMVS was built on the strong foundation established by an earlier IDA-funded hydropower development project in Mauritania, Senegal and Mali, which promoted joint ownership of water infrastructure. The positive impact that ensued led to the following two concrete results, amongst others:

- Preparation of a Water Charter establishing principles for guiding water resources management and allocation among the signatory States;
- Construction and establishment of operational procedures for the Manantali dam in Mali resulting in managed flooding of about 50,000 ha for traditional recession agriculture.

The design of the project took into account the water balance of the Senegal River and the differences in the interests and levels of capacity and development in the countries involved, and tailored the activities to suit regional, national and local levels. This resulted in equitable sharing of costs and benefits among all riparian countries, higher agricultural productivity and incomes flowing to 2 million people through improved water and land management.

The Manantali dam provides hydropower, irrigation and navigational improvement benefits to three of the four riparian countries. In the sharing of the benefits, Mali receives 52 per cent of the energy generated, Senegal 33 per cent and Mauritania 15 per cent. The project became fully operational in 2002.

### (iii) Lake Chad Basin context

The framework provides adequate materials for understanding and resolving the complex issues involved in the Lake Chad Basin Commission's (LCBC) project on Regional Inter-Basin Water Transfer from the Oubangui to the Lake Chad Basin. The project commenced with the Summit decision in 1996-1997 that the long-term solution to the drying up of Lake Chad lied in a campaign to save the latter through transferring water from the presumed "water surplus" adjacent Congo river basin to augment the dwindling water resources available in Lake Chad basin.

In translating this Summit decision into a concrete project, the immediate challenge in 1998 was how to achieve the set objective in the most efficient manner. A project that would depend on massive energy to pump the required water over the mountainous catchment divide between the two adjacent basins, with its economic incidence on LCBC member States among whom some of the poorest on the continent, was ruled out in favor of a gravity transfer scheme for efficiency.

Among the previously studied dam sites on the Oubangui River, the Palambo dam site located at about 64 kilometers upstream of Bangui, the capital of the Central African Republic (CAR), stood tall. The site was previously studied at prefeasibility level by a French consulting firm (SOGREAH), with funding from the French foreign cooperation Ministry. Copy of the study report was eventually procured from SOGREAH in France by the then President of Central African Republic (CAR) - Ange Félix Patassé - through some of the French companies based in Bangui at the time.

The effort paid off as the report revealed that the site was studied for prefeasibility of constructing a low dam at the site for hydropower generation to supply Bangui and other smaller towns in CAR, the Republic of the Congo and the DRC, as well as to improve navigation downstream to the confluence of the Oubangui on the Congo river, and to open up the northwestern parts of the DRC accessible only through navigation. The report also revealed that the dam site could accommodate a larger and higher dam that could raise the water storage level to much higher elevations than the altitudes indicated on the existing topographic maps of the adjacent Lake Chad basin. Thus by reconfiguring (scaling up) the initially studied SOGREAH design it would be possible to transfer water by gravity through a tunnel from the "donor" basin (Congo) to the "recipient" basin (Lake Chad).

The interests of CAR were to have the water conveyance structure studied as a navigable tunnel or open canal with a fluvial port at Boucar, to diversify the mode of goods supply to the landlocked country. Furthermore, to accommodate this request, the Chari River was to be linked to the Logone and Mayo Kebbi from where merchandises coming by Ships through the Niger and Benue rivers (perennially navigable rivers) could branch off to Lake Chad basin. The project would also involve the construction of ship passing facilities. The interest of Cameroon factored into the project beyond joint infrastructure ownership was the rehabilitation of the existing fluvial Port at Garoua, to compensate for the diversion of goods previously channelled through the Douala Port to the new supply route.

This web of inter-connected infrastructure introduces many issues in its detailed study, not least issues relating to cost-benefit analysis and cost- and benefit-sharing schemes for different project component parts. For example, since the water to be transferred is to attract charges, and since there would be future responsibilities for ensuring sustainability of project through recovery of operation, maintenance and replacement costs, questions would be asked how the costs and the benefits of the economy of scale achieved for the Palambo dam would be allocated to the various objectives of hydropower, navigation and water transfer as well as among the countries parties to the project, both in the "donor" and the "recipient" basins; how the costs and benefits of the proposed navigable tunnel or open canal would be allocated between water transfer and navigation objectives particularly between CAR and other LCBC countries ; how the costs and benefits of the canal proposed to link Chari with Logone and Mayo Kebbi would be allocated among concerned LCBC countries; and how the cost of rehabilitating the existing Garoua port (Cameroon) as well as other navigational infrastructure would be allocated among LCBC countries.

### (iv) Niger River Basin

There are a number of proposed dam construction projects in Niger River basin that are currently promoted as national projects but that could be harnessed and implemented as joint projects of sub-coalitions of the nine countries (or the grand coalition) that share the watercourse. Examples of these projects include the Fomi dam in Guinea, which could also be harnessed to augment the low flow available for dry season irrigation at the Office du Niger in Mali. The Malian authorities incessantly promote the irrigable potentials at the Office du Niger as being more than a million hectares. However, due to lack of an effective water storage at the project's water intake structure located at Markala, the existing 82,000 hectares development could not be fully irrigated during the dry season without the risk of field abandonment at critical flowering periods due to lack of water for irrigation. Since this problem needs to be resolved before any project expansion can be justified, apart from groundwater supplementation, joint implementation of the proposed Fomi dam by Guinea and Mali offers another possibility for Mali to avail more water to its project for dry season cropping on the scheme. Here again, the issue that would need to be addressed by promoters of such joint projects is how the costs and benefits of the joint infrastructure would be allocated among the parties.

Kandadji dam on River Niger offers another example, which could be promoted as a joint project between the Niger Republic and Nigeria (possibly including Mali). Since the Kainji dam was completed in Nigeria in the early sixties, the project which is now threatened by the proposed Kandadji dam has supplied Niger with electricity. Nigeria has raised concern about the potential impacts of the dam downstream, since hydropower generation at Kainji dam may be foregone. However, the concern may be turned into opportunity for cooperation if the project is promoted as a joint project of the two countries. Rather than Nigeria sending power to Niger as is currently the case, the power line may provide service in the reverse direction to the northern parts of Nigeria. Again, the issues to be tackled in order to convince the two countries on the need for cooperation will include how the costs and benefits (achievable through economy of scale) of the joint project would be allocated among the two parties to achieve optimality, efficiency, equity and fairness as extolled by the UN Convention.

In the same vein, Kafin Hausa dam site could be promoted as a joint project of Cameroon and Nigeria, to promote regional cooperation among the two neighbouring countries.

### (v) The Nile River Basin

From the perspective of water resources management, this is one of the most contentious river basins in Africa. A 1959 Agreement concluded between the colonial power representing some of the upstream countries (Uganda, Kenya, Tanzania) as well as Egypt and the Sudan, fully allocated the annual flow of the river to Egypt and the Sudan. However, the upstream countries have since become independent, with galloping population and water scarcity due to climate variability, leading them to join forces with other upstream countries like Ethiopia, Rwanda and Burundi, to demand a fairer share from the available water resources within the basin.

### Box 5. The Costs of Non-Cooperation along the Nile

The 10 countries sharing the Blue and White Niles gain hundreds of millions of dollars worth of water by cooperating. Under a 1959 treaty including the building of Aswan High Dam, Egypt and the Sudan allocated the yearly total flow of the two rivers (averaging 84 billion cubic meters) to themselves. However, building dams upstream along the Blue Nile in Ethiopia would have increased the available water by an estimated 6 billion cubic meters or more. This cooperation would have been worth $US600 million annually to Ethiopia and its downstream neighbours. The water stored in Ethiopia could also have been used to generate three times more hydropower than produced by the Aswan Dam.

The problems with reaching a cooperative solution arises from the unbalanced distribution of benefits and costs, with Ethiopia gaining $US1.2 billion and Egypt and the Sudan both losing $US300 million and Egypt and the Sudan's dependency on water supply from Ethiopia. This asymmetry could clearly have been addressed by transfers leaving net gains all year round, but Egypt and the Sudan did not seem to trust Ethiopia to make appropriate transfers and or water deliveries in the future.

(***Source:*** Maurice Schiff and L. Alan Winters, 2002)

One way to resolve the lingering conflict and promote regional cooperation among the contending parties may be to conduct a study for potential projects that may improve optimality, efficiency, equity and fairness of existing distribution of available water resources. In this regard, the present Report may serve as a potential tool for motivating proper review of existing studies in all the various countries to identify projects with potential economies of scale that can promote upstream-downstream cooperation among the countries and to demonstrate how the costs and benefits of such cooperation could be allocated to the parties.

### (vi) Zambezi River basin

This is the basin selected for the practical demonstration of the Framework, with the benefit of funding from the implementation of a Development Account project. The Zambezi is the largest of the more than fifteen shared watercourses in Southern Africa. Although SADC adopted an Action Plan for the Zambezi River Basin (ZACPLAN), with nineteen (19) projects, that dates back to 1987, the formation of a basin-wide regulatory institution to enhance cooperation and coordinate development activities within the basin has eluded the region. The Agreement produced in 1998 coincided with Zambia withdrawing from negotiations for fear of entering into an agreement that did not include water allocation to parties.

This issue highlights one of the advantages of having a conceptual framework in order to clarify some of the concepts like the principles of equitable uses that may have previously been misconstrued by riparian stakeholders. It also justifies the choice of the Zambezi river basin for the demonstration of the application of some of the principles outlined in the framework.

An important regional integration project on the Zambezi begging for the demonstration of these concepts is the Shire-Zambezi Waterway Project. The project spans the Shire River in Malawi and Mozambique, and the Zambezi River in Zambia, Zimbabwe and Mozambique. The Shire Zambezi Waterways was originally used as a transport route by explorers and missionaries to Malawi a century and a half ago. During that time, the port of call in Malawi was Nsanje, formerly known as Port Herald along the Shire River. As recently as 1970, Mawtam Ltd. operated a barge service transporting molasses from Chiromo in Malawi to Chinde on the coast of the Indian Ocean in Mozambique.

The Shire-Zambezi initiative has been adopted as priority project both by SADC and COMESA Ministers responsible for Transport at various times. The Ministers urged that priority be given to undertaking the required studies in order to integrate the Shire-Zambezi Waterway with the surface transport networks in the subregion and with the maritime regime of the Indian Ocean. The Government of Malawi started construction of the Nsanje port in 2005 and later signed an MoU with Mozambique and Zambia for the feasibility study of the project on 15 August 2009, witnessed by SADC. A consortium based in Zimbabwe was hired to carry out the studies, but Mozambique announced withdrawal from the project few months later, doubting competence of the consortium. The commissioning of the Nsanje Port in 2010 suffered a major blow not only because it was boycotted by Mozambique, but because Mozambique also confiscated the barge that would have signaled the inauguration, within its territorial waters.

Although Malawi may have based its Nsanje Port construction on cost-benefit analysis that showed economic efficiency for opting for the project, trans-boundary waters management requires more investigations and considerations to obtain the buy-in of other riparian actors.

## 3.5 Conclusions

The analytical framework outlined above has attempted to frame cost-benefit analysis in a way conducive for fostering regional integration around the implementation of regional or multipurpose water infrastructure in Southern Africa. The principles are also applicable to other African shared watercourses. In this regard, some glimpses of contexts in which the principles outlined in the document can be of value to the management of African shared watercourses were provided. The principles discussed was placed in the context of the 1997 UN Convention on the Law of the Non-navigational uses of International Watercourses that required such attributes as cooperation among countries that share the river basin, optimality, economic efficiency, equity and fairness in the development and management of the water resources in order to maximize economic, social and environmental benefits.

Such principles require the use of the river basin as the unit for planning and management as emphasized by numerous global fora, including the Dublin Principles and Agenda 21 of the Rio de Janeiro UNCED Summit of 1992. The possibilities for the application of cost-benefit analysis to water resources management as interpreted from the UN Convention were seen in two different lights: for the evaluation of economic feasibility of individual projects, be it in a non-cooperative game or in a manner designed to achieve Pareto efficiency; and for cost and benefit allocations to multipurpose objectives and to multiple beneficiaries, either with respect to a single project or with respect to several projects within the same river basin.

The need for standardization of measuring costs and values of water services during project formulation was underscored. The issues that militate against cooperation and those in devising incentives for cooperation were analyzed. The need for exploring the opportunities of potential economies of scale and the application of the principles to forge regional cooperation around such opportunities premised on establishing River Basin Organizations or strengthening existing ones, was articulated. The concept of equity and other relevant considerations was thoroughly examined and the corresponding principles for the allocation of costs and benefits for multiple purposes such as the Shapley value, nucleolus and the core as well as their axiomatic formulations and their relationships to the common separable and non-separable cost and benefit methods were outlined in Annex D.

Finally, it is hoped that the quest of countries and RBOs for optimality, economic efficiency, equitable and fair share and sustainable water resources development on Africa's international watercourses will motivate them to apply the framework in their routine management activities.

# Chapter IV – Economy of scale in the SADC Power Sector

## 4.1 Status of power supply and demand

The twelve member countries of SADC on continental Africa consist of Angola, Botswana, the Democratic Republic of Congo (DRC), Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe. Three other countries namely Mauritius, Madagascar and Seychelles complete the fifteen member SADC assembly and are located off shore from Continental Africa. In 1995, SADC established the Southern African Power Pool (SAPP) with the aim being to optimize the use of available energy resources in the subregion and for countries to support one another during national emergencies. The SADC region has an estimated population of 240 million people.

For the last ten years, electrical energy demand has been growing at an average annual rate of 3 per cent and in 2007, posted an annual growth of 4.6 per cent. In 1995, when SAPP was established, the region enjoyed excess capacity with reserve margins in excess of 20 per cent. With increasing customer demands, however, the excess capacity was eroded and the reserve margin dropped to a lower value of 5 per cent. At times of system peak, this is reduced even further. Table 4.1 provides the SAPP installed, available and national demand levels as at March 2010. Figure 4.1 shows the generation mix consisting of 74 per cent thermal coal (mostly in the Southern Networks), 20 per cent hydro (mostly in the Northern Networks), 4 per cent nuclear in South Africa and 2 per cent gas and diesel as distributed generation. Figure 4.2 shows country contribution to regional generation, with South Africa being the dominant country.

Angola, Malawi and Tanzania are not electrically interconnected to the SAPP Regional Grid and their data is testimony. All the other countries are interconnected to form the SAPP regional grid and in most cases rely on trading bilateral contracts to make up the national deficit in power generation. This is certainly the most efficient outcome emanating from a regional power pool model: the sharing of natural resources. This benefit translates into financial savings and is a positive contributor to the national and regional economy.

The SAPP has been experiencing power shortages in the last four years due to lack of investments in both generation and transmission infrastructure. Investments in the power sector have been hindered by (i) low tariffs, (ii) absence of an enabling environment, and (iii) inconsistent legal and regulatory policies.

## Table 4.1: SAPP Installed, Available and National Demands as at march 2010

| Country | Installed Capacity[MW] | Available Capacity [MW] | 2009 Peak Demand [MW] |
|---|---|---|---|
| Angola | 1,187 | 930 | 668 |
| Botswana | 132 | 90 | 553 |
| DRC | 2,442 | 1,170 | 1,028 |
| Lesotho | 72 | 70 | 116 |
| Malawi | 287 | 267 | 260 |
| Mozambique | 233 | 174 | 435 |
| HCB | 2,075 | 2075 | |
| Namibia | 393 | 360 | 451 |
| South Africa | 44,170 | 40,483 | 35,850 |
| Swaziland | 70.6 | 70 | 200 |
| Tanzania | 1,008 | 680 | 705 |
| Zambia | 1,812 | 1,200 | 1,483 |
| Zimbabwe | 2,045 | 1,080 | 1,714 |
| Total SAPP | 55,927 | 48,649 | 43,463 |
| Total Interconnected | 53,445 | 46,772 | 41,830 |

Source: SAPP Report to SADC Energy Ministers, April 2010

## Figure 4.1: Generation mix in the SAPP

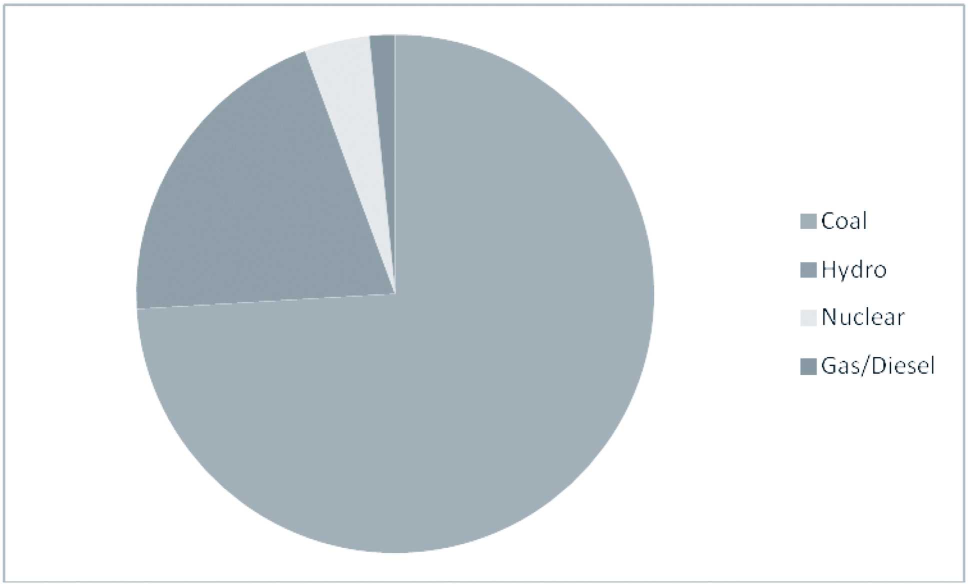
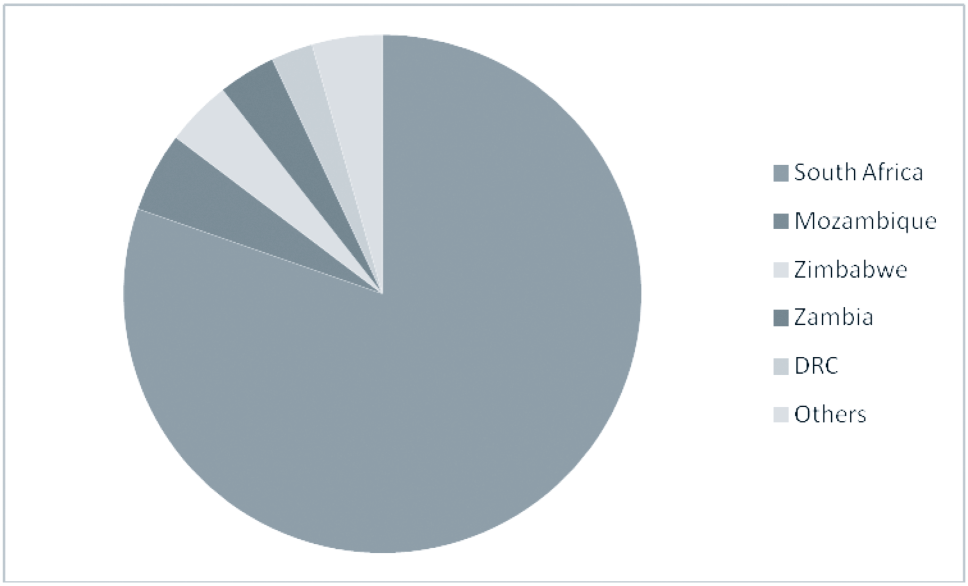


Figure 4.2: Country contributions




### 4.1.1 Benefits of regional Interconnectors

The major benefits of regional interconnections as experienced by the SAPP are:

*i.* *Security of supply increases* and this makes provision for emergency support, sharing of spinning reserve capacity and a balancing generation mix;

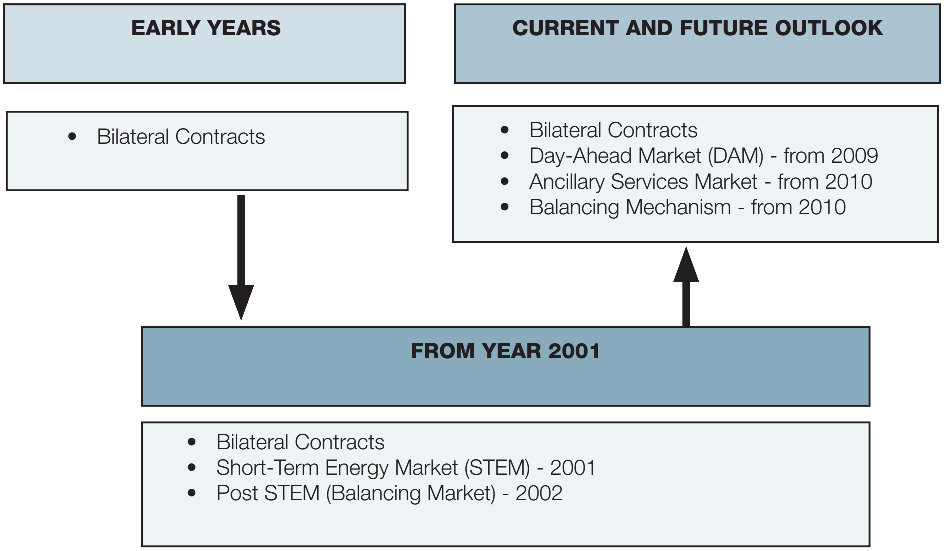
*ii.* *Improved sector investment environment* as a result of the aggregation of the individual power markets creating an improved access to credit and diversification;

*iii.* *Reduced operating costs*: There is merit order to be followed when dispatching generation units and thus eliminating expensive generation in the dispatch process. The System Operator also balances non-coincidental peak loads and optimizes generation resources;

*iv.* *Reduced and deferred investment costs*: Interconnection gives rise to the advantage of economies of scale. The SAPP has managed to reduce the total reserve margin requirements from 20 per cent to 10 per cent. Investments in new peaking power capacity were postponed and the region saw a reduction in hydro system investments.

The other benefit of regional interconnection is *energy trading*. Energy trading in the SADC region has been facilitated by the fact that some members have excess power supply and others are in a deficit. Therefore, balancing supply and demand is done via energy trading arrangements established by the SAPP. The SAPP had been trading energy via bilateral contracts until 2001 when the short-term energy market (STEM) was established as a precursor to a competitive market. Figure 4.3 shows the transition in energy trading arrangements in the SAPP.

**Figure 4.3: SAPP energy trading arrangements**




If there was no energy trading in the SADC region, countries such as Botswana, Namibia, Swaziland and Zimbabwe would have built by now at least a combined 2,000MW power generation plant, but this has not been the case because of the interconnections to other countries. The establishment of the STEM in 2001 created a platform to trade a fraction of electricity in the region competitively. From 2003, the SAPP started the development of a full competitive electricity market in the form of a day-ahead market (DAM). This market was opened in December 2009 and combined with the STEM. The markets were developed to:

- Help optimise the use of subregional energy resources;
- Assist the subregion in determining the correct electricity price in the pool;
- Send price signals for investments and real time use of existing assets; transmission, generation and consumption; and
- Enable the demand side to respond to the supply side price signals.

A number of planned generation and transmission projects are based on the fact that the SAPP trades energy and whatever that is generated could be traded across the region and not only in the country where the infrastructure sits. This is important for investment as a regional market is better than individual country markets in terms of economies of scale.

### 4.1.2 Current Challenges

Despite energy trading arrangements, SADC has moved from an era of excess capacity to that of power shortages. The decision not to invest timely in new generation and transmission capacity will haunt the industry for years to come until new generation comes on line. On many a day, the regional power system operates with no reserve margin; the slightest disturbance is amplified. The diminished generation capacity has been attributed to the following key factors:

i. Economic growth of more than 5 per cent per annum for most members has resulted in unprecedented growth in consumption and demand. Sustainable economic growth requires adequate electricity supply. The shortage of power has affected the economic and social development of the entire SADC subregion. Few countries are now expected to grow above 5 per cent from 2010.

ii. Increase in base metal demand on the world market resulting in huge mining companies opening up in Southern Africa. In Zambia and the DRC for example, most of the copper mines closed at one time and deemed unprofitable then, are now back in operation. At the same time, new mines have been opened in both countries and also in other countries requiring high power demand from the SAPP.

iii. There have not been sufficient investments in generation and transmission infrastructure over the last twenty years. The subregion had excess capacity and electricity was cheap. Some power stations were actually closed in South Africa at the time as they were expensive to run and operate.

iv. Electrification programmes have partly contributed to the current power supply challenges. Most members have embarked on massive rural electrification projects aimed at increasing accessibility to electricity in a region where on average 70 per cent of the population have no access to electricity [Table 4.2].

### Table 4.2: Levels of Electrification in SADC

| No | Country | Percentage | |
|---|---|---|---|
| | | 1999 | 2009 |
| 1 | Angola | 8.0 | 15.0 |
| 2 | Botswana | 15.0 | 22.0 |
| 3 | Congo, Dem Rep | 4.0 | 6.7 |
| 4 | Lesotho | 3.0 | 5.0 |
| 5 | Malawi | 3.0 | 5.0 |
| 6 | Mozambique | 6.0 | 7.2 |
| 7 | Namibia | 26.0 | 34.0 |
| 8 | South Africa | 65.0 | 70.0 |
| 9 | Swaziland | 21.0 | 28.0 |
| 10 | Tanzania | 5.0 | 10.5 |
| 11 | Zambia | 12.0 | 20.0 |
| 12 | Zimbabwe | 20.0 | 39.7 |

v. Electricity generation in Southern Africa is dominated by coal-fired thermal power stations. Most of these plants are in South Africa which accounts for over 80 per cent of the SAPP installed capacity. In the last few years, coal price volatilities and quality of coal delivered to the power stations have affected electricity generation. As a result, South Africa's future plans are now centred on increasing nuclear power capability and plans to install over 10,000MW of nuclear power by 2025.

vi. As far back as 1999, the SAPP had predicted that the SADC region would run out of generation surplus capacity and had informed the Governments. The problem was thus identified then, but unfortunately was not fully mitigated.

Despite the power deficit in the SADC region, the development of power infrastructure has been very slow. Until recently, SAPP members have started investing in generation and transmission projects. In 2007 for example, a total of about 1,700MW was commissioned by the SAPP. At the end of 2008, the SAPP commissioned a further 1,700MW and another 2,187MW in 2009. Taking into account that power demand is rising at about 4 per cent per annum, the commissioned generation projects are below the rise in demand and power shortage would continue.

In South Africa, Eskom has embarked on a massive expansion programme to return to service the power stations that were closed at the time that the region had excess capacity under the de-mothballing project. At the same time, the expansion programme is expected to commission new Greenfield generation projects. South Africa has announced and is planning to invest over R100 billion (about $US12.5 billion) over the next 5 years in generation, transmission and distribution infrastructure. For this amount of money to be raised, either the Government would have to bailout Eskom or tariffs would need to be increased substantially to pay for the expansion programme. This picture is not different in other countries.

### 4.1.3 Regional projects

A project is said to be regional when it has an impact on the subregion. If the project is a *generation project*, it should be able to add reserve margin to the SAPP grid and reduce the diminished surplus capacity of the subregion. As an example, the 4,800MW Medupi generation project in South Africa, though an internal country project, is considered a regional project because it will add generation capacity to the interconnected SAPP grid and reduce South Africa's imports from the subregion which could then be used by other countries. The same argument goes for any other generation projects undertaken by any SADC member States. If the project is a *transmission project*, it should be able to interconnect two or more countries and either (i) reduce congestion on the SAPP grid or (ii) increase trade between north and south. Some internal country transmission projects are also considered regional when they reduce congestion on the SAPP grid and promote trade between member States such as the proposed reinforcements of the Zimbabwe transmission networks. Zimbabwe sits between north and south of the interconnected SAPP grid and any reinforcements on the Zimbabwe grid would reduce congestion and improve regional trade.

Projects are normally in the hands of Project Owners and Sponsors and these are usually Power Utilities. The Project Owner normally finances feasibility studies and in the last few years the SAPP-CC has been requested to assist Power Utilities to seek financial support to package the project.

### 4.1.4 Renewable energy

Climate change dimension has had an impact on the SAPP's selections of generation technology and generation mix. SAPP members have now started to move towards the implementation of some renewable energy technology alternatives. In the next five years, the SAPP is planning to install over 200MW of renewable energy in the form of wind power in Lesotho, South Africa and Namibia as shown in Table 4.3 below.

**Table 4.3: Expected wind power generation**

| No | Utility | Country | Name | Type | Expected Year | Capacity [MW] |
|---|---|---|---|---|---|---|
| 1 | LEC | Lesotho | Lesotho Highlands | Wind | 2011 | 25 |
| 2 | IPP | South Africa | Eskom South | Wind | 2012 | 100 |
| 3 | IPP | Namibia | Luderitz | Wind | 2012 | 40 |
| 4 | IPP | South Africa | Eastern Cape | Wind | 2013 | 40 |
| **Total expected wind capacity** | | | | | | **205** |

The SAPP already has approximately 20MW of installed wind power and the planned generation capacity in the next few years will make wind power contribute around 1 per cent of the total installed generation capacity in the SAPP.

## 4.2 Cost of regional power infrastructure

### 4.2.1 The SAPP Pool Plan

In 2001, the SAPP completed the development of a Pool Plan that was not widely accepted by its members. This is because the plan listed projects that were deemed to be priority to the subregion, but because they were concentrated and located in a few countries, it politically became a challenge to accept them. In 2006, the SAPP received a World Bank grant to revise the Pool Plan of 2001. The Revised Pool Plan was completed in 2009 by a consultant but is yet to be adopted by the subregion. The subregion, however, agreed in 2005, that in order to mitigate the shortage of power supply in the SADC subregion, the SAPP should redefine priority projects in order to speed up their implementation and avert a regional crisis.

In 2005, the SAPP priority projects were then redefined as follows:

i. *Rehabilitation projects;*

ii. *Short-term generation projects* with full feasibility studies; completed and approved environmental and social impact assessments (ESIA); and the ability to be implemented before 2010, so as to adequately prepare for the FIFA 2010 World Cup;

iii. *Medium-term projects* with full feasibility studies and completed ESIA and having the ability to be implemented before 2020;

iv. *Long-term projects* - most of these projects have no feasibility studies done and would require some work to move them to a bankable stage before financial commitments could be secured. The projects would be implemented after 2025.

SAPP members have been working on rehabilitation projects because these are existing infrastructure and only require new capital injection to deliver to their full rated capacities. As an example, the DRC has an installed capacity of 2,442MW but only about 1,200MW is operating. The other capacity is not available either because the units are out of service or are lacking spare parts for their maintenance and return to service. Such projects are first priority for the SAPP because they can easily be implemented in the short-term.

The SAPP Pool Plan of 2009 has given SADC an indication of the cost of new generation projects. Table 4.4 shows the average generation costs the subregion has now adopted after the results of the SAPP Pool Plan. The *overnight construction* cost is the total initial capital cost required to setup the generation plant. The *levelised cost* spreads total generation cost over total output, producing a figure which would exactly balance costs and income if charged for each kWh. Notice that to construct an OCGT plant takes less capital than a hydro plant, but over a period of say thirty years, a hydro plant is cheaper to run, maintain and operate compared to OCGT. Hence, the overnight construction for OCGT is lower than hydro but the levelised cost for OCGT is higher due to operations and maintenance costs.

### Table 4.4: SAPP benchmark levelised generation costs

| Technology | Overnight Construction Cost [USD/KW] | Benchmark Levelised Cost [USD/MWh] |
|---|---|---|
| Nuclear | 2,500 | 44.69 |
| Coal | 2,222 | 29.67 |
| Hydro | 1,700 | 17.85 |
| CCGT_LNG | 550 | 77.3 |
| OCGT_Distillate | 350 | 139.5 |

***Source:*** Revised SAPP Pool Plan 2009

As a benchmark, the SAPP was invited to Ethiopia to witness the commissioning of Gilbe-II hydro power plant. This is a 420MW hydro project and the cost was given as EUR 375 million (approximately $US525 million). This translates into $US1,250 per KW and is well within the SAPP estimate considering that the project in Ethiopia used an existing dam.

The cost of developing different types of technologies varies in different regions as experienced by EDF[15] of France and the reported variation is as follows:

### Table 4.5: EDF Technology costs

| Technology | Levelised Cost [EUR/MWh] |
|---|---|
| Coal | 45 - 60 |
| Nuclear | 55 - 80 |
| Wind | 80 -90 |
| Photovoltaic | 250 -300 |

***Source:*** EDF of France, March 2010

Zambia and Zimbabwe are planning to build a 1,600MW power generation project at the Batoka Gorge to be owned jointly and each country to share 800MW. Using the cost data of Table 4.4, the total cost for the Batoka project could be estimated at $*US2.72 billion*, as shown in Table 4.6.

15 *Gerard Wolf, (EDF, France), "Forward looking & securing a global energy supply" Power & Electricity World Africa March 2010, South Africa*

### Table 4.6: Batoka Hydro Generation Project

| Country | Capacity [MW] | Unit Cost [USD/KW] | Cost of Project [USD] |
|---|---|---|---|
| Zambia | 800 | 1,700 | 1,360,000,000 |
| Zimbabwe | 800 | 1,700 | 1,360,000,000 |
| | | **TOTAL** | **2,720,000,000** |

Generally power projects are long-term projects and such projects would be expected to be repaid back in twenty or more years. Table 4.7 shows the minimum tariffs that could be charged at generation level without considering transmission, distribution, return on assets and other operating costs. If these are taken into consideration, the minimum tariffs would have to increase to at least five times the indicative values. For 15-years lifespan, the overall tariff in each country would have to be 9.25 cents/kWh (US) at least, using a load factor of 0.7. Unfortunately for both Zambia and Zimbabwe, the current tariff levels are much below the minimum tariffs. This makes investment into the project more difficult with the current tariffs.

### Table 4.7: Batoka Hydro Generation Project – Minimum generation tariffs

| Project Lifespan [Years] | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|
| **Minimum Tariffs [UScents/KWh]** | 1.85 | 1.39 | 1.11 | 0.92 | 0.79 | 0.69 |

*Note:* the minimum tariffs in any of the countries are calculated as follows:

$$\text{Tariff} = \frac{\text{Cost of the country project [USD]}}{\text{Capacity [MW]} \times 1000 \times \text{Lifespan} \times 365 \times 24\ \text{[hours]} \times \text{Load Factor}}$$

New generation would require new transmission infrastructure to evacuate power from the generating stations to the load centres. The cost of transmission is summarized in Table 4.8 below.

### Table 4.8: Cost of Transmission lines, including feeder bays

| No | Line Voltage | Cost per km |
|---|---|---|
| 1 | 132 kV | $US140,000 |
| 2 | 220 kV | $US160,000 |
| 3 | 330 kV | $US199,000 |
| 4 | 400 kV | $US200,000 to $US236,000 |

***Source:*** SAPP Pool Plan 2009

### 4.2.2 Challenges faced by the SADC Power Sector

The SADC power sector is currently faced with the following issues and challenges:

i. High technical losses.
ii. Lack of maintenance of the existing infrastructure leading to blackouts.
iii. Managerial weaknesses which makes it difficult for the power utility to make a concrete decision.
iv. Illegal electricity connections leading to consumed electricity but unpaid bills.
v. Non-cost reflective tariffs, making it difficult to sustain the business.

The issues need to be resolved if the power sector of the region is to move forward.

## 4.3 Development of Power Sector Infrastructure in the SADC subregion

The development of the SADC power infrastructure has been slow and very limited. There are a number of reasons why development is not taking place at the required rate and pace:

i. The subregion has not yet created an enabling environment for other players such as Independent Power Producers (IPPs) to participate. IPPs require a good rate of return for their investments and the current tariffs are not cost-reflective enough to attract them to the subregion.
ii. Differences in policies and legislation in different countries cause delays in concluding power purchase agreements (PPAs) and wheeling agreements. PPAs and wheeling agreements are necessary for any project to be funded. In the past, most of SAPP projects depended on Eskom for a PPA. Eskom now has its own build programme and could not guarantee a PPA, causing some projects (i.e. Mmambula in Botswana) to be put on hold.
iii. Need for government support for PPAs and/or wheeling agreements to underpin investment projects. The utilities balance sheets are generally weak and need government support to underpin projects.
iv. Project Coordination Aspects, including the need for a dedicated Project Coordinator, and for Project Development Agreements (Inter-Governmental MoU and Inter-Utility MoU). Most of the projects are poorly packaged and would need specialist firms to re-package them and bring them to bankability stages.
v. Impact of government internal costs on the cost of the project, e.g. fees for environmental impact assessment (EIA) report reviews and approvals; VAT duties and taxes in some countries are high and thus do discourage investors. The cost of evaluating an EIA report could be as high as 3 per cent of the cost of the project. This has to be paid before approvals are given in some cases.

vi. Delays in the approvals of key project documents such as wheeling and power purchase agreements by the Regulators have been another source of concern.

The responsibility for regional harmonization of the legal and regulatory frameworks within the SADC region has been given to RERA. In the last few years, RERA has produced guidelines for member States to adhere to when establishing national energy regulators and these guidelines have become the standard guidelines for the region. This has helped to harmonize both the legal and regulatory frameworks in the SADC region.

## 4.4 Case Study of a major regional power infrastructure project

### 4.4.1 The Project

The Western Power Corridor (WESTCOR) Project was identified in 2002 by the SAPP, as a key initiative for the subregion. The WESTCOR project was to exploit the environmentally friendly, renewable, hydroelectric energy of the INGA rapids site in the Democratic Republic of Congo (DRC). The "Societé Nationale d' Electricité" (SNEL) of the Democratic Republic of Congo owns and operates the two existing power stations, INGA I and II, with a combined output of 1770MW. INGA III represents the next phase of the development of the INGA site, with a rated output of 3500 MW. The final phase is the Grand INGA, with a potential rated output of 39,000 MW. Load growth in the southern networks has outstripped expectations as a result of energy intensive investments taking advantage of the excellent quality of supply available in the subregion at world competitive prices. Studies had also shown that additional generating capacity would be required in the southern networks of the SAPP to be in regular commercial service as early as 2005.

Furthermore, the Empresa Nacional De Electricidade (ENE) of Angola reported that the hydroelectric potential of the Cuanza Basin in northern Angola is approximately 6,000 MW. ENE expressed interest in developing this resource and exporting the energy to WESTCOR and other customers in the SAPP. An additional 2,500 MW can be potentially captured from gas presently flared off in the northern Angolan oilfields. Elf Aquitaine and GEC Alsthom did a preliminary scoping study during the mid -1990s to export this available energy to South Africa.

WESTCOR would develop power generation at Inga-3 in the DRC and in Angola and then supply power to the DRC, Angola, Namibia, Botswana and South Africa using extra high voltage transmission lines. The Governments from the five participating countries (Angola, Botswana, DRC, Namibia and South Africa) entered into a memorandum of understanding (MoU) that then allowed their respective national power utilities (ENE, BPC, SNEL, NamPower and Eskom) to enter into an Inter-Utility MoU for the development and implementation of the WESTCOR project.

A special purpose vehicle (SPV) named WESTCOR was established and a CEO appointed to move the project forward. WESTCOR offices were located and registered in Gaborone, Botswana. The responsibilities of the WESTCOR CEO included:

- Mobilization of finance to conduct feasibility study for the project which when proven could proceed;
- Acting as the appointed and official representative for WESTCOR.

The objectives of WESTCOR were:

i. Generation of renewable electricity at Inga-3 in the DRC;
ii. Transmitting the generated power at Inga-3 to the load centres in the five countries and the SAPP; and
iii. Providing a telecommunication link using fibre optic technology to be installed on the transmission lines to the five countries.

Figure 4.4: WESTCOR planned transmission grid


## 4.4.2 Issues and challenges faced

The cost of generating power at Inga-3 is calculated as shown in Table-9 below.

### Table 4.9: WESTCOR Project – cost of generation at Inga-3

| Country | Capacity [MW] | Unit Cost [USD/KW] | Cost of Project [USD] |
|---|---|---|---|
| DRC | 3500 | 1,700 | 5,950,000,000 |

WESTCOR would have to mobilize close to $US6 billion to construct the generating station at Inga-3 in the DRC. This did not include the cost of the long transmission lines to the south. It was a massive challenge to raise these funds for the project. Three years after the creation of WESTCOR, the following issues and challenges emerged and stalled the project:

i. The Government of the DRC reported back that the shareholding arrangements in WESTCOR were not in the best interest of the country. Each of the five participating utilities had a 20 per cent stake in WESTCOR but this was later revoked by the DRC Government.
ii. The Government of the DRC wanted compensation for using natural resources (water) from the other four members. This became a stumbling block but could have been resolved.
iii. The Government of the DRC received a counter offer from BHP Billiton, a mining company, that BHP could actually build a smelter in the DRC using the power within the DRC and thus could provide long-term benefits to the country in terms of job creation and finances for the people of the DRC and the Government.

As a result, the project stalled and WESTCOR entered the process of being dissolved.

## 4.4.3 Cost -benefit analysis of the WESTCOR Project

The total cost for WESTCOR was estimated at about $US6 billion and no single country could afford that amount without entering into a long-term debt. The projected income after the project is completed was estimated at $US1.5 billion per year with the assumption that power would cost around *5-UScents/KWh* with a load factor of *0.8* to *0.9*.

The benefits of the project would have included:

- Job creation in the five countries during construction works, commission and maintenance of the infrastructure afterwards;
- Massive income to the five countries for a long period of time, of approximately $US1.5 billion per annum. This income does not include the income that would have been generated from the leasing out of the telecommunications optic fibre to the telecoms companies;

- Investors would have flocked to the region when they knew that there was sufficient and reliable power to support their activities. The availability of power would have triggered further investments in the region from other sectors as energy is the engine for economic development.

The long-term benefits clearly outweigh the initial cost of the project, but the project failed to take off because of the issues and challenges cited above. Furthermore, the core incentives for cooperation among WESTCOR member States, the principle of international cooperation or equality of States, appears to have been wrongly applied in this case instead of the principles of equity and other concepts extolled under section 3.3 above that apply to the management of water and other natural resources. As explained under section 3.3, the request by the DRC to be compensated for the use of its natural resources appears to be legitimate and imperative for incentivizing regional cooperation within the WESTCOR arrangement. The lessons learned from the WESTCOR project were that:

i. SADC Governments have different legal and regulatory frameworks;
ii. Projects should be executed on commercial terms for them to succeed, with high political support from the Governments;
iii. Clarity on ownership, SPV structure and the roles of the parties should be dealt with from inception of the project; and
iv. Partial commitment to a project by the participating Governments will not deliver and see the project to completion. Political will with proper policies is an important ingredient for projects.

## 4.5 Policies and strategies for financing power projects in Southern Africa

### 4.5.1 Issues to address

In 2008, the SADC Energy Ministers Task Force tasked the SAPP, with the coordination assistance of the Development Bank of Southern Africa (DBSA), to commission a study whose ultimate aim was to develop and propose a financing model for cross-border power projects that would be suitable for the SADC subregion. The Ministers had noted with concern the slow pace of project implementation in the subregion. The aim of the study was, firstly, to give a diagnosis of the current state of the power sector and highlight the factors inhibiting the development of power projects in the subregion. With this information at hand, the appointed consultant (UTHO Capital of South Africa) was then requested to develop a financing model that would serve to unlock the public funding that is available and has been pledged, and attract as well as motivate investment from the private sector.

After the study, the SAPP summarized the major issues that affect cross-border project closure and hence inhibit project development, as follows (UTHO Capital, 2009):

## Political commitment

The extent to which the countries are committed to the projects is directly related to the level at which projects are endorsed. The one critical element that all key stakeholders agree on and emphasize is the political buy-in and endorsement of cross -border projects by the Heads of State, accompanied by strong oversight mechanisms to ensure speedy implementation and accountability. The recommendation was to have regional projects endorsed at Heads of State level rather than at Ministerial level as was the present cases for almost all cross -border projects in the SADC region. Political commitment could then endorse a Project Coordinator and government underwriting of the tariff gap could set the appropriate policy to enable regulators to implement cost pass through.

## Institutional Framework

The SADC framework was perceived as having a primary focus on political issues rather than economic integration. The SADC secretariat is presently not set up to operate at an appropriate level and its role needs to be significantly enhanced to effectively support the development of the power sector in the region. The SAPP model is premised on providing a platform for competitive trading rather than security of supply as was the case with the West African Power Pool (WAPP). An appropriate institutional framework to provide project preparation capacity, mobilization of capital and implementation of the projects is required.

## Project Preparation Capability

Projects should be properly prepared, designed and packaged. At present this does not appear to be the case. There is a strong requirement for risk capital to get projects to bankability. The SAPP and the regional electricity regulators association (RERA) should play relevant roles in mobilizing and coordinating risk capital for generation projects in conjunction with Project Sponsors. An appropriate institutional framework to drive the projects and an enabling environment is required to give the providers of risk capital the confidence to make such facilities available.

## Dependence of project funding on power purchase agreements (PPAs)

There is a strong dependence of project funding on power purchase agreements (PPAs). In the past Eskom of South Africa was responsible for signing PPAs for a number of cross -border projects, but Eskom is no longer in a position to continue to do so. The way out of this is for the subregion to allow a limited number of energy intensive users, such as large mining companies, to sign and buy directly from cross-border projects by way of PPAs to make the projects funded.

## Project Finance

Coordination and harmonization between traditional and non-traditional (e.g. Chinese) funding is required in order to build constructive partnerships to maximize the funding that can be made available for infrastructure projects.

### 4.5.2 Recommendations

Based on the SAPP study conducted with assistance from UTHO capital, the key recommendations for implementing cross -border projects in the SADC subregion include the following:

- Political endorsement for an interconnected SAPP grid and a selected basket of generation projects;
- Government underwriting of the tariff gap to ensure cost pass through;
- Open access to the grid for some of the intensive energy users as is required to develop the priority generation projects;
- Appropriate regulatory oversight; and
- Appropriate institutional framework to provide project preparation capacity, mobilization of capital and implementation of projects.

This could be achieved through

- Obtaining political sign-off from the SADC Heads of State for the projects to interconnect and strengthen the SAPP grid and for the identified basket of generation projects to ensure security of supply in the medium term, with each member State having the option of taking up equity in each regional generation project and an entitlement to power supply;
- Ensuring that the tariffs are cost reflective by getting Governments in SADC to underwrite the tariff gap between projected future tariffs and the long -run marginal cost;
- Allowing open access to the grid for some of the intensive energy users (via the self provision basis where applicable legislation permits) as is required to develop the priority generation projects;
- Providing an appropriate regulatory framework to address the issues of cross-border trade, cost pass-throughs in PPAs and security of supply for a country that is importing its power from a plant in another country and assisting on standardizing PPAs, tariffs and other related items.
- Increasing the scope and mandate of the SAPP to:

  » mobilize capital and ensure the implementation of power projects and the grid interconnection of the SAPP members as necessary, i.e. the main transmission grid cross -border interconnections (transmission projects to be structured as public partnerships using concessionary funding & grant funding); and
  » facilitate the updating and completion of feasibility studies to bankability of an identified basket of generation projects with associated grid connections by mobilizing the risk capital.

- Getting the DFIs and other funders (including the Chinese funding agencies) to commit to an agreed percentage of the total capital required for the SAPP cross -border projects as part of donor/DFI commitments to multi-year funding programmes, based on the above framework. SADC had recommended and requested DBSA to take the lead in mobilization of funding from DFIs.
- Role of promoting countries: While the ideal situation is to get all the SAPP and SADC countries to agree to a project priority pool plan, signed off by the Heads of State and implemented through the proposed funding model, countries are at varying levels of preparedness, and it would be incredibly difficult to arrive at this general agreement in the short to medium term. While the intention remains to invite all countries even though the SAPP was initially formed around a small group of countries, it is anticipated that this structure will grow and evolve gradually, getting more regional projects on-stream in the process. Each member State would have the option of taking equity in each regional generation project and obtaining an entitlement to a defined amount of power.

# Chapter V - Issues and challenges in developing regional energy and water infrastructure

## 5.1 Energy Sector

Africa has abundant energy resources—oil, coal, hydroelectricity, natural gas, biomass and other renewable energy sources. These resources, however, are unevenly distributed and often located far from demand centres. Africa's commercial energy resources are still underdeveloped, and its commercial energy infrastructure—gas pipelines and electricity transmission and distribution networks—is unable to provide reliable and cost-effective services to consumers. The potential for energy exchange across Africa is key to guaranteeing a sufficient, sustainable supply of commercial energy and ensuring efficient use of Africa's energy resources (UNECA, 2003).

Even though the SADC region is well endowed with both renewable and non-renewable energy resources, energy demand still outstrips supply. Underutilized energy resources in the SADC region include solar, wind and hydro power, with some priority projects identified as far back as the 1980s still unimplemented. Currently, the region's electricity generation mix is as follows: thermal 74.3 per cent, hydro 20.1 per cent, nuclear 4 per cent and gas/diesel 1.6 per cent. Country contributions to the generation mix consists of 80.4 per cent South Africa, 5.0 per cent Mozambique, 4.1 per cent Zimbabwe, 3.6 per cent Zambia, 2.6 per cent DRC and 4.4 per cent the rest[16].

### 5.1.1 Southern African Regional Energy Instruments

The principal regional energy document is the SADC Energy Protocol that outlines the region's energy objectives as follows:

i. Harmonization of national and regional energy policies, strategies and programmes on matters of common interest based on equity, balance and mutual benefit;
ii. Cooperation in the development of energy and energy pooling to ensure security and reliability of energy supply and the minimization of costs;
iii. Cooperation in the development and use of energy in the region in the following sub-sectors: wood fuel, petroleum and natural gas, electricity, coal, new and renewable energy sources, energy efficiency and conservation, and other crosscutting themes of interest to member States;
iv. Ensuring the provision of reliable, continued and sustainable energy services in the most efficient and cost-effective manner;

16 Southern Africa Power Pool (SAPP)

v. Promotion of joint development of human resources and organizational capacity building in the energy sector;
vi. Cooperation in the research, development, adaptation, dissemination and transfer of low-cost energy technologies; and
vii. Striving to achieve standardization in appropriate energy development and application, including the use of common methods and other techniques.

Other instruments include the SADC Energy Cooperation Policy and Strategy, SADC Energy Sector Activity Plan, SADC Energy Policy and SADC Energy Access Strategy and Action Plan. These instruments provide a broad framework for the development of the enabling environment for trans-boundary projects to be created. However, most of the SADC Energy Sector Action Plan initiatives have not been implemented due to a wide range of factors, including the reform and transition processes in the region's energy sector. There have been calls by SADC Energy Ministers to review and rationalize these instruments.

The Regional Indicative Strategic Development Plan (RISDP 2008) provided a strategic direction with respect to SADC programmes and activities, and aligned the strategic objectives and priorities of SADC with the policies and strategies for achieving its long-term goals. The RISDP merely outlines the necessary conditions that should be established towards achieving those goals and, hence, making them indicative in nature.

### 5.1.2 Current Southern African Regional Energy Projects

Regional energy projects are either of generation or of transmission in nature. The Southern African Power Pool (SAPP) defines a *generation project* as one that should be able to add reserve margin to the SAPP grid and reduce the diminished surplus capacity of the region. A *transmission project* is defined as one that should be able to interconnect two or more countries and either reduce congestion on the SAPP grid or increase trade between north and south. Some internal country transmission projects are also considered regional when they reduce congestion on the SAPP grid and promote trade between member States, for example the proposed reinforcements of the Zimbabwe transmission networks.

*(i) The Southern Africa Power Pool (SAPP)*

The SAAP was established within the framework of the SADC Energy Protocol. The power pool was created in 1995 and has 12 member States represented by their respective national power companies, with each having equal rights and obligations. The SAPP underlying objectives are: to (i) provide a forum for the development of a world class, robust, safe, efficient, reliable and stable interconnected electrical system in the Southern African subregion; (ii) coordinate and enforce common regional standards of quality of supply; (iii) measure and monitor systems performance; (iv) harmonize relationships between member utilities; (v) facilitate the development of regional expertise through training programmes and research; (vi) increase power accessibility in rural communities; and (vii) implement strategies in support of sustainable development priorities.

*(ii) Challenges faced by the Southern Africa Power Pool (SAPP)*

The predominant challenges in the power utilities include non-cost reflective tariffs (*low and unsustainable*), high technical losses, lack of maintenance of existing infrastructure, managerial weaknesses and illegal electricity connections. These challenges often make it difficult for power utilities to mobilize resources and implement projects, consequently affecting the performance of the power pools. Non-cost reflective tariffs in particular make it difficult to attract Independent Power producers (IPPs). In addition, the SADC Infrastructure Report 2009 notes the following challenges and threats to regional power integration:

- Dilapidated power generation and transmission equipment which is in dire need of rehabilitation and/or replacement;
- Slow pace of implementation of power projects chiefly due to the inadequate project packaging capacity among member States and relevant institutions to match bankable projects with appropriate financing;
- Over -dependence on ESKOM of South Africa to sign Power Purchase Agreements to secure project funding;
- Single buyer model that discourages other creditworthy customers from participating in PPAs; and
- Complex project financing deals driven by lenders.

The growth in power demand, global financial crisis resulting in reduction in FDIs, political instability in resource areas, climate change and member States prioritizing national against regional projects are also some of the threats facing the SAPP.

*(iii) SADC Transmission Projects*

The Energy protocol provides agreements between two or more member States and non-member States, for utilities to develop specific electricity projects and trade. Many of the transmission projects are facing challenges, and progress in their implementation is stalled.

- *Zambia-Tanzania- Kenya Interconnection:* There has been little progress on the project due to coordination challenges and the need to identify the power purchase agreements (PPAs) to drive the project.
- *Mozambique- Malawi Interconnection Project:* The work was expected to start in July 2009; however, the loan facility from the World Bank has since expired.
- *Zimbabwe-Zambia-Botswana-Namibia (ZIZABONA):* The project is reported to be progressing well.
- *Mozambique Backbone project***:** The terms of reference for the Environmental Impact Assessment (EIA) were done and awaiting a no -objection decision from the World Bank.
- *Westcor:* A SADC project conceived through the combined initiative of the SADC secretariat and the power utilities of Angola, Botswana, the

Democratic Republic of Congo (DRC), Namibia and South Africa. The project was aimed at harnessing the large water resources of the Congo River at Inga, to produce and supply electric power to the participating countries, and other countries through the SAPP. The project faced a number of challenges including policy inconsistencies which forestalled the resource mobilization and project implementation. Unfortunately, the project was derailed in 2007-2008 and, currently, is in the process of being dissolved.

### 5.1.3 Developmental challenges of regional power infrastructure

The key regional challenges in the development of the SADC power infrastructure include the following:

- Lack of an enabling environment for other players to participate;
- Differences in policies and legislation in different countries cause delays in concluding Power Purchase Agreements (PPAs) & Wheeling Agreements (WAs);
- Need for government support for PPAs and/or wheeling agreements to underpin investment projects;
- Project Coordination Aspects, including the need for a dedicated Project Coordinator and the need for Project Development Agreements;
- Impact of government internal costs on the cost of the project: fees for EIA report reviews and approvals, VAT duties and taxes; and
- Non-cost reflective tariffs.

### 5.1.4 Achievements and Opportunities

There have been notable achievements towards regional power infrastructure integration in the SADC region in the form of:

- The development of the Pool plan;
- The completion of the Tariff report;
- Legal and institutional frameworks are already in place;
- Diagnostic Statistical Manual (DSM) measures under -implementation; and
- Some utilities moving to cost -reflective tariffs.
- A successful SAPP Roundtable Investment conference held in Livingstone, Zambia, in July 2009, which saw investors pledging financial support to ten presented bankable projects;
- Regulatory oversight strengthened with more national regulators established in member States and harmonization of regional regulatory oversight under the regional body RERA, was implemented comprehensively.

### Box 6: Key Policy Issues for the Energy Sector

- Reviewing and rationalizing of energy instruments is essential for them to be relevant in addressing the current challenges in the sector.
- Rehabilitating and expanding the cross-border transmission infrastructure to increase the potential for trade.
- Harmonizing regulations and system operating agreements to ensure smooth implementation of projects (World Bank, 2009).
- Formulating market trading mechanisms so that additional energy generated from large projects can be priced and allocated efficiently and fairly.
- Need to speed up tariff reforms in member States yet to do so, for viability of utilities.
- Strengthening of institutional reforms for improvement of utilities performance.

## 5.2 Water Sector

The stock of hydraulic infrastructure in SADC countries vary greatly in comparison with the rest of the world. Africa's water resources are greatly under-utilized - only 3 percent of its renewable water is withdrawn annually for domestic, agricultural and industrial use. About 40 percent of the population has inadequate access to water and sanitation, only 6 percent of Africa's cultivated land is irrigated and less than 5 percent of its hydropower potential is developed.

In the SADC region, South Africa has the largest share of existing hydraulic infrastructure development due to its strong and diversified economy.

### 5.2.1 SADC Water Instruments

The Regional Strategy Action Plan 1 (RSAP-1) developed in 1998 focused on creating an enabling environment for executing hard infrastructure projects. RSAP-1 saw the development of the SADC Protocol on Shared Watercourses and subsequently the SADC Water Policy and Strategy for providing policy direction. The action plan was revised in 2004 to become RSAP-2 aimed at providing leadership and water resources development and management, including infrastructure development at both member States and regional levels (*SADC Infrastructure Development Status Report 2009*).

The Regional Water Infrastructure Programme under RSAP-2 comprises capacity building, project preparation and implementation components. It also covers the regional water infrastructure projects aimed at providing water for irrigation to increase food production and ensure food security; energy security; water supply and sanitation; and the mitigation of the impacts of climate-related extreme events, i.e. floods and droughts.

### 5.2.2 Southern Africa Regional Water Projects

The main factors influencing regional cooperation on International Watercourses are the following (see 3.2 above):

(a) Type of good, i.e. its subtractability – for example, the expected gains from agreement may be greater with non-renewable resources where degradation is irreversible than with renewable resources where regeneration may be possible;

(b) Number of "players" (riparian States) – in general, the larger the number of players, the more difficult it is to achieve cooperation outcomes, holding other things constant;

(c) Heterogeneity or homogeneity of riparian States in terms of:

i. capabilities (relative power – including economic, political and geographic, as well as bargaining strength of the riparian State);
ii. preferences or interests (valuation, in terms of costs and benefits of potential strategies and outcomes); and
iii. beliefs or information.

The factors under (c) above affect the costs of transacting and the ability to communicate and make credible commitments. Changes in any of these variables, therefore, may alter the incentives of players to cooperate.

*The River Basin Organizations (RBOs)*

The RBOs are provided for under article 2(a), Article 5, 1(b) and 3 of the SADC 2000 Protocol on Shared Watercourses. The main functions of RBOs (SADC Infrastructure Report, 2009) are:

- To facilitate coordinated, judicious and sustainable utilization of shared water courses;
- Act as advisory bodies and joint programme implementation agencies on behalf of member States;
- To develop joint Strategic Action programmes and projects for implementation along shared water courses; and
- To offer a platform for discussions, information sharing and conflict prevention at river basin level.

Out of the fifteen trans-boundary surface water sources identified in the SADC region, six have so far been successfully transformed into RBOs through SADC secretariat facilitation. The continuing institutional reforms of the RBOs have facilitated the provision of structure to manage the river basins, including the implementation of economic gain. However, the process is being held back by the delay in signature, ratification and accession to the instruments.

## Zambezi River basin

The Zambezi River is the largest of the more than fifteen shared watercourses in Southern Africa. Although SADC adopted an Action Plan for the Zambezi River Basin (ZACPLAN), with nineteen (19) projects, that dates back to 1987, the formation of a basin-wide regulatory institution to enhance cooperation and coordinate development activities within the basin has eluded the region. Zambia withdrew from negotiations of the Zambezi Watercourse Commission (ZAMCOM) Agreement in 1998 out of fear of entering into an agreement that did not include water allocation to parties. The seven other riparian countries endorsed the agreement in Kasane, Botswana in July 2004. Five countries have ratified paving way for the establishment of a ZAMCOM interim secretariat (IS) on 6 May 2011, with financial support from the Norwegian Government. Ratification instrument from a sixth country is still required for the establishment of a permanent secretariat.

An Integrated Water Resources Management (IWRM) Bill was presented in Zambia Parliament in October 2010 and the SADC Portal indicates that Zambia has promised to sign the Agreement.

*Priority Strategic Water projects*

These projects are implemented within a short time frame (3-5) years and require relatively less capital investment[17]. The top ranked projects within this package include the rehabilitation of the Nordoewer Irrigation Scheme on the Orange River (a joint project of Namibia and Republic of South Africa), construction of Movene Dam in Mozambique and construction of 29 medium and small dams in Zambia (SADC Infrastructure Report, 2009).

*Large Hydraulic Infrastructure Projects*

These are strategic projects which are too large, highly complex and costly to implement in one phase. Such projects include programmes with a broad geographical focus within member countries, a number of individual projects at different localities, and contain components not necessarily at infrastructure construction stages, e.g. feasibility studies and management.

*Integrated Water Resources Management (IWRM) Demonstration Projects*

These are designed to promote awareness of the importance of IWRM which is crucial in construction and operation of hydraulic infrastructure projects. They include small projects such as the establishment and rehabilitation of small irrigation as well as water supply and sanitation schemes, and catchment management projects. The IWRM demonstration projects are targeted at poor communities, and already five (5) such projects have been implemented in Kafue basin in Zambia, Lavumisa irrigation scheme in Swaziland, Dzimphutsi area in Malawi, Lower Limpopo catchment in Mozambique and Omaruru-Lower Swakop Basin in Namibia.

17 less than $US10 million

### 5.2.3 Challenges facing the SADC Water Sector

Some of the challenges confronting the development of regional water infrastructure include the following (SADC Infrastructure Report, 2009):

- The existing disparities between available water infrastructure and potential for development;
- Capacity to develop, implement, operate and maintain infrastructure systems;
- Inadequately prepared (studied) projects in terms of bankability and project technical details;
- Funding for both project development and implementation; and
- The need to balance the development drive with adequate environmental, social and economic benefits.

Current and impending threats to regional water infrastructure development also include:

- Delays in concluding some of the agreements governing shared water courses;
- Unwillingness of countries to cooperate on joint infrastructure projects;
- Reduction in political will and support;
- High hydro-climatic variability;
- Increasing demand;
- Inadequate storage;
- Lack of trans-boundary cooperation among riparian countries; and
- Global financial crisis.

### 5.2.4 Achievements and opportunities

In a recent assessment of achievements and opportunities in the subregion the Ministers responsible for water noted that there had been progress in the implementation of the regional action plan that seeks to improve the management of water resources.[18] Achievements had been made in the preparation of regional water policy with assistance from ICPs. The SADC ministers also noted progress in the development of strategic water infrastructure, regional water supply and sanitation programme and in supporting the establishment and strengthening of RBOs.

Some of the achievements as well as opportunities in the regional water infrastructure integration in Southern Africa included the initiation of Kunene trans-boundary water supply and sanitation and the conclusion of community based high impact poverty alleviation small infrastructure projects as well as the documentation of lessons learnt. The large projects have progressed to design and construction while the institutional capacity of trans-boundary water management institutions was being strengthened.

18 Southern Africa Today Volume 12, (June 2010).

### Box 7: Key Policy Challenges for the Water Sector

- Need for a strategy that provides a long -term perspective for the development and management of the region's water resources as well as give strategic direction to short-term interventions.
- Lack of meaningful investment in research and technology development for the region's infrastructural projects (RISDP, 2008).

# Chapter VI - General conclusions

The Report documents several useful concepts, principles and guidelines for project appraisal, and thus brings into focus a wide spectrum of cost-benefit analysis methodologies. These principles are perfectly general and applicable to both public and private investment projects. The utility of this effort is consistent with the objective of applying the same standards and methods of evaluation in all the countries of the subregion so as to have comparable results.

The treatment of the traditional cost-benefit analysis methodology in Chapter II emphasizes that the evaluation procedure should consist of measuring direct costs and benefits and take into account secondary benefits and costs. Traditional cost-benefit analysis addresses the following question: whether the project under consideration results in a net benefit to the economy or not? This is an important question as no one wants to invest in projects that impede overall economic development. However, the answer to this question says nothing about whether the project internalized potential externalities, particularly with respect to projects on trans-boundary water resources systems. Furthermore, the traditional approach may often fail to address other fundamental questions of concern to policymakers and donors today.

The CBA methodology is very useful in informing decision-makers as it spells out the social, economic and environmental impacts of a project. However, the accuracy of CBA results depends on the availability of relevant and up -to -date information as well as an independent and honest environment that is crucial for project evaluators to bring about the best possible analysis. Political commitment is, a key factor to regional infrastructure development. The extent to which the countries are committed to the projects is directly influenced by the level at which projects are endorsed. It is recommended that regional projects be endorsed at Heads of State level rather than at ministerial level as is the case at present.

There is need to speed up the establishment of a SADC project preparation unit with the requisite capacity to prepare bankable infrastructure projects and to mobilize capital for project implementation. Leading countries in implementing regional infrastructure projects need to set up Special Purpose Vehicles in order to secure partial risk guarantees. National plans and budgets should incorporate regional infrastructure projects and resource mobilization should be consistent with the financial strategies of Governments. Funding of infrastructure projects will require coordination and harmonization between traditional and non-traditional development partners to optimize funding.

Appropriate governance structures need to be established for each regional infrastructure project. Member States should clearly define the objectives and beneficiaries of the projects. Furthermore, member States need to identify and address skill gaps. Countries that share trans-boundary river basins should forge cooperation in order to harness the benefits of investment projects within entire river systems.

Chapter III on joint water resources infrastructure project appraisals highlights the need for all evaluation procedures to be revised to apply to multiple-purpose basin programmes and to individual projects constituting the constituent parts of such basin programmes. In this case, the optimum scale of development, as indicated by economic analysis, can only be established by arriving at the proper relationship not only of phases within a project, but also among a number of projects considered as incremental parts of a comprehensive programme. In essence, the use of the concepts, principles and guidelines would assist decision makers on whether a project should be undertaken, when the project should be built, and how. Furthermore, countries of the subregion could benefit greatly from cooperation when they share common resources such as trans-boundary waters and hydroelectric power. In the presence of trans-boundary externalities, market solutions are generally sub-optimal and failure to cooperate can be very costly.

Recognition of the need for consistent evaluation practices led to the choice in the ECA-SADC Multi-Year Programme of work to undertake the analytical study, to enable all countries and agencies that have responsibility for water and power developments in the subregion to employ uniform standards and methods of evaluation. With the role of economic analysis recognized and the use of sound economic principles brought into project formulation, many issues would be addressed. If, for example, economic analysis is brought into play to achieve the optimum balance between purposes that are served by multiple-purpose undertakings, then many of the problems of joint cost allocation can be resolved equitably and understandably on the basis of relative net benefits accruing to each purpose. This assumes that uniform basic standards of measuring values would be employed throughout project formulation, in the allocation of joint costs and in establishing prices or other levies on the consumers of the project.

Chapter IV on exploiting economy of scale in the SADC power sector makes the case for rehabilitating and expanding cross-border transmission infrastructure to increase the potential for trade and harmonize regulations and system operating agreements. Market trading mechanisms need to be formulated so that the additional energy generated from large projects can be correctly priced and thus allocated efficiently and fairly. There is also need to speed up tariff reforms in member States to ensure viability of utilities. The Chapter also provides a case study on the WESTCOR project that failed due to non-respect of the principles of equitable allocation of costs and benefits in cooperation agreements between member States.

The need to develop a strategy that provides a long -term perspective for the development and management of the region's water and energy resources as well as to give strategic direction to short -term interventions is highlighted in Chapter V on issues and challenges.  In addition, desperate need for meaningful investment in research and technology development for infrastructural projects in the subregion is emphasized. The chapter also discusses the need for developing effective policies, financing mechanisms and institutions for harnessing the benefits of regional infrastructure. The financial challenges in regional infrastructure development derive from lack of a coherent policy framework for infrastructure development as well as financing socially desirable but non-bankable projects. The high transaction costs due to inadequate infrastructure and lack of adequate funding also add to the list. The financial viability of existing utilities is a key foundation of healthy power and water sectors.

The chapter makes a distinction between issues arising from the CBA in its application to projects, and those arising from political actions of Governments at the centre of which is the importance of political commitments. The need for increased private sector participation in the provision of infrastructure in the SADC subregion was also stressed. Financing mechanisms in regional infrastructure have mainly been in the form of Public–Private Partnerships (PPPs), domestic and capital markets, private equity and venture capital, the SADC Development Fund and donor support. Other possible ways of raising finance include:

- Use of Pension funds;
- Issuing of infrastructure indexed bonds;
- Use of the Global Financial Markets;
- Special Government credits to private investors in infrastructure development;
- Establishing regional infrastructure banks;
- Member States dedicating a fixed percentage of their GDP to infrastructure development; and
- Levying special taxes to support infrastructure development.

These issues call for member States to continue to be major players in the financing, development and delivery of infrastructure services. Other specific mechanisms recommended for enhancing infrastructure development in the subregion include the following:

i. Governments to set up an African Investment Guarantee Agency to provide risk-mitigation instruments (including guarantees and political risk insurance);
ii. Strengthening of capital markets in member States to support the participation of the private sector in the development of infrastructure;
iii. Debt clearing strategies to be put in place to help improve Governments' creditworthiness, crucial in facilitating access to global and domestic capital markets, as well as to bring in private equity investments to a range of public-private partnerships;
iv. Institutional reforms should be pursued in order to provide transparency, good corporate governance, good regulatory framework and the appropriate enabling environment to help private and public enterprises to thrive;
v. Strong institutional framework for protecting creditors' rights, effective covenants and sound legal systems for substantial investments in infrastructure to be implemented;
vi. Stable macro-economic policies for infrastructure investment promotion.

Finally, it is hoped that the report would be widely disseminated and the tools contained therein widely accepted and applied.

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# Annexes

## Annex A: Basic Structure of Project Appraisal[19]

### Step 1: Project Objectives

### Definition of project in the socio-economic context

There is need for a clear statement defining the project's objectives in order to understand the net benefits to be achieved. The benefits of the project to be considered are both physical indicators as well as socio-economic variables that are quantitatively measurable.

### Step II: Project Identification

The boundaries of the analysis should be properly defined. The project has a direct impact on users, workers, investors, suppliers, etc. but also indirect impacts on third parties. The risk of double counting project benefits should be carefully considered. In general, indirect impacts in secondary markets should not be included in the economic appraisal, whenever an appropriate shadow price has been given for the benefits and costs.

### Step III: Feasibility and Option Analysis

A standard feasibility study provides information regarding the institutional context, availability of appropriate technology, demand forecasts, organization and management, location, human resources, financial capacity of the private company and all other aspects potentially influencing the success or failure of the project.

Option Identification**:** involves identifying the range of options that can ensure the achievement of the objectives of the project, e.g. energy efficiency improvements rather than (or in addition to) the construction of new power plants.

### Step IV: Financial Analysis

This should be based on the discounted cash flow approach. *The EC suggests a benchmark real financial discount rate of 5 per cent.* Financial analysis involves determination of cash inflows and outflows related to:

- Total investment costs;
- Total operating costs and revenues, i.e. estimation of how large the total investment cost will be;
- Financial return on the investment costs: FNPV(C) and FRR(C);

19 European Commission (2008): GUIDE TO COST -BENEFIT ANALYSIS OF INVESTMENT PROJECTS – Structural Funds, Cohesion Funds and Instrument Pre-Accession, EU Regional Policy

- Sources of finance;
- Financial sustainability; and
- Financial return on national capital: FNPV(K) and FRR(K).

It is imperative that time horizon of the project must be consistent with the economic life of the main assets and the appropriate residual value must be included in the accounts in the final year. General inflation and relative price changes must be treated in a consistent way. In principle, FRR(C) can be very low or negative for public sector projects, but FRR(K) for private investors or PPPs should normally be positive.

The main purpose of the financial analysis is to use the project cash flow forecasts to calculate suitable net return indicators. The commonly used being the Financial Net Present Value (FNPV) and the Financial Internal Rate of Return (FRR), respectively in terms of return on the investment cost, FNPV(C) and FRR(C), and return on national capital, FNPV(K) and FRR(K).

## Step V: Economic Analysis

CBA requires an investigation of a project's net impact on economic welfare. This is done in five steps:

i. Observed prices or public tariffs are converted into shadow prices, that better reflect the social opportunity cost of the good;
ii. Externalities are taken into account and given a monetary value;
iii. Indirect effects are included if relevant (i.e. when not already captured by shadow prices);
iv. Costs and benefits are discounted with a real social discount rate[20];
v. Calculation of economic performance indicators: economic net present value (ENPV), economic rate of return (ERR) and the benefit-cost (B/C) ratio.

## Step VI: Risk Assessment

A project appraisal document must include an assessment of the project risks. Again, five steps are suggested:

i. Sensitivity analysis (identification of critical variables, elimination of deterministically dependent variables, elasticity analysis, choice of critical variables, scenario analysis);
ii. Assumption of a probability distribution for each critical variable;
iii. Calculation of the distribution of the performance indicators (typically FNPV and ENPV);
iv. Discussion of results and acceptable levels of risk;
v. Discussion of ways to mitigate risks.

20 EU suggested SDR benchmark values: 5.5 per cent for Cohesion and IPA countries, and for convergence regions elsewhere with high growth outlook; 3.5 per cent for Competitiveness regions

# Annex B: Formula Table

## Summary of the main analytical items for Cost-benefit analysis

| | Definition | Value/Formula |
|---|---|---|
| Social Discount Rate | The rate at which future values in the economic analysis are discounted to the present. It reflects the social view on how net future benefits should be valued against present ones. | May be determined using any of the following:<br>• Use the real financial rate of return, supposing that the marginal public investment should have the same return as the private one<br>• Use a formula based on the long -term growth rate of the economy;<br>• Use a standard conventional cut-off rate (World Bank and European Bank for Research and Development use a quite high real required rate of return of 10%). |
| Welfare weight | Weight for adjusting the project net benefits in order to include distributive effects in the analysis. | W=(C/Ci) |
| Standard Conversion Factor see note 2 | General factor for adjusting market prices to accounting (shadow) prices | SCF = (M + X) / [(M + Tm) + (X - Tx)] |
| Shadow Exchange Rate see note3 | The economic price of foreign currency which may diverge from the official exchange rate. | SER = Σ [OERt * (CIt / COt)] / n |
| Marginal Cost of Public Funds | The ratio between the shadow price of tax revenues and the population average of the social marginal utility of income | Country-based values, dependent on taxation system |
| Shadow prices | Prices to be used in the economic analysis, reflecting inputs opportunity costs and/or consumers' willingnesstopay for outputs. | |
| Traded items | The shadow prices are the international or border prices | CIF for imports and FOB for exports |
| Non-traded minor items | The national Standard Conversion Factor should be used to correct their prices | SCF = (M + X) / [(M + Tm) + (X - Tx)] |
| Non-traded major items see note 4 | Sector-specific conversion factors should be used to correct their prices | SCFi= WTP/p or MC/p |

| | Definition | Value/Formula |
|---|---|---|
| Shadow wage see note 5 | The opportunitycost of labour. The value depends on the different types of unemployment:<br>(1) Full employment<br>(2) mild unemployment<br>(3) dualistic labour market<br>(4) strong involuntary unemployment | (1) SWR = W<br>(2) SWR = mc + zd<br>(3) SWR = n(Δu/ΔL) + zd<br>(4) SWR = W(1-u)(1-t) |
| Performance Indicators see note 6 | | |
| Economic net present value | The difference between the discounted total social benefits and costs. | $\sum_{t=0}^{n} a_t S_t$ |
| Economic rate of return | The discount rate that zeros out the ENPV. It is compared with a benchmark in order to evaluate the project performance | 0=∑St/(1+ERR)t |
| Benefit-cost ratio | The ratio of the present value of social benefits to the present value of social costs over the time horizon. | B/C= PV(B)/PV(C) |

***Source:*** Adapted from the EU- CBA for Investment Analysis Economic Commission

i. Welfare weight: C: average consumption level; Ci: per capita consumption; e: constant elasticity of marginal utility of income.
ii. Standard Conversion Factor: M: Total imports; X: Total exports; Tm: import taxes; Tx: export taxes
iii. Shadow Exchange Rate: OER: official exchange rate; CI: currency inflow; CO: currency outflow; n: number of years; t: time
iv. Shadow Prices: MC: marginal cost; WTP: willingness-to-pay; p: price
v. Shadow wage: W: market wage; L: labour; c: conversion factor; d: conversion factor; m: lost annual output of hiring a new employee; n: reservation wage; t: rate of social security payments and relevant taxes; u: unemployment rate; z: additional cost of transferring workers (relocation)
vi. Performance indicators: PV: present value; St: balance of cash flow funds; at: discount factor; i: discount rate

# Annex C: Recommendations from the AEGM in Lilongwe

The following are recommendations which came from group discussions at the AEGM in Lilongwe, in March 2010.

**Political commitment:** Countries should demonstrate their commitment to regional projects through all stages of implementation.

**Institutional framework:** The COMESA/SADC needs to enhance its economic initiatives in infrastructure development. They should speed up the establishment of the SADC project preparation unit with the requisite capacity to prepare bankable infrastructure projects, mobilize capital and implement projects.

**Financing:** Joint project resource mobilization, coordination and harmonization between traditional development partners should be in place for optimization; National plans/budgets should incorporate regional infrastructure projects (resource mobilization should be consistent with the financing strategies of Governments).

The member States are urged to intensify efforts to implement cost -reflective tariffs.

**Gender mainstreaming:** Member States are urged to mainstream gender in infrastructure decision -making; Member States are urged to develop appropriate indicators to measure gender mainstreaming in the infrastructure development.

**Water sector–specific recommendations** (a) SADC regional water infrastructure projects should be designed with a multi-purpose focus that ensures collateral use across various economic sectors; (b) Countries that share a trans-boundary river basin should seek opportunities to cooperate on all water projects in order to harness the potential of downstream benefits from upstream investment projects and vice versa.

**Power sector-specific recommendations** (a) SADC needs a regional master plan which is informed by member States specific needs; (b) The wide disparity in power sector infrastructure cost estimate needs to be resolved and (c) Power infrastructure should include renewable energy technologies in the energy mix.

**Methodology for Cost - Benefit Analysis:**- (a) The design of CBA methodology should permit each member State to gain an understanding of their individual costs and benefits arising from  a regional infrastructure investment; (b) Costs and benefits must target the interests (i.e. social, economic and environmental interests) of all stakeholders in a decision -making tree(e.g. national Governments, financial backers, regional groupings; (c) Member States are urged to allocate adequate resources to ensure reliable data.

# Annex D

## Mathematical Concepts of Cost and Benefit Sharing Problems

***(i) Cost-benefit analysis (CBA)***

The economic feasibility of an investment in a multipurpose water project can be written as:

$$\mathrm{PVNB} \quad = \sum_{t} [\sum_{i} (\mathrm{B}_{it}) / (1 + \mathrm{r})^{t}] - \sum_{t} [(\mathrm{C}_{t}) / (1 + r)^{t}] - \sum_{t} [(\mathrm{D}_{jt}) / \ (1 + r)^{t}]$$

where:

PVNB = Present Value of Net Benefits;

$B_{it}$ represents Incremental Benefit (willingness to pay) for incremental water use or availability in sector *i* in year *t*;

$C_t$ is capital and operating costs in year *t*;

$D_{jt}$ represents incremental project-induced dis-benefit (foregone benefits or external costs) to sector j in year t; and

r is the discount (interest) rate

The PPI (Potential Pareto Improvement) hypothesis to be tested is:

Is PVBN > 0?

The PPI test can be also expressed in the largely equivalent forms of Benefit-Cost Ratios or Internal Rate of Return. In implementing this test, economic valuation will be required for the terms $B_{it}$ and $D_{jt}$.

Another likely welfare improvement opportunity is for reallocating water among use sectors. The analytic question is: can a reallocation from sector *i* to sector j yield incremental gains to sector j in excess of the foregone benefits in sector *i*? The hypothesis (for a Potential Pareto Improvement) to be tested is:

Is: $\sum_{t} MB_{i} /(1+r)^{t} \neq \sum_{t} MB_{j} /(1+r)^{j}$ ?

(for if they were equal, no gains from reallocation would be possible). MB is the marginal benefit.

In the case of a proposal to reallocate water from agriculture to municipal uses, with expected indirect impact on hydropower, for example, the PPI test can be expressed by developing measurements for two conditions. The first condition is that the benefits (both direct and indirect) to the municipal sector exceed the sum of: (foregone direct benefits to the selling sector plus foregone indirect benefits to the selling sector plus foregone indirect benefits to the hydropower sector:

(1)

$$DB + IB > FDB + FIB + TC + CC$$

Where:

DB: Direct Economic Benefit (Value) to receiving sector

IB: Economic Benefit to Indirectly affected sector(s)

FDB: Foregone Direct Benefit (value foregone) in source sector

FIB: Foregone Benefit in Indirectly affected sector(s)

TC: Transactions costs (for information, contracting and enforcement)

CC: Conveyance and Storage Costs

A further condition is that the Direct Foregone Benefits in irrigated agriculture be the least-cost source of water for the purchasing sector:

(2)

$$FDB + FIB + TC + CC < AC$$

In other words, condition 2 asserts that the sum of direct and indirect foregone economic benefits and the transactions and conveyance costs should be less than the cost of the next best alternative water source.

The degree of certainty with which supplies are available, in addition to its quantity and quality, is another important factor influencing the willingness to pay for water. In the case of municipal water supply, for example, system reliability is defined in terms of probability (P) of occurrence of the SASE ("Standard Annual Shortage Event" defined as drought of sufficient severity and duration that certain specified restrictions on water use would be put in place).

$$R(SASE) \equiv 1 - P(SASE)$$

Next, a *loss function* L(SASE), is introduced representing the reduction in economic value accruing if the SASE were to occur. The desired economic measure, the *marginal benefit of improved reliability* is given by the incremental reduction in expected losses.

The *with and without* principle holds that policy appraisal should contrast the "state of the world" as it would be with the policy to the "state of the world" as it would be without the policy. Implication of the principle is that project evaluation is not adequately accomplished by comparing conditions before the project with conditions after its implementation. Many changes in the world from "before" to "after" would have occurred without the project, so such effects should not be credited or charged to the project.

The *accounting stance* is the defined geographical area or political subdivision within which benefits, costs or other impacts are counted in a CBA. A project may have impacts that are confined to a local area, or they may extend to the nation or even internationally. For example, an irrigation project might generate benefits in a local area. The conventional direct costs of construction and operating would normally be met by water users (or taxpayers) in the project area. Other costs, particularly indirect or external costs, such as foregone electric power generation or lower water quality imposed on downstream water users, will accrue well beyond the borders of the area benefited, but need to be accounted for in a full economic evaluation. Indirect benefits outside the project region can also occur. For example, interception of flood waters by irrigation or power reservoirs may yield benefits far downstream.

Because policy decisions relating to water entail a range of cases, from major long-lived capital investments to one-off allocations in the face of intermediate events such as droughts, it is often important to distinguish carefully between long -run and short -run values. The distinction relates to the degree of fixity of certain inputs, and is particularly important for cases in which water is a producers' or intermediate good, such as in irrigation, industry and hydropower.

***(ii) Criteria for gauging effectiveness***

An assessment of development effectiveness cannot be undertaken without first delineating the criteria to be used in judging effectiveness. As demonstrated by the case study of the GCD and CBP, applicable criteria can be categorized into economic efficiency, income distribution, regional economic development and environmental quality.

Economic efficiency refers to the condition in which the difference between the present value of economic benefits of a project and the present value of economic costs are as large as possible. Although economists have several conceptions of economic efficiency, the maximization of net benefits is the one commonly used in the US water resources planning. A national accounting stance is adopted and benefits and costs are counted without regard to who would obtain the benefits and who would shoulder the costs.

Regional development refers to the objective of fostering growth in particular areas. In the case of GCD and CBP, the vision for regional development was to have the project area populated by a large number of individual farm families living in an economically productive region that had agriculture as its economic base.

Equity refers to the fair distribution of a project's positive and negative effects among stakeholders. One dimension of equity concerns how the project changes the distribution of income. Another dimension concerns the distribution of environmental benefits and costs.

Environmental quality includes a project's effects on the biological and physical environment as well as effects on social conditions and cultural resources.

While it is possible to conceive of additional objectives of water resources development projects, such as ensuring national food security, the four categories of factors defined above are considered appropriate for characterizing development effectiveness in the case of GCD and CBP.

### *(iii) Cost and Benefit Sharing Methods for Multiple-Purpose Water Projects*

Joint cost allocation problem makes use of concepts from the theory of cooperative games. The most widely used concepts include: (i) the Shapley value; (ii) the nucleolus; (iii) variants of the nucleolus; and (iv) the core and variants of the core.

Several allocation methods most commonly considered in water resources projects are based on separable and non-separable costs. Chief among these methods is the so-called separable costs, remaining benefits (SCRB) method which is the most widely used method in multi-purpose water development projects (Driessen, T.S.H, *et al.* 1984). Heaney and Dickinson (1982) proposed the minimum costs, remaining savings (MCRS) method which can be viewed as a generalization of the SCRB-method. Both methods can be described with the aid of lower and upper bounds for the core of the involved cost game, but for the MCRS-method those bounds are as sharp as possible.

### *(iv) The Game Theoretical Approach to the Cost and Benefit Sharing Problem*

Whenever individuals, cities, firms and other institutions decide to undertake a joint project, there arises the problem of apportioning the total project costs among the project participants in a fair manner. An analysis of this joint cost allocation problem can be carried out using game theory since the joint cost allocation problem can be modelled as a cooperative cost game by taking into account the strategic aspects of the problem.

A cooperative N-person cost game (in characteristic function form) consists of a finite set N of players along with a characteristic cost function c. The cost function c assigns to any subset S of players the real number c(S) which represents the least costs of a project, simply and solely undertaken by the members of S in order to fulfill their own purposes. In particular, $c(\emptyset) = 0$ where $\emptyset$ is the empty set. The cost function c so defined must be sub-additive, i.e.

$$c(S) + c(T) \geq c(S \cup T) \quad \forall\ S, T \subseteq N\ with\ S \cap T = \Phi \tag{1}$$

since the ways of serving the purposes of S together with T, which does not overlap S, include the possibility of serving S alone and T alone.

Nonempty subsets S of the players set N are called coalitions. It is usual to index the players by the numbers 1, 2,…..and n if there are n players.

If the potential players in N decide to undertake a joint project, then the cost allocation problem consists of allocating the joint costs c(N) among the players in a fair manner. The cost allocated to player $i \in$ N is denoted by $y_i$. Because it is required that the principle of efficiency be met, a cost allocation y is defined to be a vector

$= (y_1, y_2, \dots y_n) \in R^n$ such that

$$\sum_{j=1}^{n} y_j = c(N) \quad \text{and} \quad y_j \geq 0 \quad \forall\ j \in N \tag{2}$$

i.e. problem is to choose a unique cost allocation in a fair manner. It is also reasonable to require that the principle of individual rationality be met, which states that the cost allocated to any player is less than or equal to the cost of acting independently, i.e.

$$y_j \leq c(\{j\}) \quad \forall\ j \in N \tag{3}$$

There exist always individually rational cost allocations for cost game (N; c) since

$$c(N) \leq \sum_{i=1}^{n} c(\{i\})$$

by the subadditivity condition (1) for c.

A third principle is the principle of group rationality which states that the total cost allocated to the members of a coalition S is not more than the alternate cost of S in the cost game, i.e.

$$\sum_{j \in S} y_j \leq c(S) \quad \forall\ \Phi \neq S \subset N. \tag{4}$$

those cost allocations y that satisfy (4) are called stable in the cost game (N; c). The core CORE (c) of a cost game (N; c) is defined to be the set of all stable cost allocations in the cost game and hence, the core represents those cost allocations that cannot be improved upon by any coalition. However, for some cost games the core may be empty. Any stable cost allocation is individually rational since a coalition may consist of a single player.

The principles of individual and group rationality were already required by *Ransmeier* (1942) in his first "preliminary criterion of a satisfactory allocation" in his presentation of the cost allocation problem concerning the Tennessee Valley Authority (TVA) project during the 1930s. So, the work of *Ransmeier* (1942) foreshadowed the idea of the core of a cooperative game introduced and named explicitly in game theory by *Gillies* (1953). *Ransmeier* did not notice that the core of a cost game may be empty. This might be because the TVA cost games were always convex, i.e.

$$c(S) + c(T) \geq c(S \cup T) + c(S \cap T) \quad \forall\ S,T \subset N \tag{5}$$

Convex cost games possess many nice properties, e.g. the core has a very regular structure (Shapley, 1971) and in fact is always large (Sharkey, 1982). *Straffin* and *Heaney* (1981) drew attention to the fact that independently developed ideas by the TVA during the 1930s are related to certain game theoretical concepts, such as the core and the nucleolus (*Schmeidler*, 1969). Some of those ideas by the TVA are also related to another game theoretical concept, the $\tau$-value (*Tijs*, 1981).

### *(v) Cost and Benefit Sharing Methods Based on Separable and Non-Separable Costs: The ENSC-, SCRB- and NSCG-Methods*

Another principle, which is often required on the evaluation of water resource projects, states that the cost allocated to any player is not less than the marginal cost of including him in the project. Thus, the separable cost of player *i* in a cost game (N; c) can be defined by

$$SC_i(c) := c(N) - c(N - \{i\}) \tag{6}$$

Given that any player has been allocated his separable cost, there remains the problem of how to allocate the remaining costs in the game. Those remaining costs are called the non-separable cost and are given by

$$\text{NSC (c)} := c(N) - \sum_{j=1}^{n} \text{SCj(c)} \tag{7}$$

In general, the allocation of the non-separable cost among the players can be based on the ratio of suitable chosen real numbers $\beta_i(c)$, $i = 1,2,\ldots$ n. which may depend on the cost game involved.

The easiest way is to choose $\beta_i(c) = 1$ for all $i \in N$, so independently of the cost game. Then the non-separable cost is proportioned equally and hence, this method is called the egalitarian non-separable cost (ENSC) method. The cost allocated to player *i* by this method is given by

$$\mathrm{ENSCi}\ (c) = SCi\ (c) + n^{-1} NSC\ (c) \tag{8}$$

A major problem with this allocation method is that it may even fail to meet the individual rationality principle.

The separable costs remaining benefits (SCRB) method is obtained by choosing $\beta_i(c) = \min[b_i(c), c(\{i\})] - SC_i(c)$ for all $i \in N$ where $b_i(c)$ represents the benefit to player *i* in the game (N; c) by acting independently. By the SCRB-method, the non-separable cost is allocated in proportion to each player's willingness to pay minus the separable cost already allocated.

However, player *i* is not willing to pay more than his benefit $b_i(c)$ or his alternate cost $c(\{i\})$ in order to participate in the joint project. If the benefit of any player exceeds his alternate cost, then $\beta_i(c) = c(\{i\}) - SC_i(c)$ for all $i \in N$.

The alternate cost avoided (ACA-method) was first proposed by a TVA consultant in 1938. Since the benefits usually exceed the alternate costs, the cost allocated to player *i* by the SCRB-method is usually given by

$$SCRB_i(c) = SC_i(c) + [c(\{i\}) - SC_i\ (c)][\sum_{j=1}^{n} (c(\{j\}) - SCj\ (c))]^{-1}\ NSC\ (c). \tag{9}$$

In case NSC (c) ≥ 0, the subadditivity of c and (9) imply that

$$SC_i\ (c) \le SCRB_i\ (c) \le c(\{i\}) \qquad \text{for all } i \in N.$$

So, (3) is satisfied and hence, the SCRB-method is then individually rational, but in general not stable.

Given that any player has been allocated his separable cost, the allocation of the remaining non-separable cost by the SCRB-method is mainly based on the remaining alternate costs of the one-person coalitions. However, the remaining alternate costs of other coalitions should also be taken into account in the allocation of the non-separable cost. Thus, for any cost game (N; c), its cost gap function $g^c$ which assigns to any coalition S the remaining alternate cost of S is given by

$$g^c(S) := c(S) - \sum_{j\in S} SCj\ (c) \qquad (10)$$

The figure $g^c$ (S) is called the cost gap of coalition S in the game (N; c). The cost gap of the grand coalition is equal to the non-separable cost, i.e. by (7) and (10)

$$g^c(N) = NSC\ (c).$$

Further, let $g^c(\emptyset) = 0$. In general, considering only cost games for which the cost gap function is non-negative, and assuming that

$$g^c(S) \geq 0 \quad \forall \quad S \subset N \qquad (11)$$

In order to describe the non-separable cost gap (NSCG) method, which is derived from the game theoretical concept of the τ-value [*Tijs*, 1981], consider a cost game (N; c) with a non-negative cost gap function $g^c$ and a player $i \in$ N. Let T be a coalition to which player *i* belongs. The player *i* will reject any cost allocation that charges to him an amount that is more than the figure $SC_i(c) + g^c(T)$. The motive of player *i* for this rejection is as follows:

Player *i* can threaten to try to form the coalition T and to allocate the alternate cost c(T) among its members in such a way that all members of T, except *i*, are charged only their separable costs, while player *i* himself is charged the remaining cost which equals

$$c(T) - \textstyle\sum_{j\in T-\{i\}} SCj\ (c) \quad \text{or equivalently} \quad SC_i(c) + g^c(T).$$

This motive of player *i* applies to any coalition T which contains player *i* and hence, player *i* is not willing to pay more than the amount

$$\min_{T;i\in T}[SC_i(c) + g^c(T)] \quad \textit{or equivalently} \quad SC_i(c) + \min_{T;i\in T} g^c(T).$$

In view of the above reasoning, the concession amount of player *i* in a cost game (N; c) may be defined by

$$\lambda_i(c) := \min_{T;i\in T} g^c(T). \qquad (12)$$

The concession amount $\lambda_i\ \lambda_i$ (c) of player *i* is seen as his maximal contribution to the non-separable cost NSC(c). Assuming also that the total of these maximal contributions is at least the non-separable cost, so

$$\sum_{j=1}^{n} \lambda_j(\mathrm{c}) \geq \mathrm{NSC}\ (\mathrm{c}) \qquad (13)$$

The non-separable cost gap method is obtained whenever the non-separable cost is allocated among the players in proportion to their concession amounts. Hence, if the cost game (N; c) satisfies (11) and (13), then the cost allocated to player *i* by the NSCG-method is given by

$$= \mathrm{SC}_i(\mathrm{c}) + \lambda_i(c)[\sum_{j=1}^{n} \lambda_j(\mathrm{c})]^{-1}\mathrm{NSC}\ (\mathrm{c}) \qquad \text{if NSC(c)} > 0 \qquad (14)$$

$$\mathrm{NSCG}_i\ (\mathrm{c}) = \mathrm{SC}_i\ (\mathrm{c}) \qquad \text{if NSC(c)} = 0$$

### *(vi) Cost and Benefit Sharing Methods Based on Bounds of the Core*

The separable costs can be seen as a lower bound for any stable cost allocation, i.e.

$$\mathrm{SC}_i\ (\mathrm{c}) \leq y_i \qquad \text{for all } i \in \mathrm{N} \quad \text{whenever} \quad y \in \mathrm{CORE}\ (\mathrm{c}) \qquad (15)$$

This result is a direct consequence of (6), (2) and (4), applied to S = N – {*i*} [*Tijs* and *Lipperts*, 1982]. The figure $\mathrm{SC}_i$ (c) is said to be a sharp lower bound for the core if there exists a stable cost allocation y with $y_i = \mathrm{SC}_i$ (c).

Further, in view of (4) applied to the one-person coalitions, the alternate single costs can be seen as an upper bound for any stable cost allocation, i.e.

$$y_i \leq \mathrm{c}(\{i\}) \qquad \text{for all} \quad i \in \mathrm{N} \quad \text{whenever} \quad y \in \mathrm{CORE}\ (\mathrm{c}) \qquad (16)$$

The figure c({*i*}) is said to be a sharp upper bound for the core if there exists a stable cost allocation y with $y_i = \mathrm{c}(\{i\})$. These figures turn out to be upper bounds for the core in general. So,

$$y_i \leq \mathrm{SC}_i\ (\mathrm{c}) + \lambda_i\lambda_i\ (\mathrm{c}) \quad \text{for all} \quad i \in \mathrm{N} \quad \text{whenever} \quad y \in \mathrm{CORE}\ (\mathrm{c}) \qquad (17)$$

In view of (9), (14)-(17), a geometrical characterization of both the NSCG- and the SCRB-method for cost games with a non-empty core can now be stated as follows: The cost allocation for a cost game with a non-empty core by the NSCG-method (respectively SCRB-method) is equal to that unique cost allocation, that lies on the straight line segment with end points the lower bound of the core determined by the figures $\mathrm{SC}_i$ (c) + $\lambda_i\lambda_i$ (c), *i* = 1, 2, ….., n (respectively the alternate single costs c({*i*}), *i* = 1, 2, ….., n). It follows that the cost allocations by both methods coincide whenever $\lambda_i\lambda_i$ (c) = c({*i*}) – $\mathrm{SC}_i$ (c) = $q^c$ ({*i*}) for all $i \in$ N.

*Heaney* and *Dickinson* [1982] propose the so-called minimum costs, remaining savings (MCRS) method which is based on lower and upper bounds for the core that are as sharp as possible. For games (N; c) with a non-empty core those sharp lower and upper bounds can be found by solving for any $i \in N$ the following linear program:

minimize or maximize $y_i$

(18)

$y_i^{min}$ and $y_i^{max}$ , 1,2,………,n.

subject to y satisfying (2) and (4).

The constraint set of any of these 2n linear programs is identical. Let the solutions be given by

$$\mathrm{MCRS}_i(c) = y_i^{min} + \mathrm{u}_i(c)[c(N) - \sum_{j=1}^{n} y_i^{min}]$$

These solutions will depend on the cost game involved, and the cost allocated to player *i* by the MCRS-method is given by

where

$$\mathrm{u}_i(c) = [y_i^{max} - y_i^{min}][\ \sum_{j=1}^{n}(y_j^{max} - y_j^{min}]^{-1}$$

### *(vii) The Loehman-Whinston Axioms (Daniel L. Jensen, 1977)*

In the allocation problem addressed by Loehman and Whinston, a group "with fixed positive demands…. for capacity agree to use a common facility" [Loehman and Whinston, 1974]. In addition, the group accepts five propositions or axioms that characterize the allocation or charge to each user or group member. "These axioms serve to define a notion of equity in providing a public service and may be viewed as a constitution to which users of a public service agree prior to undertaking a collective investment". The axioms are not restricted to public goods and services but extend to any jointly used plant for which the group finds the axioms acceptable.

If the five axioms are mutually satisfactory to a group with fixed, positive demands for use of a common facility, then a unique allocation is implied and it is given by the Shapley function. In other words, the group needs not agree on the allocation formula itself. In some settings, behavioural and organizational factors may operate to make agreement on a set of generalized properties for an allocation easier to reach than agreement on the allocation itself.

The first axiom requires that the sum of the allocations equals the total cost of the facility. In the context of a cooperative venture, this means that no subsidy from outside sources is required and no excess over total cost is charged.

The second axiom requires the allocation to each user "to be based only on the incremental costs caused by the user and not on the incremental costs of other users". Incremental cost, is the increase in the total cost of a joint facility caused by the addition of a user to a coalition of other users. Multiple increments are associated with each user – one for each coalition of other users – and a different set of such increments is calculated for each user. Under the second axiom, the increments for each user are isolated and the allocation to each user is calculated without reference to the cost increments of other users.

The third axiom requires that the allocation be "independent of labeling or ordering of users". In other words, if two users exhibit equal demands, then they must receive equal allocations. The third axiom precludes an allocation method that discriminates between users on a basis other than their demands for capacity.

The fourth axiom requires that the allocation to each user be "homogeneous of degree one in the incremental costs". In other words, if all cost increments for a user increase by a certain percentage, then the allocation to the user will increase by the same percentage. The fourth axiom also means that the change in the allocation for a change in one of the cost increments depends only on the ratios of the increments to one another and not on the absolute magnitude of increments.

The fifth axiom requires that the function giving the allocation to each user be "twice continuously differentiable". In other words, the allocation must be a continuous function of the cost increments whose second derivative with respect to cost increments exists for all increments. The fifth axiom precludes the allocation function from exhibiting breaks or kinks in response to small alterations in any one of the cost increments. Instead, the response of the allocation function to small changes in cost increments must be smooth and continuous.

### *Relationship to Shapley's Axiom System*

The allocation function that Loehman and Whinston derive from the five axioms listed above coincides with the function derived by Shapley [1953] from a set of three axioms. Shapley's first two axioms are analogous to Axioms I and III above. Shapley's third axiom imposes a decomposition requirement on the allocation on the allocation function which Loehman and Whinston avoid by requiring: (1) the allocation to depend on the incremental costs of only the user in question (Axiom II) and (2) homogeneity, continuity and differentiability (Axioms IV and V).

The counterpart to Loehman-Whinston's cost function in Shapley's analysis is the superadditive characteristic function for a game. In Loehman-Whinston's analysis, Shapley's superadditivity requirement is analogous to a subadditivity (or economies of scale) requirement on the cost function [Littlechild and Owen, 1973]. Although economies of scale may be necessary for users to undertake the joint venture and to accept the allocation system, however, the five axioms are sufficient conditions for the allocation function without an economy of scale requirement.

### ***(viii) General Form of the Sharing Function***

If more than two, say I, users are involved in a joint facility, then the number expansion paths is I! which is a rapidly increasing function of the number of users. Since each of I users associates a distinct incremental cost with each expansion path, the number of cost increments that needs to be considered is also a rapidly increasing function of the number of users. Fortunately, the number of increments that must be calculated is substantially smaller than the number of expansion paths multiplied by the number of users owing to the existence of Shapley's function [Shapley, 1953] for the allocation to the $i^{th}$ user, $a_i$:

$$a_i = \frac{1}{I!} \sum_{H \subset N} [h!\,(I - h - 1)!] \cdot [C(K_{H+i}) - C(K_H)] \qquad (1)$$

where N is the set of all possible leading-demand sets, H, formed from the viewpoint of the $i^{th}$ user when there are n users or demands in all. The summation notation means the sum over all proper subsets of N, that is, all subsets that exclude at least one demand in N. Loehman and Whinston [1974] show that this form of Shapley's function can be derived from the five axioms considered earlier.

The cost function, C, gives the minimum cost of serving any subset of demands with the most efficient plant. The general form of the cost increment is $[C(K_{H+i}) - C(K_H)]$, where $C(K_{H+i})$ is the cost of serving a set of leading demands augmented by the demand of the $i^{th}$ user and $C(K_H)$ is the cost of serving just the leading demands. For the expansion path (1, 2, 3, 4, 5), $C(K_{H+3})$ is the cost of serving 1,2 and 3, and $C(K_H)$ is the cost of serving just 1 and 2. In other words, H denotes an unordered set of leading demands, demands that precede the $i^{th}$ demand in the sequence, and H+I denote that set augmented by the demand of the user for whom the increment is calculated.

In general, expansion paths exhibit the same incremental cost for a user if they differ only with respect to the order of demands that *follow* the user in the sequence. Furthermore, expansion paths exhibit the same incremental cost for a user if they differ only with respect to the order of leading demands. Consequently, the number of different incremental costs will not exceed the number of different (unordered) sets of leading demands – a number, though capable of being large, that is far less than I!.

### *(ix) Moriarity's Sharing Formula*

Moriarity [1975, 1976] sets forth an ingenious method of allocating joint cost that is based on cost increments or savings. The allocation is calculated by reducing the minimum cost of obtaining services separately by a share of the total savings of a joint facility over separate facilities for each user. The allocation to the $i^{th}$ user of a facility built to meet the demands of I users is given as follows:

$$\mathrm{a}'_i = C(k_i) + Q_i[(\sum_{i=1}^{I} C(k_i)) - \mathrm{C(K)}] \qquad (2)$$

where $C(k_i)$ is the minimum cost of satisfying the $i^{th}$ demand, the bracketed term is the total savings effected by the joint facility and $Q_i$ is the fraction of the savings offset against the cost $C(k_i)$.

$$\mathrm{Q}_i = C(\mathrm{k}_i)/\sum_{i=1}^{\mathrm{I}} C(\mathrm{k}_i)$$

Moriarity suggests that savings be assigned in proportion to each user's share of the total cost of providing for their demands separately, that is,

In essence, Shapley's function can also be written as the difference between the minimum cost of obtaining services separately and a weighted sum of cost savings terms:

$$\mathrm{a}_i = C(\mathrm{k}_i) - (\frac{1}{\mathrm{I}!}) \sum_{H \subset N} [h!\,(I-h-1)!] \cdot [C(\mathrm{k}_i) + \mathrm{C}((\mathrm{K}_H) - \mathrm{C}((\mathrm{K}_{H+1})] \qquad (3)$$

where the term

$[C(k_i) + C(K_H) - C(K_{H+1})]$

is the amount saved by serving the $i^{th}$ user jointly with the users in H rather than serving the $i^{th}$ user separately. One cost savings term arises for each set of leading demands. In the two-user case, only one cost savings term arises for each user and the term is the same amount for each user. Moreover, the term equals Moriarity's single savings term. But if the number of users exceeds two, then the number of savings terms for each user also increases, and users do not necessarily exhibit the same sets of such terms. Consequently, the similarity disappears between the savings implicit in Shapley's function and Moriarity's savings term when more than two users are considered.

Moriarity lists five advantages for his allocation method: First, a user "is never charged more than the next best alternative method of providing the product or service". Provided that savings are nonnegative, this means that the allocation $a_i$' cannot exceed the cost $C(k_i)$ of satisfying the $i^{th}$ demand separately (that is, $a_i' \leq C(k_i)$). If savings are positive, the allocation is strictly less than the separate cost (i.e. $a_i' < C(k_i)$). This condition corresponds to the third advantage cited by Moriarity – that every user "shares in the savings resulting from the decision to incur joint cost."

The Shapley function exhibits a parallel property [Loehman and Whinston, 1971] which can be seen by inspection of equation (3). If there are economies of scale (decreasing costs), then the bracketed term giving savings is always positive, indicating savings through cooperation, the weighted sum of savings terms is also positive, and $a_i$ must be less than $C(k_i)$. On the other hand, if there are diseconomies of scale (increasing costs), then both the bracketed term giving savings and the weighted sum of savings terms are negative and $a_i$ will exceed $C(k_i)$, which would encourage the $i^{th}$ user to leave the grand coalition of users.

A second advantage cited by Moriarity is that the allocation formula, in requiring both the cost of separate services and the cost of joint services, facilitates evaluation of the decision to cooperate. In other words, if the savings are negative, then separate facilities should be considered. The Loehman-Whinston allocation lacks such a simple **test of optimality** because it contemplates the full set of expansion paths; but the allocation brings forth sufficient data to enable a determination on the optimality of the joint facility for the group of users under consideration.

The fourth advantage cited by Moriarity is that "some cost is allocated to every cost object using the joint product or service" provided total savings are positive. In other words, there are no "free riders"; if $k_i$ is positive, then so is $a_i$. As long as a user's demand occasions an increment in total cost on at least one of the possible expansion paths, the same results hold for the Shapley allocation function, provided all increments are nonnegative.

The fifth advantage cited for Moriarity's allocation is that it "provides an incentive to managers to continue to search for less costly means of obtaining the joint product or service." If a user can reduce the cost of separate service, $C(k_i)$, by whatever means, then total savings are increased and his or her allocation is reduced. The Shapley function exhibits the same advantage.

In summary, the Shapley allocation function exhibits the five advantages listed by Moriarity for his allocation method.

***(x) Reduced Forms of the Sharing Function***

Neither the cost function nor the relationship between individual and group demands is specified in the development of the general allocation function. Various specifications of the cost function and the relationship between capacity and individual demands lead to different simplifications of the general allocation function. The various simplifications are of interest for four reasons.

First, although different specifications produce different simplifications of the general allocation, the seemingly different allocations all derive from the same general allocation function. The difference between them arises solely from differences in the underlying cost and demand. Second, some simplifications mitigate computational problems encountered by the general allocation function when the number of individual demands is large. Third, some simplifications can be calculated without full knowledge of the cost function, $C(K_H)$. And fourth, some simplifications correspond to practiced or recommended allocation techniques.

### *Capacity as a Function of the Number of Users*

If group capacity, $K_H$, can be written for all groups, H, as a function of the number of users in the group, h, and known parameters, then the Loehman-Whinston axioms allocate the cost of serving all users equally among the users, that is

$$a_i = C(K)/I \tag{4}$$

$$K_H = \sum_{i \in H} k_i$$

This means that the allocation requires only one value of the cost function, $C(K_H)$, namely the cost of serving subsets of the *i* demands, although implicit in the allocation, need not be known.

A variety of functions might characterize the relationship between a group of h individual demands $(k_1, k_2 \ldots, k_h)$ and the minimum capacity, $K_H$, required to serve them. Some important examples are the following:

*Joint capacity may be the product of the number of demands served and a known constant*

This occurs when individual demands are equal and sum to the joint capacity. More precisely, when $k_1 = \ldots = k_I = k$ and then $K_H = k \cdot h$, which is a function of h and the known parameter k.

*Joint capacity may be simply a known constant*

This will occur when individual demands are equal and each unit of capacity serves every user. More precisely, when $k_1 = \ldots = k_I = k$ and

$$K_H = \max_{i \in H} k_i$$

then $K_H = k$. This relationship is exhibited when sequential rather than simultaneous demands are presented.

In general, if customer demands are homogeneous, that is, if $k_1 = k_2 = \ldots = k_I = k$, then the joint cost of capacity is allocated equally among the I users. However, the relationship between joint capacity, $K_H$, and the level of homogeneous demand, k, is not always the same. When joint capacity is the sum of individual demands, then $K_H = k \cdot h$ and when joint capacity is the maximum demand, $K_H = k$. Yet the Loehman-Whinston allocation is the same despite the fundamental difference.

In some cases of homogeneous demand, joint capacity must include an allowance for additional capacity beyond the portion attributed to individual demands. For example, an additional segment of capacity may be required to provide for down-time due to maintenance with the result that $K_H = a + k \cdot h$ or $K_H = a + k$. However, $K_H$ remains a function of h and known parameters (a and k); consequently, the cost of the joint facility – including the cost of planned excess capacity – still is assigned equally among the users.

*Capacity as the Maximum Individual Demand*

An important simplification arises when joint capacity is the maximum among the demands served, that is,

$$K_H = \max_{i \in H} (k_i).$$

Every unit of capacity serves each of the h users. If individual demands are numbered in order of their size and if larger demands never entail less total cost, then Littlechild and Owen [1973] provide the following reduction of the general allocation function:

$$a_i = \sum_{j=1}^{i} [C(k_j) - C(k_{j-1})]/(I - j + 1) \qquad (5)$$

where

$0 = C(k_0) < C(k_1) < \ldots < C(k_j) < \ldots < C(k_I)$.

*Linear Cost Functions*

If the cost function $C(K_H)$ is linear, the allocation assumes a familiar form. Recall that $K_H$ is the capacity required to satisfy a group of individual demands designated H. We shall consider only simple linear functions of the form $C(K_H) = v \cdot K_H + f$, giving cost as the sum of a fixed cost, f, and a variable cost, $v \cdot K_H$. In the special case that H is empty, $C(K_H)$ is defined to be zero.

The form of the simplification for linear cost functions depends on the relationship between joint capacity and individual demands. An important example is the case in which joint capacity is the sum of individual demands, that is,

Whenever joint capacity is the sum of individual demands and cost of capacity among the time periods require equity, the general allocation function reduces to

$$a_i = v \cdot k_i + f/I, \tag{6}$$

$$K_H = \sum_{i \epsilon H}^{i} k_i \, .$$

that is, the allocation to each user is a two-part charge – the variable cost occasioned by the user's individual demand and an equal share of the fixed cost.

Fixed cost is allocated in the same way if capacity is the maximum individual demand. When a linear cost function is added to the conditions required for Littlechild's simplification, the formula given above becomes:

$$a_i = \frac{f}{I} + \sum_{j=1}^{i} v \cdot (k_j - k_{j-1})/(I - j + 1) \tag{7}$$

where $k_0 = 0$. In other words, the fixed cost is shared equally by the *i* users and the cost of each increment in capacity $v \cdot (k_j - k_{j+1})$ among the (I - j + 1) demands that use it.

***(xi) Other Axiomatic characterizations by General Principles of Equity***

The imposition of general principles, or axioms, often leads to a unique determination of a solution. This approach is repeatedly used in game theory, as illustrated by the short summary below.

*Nash's axioms*. Nash (1950) characterizes his bargain solution by the following axioms: individual rationality, symmetry, Pareto optimality, invariance to utility scale, and independence of irrelevant alternatives (IIA).

*Invariance to utility scale* means that changing the scale of the utility of a player does not change the solution. But this axiom goes further by disallowing all methods that use information extraneous to the game, even if such methods are invariant to scale.

Nash's IIA axiom requires that a solution that remains feasible when other payoff profiles are removed from the feasible set should not be altered.

*Shapley's axioms*. Shapley (1953) characterizes his TU value by the following axioms: symmetry, Pareto optimality, additivity, and dummy player.

A value is *additive* if in a game that is the sum of two games, the value of each player equals the sum of his values in the two component games.

A *dummy player*, i.e. one who contributes nothing to any coalition, should be allocated no payoff.

*Monotonicity axioms*. Monotonicity axioms describe notions of fairness and induce incentives to cooperate. The following are a few examples.

Kalai and Smorodinsky (1975) characterize their bargaining solution using *individual monotonicity*: a player's payoff should not be reduced if the set of imputations is expanded to improve his possible payoffs.

Kalai (1977) and Kalai and Samet (1985) characterize their egalitarian solutions using *coalitional monotonicity*: expanding the feasible set of one coalition should not reduce the payoffs of any of its members.

Thomson (1983) uses *population monotonicity* to characterize the n-person Kalai-Smorodinsky solution: in dividing fixed resources among n players, no player should benefit if more players are added to share the same resources.

Perles and Mascler (1981) characterize their bargaining solution using *superadditivity* (used also in Myerson [1981]): if a bargaining problem is to be randomly drawn, all the players benefit by reaching agreement prior to knowing the realized game.

Young (1985) shows that Shapley's TU additivity axiom can be replaced by *strong monotonicity*: a player's payoff can only depend on his marginal contributions to his coalitions, and it has to be monotonically non-decreasing in these.

***(Footnotes)***

1 Economic Consulting Associates 2009 "Power Sector Integration Literature Review"

2 Adapted from the AEGM presentation by Ayaya Onesmus, Lesotho Highlands Water Project-Highlights: March 2010 Lilongwe Malawi