Engineering Sustainable Dams

Planung und Bau von zukunftsfähigen Talsperren

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Abstract

The concept of sustainable infrastructure and an approach to achieving it through the Engineered Sustainable Infrastructure Cycle (ESIC) is explained. ESIC optimises the sustainability of infrastructure to meet societies' needs by iteratively examining the economic and environmental sustainability of alternative infrastructure. Dams meet several of societies' infrastructure needs and ESIC is used to examine how dams might be engineered to optimise their contribution to a sustainable future.

Zusammenfassung

In diesem Beitrag wird das Konzept der zukunftsfähigen Infrastruktur und die methodische Herangehensweise mittels des sog. „Engineered Sustainable Infrastructure Cycle (ESIC)" erläutert. ESIC optimiert mit einer iterativen Untersuchung der Wirtschaftlichkeit und Umweltverträglichkeit der Alternativen die Nachhaltigkeit von Infrastruktur, um den Bedürfnissen der Gesellschaft zu entsprechen. Talsperren befriedigen zahlreiche Infrastruktur-Bedürfnisse der Gesellschaft. ESIC wird herangezogen, um zu untersuchen, wie Talsperren geplant und gebaut werden müssen, um ihren Beitrag zu einer zukunftsfähigen Entwicklung zu optimieren.

Sustainability, sustainable development and sustainable infrastructure

In 'Dams: setting a new standard for sustainability' [1], the author explained how progress in dam engineering, environmental objections to dams, and the World Commission on Dams, led to the realisation that dam engineers, with assistance from other professionals, should take responsibility for all aspects of the sustainability of dam projects. As dams are elements of civil engineering infrastructure, the lessons about sustainability from dams have relevance to all infrastructures.

The simple model of sustainable development represents it as three pillars – environment, economic, social. This model somehow suggests that the only sustainable development is environmental, and that others are undesirable, and cannot be sustained by the environment.

Civil engineers have a responsibility to provide infrastructure in power, water and transport, to sustain lives and livelihoods within the resources available in nature. To fulfil this responsibility they have to engineer development that nature can sustain. This responsibility becomes severe when in reality all development, all human activities, are sustained by the environment.

However, civil engineers are not and could not be responsible for supporting all development or all human activities, nor should they tell people what they can or cannot do. Their responsibility is to provide infrastructure that will support the activities people have decided to do. Societies must decide, preferably through democratic processes, what development they want. This thinking led to the concept of sustainable infrastructure.

Engineered sustainable infrastructure cycle

Sustainable infrastructure is provided to meet societies' needs and deliver economic benefits within the resources available in the environment. The 'pillars' of sustainable infrastructure are not free standing, they are inter-dependent. This led to the development of a simple tool, the Engineered Sustainable Infrastructure Cycle, ESIC, **Figure 1**, to assist civil engineers to systematically design and deliver sustainable infrastructure services.

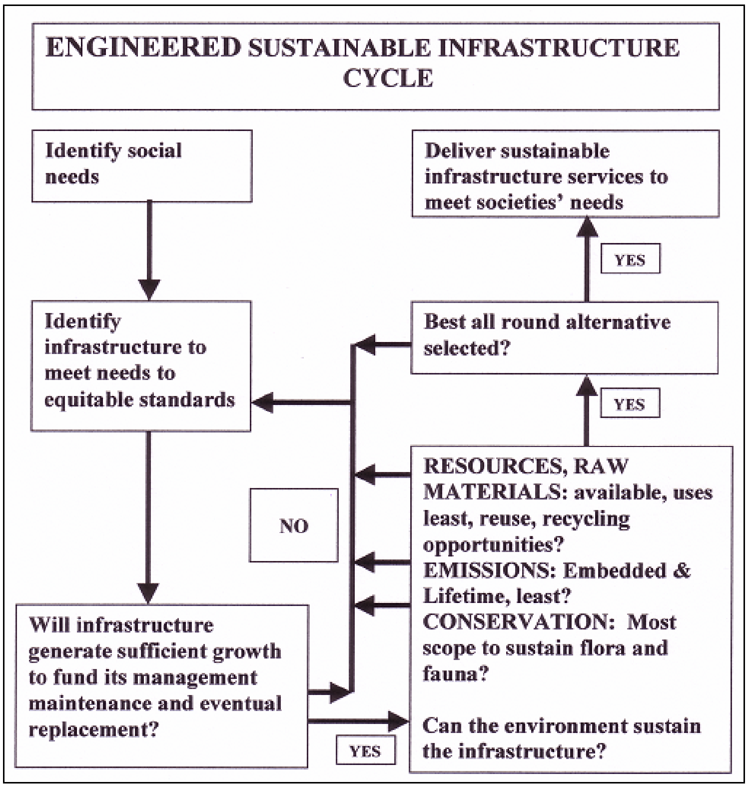

Figure 1: Engineered sustainable infrastructure cycle [1]

It is essential to enumerate the analyses in order to demonstrate in an impartial, apolitical and transparent manner that the most sustainable solution has been selected. ESIC can be used at any scale, from comparisons of improvements to an already selected optimal alternative, through to decision making on broad global issues such as optimising land use through rain-fed or irrigated food production.

Using ESIC

ESIC is used iteratively and applies engineering principles and enumeration at each step to optimise the sustainability of infrastructure. After confirming the social needs, infrastructure to meet those needs is engineered. Next economic sustainability, whether the infrastructure will generate sufficient economic benefits to sustain it, is enumerated. If necessary, the economics might be 'engineered' to achieve a satisfactory outcome, or alternative infrastructure may have to be considered.

Then the environmental sustainability, whether the resources in the environment can sustain the infrastructure, and whether the infrastructure proposed optimises conservation opportunities, is examined, ‘engineered’ if possible to improve environmental sustainability, or alternative infrastructure may have to be considered before an optimal outcome is achieved.

After a final check, ESIC makes it possible to demonstrate numerately that the most sustainable alternative has been selected, and that it can be expected to sustain the infrastructure service to meet societies’ needs in the future until wear and tear and changing demography make rehabilitation, following a review by ESIC, necessary.

Engineering infrastructure standards to meet social needs

Currently people benefit from different standards of infrastructure. US citizens each have 400 gallons of water delivered daily to the taps in their houses. People in Ghana might have 5 gallons daily which they have to pump from a well as much as 100 metres from their house. In a world engineered to be sustainable, the sustainability of which depends on global resources, equitable and universal standards must be applied.

Quantitative risk assessment in dams [2], which delineates acceptable and unacceptable standards for likely loss of life against the probability of failure, suggests that infrastructure standards could also be risk-based. The standards of infrastructure provision could be determined to limit likely loss of life or, stated more positively, to generate life expectancy to universally acceptable standards. It should be noted that reducing deaths of babies and children leads to a marked and rapid improvement in life expectancy. In countries with already high life expectancy, infrastructure should at least maintain present life expectancy; new infrastructure provisions should not increase the risk of premature death.

The challenge is to determine how much infrastructure people would need to achieve acceptable life expectancy. While existing conditions would provide this data, the standards set by the Millennium Development Goals should be followed for the time being, because when they are achieved in 2025 they will have corrected the worst of today’s inequities.

Dams as sustainable infrastructure

A further challenge for dam professionals is to determine how much of the infrastructure should be dam-based to achieve acceptable life expectancies by the most sustainable means. Lempérière [3] examined the role of dams in sustainable development in the 21st century. He noted that dams meet social needs for electricity, irrigation, water supply, flood mitigation, navigation, recreation and aquaculture.

However, he has no means of assessing the extent of the needs for these infrastructure services or enumerating the advantages and disadvantages of various dam-based options, or of dam-based options against alternatives based on other infrastructure, nuclear power, for example. ESIC, when developed, provides a rational means of addressing such issues. Here it will be used to explore, qualitatively, a few aspects of the sustainability of dam-based infrastructure and to suggest how improvements might be engineered.

Economic sustainability

Dams are capital intensive, and only in a few countries can they be constructed by businesses alone without internal or external financial support. In poor countries, economic sustainability, in the sense that the benefiting community can afford to pay for the operation, maintenance and replacement of the infrastructure, often cannot be achieved because of the 'funding gap', the years before the new infrastructure generates sufficient prosperity to make it possible for the beneficiaries to pay for it.

It may be possible to 'engineer' outcomes to overcome this flaw. Investors from wealthy countries, recognising that they are investing to generate economic growth, might accept payment for the infrastructure service related to an indicator of economic growth such as GDP. Growth rates of 15%, sometimes achieved in rapidly developing countries, would increase income by sixteen times over a 20-year concession period.

Environmental sustainability

Dealing with environmental sustainability in the numerate, dispassionate and apolitical way that ESIC requires is difficult because dam professionals are ill-equipped to distinguish between true science and misinformation. The IPCC view of carbon emissions and climate change has recently been questioned [4]. Available resources are disputed, as debates about oil reserves show.

However, progress has been made in enumerating environmental factors, flood hydrology, sedimentation and sediment flushing, for example. The enumeration of the impacts of dams on flora and fauna can be addressed through the application of scientific principles. Such impacts are not necessarily adverse because, as indicated by **Figure 2**, modulated flow conditions downstream of a dam may create conditions favourable to a wider range of species than could survive in the variable pre-dam conditions.

ESIC sustaining people, nature and our planet

Sustaining the lives and livelihoods of the nine billion people expected to populate the planet from 2060, as well as conserving viable populations of flora, fauna and other living organisms, all within the resources available in nature, will be accomplished only if supported by carefully engineered sustainable infrastructure.

To meet this challenge, dam engineers and professionals, guided by ESIC, should analyse, enumerate and deliver all aspects of dam-based infrastructure services. These will embrace, in addition to technical issues, social issues, particularly rationalising the standards of infrastructure services needed by the public; economic issues, particularly engineering economic systems to deliver infrastructure to those most in need; and environmental and conservation issues, recognising the many opportunities that reservoirs and catchments offer for conservation and improving, where sustainably achievable, conditions downstream of dams.

Finally, they should interact more closely with the public, to understand their needs, maintain their trust, and work with them to sustain lives and livelihoods and nature on our planet, at least for the remaining nine billion years of its life!

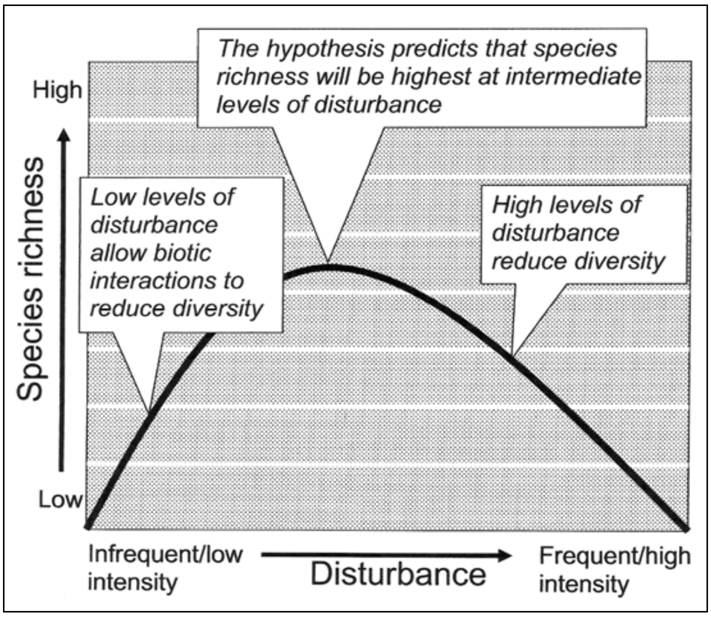

Figure 2: Showing how species richness is influenced by degree of disturbance. Balancing ponds downstream of hydro dams would maintain intermediate disturbance and encourage high species richness [1] [3]

Literature

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