Design and Assessment of
water-energy-food-environment
Mega-Systems

An analytical framework for understanding risk and risk mitigation in the context of financing large hydropower projects in low- and lower-middle-income countries

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FutureDAMS

Working Paper 011

July 2020

ISBN: 978-1-913093-10-5

Cite this paper as: Plummer Braeckman, J., Markkanen, S., and Seega, N. (2020) An analytical framework for understanding risk and risk mitigation in the context of financing large hydropower projects in low and lower-middle income countries. FutureDAMS Working Paper 011. Manchester: The University of Manchester.

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Abstract

Large hydropower projects in low-income countries (LICs) and lower-middle-income countries (L-MICs) carry various risks. While many of these are similar to those for other large infrastructure projects in developing country contexts, some – like geotechnical or hydrological risks – are unique to large hydropower development. In the next three decades, the demand for large-scale energy generation from renewable sources will grow all over the world. This growth will need to be particularly substantial in LICs and L-MICs, where electrification rates remain low, often below 75% nationally. Large hydropower, when properly planned and implemented, provides an affordable, reliable, sustainable and modern source of low-carbon electricity. It can help communities, nations and regions to access a stable supply of electricity, thus supporting economic and social development and environmentally sustainable industrialisation. Given the shortage of public funds for infrastructure investment, these projects will need to be increasingly financed and developed by private sector actors through alternative financing arrangements such as public–private partnerships. However, as private financing organisations need to generate financial returns, they tend to be reasonably risk-averse and are often reluctant to engage in ventures in country contexts with which they are less familiar. The combination of growing demand for low-carbon electricity generation infrastructure development in LICs and L-MICs and the increasing dependency of such projects on private sector financing have therefore intensified the need for these actors to access information that enables them to comprehensively and accurately understand and estimate the risks associated with infrastructure investment. To aid in risk identification, measurement and management for large hydropower projects in LICs and L-MICs, this paper addresses the gap in the existing knowledge base by developing a conceptual analytical framework for public and private sector actors. The framework provides a structured approach to the analysis of risk which can aid governments, developers, lenders and investors in maximising the likelihood of a project obtaining sustainable finance.

Keywords

Hydropower, finance, project finance, developing countries, risk, risk mitigation, sustainability

JEL codes

G32, O16, O19

Acknowledgements

This work was supported by UK Research and Innovation–Economic and Social Research Council [ES/P011373/1] as part of the Global Challenges Research Fund. This paper is the first in a series of working papers with a specific focus on the questions around risk in the context of finance for sustainable hydropower projects in developing countries. The authors would like to thank David Hulme at The University of Manchester and the anonymous reviewer from the FutureDAMS consortium for their valued reviews. The authors would also like to acknowledge the unfailing support of the Cambridge Institute for Sustainability Leadership (CISL) Sustainable Finance Team, particularly Jake Reynolds, for their comments on the final draft.

Contents

1 Introduction

The aim of this research is to establish an analytical framework for understanding risk and risk mitigation in the context of financing large hydropower projects in low- and lower-middle-income countries.[1] Such a framework will enable both governments and financiers to identify, manage and mitigate risk and thus enhance the likelihood of successfully financing projects.

Many of the risks associated with large hydropower development in low-income countries (LICs) and lower-middle-income countries (L-MICs) are linked with weak governance and institutions, as well as inadequate regulations, and thus apply to all large infrastructure projects in these countries (Miller & Lessard, 2001; Bosch-Rekveldt, et al, 2011; Skinner & Plummer Braeckman, 2018). However, some of the characteristics of large hydropower projects expose them to an additional set of risks that are less prevalent for other infrastructure projects. For example, large hydropower projects are extremely capital-intensive and site-specific, with a long preparation phase, lengthy construction period, often considerable environmental risks and social impacts, and a typical project lifespan of more than 50 years. Each large hydropower project requires bespoke design and most of the remaining sites tend to be in inaccessible locations, often in areas that have a challenging physical environment and geology. Issues of seasonality and variable hydrology, local area development (or lack of it), tight equipment specifications for performance and predictability, and hydrological variation from climate change cause additional challenges that are largely unique to hydropower projects (Candee & Larson 2013).

As a result, large hydropower projects are generally perceived as a risky investment, which can make it difficult to attract financing for technologically and economically feasible projects that would boost economic development in LICs and L-MICs with low electricity access rates (Plummer Braeckman et al., 2020). In 2003, the World Bank's Water Resource Sector Strategy referred to large hydropower projects as "high-reward–high-risk hydraulic infrastructure" to highlight their complexity and the extensive range of associated economic, social and environmental risks (Fields, 2009). The fact that the early planning and construction stages can last around six to eight years or even longer reduces the relative appeal of large hydropower projects to private sector financiers (McWilliams & Grant, 2008).

The risks associated with a large hydropower project evolve during a project lifespan, with different risks being prevalent during the pre-construction phase, the construction stage, and the operational period. However, once the construction phase has been completed and the project is fully operational, many of the greatest risks associated with such projects have been eliminated or managed. Traditionally, much of the discourse on project risks has been dominated by discussion of civil construction works, as these constitute a significant proportion of the project cost and have a direct impact on the construction schedule (Plummer, 2013a). Since the early 2000s, growing attention has been directed to social and environmental impacts, which constitute a serious risk if not adequately assessed and

[1] A large dam, as defined by the International Commission on Large Dams (ICOLD, 2011, p 3), is "a dam with a height of 15 metres or greater from lowest foundation to crest or a dam between 5 metres and 15 metres impounding more than 3 million cubic metres".

mitigated, and much work has been done to improve standards through the multilateral development bank (MDB) safeguards and industry-wide guidelines on best practice. Detailed information regarding the most frequently encountered social and environmental risks is now available in the Hydropower Sustainability Assessment protocol (HSAP, 2011), which makes them easier to predict, estimate and mitigate (Locher et al, 2010). However, many of the risks that are not covered by the HSAP remain difficult to define, avoid or mitigate before completion of financing and the start of construction. Furthermore, the risk of changing hydrology has recently come to dominate, as uncertainty over the changing climate draws attention to unpredictable weather patterns and the subsequently growing frequency of floods and droughts (Foster et al, 2015; Hamilton et al, 2020; Paim et al, 2019).

There are variations in the appreciation of risk associated with a project by different stakeholder groups, as subjective views are influenced by the stakeholders' main areas of concern. For example, developers may be more concerned about penalties, while the government may be more concerned about having sufficient electricity for development (Plummer, 2013a). For the financiers and investors, all risks that affect the project's ability to service its debts and generate revenue are relevant. While some of these can be fairly easily mitigated or eliminated, others present an insurmountable barrier to involvement in the project. Risks that are particularly high during the development phases (planning and design) are often the most significant for equity investors, as the failure of the project at this stage may lead to the loss of all the finance used for preparation (Landry, 2015; Markkanen & Plummer Braeckman, 2019). This is also the stage when most environmental and social impacts are assessed and plans for their mitigation are agreed. Appropriate management of this process is a key strategy for mitigating the risk of social and environmental impacts emerging as major concerns during the construction or operational phases (HSAP, 2011).

Owing to the combination of upfront costs and high risks, risk management is a fundamental part of a professional approach to hydropower project management. The primary objective of risk management is to "increase the probability and impact of positive events and decrease the probability and impact of negative events" (PMI, 2013, p 309). It is vital for project developers to understand, thoroughly, the nature of risks, and their drivers and consequences, in terms of scope, schedule, quality and cost.[2] In some instances, however, project developers only fully appreciate the risks inherent in their projects when they begin to seek finance, especially when this involves needing to attract risk-averse private sector financiers. Indeed, it can appear that finance is delaying a project – when it is in fact drawing attention to its inadequate preparation, for example, in the form of a lack of attention to environmental and social risks.

The paper begins with a description of the methods employed in this research, develops an understanding of the risks involved and then proposes a framework for systematic consideration of risk and mitigation. The degree to which any risk may escalate to a credit or business concern is also assessed. The results are specific to hydropower, but may be of use to other infrastructure sectors.

[2] For detailed descriptions of the characteristics and roles of the various actors involved in a large hydropower project development, see Markkanen and Plummer Braeckman (2019).

2 Methods

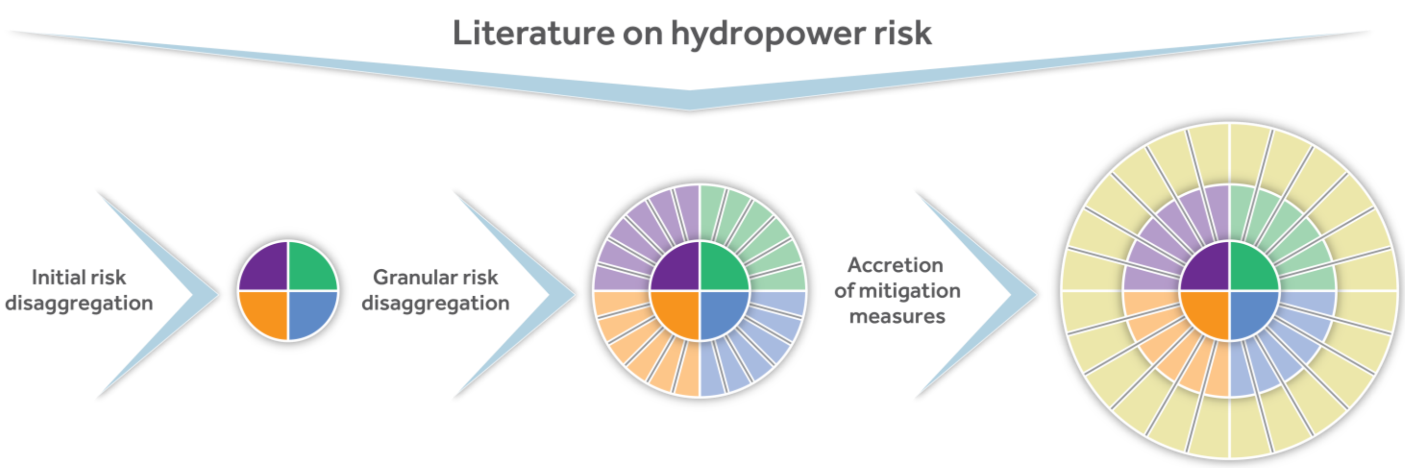
The main objective of this paper is to develop an analytical conceptual framework for identifying and understanding the risks associated with large hydropower projects in LICs and L-MICs, and the mechanisms that are current available to mitigate and manage these risks. This paper builds on previous research by Plummer (2013a), which involved a survey of 14 hydropower projects on the prevalence, and estimated impacts on costs and delays, of various types of risk that may affect hydropower projects during or after the construction period. In addition to pre-defined risk categories, the survey respondents were able to identify additional risks that they perceived as relevant to their projects, but which were not included in the survey design. A further survey of members of the International Hydropower Association considered risks at the earliest stages of project design and development (Plummer, 2013b).

The focus of the earlier work was primarily to understand the impacts of various risks on costs and delays that affect projects during the construction stage. Unlike the earlier study, the current paper has a broader objective of developing a comprehensive framework for identifying and conceptualising the various types of risks that may affect a large hydropower project throughout its lifespan. This includes the risks that are currently classified as relevant in the existing literature for various types of projects (eg run of the river, reservoir, pumped storage) at any stage of development, as well as risks that are expected to increase in importance in the future, such as those associated with climate change. The analysis also covers a set of risk mitigation mechanisms that are currently available to abate or manage such risks.

The analytical framework presented in this paper was developed through a two-stage, non-systematic literature review process as part of a broader research programme on sustainable hydropower financing in LICs and L-MICs. The first stage of the research feeding into this paper involved a comprehensive overview of the existing literature on risk in large hydropower project development in LICs and L-MICs, with a special focus on the impact of these risks on private sector investors and financiers. This process resulted in the development of the conceptual framework for categorising, understanding and analysing risk for large hydropower projects in LICs and L-MICs, as shown in Figure 1.

The second stage of research involved an analysis of the currently available risk mitigation mechanisms utilised by developers, financiers and investors for large hydropower projects in LICs and L-MICs. This process culminated in the addition of a second 'layer' to the conceptual framework to include risk mitigation mechanisms. The way in which risks are addressed can be variously described as measures to avoid, manage or mitigate adverse impacts (Irwin et al, 1998). For convenience all these terms are considered part of 'mitigation' for the purposes of this paper. Similarly, the common parlance of 'risk' is used to describe all risks and uncertainties rather than using the strict academic interpretation of the differences between risk and uncertainty (Knight, 1921).

Figure 1: Illustrative research outline



The analytical framework presented in this paper is limited to conceptualising risks associated with *large* hydropower projects, as small projects tend to have different financing structures and thus different risk assessment and risk mitigation mechanisms. It is also limited to LICs and LMICs which, while highly heterogeneous, are united by similar country risks arising from socioeconomic and political contexts that are closely interlinked with low per capita GDP, low credit ratings and high development needs. Although many of the risks described in our framework are also applicable to projects in higher income countries, the analysis and the relative importance of some of the risk categories (presented as quadrants in the framework) would be significantly different, depending on factors such as the depth of local financial markets.

While presenting a unique framework for conceptualising the risks of large hydropower project involvement for financiers, the paper draws on existing literature in framing the risks and mitigation. The framework will set the scene for two subsequent papers that draw on the material from a round of focus groups and an online survey. This further research uses the framework to collect private sector developers', investors' and financiers' views regarding risk and risk mitigation for large hydropower projects in LICs and L-MICs.

3 Understanding risk to financiers associated with large hydropower projects

3.1 Risk in the context of project finance

This research uses a long-established typology of financial risks to categorise the ways in which financial institutions can be exposed to environmental sources of risk. Market risk refers to the "risk of losses in on- and off-balance-sheet positions arising from movements in market prices" (Basel Committee on Banking Supervision, 1996). Credit risk is comprised of issuer and counterparty risk. Issuer risk is the possibility that an issuer or a borrower is not able to fulfil its obligations as a result of default. Counterparty risk comprises the risk that a counterparty defaults and is not able to fulfil its obligations (Christoffersen, 2011).

Business risk refers to the possibility that changes in circumstances undermine the viability of business plans and business models. Operational risk is the risk of losses arising from "physical catastrophe, technical failure, and human error in the operation of a firm, including fraud, failure of management, and process errors" (Christoffersen, 2011 pp7). Legal risk is the risk of significant legal consequences that flow from actions attributable to business (Moorhead & Vaughan, 2016). There are also risks that may arise when parties suffer losses related to environmental change, or their failure to manage appropriately their contribution to it. Some risk taxonomies add liquidity, country and reputational risks to these categories (Hardy, 2013).

For simplicity in this research, 'business risk' and 'operational risk' are combined into one category, labelled 'business risk'. Rapidly changing societal views of corporate behaviour relating to many environmental sources of risk mean that financial institutions often highlight reputational risk as a material factor in their decision making. This research therefore includes reputational risk in the 'business risk' category. Thus, the category of credit risks would contain issuer and counterparty risks faced by banks and institutional investors.

3.2 Risks of large hydropower projects

Large hydropower projects can have multiple benefits for their host countries. In addition to providing a large-scale, stable and cost-effective electricity supply, such dams can deliver a range of additional benefits such as flood control, irrigation and provision of potable water reservoirs associated with multi-purpose projects (World Energy Council, 2015; IEA-ETSAP & IRENA, 2015). Sustainably developed hydropower can support electrification in countries still struggling to reach full electricity access; it has the advantage that long-term electricity prices from hydropower are not subject to the fuel-price risk endemic in thermal generation.

However, hydropower is seen as a high-risk investment because of the unique geographic, geological, hydrological and economic characteristics of each site, together with the country risk (such as political or security risk) found in so many of the countries where large unexploited hydropower resources remain. Authors such as Gjermundsen and Jenssen (2001) highlight the extensive list of project risks which are particular to hydropower and not experienced to the same extent by other forms of generation. The uncertainties of climate change add to the already steep risk profile (Ray et al, 2018; Harrison et al, 2003).

Large hydropower projects tend to be complex, which makes them particularly susceptible to risk. For larger projects, risks follow an exponential track (Savino, 2011) and such projects are also known to suffer from turbulence, ie to be subject to change and unexpected circumstances (Floricel & Miller, 2001). Many of the risks associated with large hydropower projects are unforeseen, and "burst out as the projects are being shaped and built" (Miller & Lessard, 2001, p 22). For each project, the total risk represents the cumulative sum of various uncertainties that may have a negative impact on its ability successfully to achieve its objectives (Bakr et al, 2012, Fernandes et al 2018).

As will be discussed in more detail in section 4, most risks and uncertainties are a concern because of their negative impacts on the project, which generally manifest as an additional cost or delay (and which may even be sufficient to cause the project to fail). However, some risks would be considered as the likelihood of failure to achieve a separate positive goal, such as benefit for the local community. These do not necessarily affect the cost or time of the project. In the framework developed in this paper, lost benefits are included alongside the more obvious negative impacts of risk.

3.3 The relationship between risk and finance

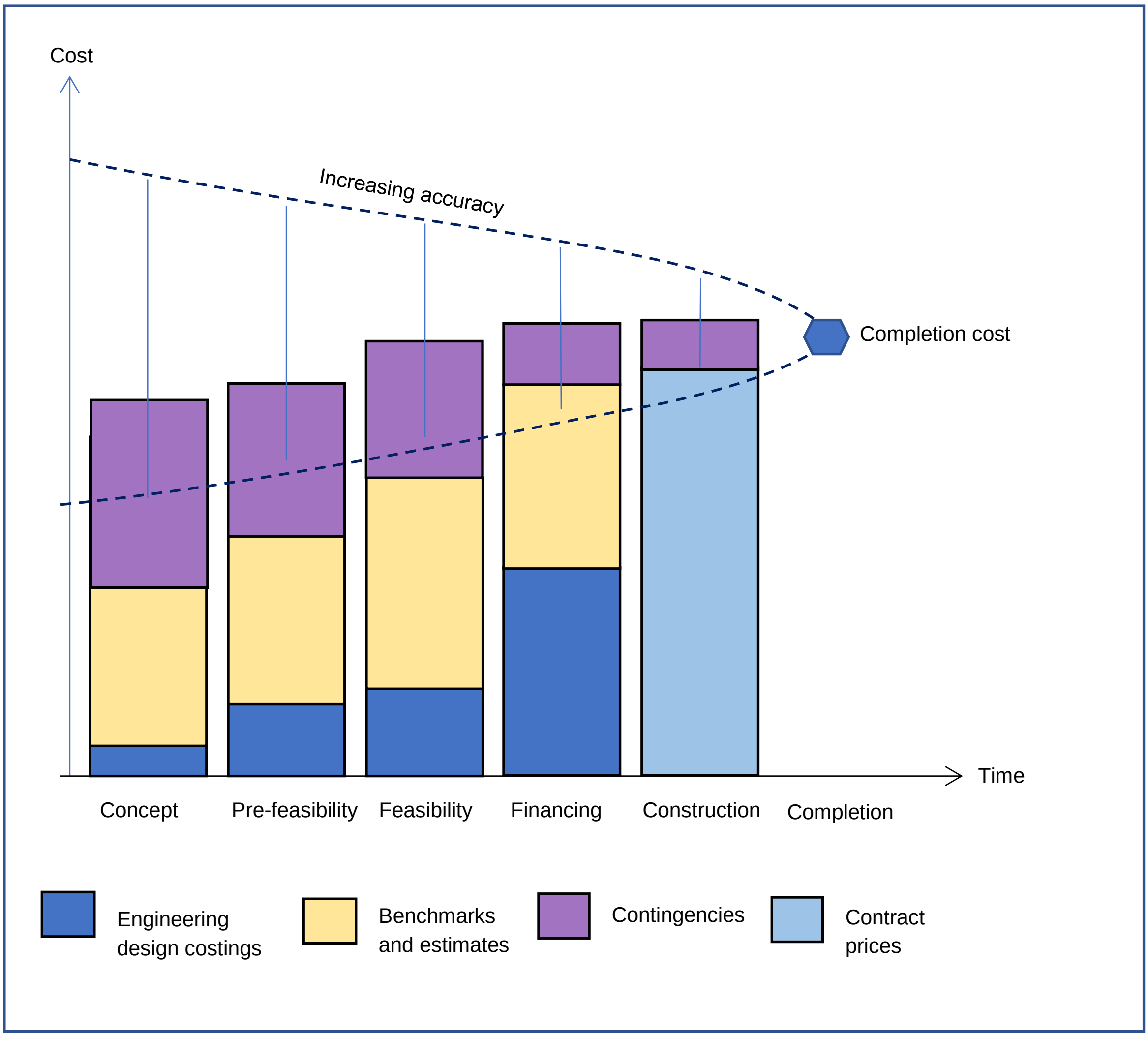
Risks associated with the overall cost of the project are vital to its finance. Considering that the budgets for large hydropower projects are typically in excess of US$500 million and frequently exceed $1 billion, planning for contingencies, which sometimes represent as much as a 30% increase in cost, adds significantly to the financing requirement.

In the development of a project cost estimate there is a base cost estimate which represents the known items of the project, such as the costed quantities of materials and labour together with the associated overheads. To this are added contingencies for those risks which can be assessed and assigned a value either by quantitative or qualitative methods. These include issues such as unforeseen underground conditions or poor slope stability, while additional allowances may be earmarked for price escalation or currency exchange fluctuations. Entirely unforeseen events, on the other hand, cannot be valued or estimated, but may be covered by a management reserve or contingent finance (Head, 2000). In addition to the above, financiers care about all risks that may delay a project, even if they do not concretely increase the costs, as any postponement of commercial operations may affect the project's ability to service its debts and reward its investors.

The accuracy of the cost estimate improves with the passage of various stages of project completion. The expected construction cost and schedule risk become clearer and in some cases the risk of a certain eventuality passes, for example geotechnical risk declines significantly once tunnelling is complete (Plummer Braeckman et al, 2019). This process has been described in the project management literature such as that of the Association for the Advancement of Cost Engineering (AACE, 2011), which illustrates how the accuracy of the cost estimate improves from ±50% at the concept phase to +30%/-15% by the point of commitment (see Figure 2). Plummer Braeckman et al (2019) have shown an average cost overrun on hydropower projects since 2000 of 34%, a median of 24% and a variance of 31%.

The challenge for the project team is to minimise the risk and uncertainty using a combination of experience, investigation and consultation to ensure that as many risks as possible are anticipated, and their likelihood and potential impacts are assessed. The results of the risk analysis must then be communicated to all stakeholders in such a way that they thoroughly and sufficiently understand the risk profile of the project, through consultations or through documents such as a geotechnical risk register.

Figure 2: Improvement of construction cost estimates over project preparation



Source: Illustrative graphic derived from AACE 2011.

3.4 The cost of mitigating risk

When all costs are taken into consideration in absolute terms – including inflation, debt servicing, and social and environmental costs – large hydropower projects may be too costly and/or take too long to deliver positive risk-adjusted returns, unless suitable risk management measures can be affordably provided. Consequently, these projects may struggle to attract finance, despite being in the economic interests of the country concerned (Markkanen & Plummer Braeckman, 2019).

It is possible to estimate the probability distribution of each risk and build them into a risk simulation model, in which the probability distribution reflects the range of possible outcomes. The form of probability distributions will vary depending on whether the variable is naturally occurring (eg hydrology), ill-defined owing to lack of information (eg underground conditions), or discrete, such as the occurrence or non-occurrence of a specific event, such as a glacial lake outburst (Rae, 2007). However, few LIC and L-MIC governments have the capacity to collect the required data to complete this form of analysis in sufficient detail and few private developers have sufficient access to the necessary information.

Financiers are typically able to select the projects they perceive to be most appealing from a range of potential investment opportunities. If hydropower is perceived as excessively risky in comparison to the returns that are available from other investments, the financier is likely to forego hydro in favour of simpler, more remunerative investment opportunities elsewhere. Thus, it is essential for those aiming to raise finance for hydropower development to have a good understanding of the risk to financiers and of available risk mitigation mechanisms.

Each risk mitigation measure added to a project structure comes with its own cost. Many of these are hidden within the costing structure of the project rather than being overtly understood as risk premiums. Each time a government asks a developer to take an additional form of risk, the developer will find a way to build the cost of that risk into the project returns. The extent of this problem can be seen from the analysis of the level of risk premium (the additional cost added to account for the risk) inherent in various aspects of the financial analysis of a hydropower project as shown in Box 1 (McWilliams, 2014). This analysis shows that, effectively, some two-thirds of the economic cost of hydropower generation may be risk premiums.

Box 1: Theoretical de-risking of a project (McWilliams, 2014)

Analysing the costs of accounting for risk

In a paper presented at Asia Hydro 2014, McWilliams assessed the level of risk premium associated with different stages of the project assessment. These included:

> **Construction cost:** with all these risks to be taken into account in pricing, it is reasonable to assume that a contingency of around one-third on top of the basic cost is included in the contract price to allow for downtime, lack of productively, re-working, low efficiency and other things that can go wrong. Hence without including risk the typical specific cost might reduce from US$2 million/MW to $1.5m/MW.
>
> **EPC premium:** many hydro projects are constructed on an Engineer, Procure and Construct (EPC) basis as a result of the owner's inability to carry risk or the financier's desire to offset it. The premium attached to the construction cost by EPC contractors to cover design, interface, performance and fixed price/fixed term risks is widely accepted to be around 30%, compounding the standard construction risk contingency above. Hence the risk-free specific cost of $1.5m/MW can be compared with a compounded EPC cost of $2.6m/MW with all risks included.
>
> **Equity return:** as a consequence of long lead times, development uncertainty, political risk and the disproportionate vulnerability of the equity investor to commercial performance (the equity investor is uniquely exposed to profit and loss), target return on equity (ROE) is typically in the region of 20%. Without such risks an ROE akin to that of long-term US Treasury Bonds might be appropriate, say 4% to 6% (the rate before the 2008 financial crisis).
>
> **Debt interest:** as with equity, risk-free interest rates close to the lower end of US Treasury Bond rates would be appropriate; say 4%.
>
> **Debt Service Cover Ratio (DSCR):** the critical indicator governing debt finance-ability is usually the minimum debt service coverage ratio, which is typically required to be around 1.3. Without risk this would be 1.0.

Using these parameters, including risk, in a simple project financial model (100 MW scheme, 50% load factor, 30:70 equity to debt ratio, four-year construction period) will result in a tariff of around **12 US¢/kWh** for commercial viability. If it was possible to 'remove' the risk premiums noted above, then commercial viability could be achieved at perhaps **4 ¢/kWh.** Although this analysis is not realistic, since many risks can never be removed from a project, it does illustrate the importance of risk in hydropower and the value of managing risk well (McWilliams, 2014).

4 Analytical framework for conceptualising risk from a financiers' perspective

4.1 Previous research

This research builds on earlier research into hydropower risk by one of the authors, in particular, a collaborative survey carried out in 2012 with the International Hydropower Association which explored the risks identified across 14 hydropower projects in South and North America, Europe, Southeast Asia and Russia (Plummer, 2012, 2013b). The sample included projects of various sizes (ranging from 5MW to over 3000MW, with a mean size of 547MW). All projects included in the sample were under construction when surveyed.

The survey sought to explore the extent to which certain risks were identified as prevalent for the projects, and the potential cost and delay implications of these risks. Building on the existing knowledge base, the defined sets of risks were divided into four categories: economic and financial, technological, environmental and social, and political risks (Plummer, 2013a). The survey also included questions about the risk mitigation measures that the projects had utilised.

The results show a high degree of divergence in the risk profiles of individual projects, as well as some commonalities. No single risk was rated as irrelevant by all 14 projects. Technical risks were of most general relevance and environmental risks of least common relevance. The low rating of environmental and social risks was influenced by fact that the projects sampled were all in construction phases and thus many environmental and social risks would already have been assessed and mitigated as a condition of implementation. Risks associated with contractual issues were regarded as relevant to all 14 projects. Contractual risk was highly relevant in three ways: (1) the direct impacts of the contract on implementation performance, including delays and budget overruns; (2) the indirect impacts such as costly delays arising from disputes; and (3) the potential longer-term impacts on plant performance and operations and maintenance costs if the long-term relationships were not clear. Contract performance and construction schedule delays were also associated with the greatest negative cost implications, followed by electricity market risk. Each of these risks was ranked as costlier than the most expensive technical risks of geotechnical–seismic and hydrological risks.

Trans-boundary issues were ranked as having the greatest delay impact, followed by long government response times. However, 'trans-boundary and security issues' were considered relevant for only three projects, possibly reflecting the decision among developers not to engage with this risk and thus with such projects being less likely to reach the construction stage. 'Government response time', on the other hand, was a risk for 12 out of the 14 projects, presenting a significant source of potential delay for each. This result highlights the fact that the prevalence of a risk is not the only consideration; some risks may only apply to a small number of projects but, for such projects, may be of overwhelming significance (Plummer, 2012).

4.2 Risk typology

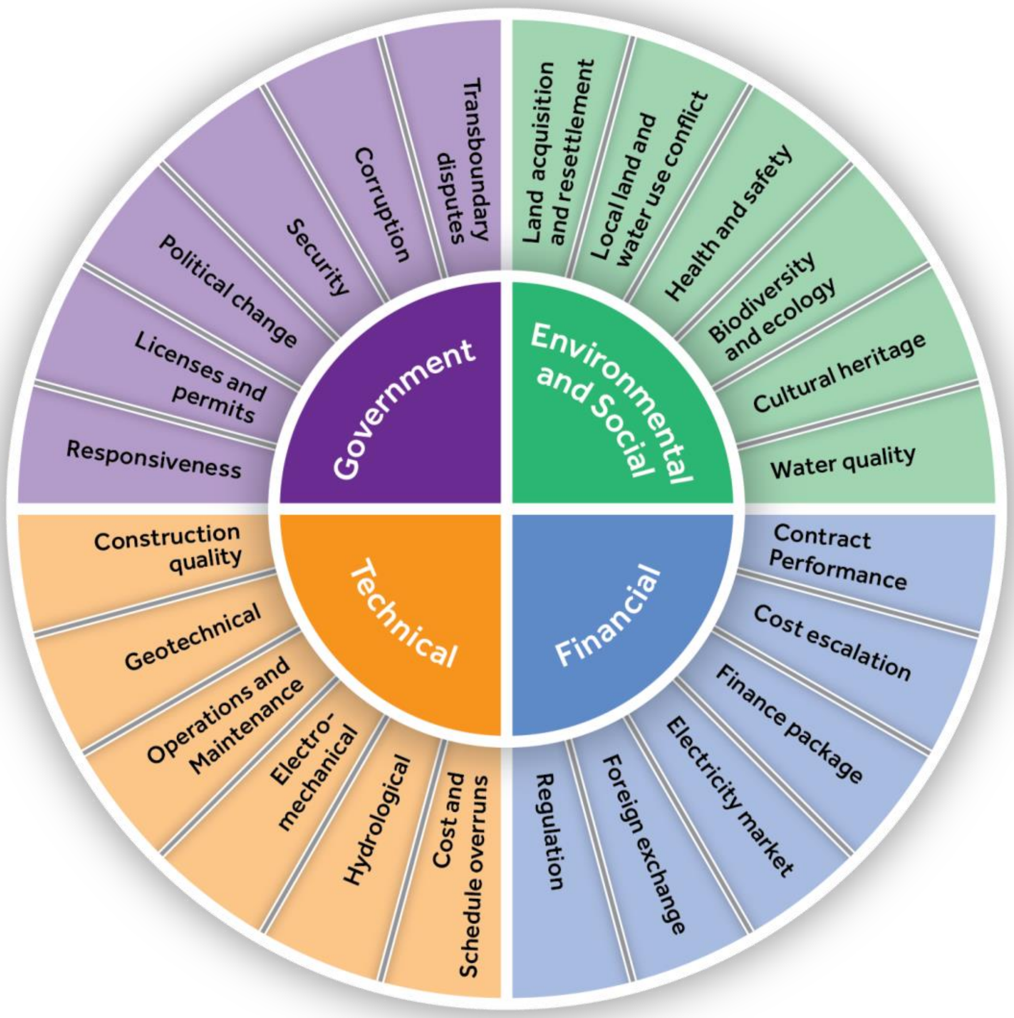
Building on the aforementioned survey results, the first step of the present analysis was to identify four key 'categories' of risk which adequately reflect the types of risk relevant to large hydropower projects in LICs and L-MICs. The existing literature indicates that technical and financial risks are generally well understood across a range of infrastructure sectors and knowledge of environmental and social risks is rapidly improving. However, institutional risks remain relatively less well comprehended. The results of the previous survey (Plummer, 2012) suggest that most of the institutional risks are, in one way or the other, government-related. The new analytical framework therefore refers to these risks as ‘government risks’ rather than institutional risks.

From a finance point of view, the survey results reveal that environmental and social risks (or safeguarding risks) are largely regarded in similar terms. These risks are typically analysed in the same document, known as the environmental and social impact assessment, and managed under the same planning framework. In situations where environmental management plans are separate from social management plans, these two sets of plans frequently overlap, and tend to be implemented under the control of the same department. Thus, for the purposes of this analytical framework aimed at capturing the issues that are of relevance to the financial sector, these two sets of risk were assigned into the same segment.

There are certain risks, such as climate change, which can affect a wide variety of other risks to varying extents. Climate change is included in the framework under hydrological risk, which is likely to be the area of most significant impact. The wider effects of climate change on risk are the subject of ongoing research.

The risk analysis framework consequently consists of four primary segments: technical, financial, government, and environmental and social, as shown in the centre of Figure 3. Within each of these segments the key risks from the literature were identified and divided into six sub-divisions according to their significance for financiers. These risks, as illustrated in Figure 3, are listed below and summarised in Appendix A. The impacts of these risks on financiers are summarised in Table 1.

Figure 3: Conceptual analytical framework for risk in large hydropower project



4.3 Government risks

Most government-related risks cause delay and uncertainty for a project and thus create concern for financiers that the project will not run to time, with implications for debt repayment. For some financiers even the uncertainty of when their finance will be required can cause them to view a project unfavourably.

- *Political change risks* are risks associated with changes in government and/or legislation at either local or national level, which may affect the long-term stability of agreements (such as concession agreements) and fiscal environment (such as tax regimes or, in the extreme, nationalisation of private assets) (Head, 2000). Political unrest is also regarded as a concern because of the effect it may have on government response times.
- *Licences and permits risks* refer to problems in obtaining the necessary licences and permits from various government and regulatory agencies. This risk is greater in contexts where the governance structures are complex and a large number of permits needs to be acquired from multiple departments or agencies. Highly complex governance structures and requirements may make it difficult to establish what is

required, and may increase the time it takes for the required permits to be issued (World Bank, 2008).

- *Government response time risk* reflects the adequacy and capacity of government and public sector agencies to respond in a timely manner in terms of issuance of licences and approvals, or other coordination with the project. Long or unspecified response times may cause the project unnecessary and expensive delays (Plummer, 2014). Delays in government response can also be linked to other risks, such as corruption.
- *Security risks* refer to a situation where access to the project site becomes compromised in a way that presents a health and safety risk to workers, or causes disruption to operations (or the progress of the construction works). This may be because of acts of aggression by another nation or by national insurgents, or local protests about the project. Large hydropower projects are often built in remote areas where sufficient water and natural head can be found without disturbing large existing settlements (World Bank, 2009). However, these sites are sometimes near borders or in areas where local law and order are not well enforced (references tend to be site specific; for an example, see Ito et al, 2016), increasing the security risk.
- *Corruption* can present a multitude of problems, ranging from risks to project implementation (eg from use of substandard materials) to damage to the developer's or financier's reputation of being associated with a project, or even a sector, found to be engaging in corrupt practices (Haas, 2008). Contractors may be reluctant to bid, or even be constrained from bidding by their home country corruption prevention laws on projects in countries where the corruption risk is deemed high. Large infrastructure projects are particularly susceptible to corruption as they involve large financial transactions. However, such projects may also be superimposed on a system which is already corrupt (Sohail & Cavill, 2007).
- *Trans-boundary disputes* emerge when a hydropower project is considered to have negative impacts on the upstream and downstream 'riparians', ie communities using the water resources beyond the borders of the country in which the project itself is located. The rights and obligations of various riparians can be protected by treaties, which can constrain or support hydropower development (Wolf, 2007). The absence of agreement on water sharing across national boundaries, however, may pose a risk for long-term hydropower operations as hydropower projects are sensitive to changes in hydrology, and upstream riparians may take actions which affect downstream hydrology without understanding the impact on downstream plants (Bakker, 1999).

4.4 Technical risks

Technical risks can cause both cost and time overruns, which are of concern to financiers because they may have an impact on repayments and income generation.

- *Construction and Installation quality* is a key issue for any large infrastructure project, but especially critical for large hydropower projects, where the impacts of poor construction or installation can be extremely costly in monetary, environmental, social and reputational terms. This risk is greater where a project is developed by a company that has little previous experience in hydropower. This risk increases further where the project owners or the host country government refuse to commission the services of international experts to supervise construction because of the cost implications (Schleiss & Boes, 2011).

- *Geotechnical risks* are problems caused by insufficient knowledge regarding the geotechnical characteristics of the project site. These risks are exacerbated by inadequate site investigations at the pre-construction stage resulting from insufficient funds or capacity (Hoek & Palmieri, 1998; McWilliams, 2016).
- *Operation and maintenance quality* may suffer in countries lacking capacity and where the allocation of resources for adequate maintenance is constrained or contractual terms are not upheld (World Bank, 2020).
- *Electro-mechanical equipment* must be fit for purpose and properly maintained. Selection of the best electro-mechanical equipment and operating regime for the plant may be a challenge, particularly given the possible changes in operating regime necessitated by future energy scenarios. Lack of expertise and experience increases the risk of inadequate assessment of electro-mechanical equipment performance (Yasuda & Watanabe, 2017).
- *Hydrological risk* arises from the impact on operation or construction of lower than expected water flows, of floods or unusual seasonal variations. Increasing hydrological risk has also been linked to climate change (Blomfield & Plummer Braeckman, 2014).
- *Project management risk* refers to a situation where poor management or lack of preparation for unforeseen events results in higher costs and delayed benefits as a result of cost and schedule overruns (Plummer Braeckman et al, 2019; Plummer, 2014).

4.5 Environmental and social risks

These risks initially create a reputational risk which may later become a credit risk if they cause project delays.

- *Land acquisition and resettlement* can present a risk to a project's progress by causing delays in securing a concession agreement or other permits, or by prompting protests which may halt construction or even result in the withdrawal of agreed funds. It is imperative for local concerns over resettlement or other issues like employment and compensation to be dealt with adequately and promptly during the pre-construction stage. Concerns over benefit sharing and resettlement may be exacerbated if there is no established system for land tenure and valuation (WCD, 2000; Kirchherr et al, 2016a).
- *Land and water use conflicts* relate to issues raised by local water users or upstream and downstream riparians on the sharing of water or catchment use. This issue may overlap with catchment protection (Johansson & Kriström, 2011) and may also relate to concerns over the construction of associated infrastructure such as access roads and transmission lines.
- *Issues of physical safety*, as well as spread of disease, during all phases of the project create public health and safety risks. These relate not only to construction safety and prevention of accidents, but also to prevention of diseases on the construction site and in accommodation facilities, and related issues such as road safety (Lerer & Scudder, 1999). Projects that attract migrant workers to previously isolated areas may need to take special precautions to prevent disease from

spreading to local communities.

- *Biodiversity and ecology risks* reflect the impact of a project on biodiversity and ecology, including risks to endangered species. Hydropower tends to affect biodiversity through changes to freshwater habitat, water quality and the land. These changes may affect various species in the river and in the surrounding area, while changes to seasonal water flow may affect the ecology of the area and have consequent impacts on biodiversity (Gracey & Verones, 2016). Further, fragmentation of rivers caused by dams may be detrimental to biodiversity (Dasgupta, 2020).
- Preservation or protection of *culturally or historically significant sites* or artefacts need to be addressed with care to protect the reputation of all parties associated with a project (WCD, 2000). In some cases, failure to address these issues sensitively can lead to stoppages in construction until the situation is resolved, often with cost implications higher than the costs associated with the original issue in contention.
- The impact of the project on *water quality* downstream of the project and consequent impacts on human and aquatic life is another issue which needs to be addressed and agreed upon early in project preparation, and monitored throughout the project's life, if it is not to cause conflict with other riparians and delays to the project (Bunea et al, 2010).

4.6 Financial risks

These risks are easier for financiers to understand. The financial risks may cause significant cost and thus repayment uncertainty for the financier.

- *Contractor performance failure risk* refers to a situation where a contractor fails to comply with the terms of the contract, resulting in legal costs associated with pursuing the failure to adhere to contract terms (Delmon, 2017). These costs can be considerable and generate further additional costs (and give rise to other risks) by causing delays if the project slows or halts while legal action is being pursued or if alternative contractors need to be employed.
- Inflation, commodity price changes, competition for resources and other local and international cost effects are grouped under *cost escalation risk*. Embedded within this is the risk that costs are not well enough investigated and forecast before the decision to proceed (Head, 2000; Awojobi & Jenkins, 2016).
- Availability, tenure and conditions precedent for debt, equity and other financing instruments all contribute to *the risk of the financial package*. In particular, hydropower projects are highly sensitive to the length and repayment conditions of debt finance (Head, 2008).
- *Electricity market risk* covers changes in the price of electricity for merchant plants, or changes in the agreed regulatory mechanism for setting the price (Trouille et al, 2008).
- *Off-take risk* encompasses payment risk and enforcement of contractual off-take obligations (Markkanen and Plummer Braeckman 2019).
- *Foreign exchange risk* refers to changes in relative exchange rates between currencies in use for the project, particularly between the main currency for 'cost' and the main currency for 'revenue'. This is a particular concern for LICs and L-MICs whose currency is not tied to an international benchmark currency (Head, 2000).

Table 1: Summary of risk impact on finance

Risk type				
	Credit risk to lenders/market risk to investors[1]			Business risk to both lenders and investors
	Construction cost overruns leading to project cash shortfalls	Construction time overruns leading to delayed viability	Operational high costs /low revenue leading to project cash shortfalls	Reputational risk
Government risks				
Political change		●		●
Licences and permits		●		●
Government response time		●		●
Security		●		●
Corruption		●		●
Trans-boundary disputes		●		●
Financial risks				
Contract performance	●	●		
Cost escalation	●			
Financing package	●	●		
Electricity market	●			
Foreign exchange	●		●	
Regulation	●			
Technical risks				
Construction and Installation quality	●	●		
Geotechnical–seismic	●	●		
Operation and maintenance			●	
Electro-mechanical	●	●		
Hydrological		●	●	
Cost and schedule overruns	●	●		
Environmental and social risks				
Land acquisition and resettlement		●		●
Land and water use conflicts		●		●
Public health and safety		●		●
Biodiversity and ecology		●		●
Cultural heritage		●		●
Water quality		●		●

[1] *Note*: The risk categorisation would also create credit risk for bond issuers. This form of finance remains rare in construction finance for large hydropower in LICs/L-MICs to date but may increase with the possible authorisation of 'green bonds' for hydropower (Markkanen & Plummer Braeckman, 2019).

5 Risk mitigation

For each of the risks listed in the previous section there is a range of mitigation, avoidance and management measures (referred to here as 'mitigations') which can be employed to reduce the risk to acceptable levels. For each quadrant of the framework and each risk, the mitigations were considered and then incorporated into the framework as shown in Figure 4.

5.1 Government risks

The risk of political change can to some extent be mitigated by the government endeavouring to get cross-party support for a project, or to enact special legislation for it. Neither of these approaches, however, constitutes a foolproof protection against potential problems in the event of political change, as political parties may alter their views, and special legislation may be reversed. Nevertheless, legislative solutions may bring an element of transparency to the issue. Moreover, enacting such legislation in good time before the project begins can also help alleviate concerns over government response time for any other project issues, mitigating some of the other government risks. Unfortunately, there is little that can be done within a country to protect a project from catastrophic situations such as a coup or a war. In these situations, a government (sovereign) guarantee is unlikely to be sufficient, and external support such as an MDB guarantee would be needed (Head, 2000; for country-level examples, see Matthews & Geheb, 2014). Similarly, a strong and stable regulatory framework or market system for financial transactions with a history of freedom from political interference can help build confidence in the stability and likely continuity of the system (Houben et al, 2004).

The risk of failures caused by lack of coordination between government departments or by excessively long response times can be mitigated by a 'single window' approach, whereby a single government office takes charge of all the relations between the host country government and a large hydropower project. This approach requires a high degree of intra-governmental cooperation and commitment, but can make a significant difference to the relationship between the government and the project, and reassure investors. The single window approach has so far been successfully used predominantly for coordination and expediting of cross-border trade (Choi, 2011), although there are some examples of this method also having been used for the promotion of public–private partnerships (PPPs) for infrastructure (Tsunoda et al, 2014). Unfortunately, the countries with sufficient coordination and control capacities to implement a successful single window may be those that least need it (Plummer, 2014).

To enhance response times and to improve mutual understanding, the host country government may take a minority equity stake in a PPP project (James & Vaaler, 2018). This ties the project more closely to government and means that the latter will have a strong vested interest in the project's financial performance as well as its delivery. A government representative on the Board of Directors for the project can help the project's management understand the government's constraints and vice versa.

Security concerns around borders and riparian rights are most easily dealt with through pre-existing treaties and agreements, as it is difficult (if not impossible) for any private party to effectively deal with these matters. A much-quoted example of a riparian rights treaty is the Indus Treaty, which has allowed the development of water resources in India and Pakistan to proceed despite their differences; another example would be the Ganga River Treaty between India and Bangladesh (Briscoe & Malik, 2006). From a project point of view, major frameworks such as treaties take far too long to negotiate to be carried out during a project preparation stage, and instead must be put in place by the government when they first contemplate their water resources development (Wolf, 2007; Salman, 2008; for a country-specific example, see Ito et al, 2016).

Questions over the internal allocation of water resources may be almost as difficult as cross-border controversies. Most hydropower projects do not reduce the quantity of water downstream of the tail race once a stable state of reservoir filling has been reached. However, the plant may substantially alter the timing and rate of the flow. This may put the hydropower plant in conflict with other water users for fishing, irrigation and water supply. On the other hand, dams may provide a service in attenuating flood levels, thereby benefiting downstream communities, although the plant is rarely compensated for this service.

River basin authorities with clear water sharing agreements can be useful in ensuring that the balance of resource allocation is equitable (Aguiar et al, 2016). Constraints on the operation of the power plant to account for the needs of other water users need to be built into the concession agreement so that they are clear to the developer from the outset. Difficulties arise primarily when attempts are made to change previously settled water sharing agreements after a plant is commissioned. For a PPP project and its financiers, it is essential to be able to rely on the agreements that were signed before construction. Upholding these agreements may require a government guarantee.

Of similar importance to riparian rights is a watershed management plan. The quantity and quality of water may be affected by other actions within the catchment area, such as deforestation, with implications for the operation of a hydropower plant. Thus, it is important for the hydropower project to sit within an overall catchment or watershed management plan. Such catchment management plans should be integrated into the benefit-sharing agreements of the project so that the local populations can see some benefit from engaging in catchment protection. Similarly, co-development or co-ownership of management plans, and even of the hydropower plants themselves, with local people can contribute to better local relationships over such issues as water sharing and catchment protection. However, ultimately there needs to be a government commitment to ensuring that law and order prevail for the security and integrity of the construction site and the hydropower plant (World Bank, 2009).

Corruption is endemic in many societies, and large infrastructure projects are particularly susceptible to corrupt practices (WCD, 2000). A generalised government push on anti-corruption, as well as project specific anti-corruption measures, can substantially reduce the risk of corruption, although not necessarily eradicate it entirely. Vetting of contractors, transparent tendering procedures, expert advice and third-party monitoring can all contribute to a project's approach to minimising corruption (Sohail & Cavill, 2007). These practices, backed up by a wider government-led position on anti-corruption, can do much to protect the financier's reputation and ensure that the project is built to standard. However, there are instances where project decision making may be adversely affected by the perceived need to protect individuals from the accusation of corruption. Individuals may not feel able to take difficult decisions alone, and instead refer them to a higher authority or to a committee rather than take individual responsibility and be accused of favouring, for example, one sub-contractor over another. The result is highly risk-averse and slow decision making. Thus, anti-corruption measures need to be aligned with strong support for clearly delegated responsibility and decision making (Plummer Braeckman & Guthrie, 2015).

5.2 Technical risks

Most financiers assume technical risks to be well covered by the developer, who has expertise in hydropower. The expectation is that issues such as construction and installation quality will be covered by the usual systems, including technical and commercial terms and conditions of the contract, supervision, inspection and quality assurance. Such systems may include measures such as lists of pre-approved contractors and the provision of penalties and bonuses for depending on performance. Overall, the financiers rely heavily on the guarantees and warranties built into the technical contracts to ensure quality and conformance (Schleiss & Boes, 2011). Some financiers also use their own technical advisers to assess technical risk – usually referred to as the 'lender's engineer' (Yescombe, 2002).

A general assumption among financiers is that specific risks, such as geotechnical risk, will have been studied before construction with appropriate investigations. They will expect expert opinion to have been taken on such issues as the appropriateness of underground installation for the powerhouse, selection of the appropriate tunnelling method and special design considerations to avoid damage arising from seismic activity. One recent development in this regard is the preparation of the geotechnical baseline report and risk register, which can be shared with the contractor to ensure that the allocation of risk is clear and transparent (Palmieri, 2015). The electro-mechanical risks can also be managed by good procurement practices and effective contracts, allied with supervision, inspection and quality assurance measures. In addition, there are specific measures such as inspections during manufacture and reliability testing that can be applied to electro-mechanical equipment (Sarzaeim et al, 2018; Yildiz & Vrugt, 2019).

Hydrology creates a range of risks and thus is subject to a range of mitigation measures. Good data are key to effective design and feasibility. The greatest risk may be that of inadequate water flows to support commercial operation of a plant, especially if this continues over a long period of time rather than being caused by short-term annual variations, such as lower than average snowfall or a poor rainy season. However, inadequate flows can be supplemented by constructing diversions or larger storage reservoirs. It may also be appropriate, particularly given the future uncertainty over changing climatic conditions, to build plants with a flexible range of operating parameters. Sometimes it is possible to enter into hydrological or energy reserve exchanges with other plants or have coordinated basin-level operating plans. Flood mitigation is an important benefit from reservoir operation and needs to be used to mitigate flood risk both for the plant and for the surrounding communities.

The ultimate protection from the risk of inadequate hydrological flows is for the tariff to be based on plant availability rather than electricity production. This entails a government assuming the hydrological risk, usually through a government-owned transmission company. Governments tend to be understandably reluctant to do this, perhaps because they generally underestimate the cost they may be paying for *not* taking this risk. If developers are concerned about hydrological risk, they will aim to design a plant for a very conservative assessment of the available hydrology. As a result, there will be little possibility of 'up-side', ie increased production when more water is available. Incentivising developers to build more flexible plants will be in the long-term economic interest of the country as it will maximise electricity availability during periods of heavy rainfall. Alternatively, developers will negotiate a high tariff for the electricity they produce to give themselves a margin to cover any possible low hydrology years – leading to a high average tariff. Governments are finding ways to share the hydrological risk with developers through a combination of support, insurance and

MDB assistance. The discussion of hydrological risk sharing is extensively covered in Blomfield and Plummer Braeckman (2014).

Cost and schedule overruns are of concern to financiers, as they may negatively influenced the financial viability of a project or timing of returns in a way that affects the ability of the project to service its debt. Financiers expect to see developers taking all necessary precautions to minimise the risk of cost and schedule overruns, including enhanced supervision, rapid dispute resolution, commissioning of expert advice (such as through an expert panel), good quality preparation through the investigation and design phases, risk sharing with contractors (eg through engineering, procurement, construction (EPC)), and use of penalties, bonuses and insurance (Mubin et al, 2019; Plummer, 2013).

For debt financiers, the operations phase (which is the time during which operations and maintenance risks materialise) is of concern only in terms of ensuring the plant makes sufficient cash flow until the debt is repaid. For equity investors, on the other hand, the plant needs to make a profit to provide them with a return on investment. High-quality operations and maintenance needs to be ensured to maximise the efficiency of operations and the life of the plant. This quality of service can be ensured by contracting specialist operators. Where the operations team are less experienced it is important to have strong technical and commercial conditions of contract, but this needs to be supported with appropriate supervision, inspection and quality assurance measures. Emergency preparedness and consideration of the occurrence of extreme events is also key to ensuring that the disruption caused by such events will be swiftly managed and minimised (World Bank, 2020).

5.3 Environmental and social risks

There are several environmental and social issues that may derail a project's progress and cause significant delay to project commissioning. As a result, these issues can threaten a project's viability. In cost terms, the amounts required to implement the average environmental management plan are often not major. For example, the Environmental and Social project associated with the Nam Theun II hydropower project was $20 million compared with the total project cost of $1.6 billion (World Bank, 2018). However, the damage done to the project in terms of delay and the reputational risk to the financier may be significant.

For most projects there is either one environmental and social impact assessment or two separate assessments. These yield either a joint or two separate environmental and social management plans, which explain the projects' approach to the avoidance, management or mitigation of adverse impacts and to ensuring that the expected benefits are achieved. There is a range of risk management techniques which can be employed to minimise failure in this area. These techniques include heeding the right expert advice at the appropriate time; consultation with stakeholders; modifications to the project (location, design or operation); agreeing an approach to heritage assets; having a transparent compensation process; and development of plans to share benefits over the full life of the project. Issues such as public health and safety can be addressed by similarly consultative and communicative processes and by developing plans such as a safety management plan (Kirchherr et al, 2016b; Johansson & Kriström, 2011; Lerer & Scudder, 1999; Gracey & Verones, 2016; Bunea et al, 2010; HSAP, 2011).

5.4 Financial risks

While one would expect financial risks to be the focus of project financiers, in some ways these issues are less of a concern, because they involve challenges with which the financiers are most familiar. Financiers understand these risks better than the other three quadrants and often have a corporate approach to dealing with them, which does not need a bespoke agreement for each project.

Contractor performance – in terms of managing the contract and abiding by it – can be mitigated by ensuring that the contractor has experience of similarly sized projects, perhaps through technical pre-qualification. Using a standard form of contract with recognised terms and conditions can also reduce risk. Contractors can be requested to provide bonds or take out insurance as to their performance, and required to give relevant warranties and guarantees. Increasingly, large infrastructure projects use pre-determined dispute-resolution mechanisms to ensure that contract disagreements are resolved promptly (Delmon, 2017).

Cost escalation can be avoided or mitigated in a number of ways. First and foremost, many future problems can be avoided through good design, comprehensive pre-construction surveys and investigations, and supervision of project activities to ensure that lagging performance and delays are flagged up at an early stage before incurring substantial additional costs. In some cases, the entire cost and time risk is transferred to the contractor through an EPC contract. However, enforcing this risk transfer may be a difficult process for developers and host country governments, and in practice the risk transfer is never entirely complete (Head, 2000). Some cost increases can be hedged by advance purchase or other agreements, particularly for materials such as cement and steel. However, better estimation and planning for projects remains a vital risk-mitigation strategy (Awojobi & Jenkins, 2016).

The arrangement of the financing package is less of a risk to financiers as they are generally involved in this process. However, such packages may take some time to assemble, given the complexity of financing packages, especially under the PPP model (Plummer Braeckman et al, 2020). While the developer can require the contractors to arrange finance for their contracts, this approach runs the risk of the preferred contractor not being associated with the preferred financing package, compelling the parties to compromise (Head, 2008).

In order to complete a financing package, it may be necessary to seek a government guarantee or even an MDB guarantee. MDB involvement focuses on crowding in finance from other sources, as the level of scrutiny associated with MDB involvement lowers the project risk profile for other financiers. For a successful hydropower project, the length of time to repay debt tends to be more important than the interest rate on the debt, meaning that negotiating long tenors is more important than negotiating lower interest rates. However, many domestic financiers in LICs and L-MICs have constraints on the length of tenor that they can offer, although this can in some instances be overcome, as demonstrated by the Nachtigal project in Cameroon, where the local banks' constraint on tenor was overcome by building in the possibility of rolling over debt at the end of the initial tenor. While this may seem like a risk, the logic is that the initial tenor will take the project through construction, meaning that, when the project comes to seek the debt rollover, the local banks will be asked to lend to a project which is already in operation, and which is thus much less risky.

In general, refinancing has a crucial role for hydropower projects, given the different risk profiles of the construction and operation stages. Lenders who would not consider financing construction may well be content to finance the operation of a hydropower project. Subsequently, it may be possible to swap more expensive short-tenor debt for longer–tenor, cheaper debt after the construction is complete and a project is operational (Landry, 2015). Thus, refinancing is generally in the interests of all financiers, as it can improve the financial situation of the plant and ensure that lenders are repaid, while investors obtain a dividend. Building in the refinancing option and terms when the finance is first agreed makes later refinancing simpler.

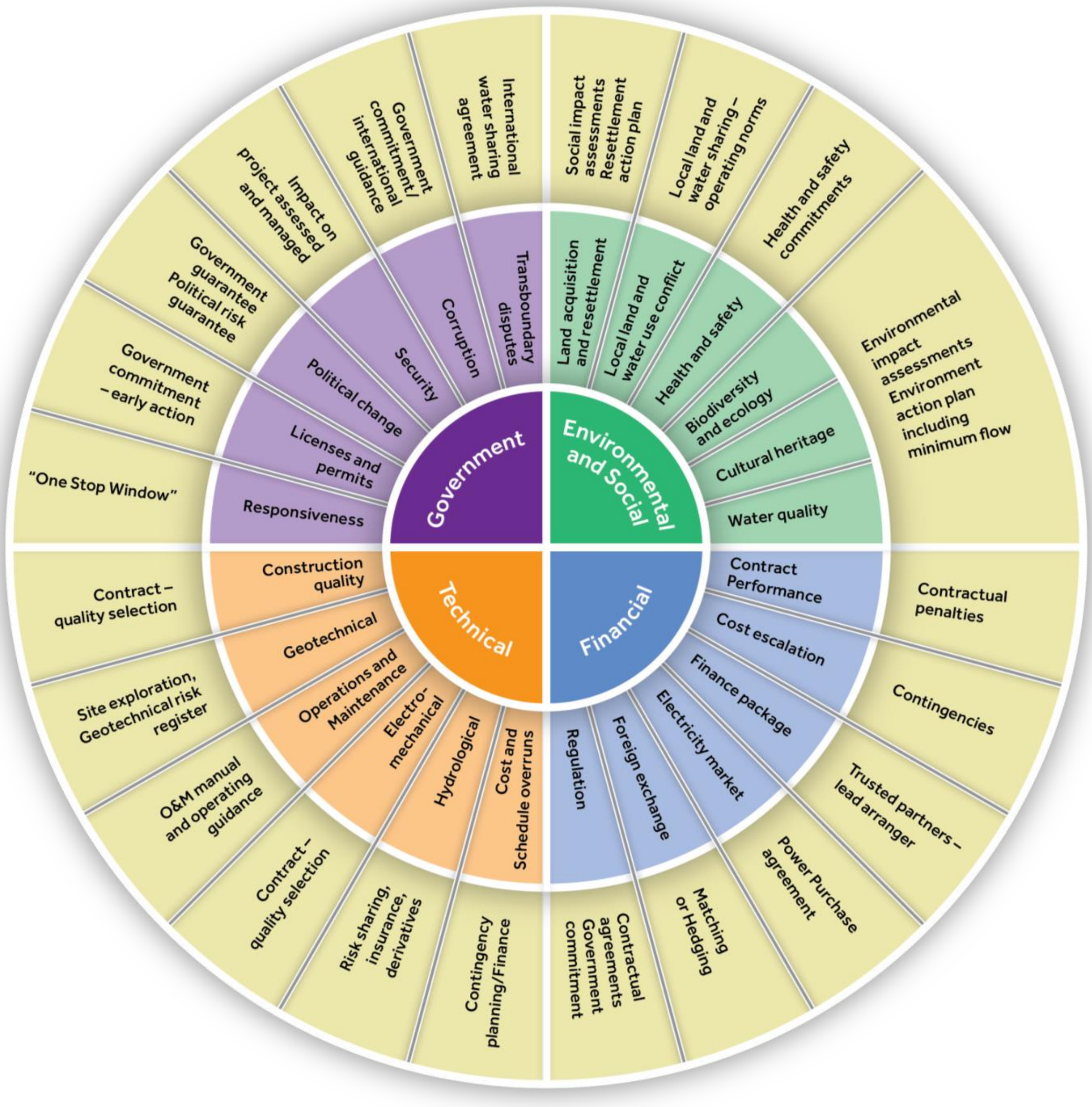
As a renewable source of electricity, hydropower is able to access some carbon or green finance funds such as the Global Environment Facility (GEF) and the Climate Investment Funds (CIFs) (Patel et al, 2020). However, these funds are generally small, and some preclude large hydropower. The possibility of hydropower being able to issue green bonds is the most significant source currently proposed in terms of green finance (Markkanen & Plummer Braeckman, 2019). Alternative structures such as Finance, Engineer, Lease and Transfer (FELT) have generated significant interest recently but have not yet been adopted at scale. The purpose of arrangements such as FELT would be to allow a public owner to separate the construction of the project from its operation, enabling the host country government to exercise greater control over the project while still making use of the skills of the private sector (McWilliams, 2014).

Electricity market risk can be mitigated with long-term electricity sales contracts or power purchase agreements (PPAs) which are, as far as possible, matched to the currency of the debt repayments. Detailed modelling can be instructive in this (Vardanyan & Hesamzadeh, 2017). A transparent and effective regulatory framework to approve price changes or a guaranteed rate of return on equity can reduce risk (Machado & Bhagwat, 2019), but ultimately most financiers require a government guarantee for public sector off-taker payments in LICs and L-MICs, sometimes backed up by an MDB guarantee.

In addition to the matching of revenues to payments, foreign exchange risk can be mitigated by financial hedging through forward contracts, futures, options and swaps. However, few LICs and L-MICs have the depth of financial market to allow such instruments and, where they do, such support is expensive and short-term. Thus, some governments try to transfer foreign exchange risk to the contractor, effectively asking the contractor to provide the government with currency risk insurance. Contractors will, however, most probably require significant extra payments for accepting a currency exchange risk that they have no way of mitigating (Plummer Braeckman et al, 2019; Head, 2000).

All financial risks are subject to the strength of the host country regulations. Investors will want to be sure that the regulatory environment for such issues as setting the electricity generation tariff and use of water resources will not change materially and affect the viability of their project. A track record of strong and stable regulation can do much to reduce this risk but, where uncertainty persists, a government may have to agree to contractual terms being used to secure these issues – effectively securing the project from regulatory change. A government commitment or guarantee, or even an MDB guarantee, may be needed to give investors confidence on this issue (Huenteler et al, 2017; Barnes & Toman, 2006).

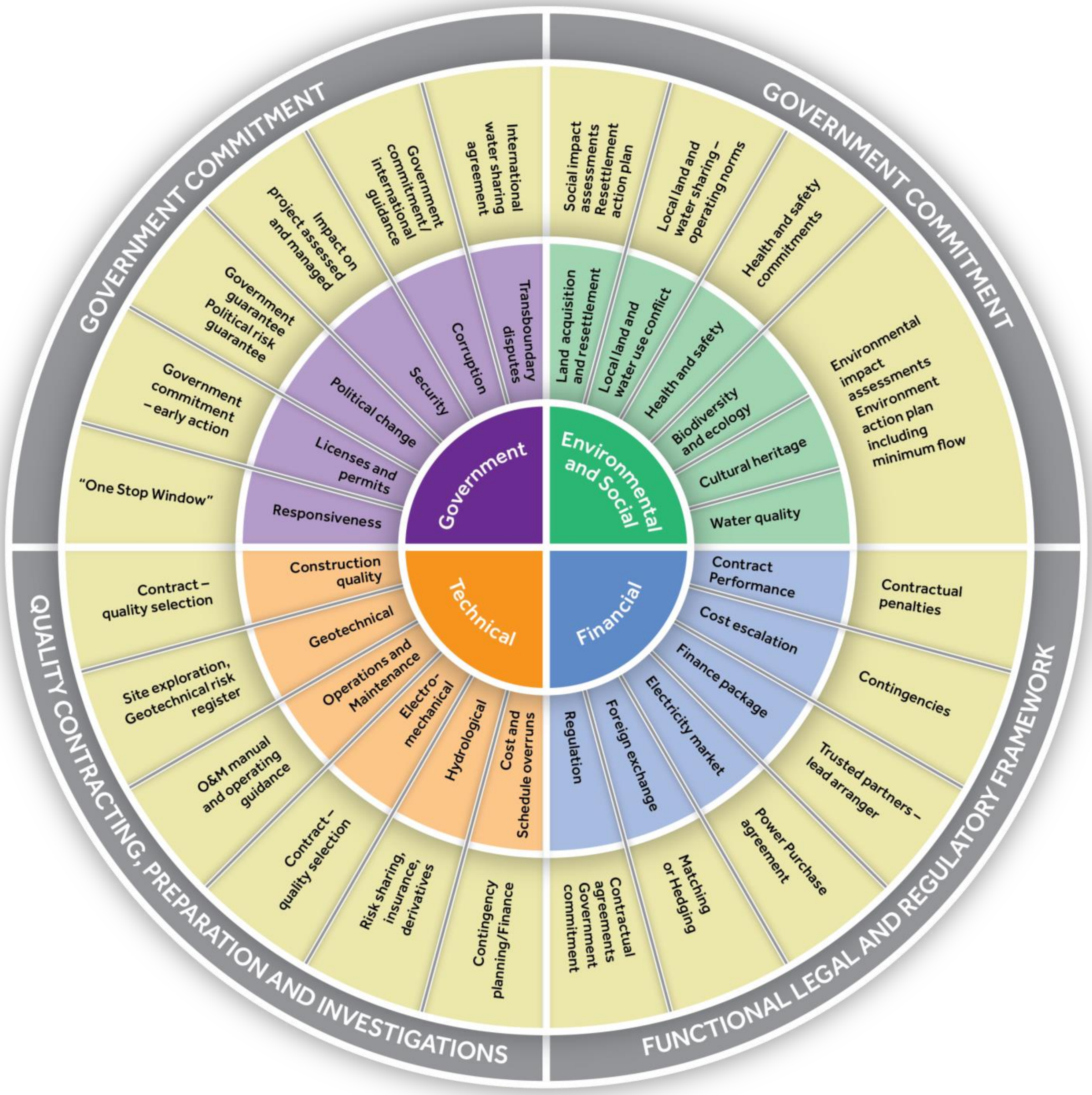
Figure 4: Conceptual analytical framework showing mitigation for risk in large hydropower projects



In addition to the individual measures outlined above, there are measures which can be seen as sectoral, and which can be used to lower the overall risk of a certain quadrant, as shown in Figure 5. For example, for the quadrants in the top half of the risk circle (government risk, environmental and social risks), a formal government commitment to facilitate the project can be seen as reassuring by financiers and investors. For financial risk, a government guarantee and support for a strong regulatory framework can lower the level of multiple risks, whereas, for technical risk, good quality contracting, investigations and studies are crucial. However, in some cases government commitments and guarantees will not be seen as sufficiently secure, and it may be necessary to take external guarantees from MDBs to back up the sovereign guarantees.

A key part of the risk management strategy for a project from a financier's point of view is the financier's own corporate approach to risk. Spreading and balancing their portfolios across a diverse range of geographical and sectoral contexts is key to financiers' internal risk management.

Figure 5: Sector wide mitigation



Overall, there are many similarities in the way in which financiers and other stakeholders perceive risk (for more on these different perspectives, see Plummer & Guthrie, 2016). However, debt financiers only concern themselves with the longevity of the project to the extent that their debt remains unpaid, whereas equity investors may take a longer-term view.

The analysis suffers from the limitations of all such generalisations. Individual hydropower projects are unique to their geographical location and there will be projects which have significantly more risk in some areas than others. As such the analytical framework cannot be typical but aims to be broadly representative.

6 Credit/market risk or business risk

The next step in the development of the framework was to consider the extent to which each of these risks constitutes a credit, market or business risk. Reviewing the original surveys used as a basis for the development of the framework (Plummer, 2014), it appeared that the classification of type of risk was largely a matter of degree. Some events may, at first, create a business risk, particularly a reputational risk, whereas for other risks there is an immediate credit or investment concern. Ultimately, all risks can become a credit risk to lenders, or a market risk to investors, if severe. In general, the technical and financial risks were more likely to constitute a credit/market risk to the financier, whereas many of the government, environmental and social risks might initially be regarded as business risks and only become credit risks if they begin to affect the product delivery timetable. Thus, for example, the failure to protect a local temple is initially a business risk, as it is an action with which the financier does not wish to be associated. However, if this leads to a work stoppage on the project, then it may also become a credit/market risk. Similarly, if a project is involved in a corruption scandal, this can present a business risk to the financier as a reputational issue but, if it means that a contractor is removed from the project, it may cause delay and create a credit/market risk. Conversely, a technical risk that materialises, such as a tunnel boring machine getting stuck, contributes a limited business risk but a significant credit/market risk. While there are variations in this typology, it can be generalised as shown in Figure 6. As the risk continues to develop, more and more risks fall into the category of credit/market risks.

Figure 6: Risk categorisation

7 Conclusions

It is vital to the ongoing finance of infrastructure development that all parties understand the financier’s view of risk in order to maximise the likelihood of a project receiving finance. This paper goes someway to enhancing that understanding, by focusing solely on the financier’s perspective on risk.

The analytical framework presented in this paper suggests that LIC and L-MIC governments could benefit from adopting a more transparent approach to project risk assessment, and by involving potential debt and equity financiers in these discussions. Attempts to oblige stakeholders to take on a risk that they do not understand and cannot bear are counterproductive, especially for large hydropower projects where the sums involved are so high that one single financial risk may be sufficient to bankrupt a contractor. Thus, by trying to pass on more risk on to the contractor than they can bear, the government is exposing itself to the risk that the contractor will go bankrupt, creating delays and costs overruns for the project, not to mention the possibility of prolonged (and often costly) litigation. Rather than trying to divert risks on to other stakeholders without considering the cost implications, governments would be better served by agreeing risk-sharing mechanisms so that no stakeholder is over-exposed to risks they cannot manage.

For equity investors, the main objective of risk assessment should be to identify and mitigate risks as far as possible, while also considering the extent of business and market exposure they can absorb. Some equity investors may have a considerable appetite for technical risk, as they feel able to utilise their technical expertise to profit from accepting and managing such risks. Others may have, say, industrial assets within the host country that would provide a market for electricity if the off-taker defaults, limiting the impact of electricity market risk. Thus, the impact of risk has to be analysed from the point of view of each investor individually, as well as from that of all the investors together.

For debt financiers of large infrastructure projects, the consideration of risk must go far beyond the basic assessment of the likely debt service coverage ratio. The list of risks discussed in this paper is extensive and difficult for any financier to assess. In some cases, financiers may use corporate approaches, such as limiting their operations to countries where they already have a good understanding of the environment, to reduce the risk of unexpected government risks materialising. Government risk is naturally easier to assess in a familiar country context but, by restricting their operations in this way, financiers may miss opportunities for a good return in unfamiliar countries. Financiers' tendency to avoid unfamiliar markets also means that LICs and L-MICs that have struggled to attract private sector investment so far will be at risk of continued disadvantage arising from their inability to finance the development of essential infrastructure.

MDBs may consider carrying out this risk analysis in their role as broker between the financing entities and the project; they can provide support such as seed finance or guarantees where necessary. In some cases, MDBs make available support which is only triggered in the event of a risk materialising, such as through contingent finance. MDBs already carry out significant risk analysis, but it may be necessary to tailor this analysis to the point of view of specific types of investor and lender.

The analysis presented in this paper raises the question as to which of the many risks identified is the most important for financiers and why. The authors have addressed this by carrying out roundtable discussions with various finance organisations and experienced professionals, alongside a survey to better understand the factors that influence financing decisions in regard to renewable energy infrastructure projects, with a focus on hydropower. The results will be discussed in more detail in reference to large hydropower projects in Sub-Saharan Africa in our next paper.

Appendix A: Summary of risks and mitigations from financiers' perspective

Risk type	Description	Likely mitigation	References
Government risks			
Political change	Risk to project caused by local or national changes in government and/or legislation which cause concern as to the long-term stability of agreements such as concessions and fiscal environment such as tax regimes or, in the extreme, nationalisation of private assets. Also political unrest has knock-on effects on government response times	Special legislation Sovereign guarantees Political risk guarantees Strong regulatory frameworks/markets for financial transactions	Head (2000) References tend to be country- or region-specific. See, for example, Matthews and Geheb (2014)
Licences and permits	Complexity of obtaining the necessary licences and permits from various government and regulatory agencies	'Single window' government coordination of all relations with the project	World Bank 2008
Government response time	The ability of government and public sector agencies to respond in a timely manner in terms of issuance of licences and approvals or other coordination with the project without causing the project unnecessary and expensive delays. This can be an issue of capacity or may be linked to other risks, such as corruption	Enact new legislation before moving project forward (rather than during preparation) Sovereign guarantees Political risk guarantees 'Single window' government coordination of all relations with the project Stable regulatory framework Government equity share	Plummer (2014)
Security	Hydropower projects are often, by their nature, built in remote areas where sufficient water and natural head can be found without disturbing large existing settlements. These sites are sometimes near borders or in areas where local law and order are not well enforced	Treaties and agreements Water/watershed management plans Benefits-sharing agreements Co-development or co-ownership of project Government commitment to providing protection and enforcing law and order	World Bank (2009) References tend to be country- or region-specific. See, for example, Ito et al (2016)
Corruption	Risk to project implementation or developer reputation caused by corruption issues. Contractors may be reluctant to bid or even constrained from bidding by their local corruption prevention laws. Large water infrastructure projects are known for significant risk of	Expert advice Anti-corruption policy Vet contractors Transparent practices for tendering, management and business	Haas (2008) Sohail and Cavill (2007) WCD (2000)

Risk type	Description	Likely mitigation	References
	corruption, but may also be projects superimposed on a system which is already corrupt	Third-party monitoring	
Trans-boundary disputes	Upstream and downstream riparian rights and treaties may constrain or support hydropower development. The absence of agreement on water sharing can pose a risk to long-term hydropower operations	Treaties and agreements Water/watershed management plans Benefits-sharing agreements Co-development or co-ownership of project	Wolf (2007) Bakker (1999) Salman (2008)
Financial risks			Kovacevic et al (2013)
Contract performance	Performance of contractor in complying with the terms of the contract. Different from technical risk, this is the risk of legal costs of pursuing failure to adhere to contract terms	Prequalification Contract terms and conditions Bonding and insurance Warranties and guarantees Dispute-resolution mechanism	Delmon (2017)
Cost escalation	Inflation, commodity price changes, competition for resources and other local and international cost effects. Combined with this is the risk that costs are not well enough investigated and forecast before the decision to proceed	Enhanced supervision of project activities Mitigate risk through engineering (enhanced investigation and design) Transfer risk through contracting methodology (eg fixed-price EPC) Hedging against future increases in price of steel, cement or other commodities Transfer risk through bonding or insurance Penalty/bonus incentive scheme Robust design which is less sensitive to change	Head (2000) Awojobi and Jenkins (2016)
Financing package	Availability, tenure and conditions precedent for debt, equity and other financing instruments	Require contractors to arrange finance Invite additional public equity and debt Use sovereign guarantees Lower overall project risk profile Build in re-finance option Involve IFIs to encourage further private equity and debt Lower debt interest rate and longer	Head (2008) Patel et al (2020) Plummer Braeckman and Markkanen (2020) McWiliams (2017)

Risk type	Description	Likely mitigation	References
		repayment period Apply for carbon/green finance Alternative structures such as FELT	
Electricity market	Changes in the price of electricity for merchant plants or changes in the agreed regulatory mechanism for setting price Off-take risk - encompassing payment risk and enforcement of contractual off-take obligations	Long-term electricity sales contracts Financial hedging (eg forward contracts, futures, options, swaps) Use of regulatory mechanisms for price increment Public utility rate base with guaranteed rate of return on equity Government guarantee for public sector off-taker payments	Vardanyan and Hesamzadeh (2017) Machado and Bhagwat (2019)
Foreign exchange	Changes in relative exchange rates between currencies in use for the project, particularly between main currency for 'cost' and main currency for 'revenue'. Also encompasses issues with the transfer of revenues to international financiers from the host country	Expert advice Transfer risk to contractor Natural hedging (matching currencies of revenues and costs) Financial hedging (eg forward contracts, futures, options, swaps)	Plummer Braeckman et al (2019) Head (2000)
Regulation	Risk that the regulatory regime will change adversely, affecting issues such as the tariff or water sharing	Track record of governance Contractual projection from changes in regulation Government guarantee MDB guarantee	Huenteler et al (2017) Barnes and Toman (2006)
Technical risks			
Construction and installation quality	Construction and installation quality is an issue for any large infrastructure project Lack of experience of hydropower as countries may engage in few projects and international expertise is expensive	Technical and commercial terms and conditions of contract Supervision, inspection and quality assurance measures Preferred contractors Penalty/bonus incentives Rely on guarantees/warranties	Schleiss and Boes (2011)

Risk type	Description	Likely mitigation	References
Geotechnical–seismic	The risk associated with insufficient knowledge regarding the geotechnical characteristics of the project site	Investigations (feasibility or design stages) Relocate power house to over ground Special design or relocation of structures to avoid damage Redesign or relocation of project to mitigate consequences of damage Geotechnical baseline report/risk register Balance risk/cost, eg drill and blast method with tunnel boring machine	Hoek and Palmieri (1998) Palmieri (2015) McWilliams (2014)
Operation and maintenance	Operation and maintenance quality	Technical and commercial terms and conditions of contract Supervision, inspection and quality assurance measures Design for a higher occurrence of extreme events Contract for operations and maintenance	World Bank (2020)
Electro-mechanical	Selection of the best equipment and operating regime for the plant, particularly given the possible changes in operating regime necessitated by future energy scenarios	Technical and commercial terms and conditions of contract Supervision, inspection and quality assurance measures Preferred suppliers Physical model testing Shop inspections Reliability tests Penalty/bonus incentives Rely on guarantees and warranties	Yasuda and Watanabe (2017) Yildiz and Vrugt (2019) Sarzaeim et al (2018)
Hydrological	Operational or construction-related risk of lower than expected flows, floods or unusual seasonal variations	Investigations (feasibility or design stages) Construct diversions or storage reservoirs to supplement river discharge Modify project design or operation Allow contingency margin for project output Hydrological or energy reserve exchanges with other hydropower facilities	Blomfield and Plummer Braeckman (2014)

Risk type	Description	Likely mitigation	References
		Flood mitigation part of emergency/contingency planning Negotiate with other water users Government takes risk and thus 'shares' risk across several projects in different locations	
Cost and schedule overruns	Risk of higher costs and delayed benefits as a result of cost and schedule overruns caused by poor project management or lack of preparation	Enhanced supervision of project activities, including rapid dispute-resolution mechanisms Expert advice/review of project schedule Mitigate risk through enhanced engineering (investigation and design) Transfer risk through contracting methodology (eg EPC) Transfer risk through bonding or insurance Penalty/bonus incentive scheme	Plummer Braeckman et al (2019) Awojobi and Jenkins (2016) Plummer (2014) Mubin et al (2019) Plummer (2013a and 2013b)
Environmental and social risks			HSAP (2011) WCD (2000)
Land acquisition and resettlement	Local concerns over resettlement or other issues such as employment and compensation	Modify project (eg location or design) Modify project operation Agreement with stakeholders Benefit sharing	Kirchherr et al (2016a) WCD (2000) Kirchherr et al (2016b) Cisse et al 2013
Land and water use Conflicts	Issues raised by local water users or downstream riparians on sharing of water or catchment use	Modify project (eg location or design) Modify project operation Formal agreement with stakeholders	Johansson and Kriström (2011)
Public health and	Issues of physical safety as well as spread of disease	Safety management plan	Lerer and Scudder (1999)

Risk type	Description	Likely mitigation	References
safety	during all phases of the project	Modify project (eg location or design) Modify project operation Agreement with stakeholders Communication	
Biodiversity and ecology	Impact of the project on biodiversity and ecology	Include in environmental management plan Modify project (eg location or design) Modify operation Compensate for impacts Pest management Manage/compensate impacts on fisheries/wetlands, etc	Gracey and Verones (2016)
Cultural heritage	Preservation or protection of culturally or historically significant sites or artefacts	Modify project (e.g. location or design) Modify project operation Specific pre-project activity to investigate or preserve Agreement with stakeholders	WCD (2000)
Water quality	Impact of the project on water quality downstream	Include in environmental management plan Modify project (eg location or design) Modify project operation Compensate for impacts	Bunea et al (2010)

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