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PAPER

Financiers' perceptions of risk in relation to large hydropower projects

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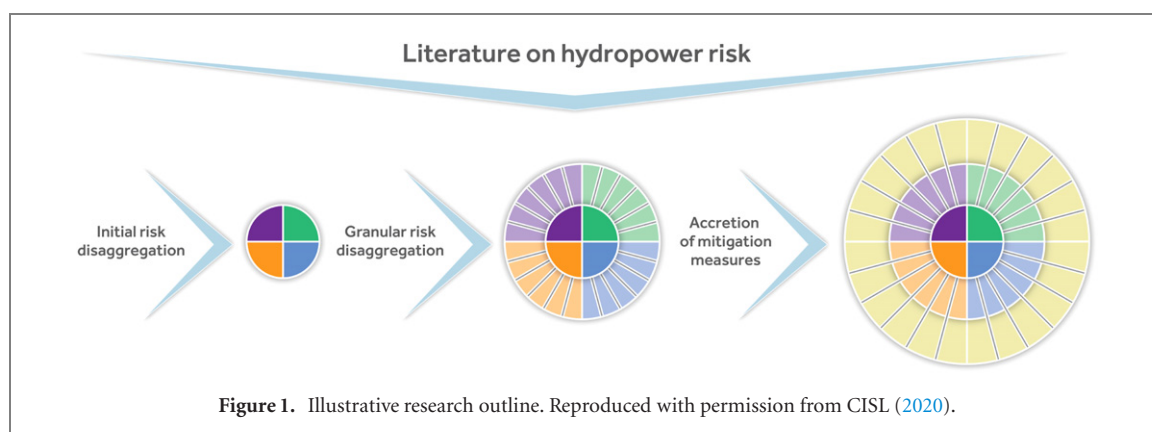
Abstract

More renewable electricity generation capacity will be needed to support progress towards Sustainable Development Goals and the Paris Agreement objective in lower income and lower-middle income countries (LICs and L-MICs). In the context of declining availability of public sector finance for energy generation, there is a widespread expectation that much of the new generation capacity will need to be financed entirely by the private sector or through public-private-partnerships (PPPs). Sustainably developed large hydropower could play a vital role in a future electricity mix dominated by intermittent renewables. In addition to generating low-cost, low-carbon electricity at a large scale, hydropower is capable of delivering ancillary services that are needed to facilitate greater penetration of intermittent renewable electricity. However, concerns over social and environmental outcomes, uncertain financial returns and thus a widespread perception of large hydropower as a 'high risk' investment has so far made it difficult to attract private sector investment for such projects, especially in many 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. The findings suggest that many of the greatest risks associated with large PPP hydropower projects in LICs and L-MICs are those that can cause reputational damage to the involved parties, such as social and environmental risks. The results presented in this paper will enable governments and developers to take targeted action to reduce risk and thus facilitate more effective use of the PPP financing model for large renewable energy infrastructure projects in LICs and L-MICs where additional large-scale sustainable electricity generation capacity is most needed.

1. Introduction

Large hydropower projects can have multiple benefits. In addition to providing a large-scale, stable and cost-effective electricity supply, hydropower 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 and IRENA 2015). Sustainably developed hydropower can support electrification in countries still struggling to reach full electricity access, and it has the advantage that long-term electricity prices from hydropower are not subject to the fuel-price risk endemic in thermal generation.

However, 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 low-income countries (LICs) and lower-middle-income countries (L-MICs) with low electricity access rates or insufficient generation capacity to meet rapidly growing demand (Plummer Braeckman *et al* 2020). Although some of these risks are linked to weak governance structures and inadequate regulations



in LICs and L-MICs, and thus apply to all large infrastructure projects in these countries (Miller and Lessard 2001, Bosch-Rekvelde *et al* 2011, Skinner and Plummer Braeckman 2018), others are particular to hydropower and not experienced to the same extent by other forms of generation Gjermundsen and Jenssen (2001).

Owing to the combination of high upfront costs and 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 cost¹. 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. This can give the impression that finance is delaying a project—when financiers are simply drawing attention to inadequate preparation, for example, in the form of a lack of attention to environmental and social risks.

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 LICs and L-MICs². Such a framework will enable both governments and financiers to identify, manage and mitigate risk and thus enhance the likelihood of successfully financing projects. 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. Methods

The main objective of this paper is to develop an analytical conceptual framework for identifying and understanding the risks³ 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 of risk in construction and a further survey of members of the International Hydropower Association which considered risks at the earliest stages of project design and development (Plummer 2013b). This survey data were combined with a literature review to develop a draft conceptual framework (as shown in figure 1).

This framework was then subject to a round of discussion and a survey of finance and other professionals working in hydropower, to fine tune the final output. The discussion focus groups took place in London, Windhoek and Singapore between November 2018 and November 2019. In these discussions, the analytical framework for conceptualising risk was presented to the participants, who were then invited to discuss the content and structure of the framework and to suggest edits based on their perceptions, experiences and expectations of future developments that might affect the hydropower sector. The focus group participants were drawn from various professional groups, including lawyers, insurers, lenders, equity investors, development

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

³ 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).

banks and lenders' engineers. Each focus group discussion involved 10–15 participants from various backgrounds, all of whom had direct experience of large PPP-financed hydropower projects in LICs and L-MICs.

Detailed notes of these focus groups were subjected to thematic analysis following the approach detailed by Nowell *et al* (2017) to ensure the trustworthiness of the data collection and analysis. Thematic analysis was regarded as the most appropriate method of analysis given the flexibility it provides in identifying, describing, and reporting and comparing the perspectives of different research participants, and generating unanticipated insights. The analysis was carried out by the same researchers responsible for the qualitative data collection and who thus attended all three focus group sessions.

Following the first two focus groups, and in the light of the preliminary findings, a survey was designed to enable remote participation in the research and to allow individuals to share their views anonymously. The survey, entitled 'financing renewable energy infrastructure—focus on hydropower', was publicly accessible online in Qualtrics from 25 August 2019 to 15 April 2020. During this time, it was promoted at various events at which the researchers were speaking. The inability of the research team to attend the events planned for the first half of 2020 because of the pandemic may have had a negative impact on the number of responses.

The main objective of the survey was to help us understand how financiers make decisions on renewable energy infrastructure projects, with a particular focus on hydropower. It contained six main question blocks, with skip logic being used to ensure that questions only appeared to those respondents to whom they were relevant. The survey attracted 36 full responses, 14 of which came from financiers including multi-lateral and bilateral development banks, investment and commercial banks, financial advisers and equity investors. Almost all these financiers were involved in financing initiatives in LIC and LMICs.

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.

3. Understanding risk to financiers associated with large hydropower projects

3.1. Risks specific to large hydropower projects

Some of the characteristics of large hydropower projects expose them to a set of risks that are less prevalent for other infrastructure projects (Gjermundsen and Jenssen 2001). 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 *et al* 2009).

The complexity of large hydropower projects makes them particularly susceptible to risk and, for larger projects, risks follow an exponential track (Savino 2011). Such projects are also known to suffer from turbulence, i.e. to be subject to change and unexpected circumstances (Florice and Miller 2001). Indeed, many of the risks associated with large hydropower projects are unforeseen, and 'burst out as the projects are being shaped and built' (Miller and Lessard 2001, p 22).

Large hydropower projects are extremely capital-intensive and site-specific, with a long preparation phase and lengthy construction period. Each site has a set of unique geographic, geological, hydrological and economic characteristics, meaning that each large hydropower project requires bespoke design. Most of the unexploited sites suitable for large hydropower tend to be in inaccessible locations, often in countries that have a country risk (such as political or security risk), and in areas that have a challenging physical environment and geology (Candee and Larson 2013).

Large hydropower projects also carry considerable environmental risks or social impacts, and a typical project lifespan of more than 50 years means that long-term profitability of the project needs to be considered at the planning stage. 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 and Larson 2013, Harrison *et al* 2003, Ray *et al* 2018).

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.

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, although some (such as hydrological risk), remain.

The early planning and construction stages of large hydropower project can last around six to eight years or even longer, reducing the relative appeal of these projects to private sector financiers (McWilliams and Grant 2008). 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 also been directed to social and environmental impacts, which constitute a serious risk if not adequately assessed and 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 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 and 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).















In addition to the HSAP, there are a range of other tools available for the analysis of risk or outcome in hydropower projects including the Hydropower Sustainability ESG Gap Analysis Tool⁴, the World Bank's Decision Tree Framework for climate risk⁵, Hydropower Sector Climate Resilience Guide. These tools tend to be either outcome focussed or concentrate on a particular aspect of risk as shown in table 1. An outcome focus is hugely valuable to some stakeholders such as the developer or the government, but financiers are more focussed on risk. Thus, this analysis provides a different perspective, but can be used in combination with other tools. Broader infrastructure risk management approaches such as the McKinsey 'risk management approach to a successful infrastructure project'⁶ are directed at internal risk management by project managers and, while they provide information to financiers the approach has a more inward focus. Specific tools which target a particular type of risk may be useful either to assess the risk or to assist in the development of a mitigation strategy. For example a geo-technical risk register is useful to document the geotechnical risk and communicate the risk allocation to various stakeholders. Similarly economic techniques such as contingent valuation may be necessary in developing environmental compensation schemes (Hausman 1993).

⁴ <https://hydropower.org/publications/hydropower-sustainability-esg-gap-analysis-tool>

⁵ https://elibrary.worldbank.org/doi/10.1596/978-1-4648-0477-9_ch3

⁶ <https://mckinsey.com/business-functions/operations/our-insights/a-risk-management-approach-to-a-successful-infrastructure-project>

Table 1. Interaction of new framework with existing tools.

| | Hydropower sustainability assessment protocol | Hydropower sustainability ESG gap analysis | World Bank's Decision Tree Framework for climate risk | IHA climate resilience guide | New analytical framework for risk in large hydropower |
|--------------------------------|---|---|---|---|---|
| Outcome focus |  |  | |  | |
| Risk focus | | |  |  |  |
| -Financial risk | | | | |  |
| -Technical risk | | |  |  |  |
| -Government risk | | | | |  |
| -Environmental and social risk | |  |  | |  |

3.2. 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, p 7). Legal risk is the risk of significant legal consequences that flow from actions attributable to business (Moorhead and 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).

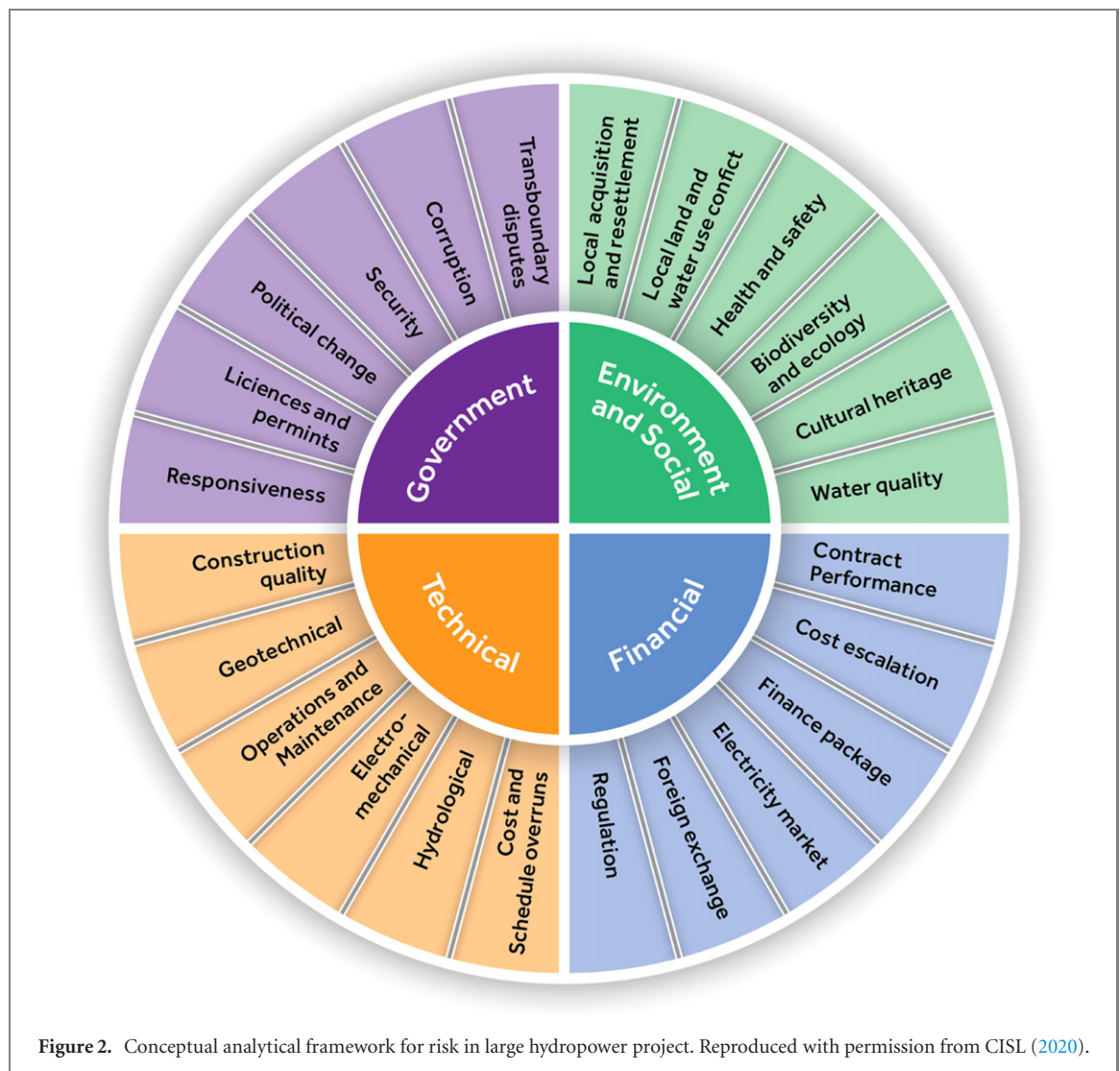
For simplicity in this research, ‘business risk’ and ‘operational risk’ are combined into one category, labelled ‘business risk’. Rapidly changing societal views of corporate behaviour relating to many environmental sources of risk mean that financial institutions often highlight reputational risk as 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.

3.3. 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, Dysert 2007), which illustrates how the accuracy of the cost estimate improves from $\pm 50\%$ at the concept phase to $+30\%/-15\%$ by the point of commitment. Cost estimates are initially created from engineering design estimates and benchmarks. Over time, as the project is



investigated in more detail, the estimates are replaced with contract prices together with contingencies to reach a final cost estimate. However, there is still an element of risk associated with the estimate and cost overruns are not unusual on large infrastructure projects, 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.

4. Analytical framework for conceptualising risk from a financiers' perspective

Building on previous survey results (Plummer 2012), the present analysis identified four key 'categories' of risk which adequately reflect the types of risk relevant to large hydropower projects in LICs and L-MICs: environmental and social, technical, financial, and government (institutional) risks. 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 as shown in the centre of figure 2. 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 2, are listed below and summarised in appendix A. The impacts of these risks on financiers are summarised in table 2.

Table 2. Summary of risk impact on finance. Reproduced with permission from CISL (2020).

| Risk type | Credit risk to lenders/market risk to investors ^a | | | 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 | | • | | • |

^aNote: 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 and Plummer Braeckman 2019).

On discussion of the draft framework with financiers, most of the risks in the framework were verified with minor textual amendments. However, in the financial segment the focus group members were concerned that the term ‘electricity market risk’ was not sufficiently explicit to include the risk of non-payment. In the survey responses the risk of non-payment scored highly, showing this as a significant concern, warranting its inclusion into the risk framework as a separate category. However, market risk was also regarded as an important concern resulting in a decision to revise the risk framework to include both of these risks individually. Thus a seventh risk category was added to the financial segment ‘risk of non-payment by off-taker’. It was also agreed that there were broader sectoral risks which were not hydropower specific but which could affect a project and that this should be noted, so a central circle for sectoral risk was added.

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. 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. Environmental and social risks initially create a reputational risk which may later become a credit risk if they cause project delays. Financial risks are easier for financiers to understand but may cause significant cost and thus repayment uncertainty for the financier. The individual risks are summarised in table 2 and a description of each risk is provided in the supplemental information (<https://stacks.iop.org/ERIS/2/015006/mmedia>) and also detailed in appendix A.

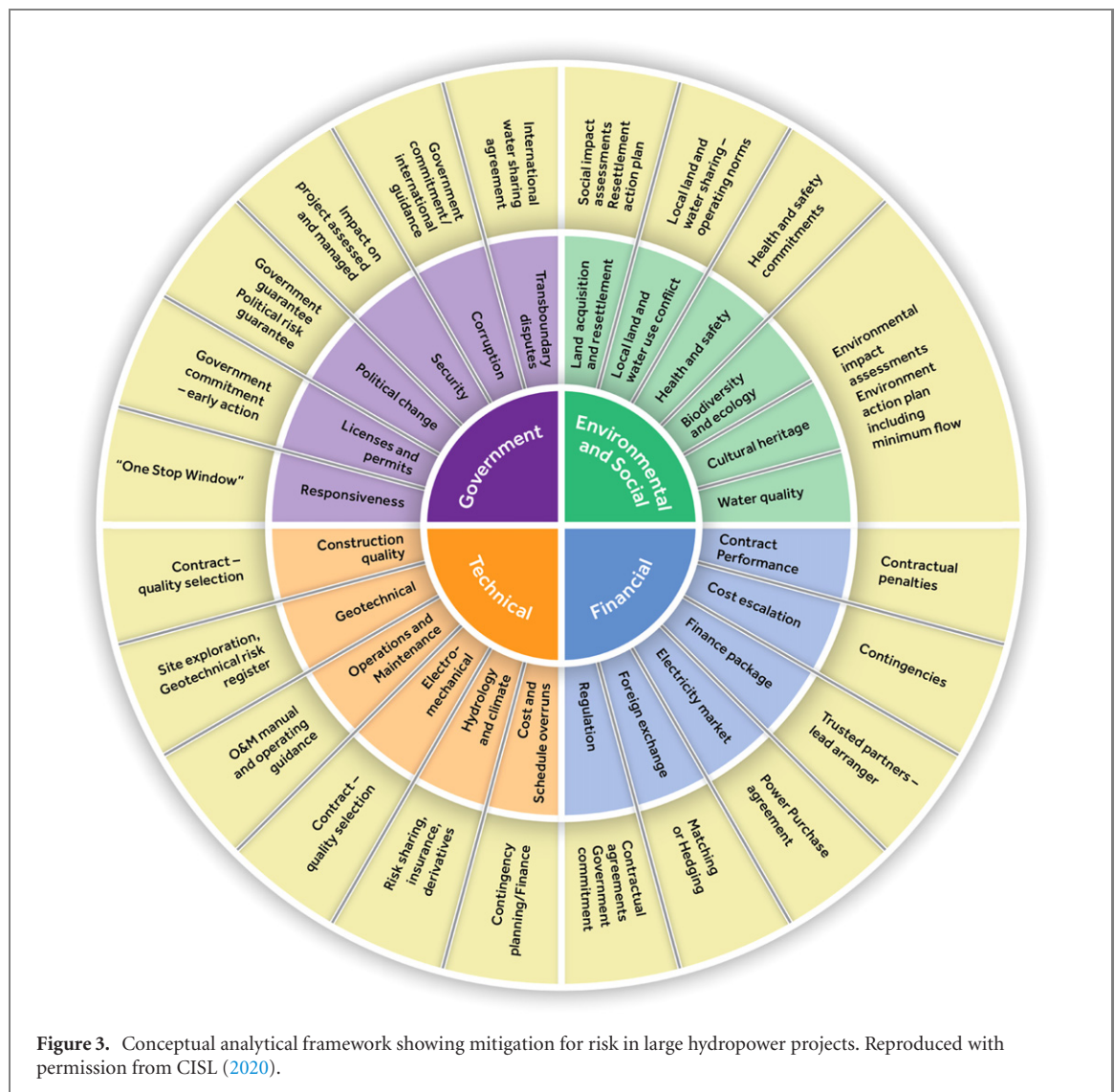


Figure 3. Conceptual analytical framework showing mitigation for risk in large hydropower projects. Reproduced with permission from CISL (2020).

5. Risk mitigation

For each of the risks included 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 3. The risk mitigations are described further in the supplementary material and appendix A.

In addition to the individual measures for each risk, 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 4. 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.

Overall, there are many similarities in the way in which financiers and other stakeholders perceive risk (for more on these different perspectives, see Plummer Braeckman and 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.

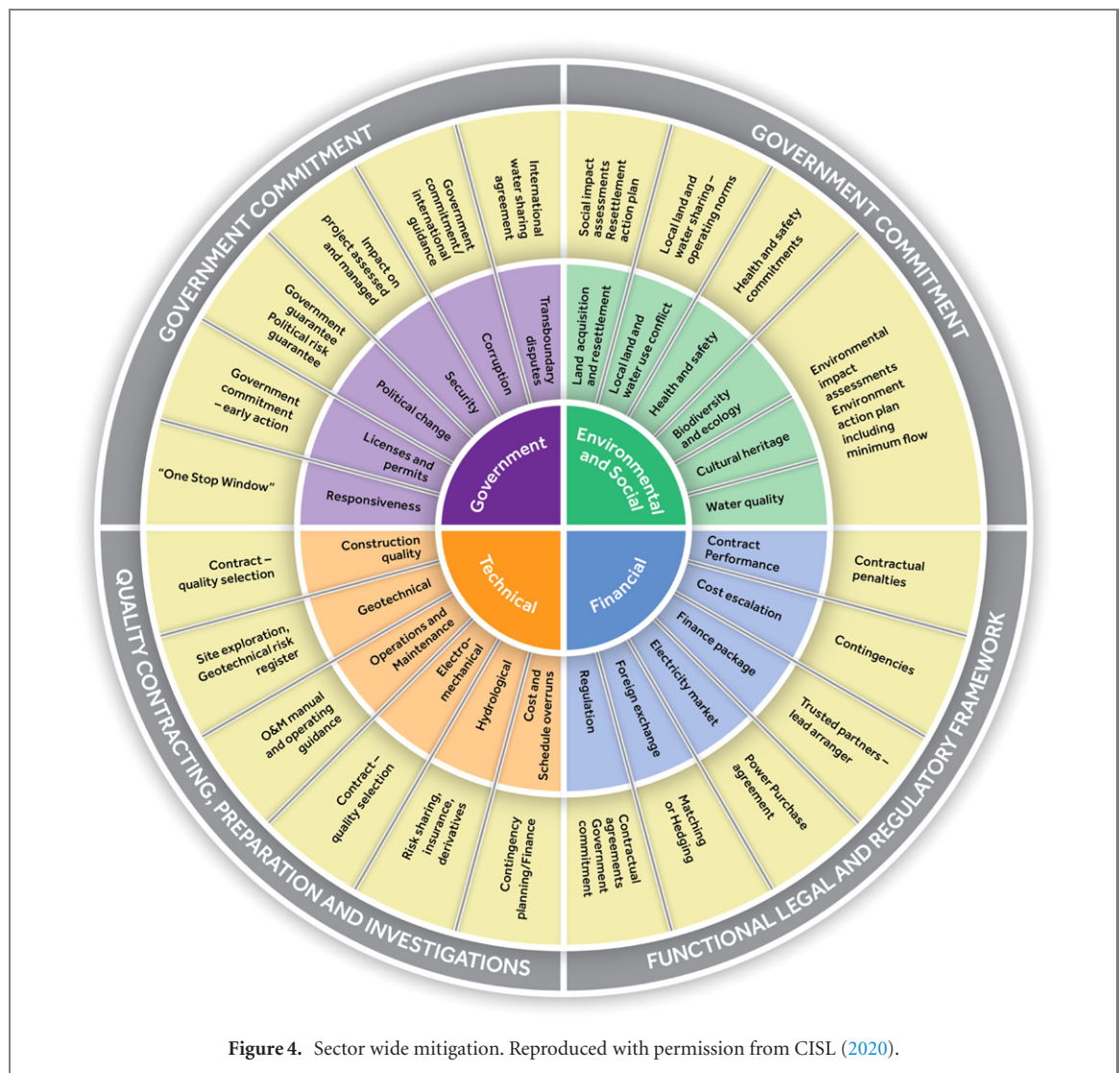


Figure 4. Sector wide mitigation. Reproduced with permission from CISL (2020).

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 2013a), 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 5. As the risk continues to develop, more and more risks fall into the category of credit/market risks.



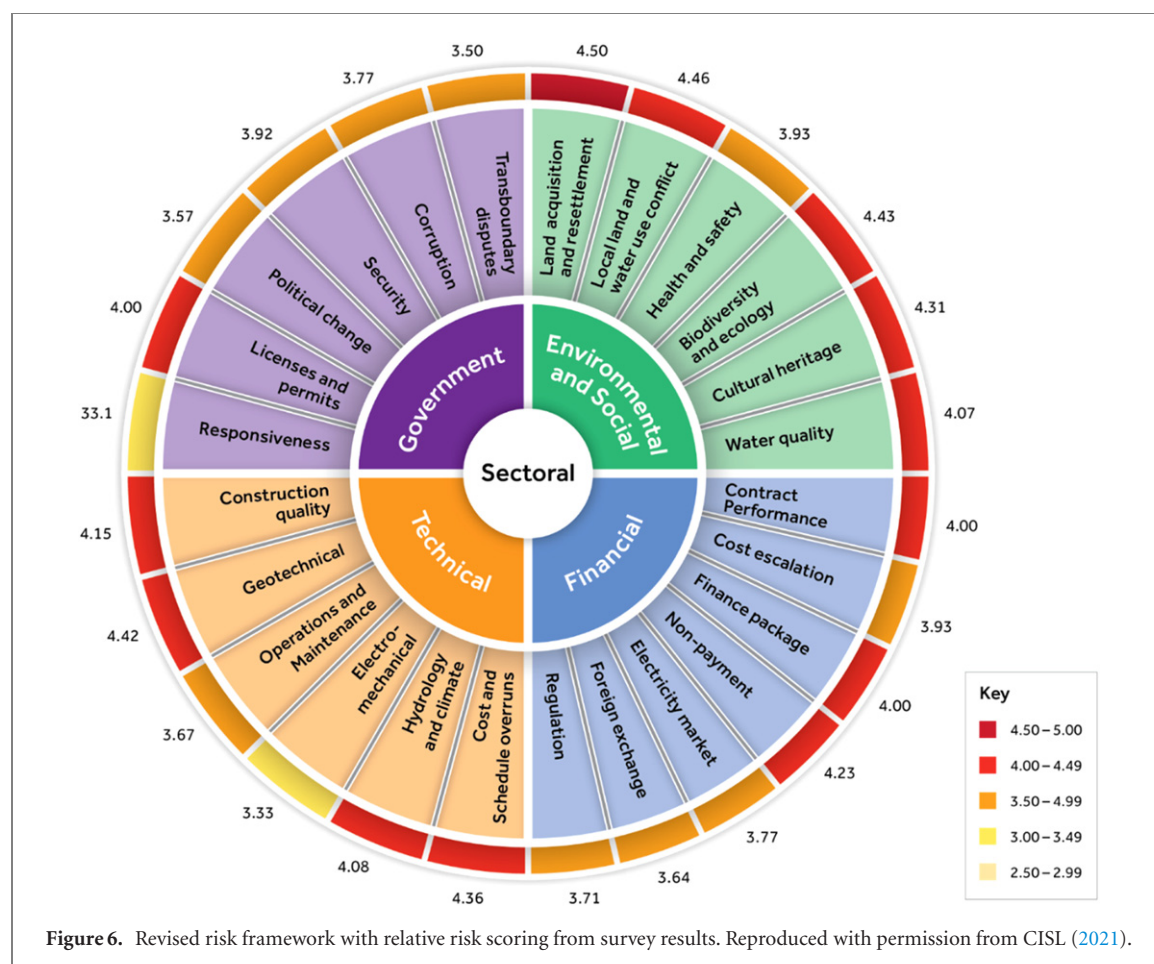
Figure 5. Risk categorisation. Reproduced with permission from CISL (2020).

7. How fit for purpose is the risk framework?

In order to validate the framework a survey of hydropower financiers was carried out. This was answered in detail by 14 financiers. They were asked to rank their concern about each risk using a Likert scale from 1 (not a concern) to 5 (very significant concern).

Most risks included in the framework were considered important by financiers as demonstrated by the overall average score of 3.9 across all four quadrants. The survey results validated the original perception from the focus groups, where all the risks included in the framework were regarded as relevant by the participants. All the risks were ranked as 'very significant' by at least one of the respondents. The environmental and social risks tended to have the most 'very significant' scores, particularly land and resettlement impacts, land and water use conflicts and negative impacts on biodiversity. Outside of the environment and social section the risk of highest concern was 'non-payment'. The largest range of scores were awarded for corruption and transboundary disputes. There was no significant difference between the responses from the private and public sector respondents. As a result of these scores a change to the risk framework was needed in that the financial risk category of 'non-payment' is separated from other market risks. Overall the process worked to validate the content of the framework as appropriate and sufficiently comprehensive. The risk framework, including the relative risk scoring from survey results, is shown in figure 6.

The visual presentation of risks in the framework was regarded by the focus group participants as a useful tool to facilitate the discussion of risks and risk mitigation mechanisms in terms of individual risks as well as 'categories' of risk, represented by the four quadrants of the framework. The framework was complemented for accurately reflecting the various risks in LICs and L-MICs, and drawing attention to risks that may constitute



less of a concern in more developed markets. For example, the ‘government’ quadrant of the framework may fade in importance in more developed countries, which tend to be more politically stable and arguably less prone to corruption. The presence of market mechanisms, strong institutions, reliable regulation and appropriate law enforcement mechanisms in more developed countries will also reduce many of the financial risks and social and environmental risks.

The framework was thought to provide a particularly helpful instrument for sharing information with new entrants to the hydropower sector, as it enables financiers to see how the risks associated with large hydropower may be different from what they expected based on their previous experience of solar PV or wind projects. Comments from the focus groups participants, such as the essential requirement for new entrants to the hydropower sector to understand the importance of government support, validates the need for this type of sector specific risk framework. It would be most useful in the planning or pre-construction stage of a project when developers are seeking finance to ensure there is a common understanding of the financial view of the project risk. It could also be useful in the case of refinancing decisions.

The combination of qualitative data from the focus groups and quantitative survey data allowed us to understand which risks are important to financiers and other actors, as well as how the various risks in the risk framework are interlinked—such as a government risk causing a non-payment risk. Understanding these interlinkages and how they arise is almost as important as descriptive detail of each risk and how it may be mitigated. The focus group discussions also revealed that the underlying reason *why* risks such as ‘corruption’ and various environmental and social risks are regarded as major concerns is because of the reputational risk that they present to the involved parties. The high level of concern over the reputational risk was confirmed by an additional question in the survey where respondents estimated their level of concern over reputational risk at an average of 71 out of 100 (median 76/100). Also, 85 per cent of the respondents agreed that hydropower presented a greater reputational risk than other renewable energy projects.

The focus group participants also identified some additional risks that are emerging or gaining more prominence in the context of climate change. These risks include both climate change itself and the impacts of climate

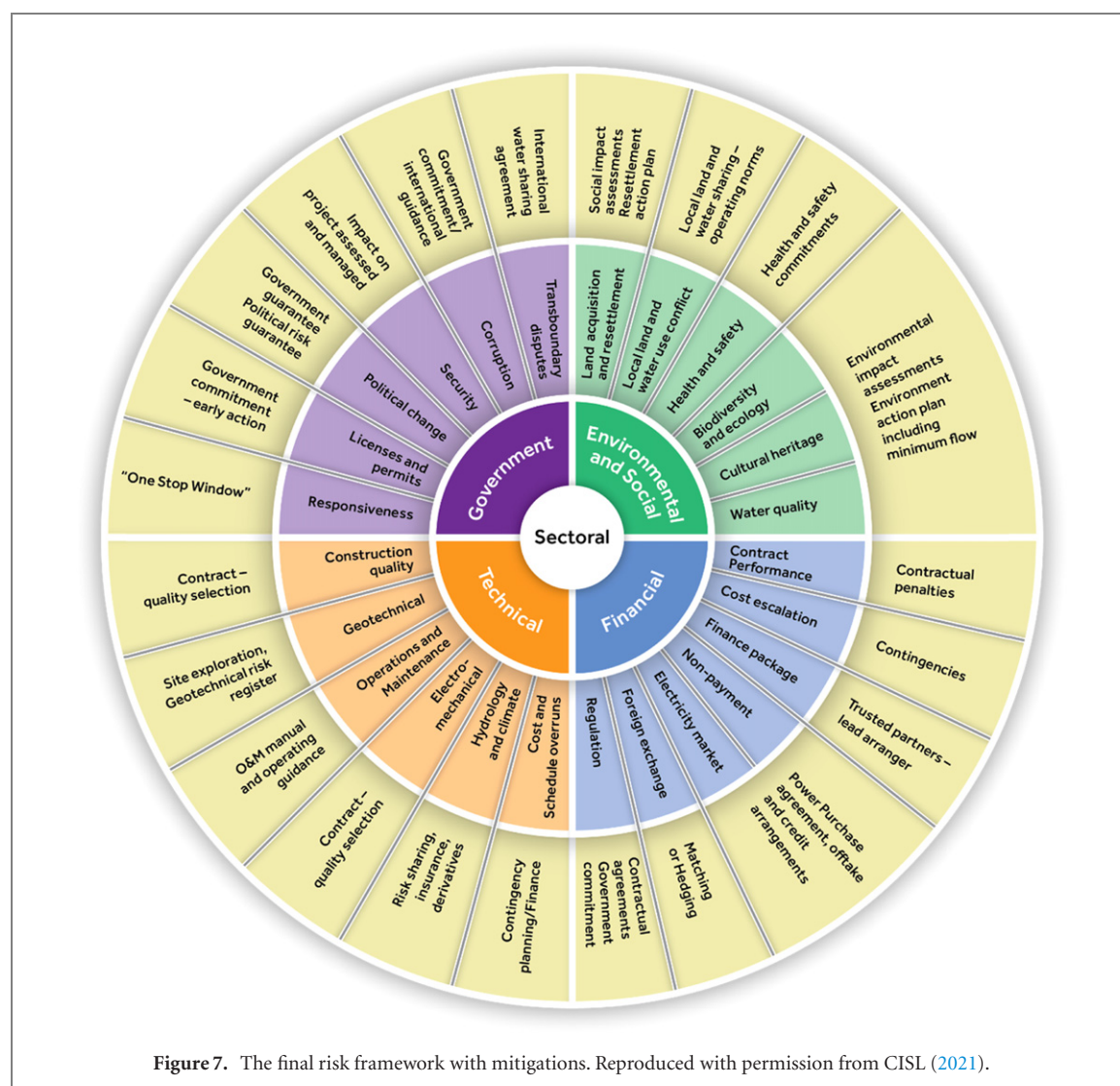


Figure 7. The final risk framework with mitigations. Reproduced with permission from CISL (2021).

change mitigation policies, in particular growing financial and political support (even preference) for intermittent renewables. However, climate change and greater inclusion of intermittent renewables are issues that will likely impact the entire energy landscape of a country and hydropower sector as a part of it, instead of presenting considerable risks to a specific project. While issues to do with climate change are certainly important to specific projects, these are primarily risks associated with hydrology, which is already included in the risk framework. To highlight the potential impacts that climate change mitigation policies may have on the broader hydropower sector (including regulation and new financing instruments to support and incentivise investment in intermittent renewable energy technologies), we considered adjusting the risk framework to include these broader contextual and sectoral factors. We also noted a reference to the importance of climate change adaptation, which the focus group participants felt may boost new interest in dam development. The various ways in which climate change, climate change mitigation policy and the need for climate change adaptation may affect the hydropower sector is a complex topic and will be addressed in a separate paper. In the meantime, the need to consider sectoral risks (such as the wider impacts of climate change or competition from other renewables) is noted as an area in the centre of the diagram in the revised framework in figure 7.

The framework is relevant to all large hydropower projects wherever they are being built, but may be particularly useful for projects in LIC/LMIC environments. Over time it is possible that new risks will emerge, but according to the survey respondents the framework is currently comprehensive. The next steps for this analysis will be to carry out detailed assessments of project risk using the framework and publish the results to enhance understanding of the impact of risk on financing decisions. This research is ongoing and will be published late in 2022 by the World Bank. However, an example of a framework prepared for a developing country project (which preferred to remain anonymous) is shown in figure 8. Red, amber and green colour

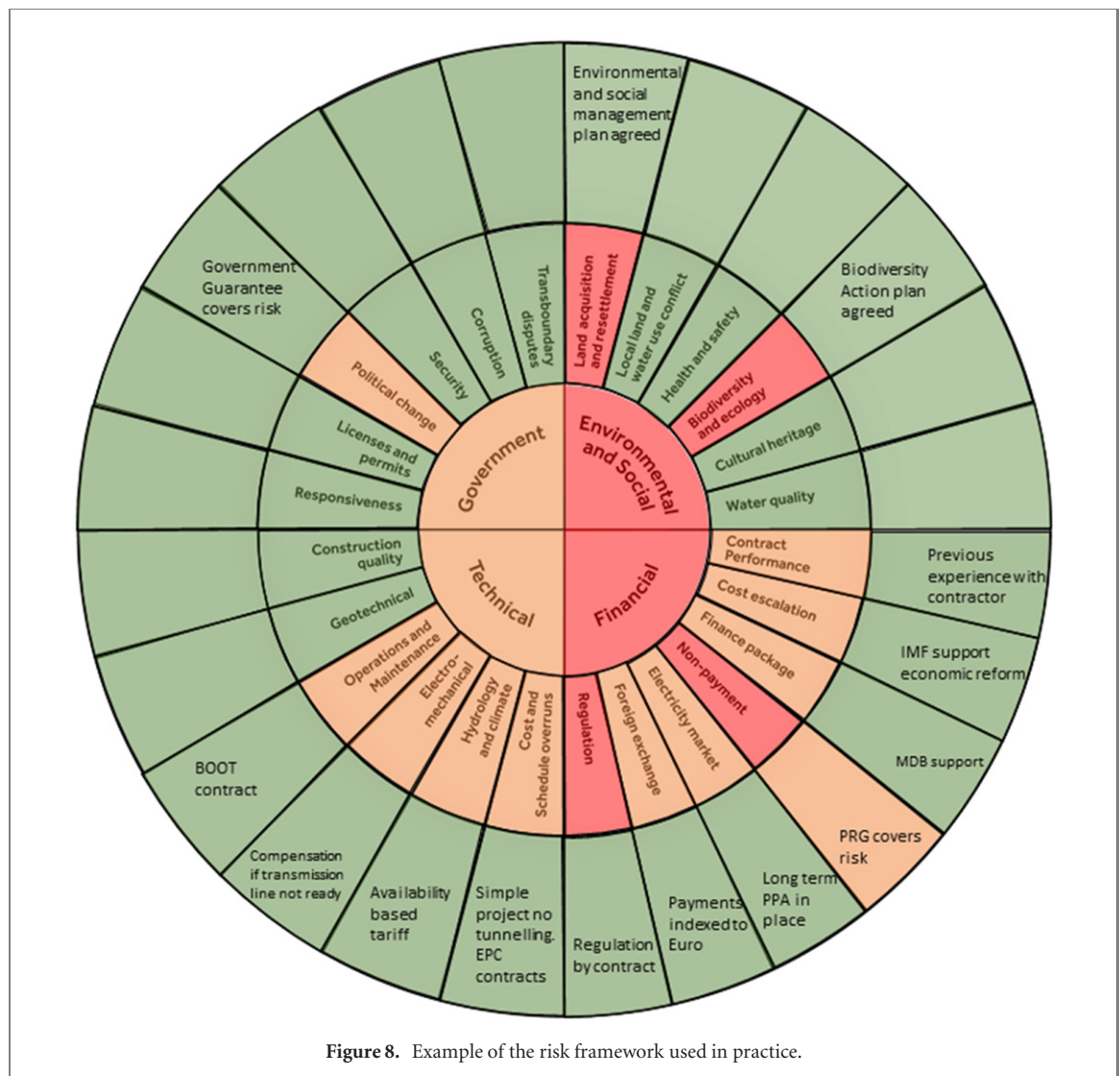


Figure 8. Example of the risk framework used in practice.

coding is used to reflect high, medium and low risk; where high risk would probably preclude private finance; medium risk might be acceptable in some circumstances, but generally private finance would be seeking low risk projects. The risk segments are coloured according to their degree of concern prior to risk mitigation and then the mitigation sections are coloured according to the degree of risk after mitigation. Thus for example biodiversity is red initially, but after a biodiversity action plan is agreed with government as mitigation the level of risk is reduced to green. This form of analysis would be useful to all stakeholders in discussing the allocation of risk.

8. Policy implications

Overall, our findings presented in this paper support the previous conclusion by the World Energy Council (2015), that markets and policy will need to evolve to appropriately incentivise investors, particularly where the private sector is expected to engage. The risks that were identified in the survey and the focus groups as greatest concerns to financiers tend to be risks for which formal mitigation strategies are not widely available or are regarded as ineffective or extremely expensive. For example, the available risk mitigation mechanisms against non-payment risks still fail to prevent off-takers, or an incoming government, from wanting to renegotiate PPAs before the concession period comes to an end. The mitigation for this issue may be to invoke a guarantee but financiers consider this a last resort option as it is time consuming and affects their standing with the government concerned, and are thus more likely to agree to negotiate instead.

Many of the risks that were regarded by the focus group participants and survey respondents as most concerning or least mitigatable are linked to the nature of large hydropower projects and thus specific to this

sector. For example, a long construction period means that the electricity market situation may change during construction. The size of the projects means that *some* environmental and social impacts will always occur (although many of these can be minimised through high quality impact assessment and mitigating action). The scale of the output capacity in terms of GW h means that finding a new off-taker for the electricity is difficult in many LICs and L-MICs, or even impossible in contexts where there is a single grid operator and no electricity market.

The results presented in this paper provide LIC and L-MIC country governments with some insights of what the private sector actors and financiers consider to be the main barriers to greater private sector involvement in large hydropower projects in these types of country contexts. Although the specific contextual factors may vary, the results from our research enable us to draw some conclusions on this. Many of the risks are overlapping and may reinforce each other: corruption and environmental and social risks are important because they increase reputational risk. These need to be addressed through good preparation and implementation following international good practice and strong government action to reduce corruption. The risk of non-payment by the off-taker is currently regarded as the most significant financial risk associated with large hydropower projects in LICs and L-MICs. However, this risk will become less of a concern as economies grow and prosper. Economic growth will also help to reduce some of the other financial risks, such as the foreign exchange rate risk, eventually easing access to finance and reducing the risk of a project having difficulties in achieving financial closure. This process is, to some extent, circular: as more projects are developed and additional electricity generation capacity enables economic growth, the government capacity develops and the economies grow, leading to improved breadth of financial options, more projects and thus more development. More prosperous societies also tend to be more politically stable, a factor which may reduce many of the government risks and the risk of non-payment by the off-taker. Some approaches that are currently detailed as a mechanism to mitigate government risk are self-reinforcing, such as 'single window' approach to reduce red tape and reduce the risk of delays in acquiring licences and permits, which can also lead to improvements that mitigate some of the risks in other quadrants, such as better financial regulation. In each area, government commitments are more valued when backed up with appropriate legislation and regulation, but only if demonstrated to be upheld in practice.

For the private sector, all risks that impact on the project's costs or its ability to service its debts and generate revenue are relevant. As our previous research shows, technical risks, social and environmental risks and government risks can all become credit or market risks because of the impact they can have on the project's ability to start generating income on schedule for profit distribution (including dividend payments) or debt service (Plummer Braeckman *et al* 2020). However, some of the risks can be more difficult to mitigate or eliminate than others, presenting an insurmountable barrier to involvement in a project. Risks that present a reputational risk fall into this category, and thus where there is a concern that these risks cannot be adequately mitigated, a project is likely to be dismissed by financiers. For LIC and L-MIC governments in countries with abundant untapped hydropower resources, addressing and mitigating these risks will be essential to create the conditions that enable greater utilisation of PPPs in large hydropower development.

9. 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 some way to enhancing that understanding, by focussing solely on the financier's perspective on risk.

Most financiers have a wide range of investment opportunities. If hydropower is perceived as excessively risky in comparison to the returns available from other infrastructure investments, the financiers are likely to seek simpler, more remunerative, investment opportunities elsewhere. However, an ability to attract private sector investment for large hydropower projects will be necessary to enable LICs and L-MICs to increase their renewable electricity generation capacity to facilitate meaningful progress towards the SDGs and the Paris Agreement objective. To this end, better understanding of the factors that currently deter private sector involvement in such projects is required.

The aim of this paper has been to explore how perceptions of risk influence the prospects of obtaining finance for large hydropower projects in LICs and L-MICs. Tools such as the analytical framework that facilitate a comprehensive understanding of risk and available risk mitigation mechanisms are essential to support environmentally, socially and economically sustainable hydropower project development in countries with below-investment grade credit ratings. Together with the analysis presented in this paper, the risk framework will enable financiers, private sector companies and country governments to develop a thorough understanding of the risks associated with large hydropower projects and how they may be mitigated either through

formal risk mitigation mechanisms or practices that are utilised by those who are already active in this sector to reduce uncertainties. The framework and the analysis can also enable financiers who are less familiar with large hydropower to improve their understanding of the nature and extent of these risks and how they may be mitigated or managed, as well as the opportunities that the hydropower sector may be able to offer to them, for example, through refinancing.

Capital intensive projects such as hydropower remain contentious and carry considerable business risks and credit risks. Although most risks can be mitigated, many of the mitigation measures are expensive or ineffective against risks such as loss or damage to reputation, and it is impossible to eradicate all risks, completely. For LIC and L-MIC country governments, it is important to acknowledge that the risks associated with large hydropower projects cannot be effectively addressed by ignoring them or hoping that other parties will not notice them. This approach will lead to bad projects, which will reinforce prevailing perceptions of large hydropower projects as ‘risky’ or likely to result in negative publicity, leaving financiers with an impression that the sector as a whole, or the country in question, is best avoided. Rather than trying to divert risks on to other stakeholders without considering the cost implications, governments could benefit from being more transparent in their project risk assessments, discussing the relevant risks with potential financiers, and agreeing risk sharing mechanisms so that no stakeholder is over-exposed to risks they cannot manage. Greater financial support from MDBs to carry out thorough environmental and social impact assessments and pre-construction studies in their role of a broker between the financing entities and the project could help reduce many of the risks that are currently regarded as most concerning and least mitigatable by the private sector.

Further research will be required into the impacts of climate change on hydropower finance and the role of hydropower in climate adaptation and mitigation. The framework could be tailored to particular contexts and the authors look forward to applying the framework in a real-world LIC/LMIC project.

Acknowledgments

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Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

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

| Risk type | Description | Likely mitigation | References |
|--|--|---|---|
| Government risks | | | |
| Political change/ political stability | 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/capacity | 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 (2013a) |
| 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 <i>et al</i> (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 corruption, but may also be projects superimposed on a system which is already corrupt | Expert advice Anti-corruption policy Vet contractors Transparent practices for tendering, management and business Third-party monitoring | Haas (2008) Sohail and Cavill (2007) WCD (2000) |
| 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) |

| Risk type | Description | Likely mitigation | References |
|---|--|---|---|
| Financial risks | | | Kovacevic <i>et al</i> (2013) |
| Contract performance/management counterparty capacity | 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 (e.g. 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 repayment period Apply for carbon/green finance Alternative structures such as FELT | Head (2008) Patel <i>et al</i> (2020) Plummer Braeckman and Markkanen (2020) McWilliams (2017) |
| Non-payment risk | Off-take risk—encompassing payment risk and enforcement of contractual off-take obligations | Long-term electricity sales contracts, government guarantee for public sector off-taker payments, flexibility to sell to other off-takers | Vardanyan and Hesamzadeh (2017) Machado and Bhagwat (2019) |
| 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 (e.g. 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) |

| Risk type | Description | Likely mitigation | References |
|---------------------------------------|--|---|--|
| Foreign exchange | Changes in relative exchange 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 (e.g. forward contracts, futures, options, swaps) | Plummer Braeckman <i>et al</i> (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 <i>et al</i> (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) |
| 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, e.g. drill and blast method with tunnel boring machine | Hoek and Palmeiri (1998) Palmieri (2015) McWilliams (2014) |
| Operation and maintenance | Operation and maintenance quality including management of ongoing risks such as sedimentation | Technical and commercial terms and conditions of contract Supervision, inspection and quality assurance measures Design for a higher occurrence of extreme events Specific plans for issues such as sediment Contract for operations and maintenance | World Bank (2020) |

| Risk type | Description | Likely mitigation | References |
|-----------------------------------|---|---|--|
| 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 <i>et al</i> (2018) |
| Hydrological and climate | Operational or construction-related risk of lower than expected flows, floods or unusual seasonal variations Methane emissions from reservoir, spillways and outfall | 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 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 Emissions reduction through aeration and other mitigations | Blomfield and Plummer Braeckman (2014) |
| 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 (e.g. EPC) Transfer risk through bonding or insurance Penalty/bonus incentive scheme | Plummer Braeckman <i>et al</i> (2019) Awojobi and Jenkins (2016) Plummer (2014) Mubin <i>et al</i> (2019) Plummer (2013a, 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 (e.g. location or design) Modify project operation Agreement with stakeholders Benefit sharing Government support backed up by legislation and regulation | Kirchherr <i>et al</i> (2016a) WCD (2000) Kirchherr <i>et al</i> (2016b) Cisse <i>et al</i> (2013) |
| Land and water use conflicts | Issues raised by local water users or downstream riparians on sharing of water or catchment use | Modify project (e.g. location or design) Modify project operation Formal agreement with stakeholders Government support backed up by legislation and regulation | Johansson and Kriström (2011) |
| Public health and safety | Issues of physical safety as well as spread of disease during all phases of the project | Safety management plan Modify project (e.g. location or design) Modify project operation Agreement with stakeholders Communication Regulations enforced | Lerer and Scudder (1999) |

| Risk type | Description | Likely mitigation | References |
|--------------------------|---|---|---------------------------|
| Biodiversity and ecology | Impact of the project on biodiversity and ecology | Include in environmental management plan Modify project (e.g. 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 (e.g. location or design) Modify project operation Compensate for impacts Enforce regulation | Bunea <i>et al</i> (2010) |

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