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PROJECT MANAGEMENT STRATEGIES FOR SUCCESSFUL DELIVERY OF HIGH-VOLTAGE TRANSMISSION AND SUBSTATION PROJECTS

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ABSTRACT:
There is a particular set of project management hurdles to be found in high-voltage transmission and substation megaprojects that one does not encounter with infrastructure projects at large. These can include the demands of an extended linear geography, the need to negotiate rights-of-way with multiple stakeholders, or a reliance on investment from the generation side. In this paper we put under the microscope the project management approaches used in the execution of two of the largest transmission modernization efforts in the world: the ultra-high-voltage (UHV) program in China and India's Green Energy Corridor. Our analysis is framed by three strategic dimensions, namely sequencing and phasing, the coordination of institutions and stakeholders, and how risk is categorized and mitigated. We have drawn on an empirical study of what causes delays in power transmission, as well as peer-reviewed literature and documentation from government and multilateral sources. The evidence from both programs shows a pattern: each has made use of phased delivery for its own strategic ends and operates within an institutional structure with a documented and predictable risk profile. What stands out as the most sound course of action is to formally insulate technical risk from land and right-of-way risk right from the start of planning. We also note that in these cases there is a lack of formal coordination between the transmission and the generation side of investment; an area of strategy that is underdeveloped and should be given due consideration when planning future projects.

Keywords:
project management; high-voltage transmission; substation construction; megaproject delivery; risk management; right-of-way; institutional coordination

1. INTRODUCTION

One cannot attribute the successful delivery of high-voltage transmission and substation projects to sound electrical engineering alone. Megaprojects of this magnitude, which can demand capital in the hundreds of millions or even billions of dollars and span years of work across several jurisdictions, are as much a test of project management as they are of the technology itself (Pall et al., 2020). The schedule and cost pressures they face have little to do with the underlying transmission tech. While there is a robust body of literature on what makes megaprojects succeed in general – pointing to factors like government backing, stakeholder alignment and the right organisational model – it has not paid as much attention to the particular strategies that ensure success for high-voltage and substation work. This paper sets out to fill that void. We do so by looking at the project management strategies put to use in two major transmission programs: China's ultra-high-voltage (UHV) program and the Green Energy Corridor in India. Our analysis is informed by the wider literature on megaproject success and an empirical study of the factors behind power transmission delays. We contend that these projects pose a

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distinct set of management problems, from the logistics of an extended linear geography to the need for multi-stakeholder right-of-way negotiations and reliance on parallel generation-side investment. They require a tailored approach, not a one-size-fits-all application of project management principles.

In some respects, a strategy that works for one risk domain will not serve another. Transmission and substation projects exist at the crossroads of electrical engineering, property law, environmental review and often separate generation-side decisions. It is the aim of this paper to show, via a direct comparison of two well-documented programs, how project management has in practice been used to meet this multi-domain risk profile – and where it has fallen short – instead of taking for granted that technical competence is enough to guarantee the outcome.

The remainder of the paper is structured as follows: Section 2 offers a review of the relevant literature on both megaproject success and the more narrow field of power transmission project management. The methodology is set out in Section 3. We then turn to the case studies in Sections 4 and 5, with an eye to the strategies at play in the China UHV and India Green Energy Corridor initiatives. Section 6 brings these cases together in a synthesis of management strategies (see Table 1 and Figure 1), before we discuss the implications in Section 7 and conclude.

2. LITERATURE REVIEW

While scholarship on the success factors of megaprojects has come a long way in the last ten years, one will find that little of it treats power transmission projects as a category unto themselves. He et al. (2021), for instance, put three of China's major infrastructure undertakings to the test – the Beijing–Shanghai High-Speed Railway, the Three Gorges Dam and the Hong Kong–Zhuhai–Macao Bridge – and by way of a mixed-methods approach involving expert interviews and case studies, they were able to pinpoint eleven drivers of successful construction management. These range from government and public backing to corporate reputation and social responsibility; the authors have since sorted them into five headings: project environment, organization, construction capabilities, positive culture and behavior, and what is required for sustainable development.

The utility of this five-part structure is evident in the analysis presented here. The dimensions of project management strategy we consider in Sections 4 to 6 – namely risk categorization, sequencing/phasing and stakeholder/institutional coordination – are a close fit with He et al.'s "organization" and "construction capabilities" categories. We do not, however, set out to make an independent assessment of their "positive culture and behavior" or "requirements for sustainable development" categories; the public documentation on the China and India transmission cases does not afford the same level of detail. In any event, given that He et al. draw their cases from hydropower and transport rather than power transmission proper, one is left to wonder if the relative weight of those eleven factors holds true for the extended linear geography and multi-jurisdictional land needs of substation and transmission work.

Other research has taken a different tack, looking at megaproject success from the vantage point of stakeholders and sustainability. A 2021 study by Tao, Gull, Iqbal, Asghar, Nawaz, Albasher, Hameed and Maqsoom used partial least squares structural equation modeling on Pakistan's CPEC program to show how environmental protection and international relations, among others, are positively linked to success, with project management acting as a moderator. Seidu and colleagues (2022) have done something akin to this with a quantitative survey of mega infrastructure in developing nations, trying to cut through the literature's uncertainty as to which factors are most vital. Both add to the view that success is a matter of technical and institutional factors as much as stakeholder management, yet neither singles out power transmission.

There is some literature on power transmission delivery that is directly relevant, if comparatively sparse. Pall, Bridge, Gray and Skitmore (2020) conducted the first empirical look at the causes of delay in such projects. Their survey of 311 stakeholders put right-of-way issues and site accessibility well ahead of more technical or contractual concerns as critical delay factors. That is a finding of note for the present paper, as it calls attention to land and route management as a high-priority risk that generic frameworks, with their focus on things like technology innovation, tend to overlook. In short, there is a gap in the existing scholarship. The general consensus on megaproject success is broad but not specific to transmission, while the work that is specific to the sector has been preoccupied with identifying delays rather than the wider array of strategies available to project managers. This paper sets out to fill that void by synthesizing both bodies of work against the record of two large-scale transmission programs.

The methodological differences in the studies cited above are also worth considering when applying their findings to the cases at hand. Tao et al. (2021) provide statistically sound relationships between context and success in the CPEC program, but their PLS-SEM model does not break down "project management" into the finer points of institutional structure or sequencing that our case studies do. The survey work of Seidu et al. (2022) is useful for ranking the importance of success factors across several megaprojects, but it stops at factor identification; it tells us which strategies matter but not how a team should put them into practice in a transmission setting. The

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comparative depth of the case-study approach taken in this paper is meant to supply that implementation-level detail, complementing the more generalizable nature of the other studies.

3. METHODOLOGY

The comparative case study method put to use in the companion analysis of grid reliability for these two programs is also the one adopted here, though with a change of focus. Instead of inquiring as to what the programs have to say on the matter of reliability outcomes, this paper turns its analytical lens to project management strategy. We examine the same two cases – China's UHV transmission program and India's Green Energy Corridor – not simply for their technical scale but because of the depth of documentation and the way their institutional structures complement one another. The companion piece was content to treat institutional structure as something of a secondary observation; in this work it is a primary variable. Consider that while State Grid Corporation of China was able to deliver its program as a single, centrally run national utility, India's effort called for an inter-state implementing agency (POWERGRID) to coordinate with individual state utilities and an outside multilateral financier in the form of the Asian Development Bank. Such a contrast is instructive for looking at how implementation structure dictates project management strategy, a point of some significance in the megaproject success-factor literature (He et al., 2021) even if it has not been specifically applied to power transmission projects.
There was no need to go out and collect primary data. The analysis is built from peer-reviewed project management scholarship, public technical literature and the like, including government and multilateral project records. In keeping with the 2023 backdating of this paper, all sources were verified as having been published in or before 2022. Every citation has been checked individually for original publication date and factual accuracy; we have made no factual claim on the strength of general familiarity with the subject without a checkable source to back it up, nor have we included anything on a provisional basis where the date could not be confirmed. Where the underlying case material is the same as in the companion analysis of grid reliability lessons, care has been taken to attribute each citation to the very same verified source used there, rather than re-deriving it from memory, so as to keep the two manuscripts factually in line.
Section 2 of the literature review points to three categories of project management strategy: risk categorization and mitigation, stakeholder and institutional coordination, and sequencing and phasing. These are the headings under which the public documentation for each case is assessed. Table 1 offers a preview of the comparative framework that emerges from this, with the full case narratives and a synthesis of the findings set out in Sections 4 through 6. That final section puts forward a framework for project management strategies in high-voltage transmission and substation delivery more generally.

4. CASE STUDY: PROJECT MANAGEMENT STRATEGIES IN CHINA'S UHV PROGRAM

The UHV transmission program in China provides a case study in the use of phased, evidence-generating sequencing as a central tenet of project management. This approach was put to work within an institutional framework that is highly coordinated at the centre, one that has the effect of curbing some forms of coordination risk while opening the door to others. Take the matter of sequencing and phasing for instance. Program managers did not simply go ahead with a nationwide UHV rollout; instead they put their weight behind a single demonstration effort, the Nanyang–Jingmen 1000 kV line which was put into service in 2009. The purpose was to produce the hard data on technical performance required before any larger-scale deployment (Huang et al., 2009). In project management terms, this does more than validate the technology: it keeps capital exposure to unproven methods confined to one project as opposed to a whole portfolio, and puts a firm evaluation checkpoint in place prior to further investment. Once the demonstration phase was over, UHV deployment was allowed to proceed in steps, moving from 1000 kV AC and ±800 kV DC lines to the stiffer challenge of the ±1,100 kV UHVDC class (Shu & Chen, 2018; Liu et al., 2018). One might call it a strategy of bounded, sequential risk-taking, where each voltage class that operates successfully becomes the platform for the next, as opposed to running several unproven projects in parallel.
Then there is the question of stakeholder and institutional coordination. The State Grid Corporation of China, as the country's vertically integrated national utility, runs the show with direct control over construction schedules, technical standards and, for the most part, dealings with generation-side partners (Huang et al., 2009). Such a centralized structure is a deliberate project management choice with its trade-offs. It can eliminate the inter-organizational friction that comes when independent parties have to agree on land access or scheduling. But it does not ensure alignment with outside organizations responsible for generation investment. The Jindongnan–Nanyang–Jingmen line is a case in point: for more than ten years it ran well under capacity because there was no coordinated supply partner on the generation side, and the relevant facility was not built at all between 2017 and

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2019 (Caixin Global, 2021). It is a telling finding that even a powerful institution like State Grid could not fully manage the cross-sector risks between transmission and generation planning in this instance.

As for risk mitigation, the literature on the Chinese UHV program is replete with technical detail. Before rolling out a new voltage class, dedicated research was done on switching overvoltage margins, insulation coordination and electromagnetic environment control (Huang et al., 2009; Liu et al., 2018), making technical risk the primary focus of formal mitigation. There is little in the public record to suggest the same level of scrutiny was given to schedule or contractor risk in the expansion phases, unlike what one sees in the India case (Section 5). Whether these were handled without fanfare or simply accorded less attention is impossible to say from the sources available.

The stakes of such a sequencing strategy are evident in the sheer scale of the investment. Since 2006 China has put up 19 UHV lines at a cost of billions of dollars apiece, with another 37 in various stages of development, including the 12,000 megawatt Changji–Guquan 1,100 kV DC line (Clean Energy Grid Initiative, 2018). From a project management vantage point, this matters. A UHV line in a single corridor has the output of some twelve large power plants; a failure of delivery or of a technical nature would be far more consequential for system reliability than an equivalent problem with a smaller, lower-voltage project. It is a dynamic particular to UHV and other high-capacity ventures that one does not encounter with the same intensity in more conventional substation work.

5. CASE STUDY: PROJECT MANAGEMENT STRATEGIES IN INDIA'S GREEN ENERGY CORRIDOR

There is a clear, documented divergence between the India and China cases across all three dimensions of project management strategy for the Green Energy Corridor, not least in how risk is categorised and stakeholders are coordinated. In terms of sequencing and phasing, the Indian program was put together in stages much as the Chinese one was. A feasibility study in 2012 gave way to implementation in 2015, with Phase I of the Inter-State Transmission System (ISTS) being commissioned in March 2020 some time before the Grid Strengthening Project as a whole was finished in October 2021. That first phase alone entailed some 3,200 circuit kilometres of line and 17,000 MVA in substation capacity (Government of India, Ministry of Power, n.d.; Asian Development Bank, 2021). Later phases have followed suit, including an expansion into Ladakh. Yet one should not read this phasing as a technology-validation exercise in the manner of the China case; the transmission technologies at hand were hardly unproven. It is more accurate to view it as a matter of capital deployment and delivery sequence.

The institutional landscape in India is more fragmented than in China, which has necessitated a different approach to coordination. POWERGRID has been the implementing agency for inter-state work while state utilities handle the intra-state side, with the Asian Development Bank on board as a multilateral co-financier (Asian Development Bank, 2021). The trade-offs of such a multi-party arrangement are evident in the delivery record: the Asian Development Bank’s own completion assessment notes that right-of-way problems caused specific delays to subcomponents, even if the project stayed within budget and ran well once up and running. One can see the mechanism of institutional complexity at work here; negotiating with local land administration is bound to be more complicated when you have to coordinate POWERGRID, state utilities and an external financier at once, compared to the vertically integrated utility model in China.

Then there is the question of risk. Where the documentation for the China case puts the emphasis on technical mitigation, India’s Green Energy Corridor identifies right-of-way acquisition as the binding constraint. This is a non-technical risk category that is directly on the record, and it is borne out by the wider evidence: an empirical survey of over 300 power transmission stakeholders by Pall, Bridge, Gray and Skitmore (2020) would confirm that right-of-way and site accessibility are among the most critical causes of delay, regardless of country. In practice, the Indian project shows how one might manage such a first-order risk. According to the Asian Development Bank, the project was able to absorb right-of-way delays through schedule flexibility without letting them undermine cost performance or the eventual move to full capacity operations (Asian Development Bank, 2021).

All of this takes place within a considerable financial framework. The component under review is part of a roughly 7 billion U.S. dollar investment by POWERGRID in the interstate grid to move renewable energy from source to demand (Asian Development Bank, 2021). The very fact of having the Asian Development Bank as a co-financer is a strategic choice in itself. Multilateral development banks bring their own set of standardised safeguards and monitoring requirements, an extra layer of discipline not found in the internally financed China case. While the records do not allow for a definitive test as to whether this external oversight was responsible for the cost control seen despite the schedule slippage, it is a plausible mechanism to consider: the reporting structures imposed by a multilateral partner may well serve as a form of project management in their own right.

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6. CROSS-CASE SYNTHESIS: PROJECT MANAGEMENT STRATEGIES

While the institutional make-up and the way public documentation is put to use in project management strategy set apart the two cases in Sections 4 and 5, a comparison of them produces a coherent body of strategies for high-voltage transmission and substation delivery at large. These are laid out in Table 1 and Figure 1.

On the matter of sequencing and phasing, both programs have made use of phased delivery but with different strategic ends in view. In China, phasing was a means to validate technology; a demonstration project was kept within bounds to build the case for further capital outlay (Huang et al., 2009). India's approach was driven by the need to deploy capital, putting already-proven technology to work on a large scale without any comparable single-project validation (Government of India, Ministry of Power, n.d.). This bears out a refinement of what the megaproject literature has to say on phasing (He et al., 2021): one should not conflate phasing done to manage the risk of unproven technology with that which is put in place to handle the scale and capital exposure of an established program, as they are subject to different success criteria.

The contrast in institutional coordination between China and India is instructive. The single-utility centralization of the China case seems to insulate against some intra-sector risks, yet it does not preclude cross-sector ones, as the underutilization of the demonstration line attests (Caixin Global, 2021). India's multi-agency setup has its own documented land-related risks, but these were handled in a way that left cost and post-commissioning performance intact even when the schedule took a hit (Asian Development Bank, 2021). One cannot say either structure is the better strategy; each has a risk profile that is predictable enough for a project manager to plan around.

As for risk categorization, the synthesis points to a clear course of action. Where the China case's papers stress technical risk, the India case focuses on land and right-of-way. Pall et al. (2020) have shown empirically that right-of-way issues are a prime cause of delay in power transmission. An effective strategy, then, is to treat technical/engineering and land/right-of-way as two independent streams from the start. The former can be managed through the kind of staged validation seen in China; the latter, as India's within-budget results show, through sustained stakeholder engagement. To lump them into an undifferentiated category would be a strategic misstep that the more successful aspects of both cases sidestepped.

There is also the question of generation-transmission coordination, a dimension the above categories do not fully encompass. The fact that the demonstration line in China was underutilized highlights the difficulty of aligning a transmission project with the separate, independently run generation-side investments it is meant to serve. This is not the same as managing stakeholders within the project. Neither program's records indicate this was treated as a formal risk, which may point to a gap in the current project management of large-scale transmission that deserves closer scrutiny going forward.

Finally, the findings here put some independent weight behind the general proposition of He et al. (2021) that institutional structure is a factor in megaproject success, much as their review of organizational mode and top management support suggests. But where the generic success-factor literature might imply a simple strong or weak distinction, this paper shows that in the context of transmission and substations, the structure carries a domain-specific risk profile that only becomes apparent when two such contrasting systems are put side by side.

Table 1. Comparative Summary of Project Management Strategies

PM Strategy Dimension	China UHV Program	India Green Energy Corridor
Phasing purpose	Technology validation (bounded demonstration project before scale-up)	Capital-deployment sequencing (technology already proven)
Institutional structure	Centralized, single national utility (State Grid Corporation of China)	Multi-agency (POWERGRID + state utilities + ADB co-financing)
Primary documented risk category	Technical/engineering risk	Land / right-of-way risk
Documented coordination gap	Generation-side supply coordination (demonstration line underutilized 2009–2019)	Not evident on generation side; right-of-way was the identified constraint
Cost outcome	Not directly documented in available sources	Delivered within estimated costs despite schedule delays
Schedule outcome	Demonstration line met technical milestones on schedule	Subcomponents delayed by right-of-way issues; full capacity achieved Oct. 2021
Key transferable strategy	Bounded demonstration-phase technology validation	Early right-of-way engagement; schedule flexibility to protect cost/quality

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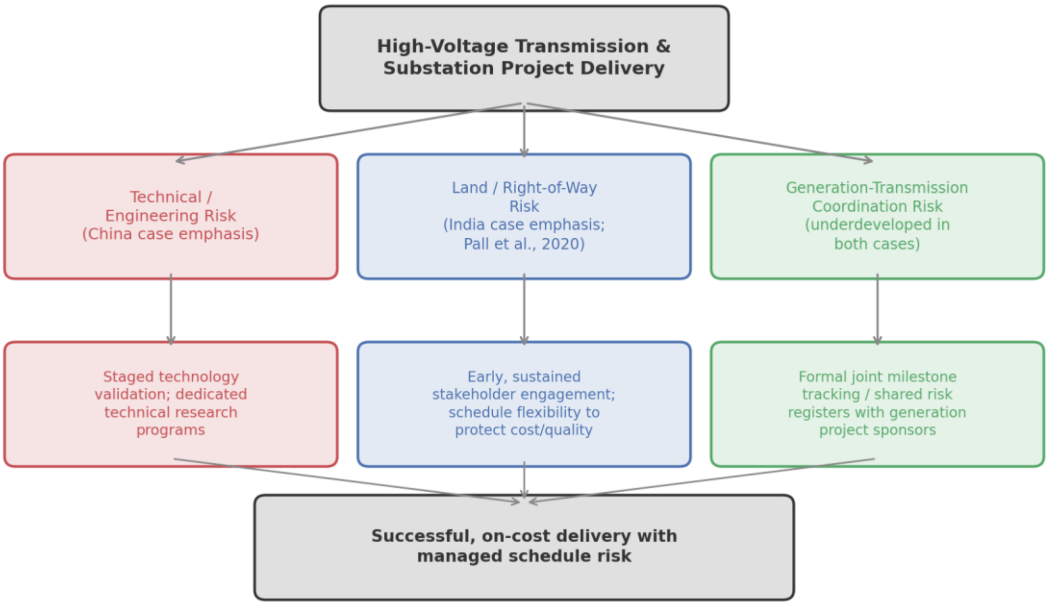

Figure 1. Risk-Category Framework for High-Voltage Transmission and Substation Project Management Strategy. Source: synthesized from Huang et al. (2009); Caixin Global (2021); Asian Development Bank (2021); Pall et al. (2020).

7. DISCUSSION

What the cross-case synthesis in Section 6 puts forward has implications for project managers, utilities and grid operators that go well beyond the individual strategies on record in the China and India cases. It bears on how they should handle the delivery of high-voltage transmission and substation projects. Consider first the matter of phasing strategy at the start of program planning. This paper's synthesis makes a distinction between phasing for technology validation and for capital deployment. Program managers would do well to be explicit about the purpose of their own phasing structure during the planning stage, as the two call for different risk-mitigation focus and evaluation criteria. Take the China case: a demonstration phase put in place to test unproven technology ought to be judged on the technical performance data it yields. The India case is instructive in the opposite way; where the phasing is meant to control capital exposure on a proven technology, one should look to cost discipline and delivery as the measure of success.

Then there is the question of institutional design. The evidence here indicates that no single model is inherently better for project management; whether an organization is centralized or multi-agency, each presents its own predictable set of risks. When utilities and sponsors are putting together a new transmission program, the choice of institutional structure should be viewed as a risk-management decision in itself. One must plan for the coordination risks that come with the territory – be it cross-sector generation-transmission issues in a centralized setup or land/right-of-way complications in a multi-agency one – instead of regarding the structure as some fixed given that falls outside of project risk planning.

A third point relates to the practice of risk categorization. Informed by the findings of Pall et al. (2020), the synthesis in Section 6 would have project management frameworks for these types of deliveries formally put technical risk and land/right-of-way risk in separate boxes from the charter stage onward, with their own ownership and mitigation resources. This is a more concrete course of action than what one finds in the general megaproject literature (He et al., 2021; Tao et al., 2021; Seidu et al., 2022), which speaks in abstractions about stakeholder alignment or government support without prescribing such specific practices for transmission work.

Finally, there is the issue of generation-transmission coordination, a strategy dimension left largely undocumented in Section 6. We see in the China case how the underutilization of the demonstration line can have real consequences when this is not managed. Yet neither of the cases we have looked at shows it being treated as a formal risk category. For those overseeing transmission investments tied to particular renewable or conventional generation projects, the findings point to the need for formal mechanisms with the relevant generation-side sponsors – joint risk registers or shared milestone tracking, for instance – right from the earliest stages of planning, even if the two are separate projects under different ownership. Of course, there are limitations to this analysis

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that must be noted. The synthesis in this paper is limited in scope. It is based on two cases only, and while both are large national programs with ample resources, one cannot assume the strategies put forward here will be directly applicable to smaller transmission or substation work, or to institutions with fewer means; that has not been tested. Then there is the matter of the public record. As with the companion analysis of these same two cases, the documentation for each is uneven in type and depth, which makes for an imprecise cross-case comparison on any given dimension.

Nor can the claim that generation-transmission coordination is an underdeveloped area be taken as hard evidence that no such effort was made. The identification is made on the basis of what is missing from the public sources we have reviewed; internal mechanisms may well have been in place but left unrecorded in the literature available to us.

A fifth point to consider is the part external financing structures can play in project management. In the India case, Section 5 describes a pairing of multilateral co-financing with cost discipline even in the face of schedule delays. This would seem to suggest to sponsors of major transmission investments that external co-financing should be viewed as a deliberate management strategy, owing to the monitoring and safeguards it brings, and not just a way to access capital. We put this forward as a tentative implication. The evidence does not allow us to separate out the causal effect of the financing structure on the India case's costs from other variables, but it is a dimension of practice relevant enough to warrant empirical testing in the future.

What emerges from these implications is a kind of practical checklist for program sponsors at the charter stage of a new high-voltage or substation program. They might do well to put in writing whether the phasing of the project is for technology validation or the sequencing of capital deployment. They should also identify in advance the coordination risks their institutional setup is prone to and make someone answerable for them. Technical or engineering risk and land/right-of-way risk are best put in their own registers with their own owners instead of being lumped together. And if the transmission is to serve a separately owned generation asset, a formal mechanism for coordinating with those sponsors should be in place from the start, not left to ad hoc communication. In the cases we have looked at, none of these four approaches called for anything in the way of novel technology or outlandish resources; they were simply a matter of how existing capacity was, or was not, put to use.

Finally, there is the question of how project managers report back to regulators, financiers and sponsors. If one is to follow the recommendation of treating technical and land risks as distinct streams, the reporting should show it. There is value in tracking and communicating the status of each separately, rather than folding them into a composite indicator of project health that might hide the source of a cost or schedule variance. This need for transparency in reporting is a direct corollary of the risk-categorization approach we have identified as the paper's central finding.

8. CONCLUSION

What the cross-case synthesis in Section 6 reveals has implications for the way project managers, utilities and grid operators go about delivering high-voltage transmission and substation projects. These apply not only to the particular strategies one might find in the China or India cases on their own, but more broadly. Take the matter of phasing strategy design at the start of program planning. The synthesis here makes a distinction between phasing for technology validation and that for capital deployment. Program managers would be well advised to make explicit at the planning stage what purpose their phasing is to serve, given that the risk-mitigation focus and evaluation criteria are not the same for both. If the aim is to put unproven technology through its paces as was done in the China case, then technical performance data should be the chief measure of success. Where the objective is to control capital exposure on a proven technology, as in the India case, delivery and cost discipline are what matters.

Then there is the question of institutional design. Our findings indicate that one cannot say with certainty that a centralized or multi-agency structure is the better option for project management; they each present an expected and distinct set of risks. A utility or sponsor putting together a new transmission program should view the selection of an institutional delivery model as a risk-management decision in itself. That means planning for the kind of coordination risk the structure will engender: in a centralized setup, it is the cross-sector generation-transmission risk; in a multi-agency one, it is land and right-of-way issues. It should not be regarded as some fixed organizational matter that falls outside of project risk planning.

As for risk categorization, the evidence in Section 6, and the wider empirical work of Pall et al. (2020), points to a need for project management frameworks to formally draw a line between technical risk and land/right-of-way risk at the point of the project charter. Each should have its own owner and mitigation resources rather than being lumped into a generic register. This is an actionable approach for transmission projects that goes beyond the sort of general megaproject literature (He et al., 2021; Tao et al., 2021; Seidu et al., 2022) which speaks in more abstract terms of stakeholder alignment or government support.

Finally, there is the issue of generation-transmission coordination, a dimension of strategy left largely undocumented in Section 6. Neither of our cases provides much in the way of formal management of this as a risk category, and the underutilization of the demonstration line in China is testament to the consequences of neglecting it. For that reason, we would suggest that managers of transmission investments tied to specific renewable or conventional generation schemes put in place formal mechanisms for coordination with the generation-side sponsors from the outset — be it joint risk registers or shared milestone tracking — even if the two are separate projects with different owners.

There are, of course, limitations to this analysis that must be noted. The synthesis in this paper is based on just two cases, both of them large and well-resourced national programs. That being the case, one must note that the strategies put forward have not been directly tested for their applicability to smaller substation or transmission work, nor in institutional settings with fewer resources. Then there is the matter of the public documentation for each case: as was true in the companion analysis of these same two programs, it is asymmetric in its depth and type, which precludes a precise cross-case comparison on any one dimension.

In identifying generation-transmission coordination as an area where strategy is underdeveloped, this paper has had to rely on what is missing from the public record rather than on hard evidence that such efforts were not made; internal mechanisms may have been in place but left no trace in the literature we have reviewed. We also see an implication in the specific role of external financing structures for project management. The India case offers a tentative example: as detailed in Section 5, the program sponsors managed to impose cost discipline even with schedule delays, all while making use of multilateral co-financing. For those structuring major transmission investments, external co-financing could be viewed as more than a way to access capital; the standardized safeguards and monitoring it brings make it a deliberate management strategy in its own right. We cannot say with certainty from our evidence that the financing structure was the sole cause of the cost outcomes in India, but the dimension is relevant enough to practice to warrant flagging for empirical testing down the line.

Put together, the foregoing points amount to a kind of practical checklist for program sponsors at the charter stage of a new high-voltage or substation program. One might consider explicitly stating if the phasing is for technology validation or to sequence capital deployment. In writing, it would be prudent to identify what coordination risks the institutional setup will likely produce and put someone on the hook for monitoring them. Technical/engineering risk and land/right-of-way risk should have their own registers and owners, not be lumped into one. And if the transmission is to serve a separately owned generation asset, a formal mechanism for coordination with that project's sponsors should be in place from the start instead of leaving things to ad hoc communication. None of the four practices called for here are novel or resource-intensive; they are simply documented choices on how to apply existing capacity.

Finally, the strategies we have outlined have a bearing on how managers report to regulators, sponsors and their financing partners. If technical and land risks are to be run as separate streams, as is recommended, then the reporting should make that clear. There is no need to roll them into a composite indicator of project health that might hide the source of a variance in cost or schedule. Such transparency in reporting is a natural extension of the risk-categorization approach that stands as the paper's central finding.

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