ACB ISSUE BRIEF

28 August 2020

Accelerating border infrastructure development – new planning methods

Vijay V
Member ACB

Introduction

Road and rail infrastructure in border areas has a direct bearing on military preparedness. In order to facilitate effective border management, security and development of infrastructure in inaccessible areas adjoining the China Border, a total of 73 strategically important roads were identified by the government as Indo China Border Roads (ICBR) and planned to be completed by 2012[1]. Besides, the Ministry of Defence approved 14 strategic rail lines in 2010[2]. Progress has, however, been slow. As of July 2018, only 34 of the 73 roads were completed[3]. Construction of four prioritized strategic railway lines along the Indo-China border was yet to be sanctioned[4]. Further, serious deficiencies in the quality of road construction have been reported. ""User feedback indicated that there were issues like improper gradient, undulating surface, improper turning radius, minimum passing places, inadequate drainage, and unsatisfactory riding comfort in 17 out of 24 roads selected for audit. Completed roads were not fit for running specialised vehicles and equipment because of the above limitations"[5].

A number of studies have suggested that cost and time overruns and quality problems seen in large-scale infrastructure projects are predominantly caused by inappropriate decisions made during the project planning & design (P&D) stage[6], [7], [8], [9], [10]. There are good reasons to believe that this holds true for our border infrastructure projects as well. These poor decisions are a consequence of prevailing P&D methods in public infrastructure projects emphasizing adherence to process rather than delivery of outcomes. Feasibility studies and Detailed Project Reports (DPR), prepared in the P&D stage, are often based on unreliable data and lack analytical content; there are few, if any, standards currently available for risk management in engineering design. Consequently, most problems manifest themselves only during construction, when they are extremely costly and time consuming to address.

Given the complexity and multi-disciplinary nature of these projects, the current approach to border infrastructure development which is predominantly construction oriented while neglecting the role of P&D is problematic. While we are now deploying modern construction equipment and methods, P&D methods have remained largely unchanged.

This article makes the case that adopting modern P&D methods which leverage digital data (terrain models, high resolution images), geo-spatial analytics and requirements engineering principles[11] will go a long way in improving the constructability and quality of border infrastructure.

Problems and Challenges

It is well recognized that many challenges to border infrastructure development are institutional and socio-political. However, the primary challenge is engineering, which can be addressed by a combination of technology, practice experience and rational analysis and synthesis.

A defining feature of large-scale infrastructure projects is their intrinsic complexity - characterized by vast geographical extents and conflicting technical, economic, environmental objectives and constraints. The engineering problem is therefore open- ended with many potential solutions.

Consider a green field linear project such as a highway or railway line. Broadly, there are two types P&D problems -

i) Route selection
ii) Structural design – of pavements, bridges, tunnels, stations etc.

The key challenge is fixing the route. No other part so cripples the resulting system if done wrong. Poor route selection could result in unnecessary diversion of forest and agricultural land or excessive damage to the natural landscape by necessitating high embankments or deep cuttings. Inappropriate siting and sizing of bridges across natural drainage channels can endanger the earthwork supporting the road or rail during floods. Defects in alignment geometry (curvature and gradients) of the route can affect safety, riding comfort, travel speeds and maintenance costs.

Pavement design affects surface drainage and hence road safety. Tunnels may be expensive to construct but they have long term advantages in terms of lower operational and maintenance costs especially in landslide and flood prone areas. Given that such design choices determine the construction specifications for the different structures, the importance of getting P&D right can hardly be over-emphasized. As shown in Figure 1, most decisions made in subsequent stages of the project such as construction will often have only a marginal effect on the utility or cost of the facilities[12].

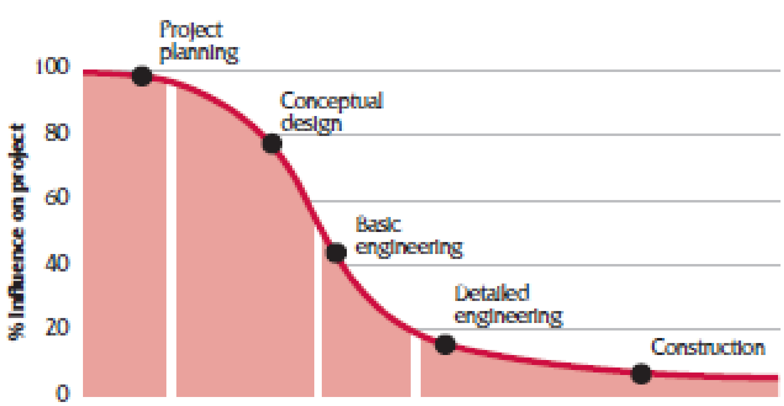

Figure 1: Influence Curve for a Project

In the context of India's border roads and strategic railway lines there are additional challenges posed by the Himalayan terrain – unstable regions prone to landslides and rock fall, project sites in remote locations necessitating extensive use of local construction materials and the greater need for erosion protection measures. Besides, the construction of the road or railway line could itself create or exacerbate these problems. Geological and geomorphologic features of the project area and characterization of the landform, therefore, become important considerations for route selection and engineering design.

Conventional approach and its limitations

The conventional way of selecting a route involves painstaking study of contour maps and extensive hand calculations to first establish the plan (horizontal alignment) and then the profile (vertical alignment). It is generally not practical to complete more than two or three iterations and it requires experienced engineers to achieve satisfactory results.

Topographic data representing terrain elevation of the project area is the most important requirement for route selection. The source is paper topographic maps published by the Survey of India[13]. The small scale (usually 1:50,000) of the maps is a very serious limitation which affects the quality of route selection.

Further, the task of marking the route on the ground from alignments prepared on paper maps is both cumbersome and subject to considerable positional error.

In summary, current P&D activities suffer from some or all of these problems:

- Data deficiencies – e.g. small scale of topographic and geological maps

- Use of iterative manual procedures requiring considerable individual experience and skill which limits the number of alternatives that are evaluated

- Impact on the environmental, social systems and economic activity in the project area are not carefully considered

- Incomplete / inflexible specifications

- Design solutions are proposed without detailed problem analysis

- Lack of clear traceability between user requirements, specifications and design proposals

- Insufficient learning from experience gained in earlier projects

A typical high altitude border road of about 100 km takes four to six years to construct which is unacceptably long[14]. However, the reasons usually advanced for the construction delays such as land acquisition problems, inclement weather, harsh geographic conditions, and non-availability of construction labour can be directly traced back to shortcomings in P&D. With the security situation in the border areas expected to remain delicate for the foreseeable future, it is imperative for India to accelerate development of all-weather roads and strategic railway lines. Improved P&D methods will go a considerable way in attaining this goal.

Technology led transformation of planning

Finding the most cost-effective and reliable alignment for a road through mountain terrain requires the evaluation and comparison of several factors, including length, cost, construction practicality, environmental impact and potential geohazards associated with landslides, flooding, and erosion. The conventional method is both inefficient and mostly, incapable of delivering optimized or even just feasible solutions in mountain terrain. An information technology led approach that leverages digital data sets, spatial search algorithms and desktop / mobile Geographic Information Systems (GIS) software offers a whole new range of possible solutions for this complex problem. However, getting the most out of this technology would require changes to P&D processes as well.

Separate feasibility study and DPR: The project feasibility study and the preparation of the DPR should be treated as two independent activities of P&D. The focus of the feasibility study should be exclusively on indentifying the optimal route. This would allow for many alternatives to be evaluated. In the current practice, route selection is part of the DPR preparation. Since the scope of work in DPR preparation is vast and the time usually allowed for its completion not commensurate, route selection does not get the attention it requires. With just two or three alternatives being evaluated, a barely feasible route usually gets approved with the consequence that the design and constructability problems that come with it are considered as a given, something immutable.

There are two other reasons, one conceptual and the other practical, why the two activities must remain separate. Route selection problems involve search in *geographic space* over vast extents. Structural design which should be the only focus of the DPR is largely concerned with individual structures (e.g. bridges, tunnels) which are site specific. Good structural design requires experienced designers working with full and accurate site details, codes, standards etc. and is an activity best described as involving search in *knowledge space*. Route selection is a mathematical problem while structural design lies wholly in the domain of surveying and civil engineering.

At a practical level, high quality route selection can be accomplished by analytical studies using remote sensed data and computing tools. With the increased availability of drone based imaging services, even the need for field checks or reconnaissance can be greatly reduced. Structural design, however, requires extensive field surveys and investigations (. e.g. geological, hydrological) to be conducted. Logistics challenges are inherent in these tasks and hence the agencies that undertake them need to have the requisite financial and management capabilities.

Plan the entire network: Economies of scale and scope can be realised if border connectivity infrastructure is planned as a network rather than as a series of independent projects. A railway line in the border areas requires an extensive network of approach roads to be built to haul equipment and material for construction. Usually, the cost of construction of the approach roads are not accurately reflected in the project cost estimate of the railway line. It would be logical to examine if the approach roads can be planned and designed as permanent border roads so that they serve dual purposes. Opportunities for reducing the financial outlay required for building the infrastructure without comprising its quality or effectiveness can be identified if the planning is centralized in the Ministry of Defence.

Ensure specifications are vetted by users: The Hill Road Manual published by the Indian Roads Congress provides guidance for design, construction and maintenance of mountain roads.[15] However, strict adherence to design standards and engineering solutions proposed in the IRC codes have been found to be not cost effective. A sustainable solution through adaptive geometric design which addresses geotechnical, geometric and construction issues simultaneously can reduce cost of repair and maintenance of these roads[16]. Since the users, i.e. local Army formations, are best aware of the geometric requirements for specialized, non-standard vehicles that may need to be deployed and the road construction and maintenance challenges, it is imperative that design specifications are verified and validated by them. If the feasibility study and DPR are already completed, it is advisable that the alignment and designs be rigorously proof checked.

Involve all stakeholders early: There is increasing pressure to harness the resources and generate economic activity in our border states. Several mining, hydropower and tourism related projects are planned or are already under construction in the mountains. Often, these become catalysts for rapid, unregulated development which could destabilize the terrain through de-forestation, changes in surface drainage patterns etc. This highlights the need for close coordination with local authorities during planning.

The revenue and forest departments should be consulted before commencement of route selection so that all issues related to land acquisition and environment / wildlife protection are understood and factored into the planning. In current practice, routes are initially planned without a detailed knowledge of environmental and social objectives and constraints that they must satisfy. Delays in forest clearances and land acquisition challenges are common because of subsequent objections from the forest department and affected public.

This points to the need to adopt performance specifications and not just technical specifications for the feasibility study. Performance specifications would derive from policy objectives and public interest requirements to be met by the project by regarding economic performance, environmental sustainability, and safety performance[17].

Continuously improve terrain data: The importance of accurate, high resolution geological, topographic, and hydrological data to large construction projects in border areas is well understood by design and construction engineers but is less appreciated by policy planners. Data of this nature is a strategic and national asset. Government bodies should continuously work towards improving data quality so that it can be used more effectively in feasibility studies in border areas. The initial cost of data acquisition should not act as a deterrent. Experience suggests that the payoff through reduced cost and time overruns from superior route selection and design that quality data enables will be substantial. Leaving the task of data acquisition to private agencies tasked with preparing the DPR is counter-productive. For reasons of time and cost, there is a tendency to cut corners in this most important activity. The implications of this for construction and maintenance are always adverse.

Open - access digital elevation models (DEM) have been made available by ISRO and other space agencies[18]. They can be analyzed and processed rapidly using GIS software. As route selection requires topography to be characterized over large extents (often hundreds of square kilometers), they are considerably more useful than topographic maps. It is possible to significantly improve planar and vertical accuracies from DEM developed by processing high resolution stereo images available from ISRO.

Conclusion

Given the geological instabilities and the fragile ecosystem of the Himalayas, sustainability has to be at the core of all transport infrastructure planning on our borders. This adds further complexity to the planning process. However, there is already both valuable data from completed projects and the ability to acquire more through newer remote sensing technologies for improving planning and risk assessment. But, to reiterate, conventional methods are simply incapable of handling both the volume and the diversity of the data and therefore unsuitable for integrated planning. The solution lies in developing appropriate information systems and tools with supporting changes in data and processes. Experience has shown that an early start to construction does not guarantee an early finish, if the planning is flawed. Going forward, this fact must guide our border infrastructure planning. The time to start making the required changes is now.

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Suggested Citation: Vijay, V., ***Accelerating border infrastructure development – new planning methods***, ACB Issue Brief, 28 August 2020

Asia Centre Bangalore is a think tank focusing on Politics and Security in the Asia Region. www.asiacentrebangalore.org/

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