Research Article

Tunnel Boring in Infrastructure Projects will Thrive from the Use of Construction Robots, Advanced Technological Innovations, and Artificial Intelligence.

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Abstract: India will become the fastest-growing tunnel construction market in the next five years, thanks to rapid growth in metro, rail, road, and hydropower projects. Even though tunnel construction started in India in the nineteenth century, little is known about the factors that affect tunnel performance and their effect on project completion. This is demonstrated by the time and cost overruns of major tunnelling programs. These aspects, as well as the use of construction robots and advanced digital technology to increase TBM performance by developing and performing a more efficient tunnelling process, are examined in the study. In the current phase, the factors have been identified by comprehensive literature exploration, and a questionnaire will be sent to tunnelling experts to study the factors and their rated importance. Case studies of a similar nature will be used to validate the model, and conclusions will be drawn. Contractors should forecast the length of time and cost of tunnelling programs based on their efficiency, considering the arbitrary effect of variables. The factors that drive the use of construction robotics and advanced technologies to improve efficiency are also addressed.

Keywords: Tunnelling, TBM, productivity, Construction Robots, Digital Technology, Innovative Technique, Innovation in Construction, Artificial Intelligence, Latest technology

1. Introduction

The site is being worked on. Even though the building is the biggest and most significant industry in most developing countries [1,] the usage of robotics and advanced technology tools to improve production on the job site is very small. Tunnels are used to link cities, cut through mountains for road or rail tunnels, transport water in lakes, and dive deep into mines all over the world. These tunnels play an important role in daily life, and their demand and usage are expected to rise in the coming years. Tunnel building, on the other hand, is extremely expensive [2].

Boring tunnels was first done about 150 years ago. But for the 1.5 km, Shakespeare tunnel in Dove [3], a lack of tunnel construction experience led to the early attempts' failures over a century ago. Tunnel boring machine (TBM) drilling, rather than digging and blasting, is a very simple means of excavating, filling, and supporting the tunnel [4]. In unfavourable conditions such as mixed strata, fractured rock, and fault zones, TBM faces more time and expense delays in a tunnel than drill and blast [5]. The ability to predict the correct penetration rate estimation for a specific project schedule is critical to completing TBM tunneling successfully. TBM usage improved in the 1960s and 1970s as technology advanced, enabling effective tunnel boring in both more durable and less competent rocks at higher advance rates [7].

When it comes to tunnel construction, the most pressing issue is not the problematic sections, which make up a small fraction of the total tunnel length, but these few percent will significantly lengthen the construction period. About the fact that the tunneling system has been used all over the world, industry leaders do not have a good understanding of the factors that affect the construction process' success. A better understanding of the variables that influence the tunneling design process will make it easier to improve and model the performance of tunneling projects [8]. No such general considerations are stated in light of particular case studies and a quantitative approach.

2. Literature Review

Productivity rate in Infrastructure Construction

Productivity is defined as the ratio of an output index to an aggregate input index. While efficiency has no precise definition, it is defined by several terms, including performance factor, production rate, and output per man-day of work [9]. The physical approach defines efficiency as the ratio of input/output or the ratio of an associated resource's input to real output (in producing economic value) [10]. Since each company has its non-standardized internal procedures, defining a generic productivity measure is challenging [11].

In the building industry, a basic concept of productivity is the job per hour. It offers contractors a starting point for enhancing on-site work, and it helps them to bring the project back on track with careful preparation. By measuring productivity, contractors may identify positive and negative trends, as well as the reasons for high and low productivity.

Factors impacting tunnel construction efficiency

Each factor may have a different impact on expectations and forecasting. Construction, performance, contractual, financial and fiscal risk factors, political and social risk factors, and physical risk factors can all be classified into different risk groups [12] [13]. Conditions that are not factored into the equation often trigger cost and time overruns in tunnel construction projects [14] [15]. A lot of effort has gone into linking tunnel productivity to geological and system factors.

Factors are categorized

After a thorough review of journals, magazines, periodicals, and books, as well as a pilot survey and on-site observation, a total of 148 variables were discovered. Based on their attributes and key expert advice, all 148 variables were categorized into six groups, as seen below. After that, the variables are categorized and grouped. This classification helps to group all variables into a single unit, making it easier to classify them. The listing of the five major factors is given below.

Conditions of management

For construction activity to flow efficiently, all site activities must be organized by deploying appropriate workers at the appropriate time, in the appropriate location, and with the appropriate quality.

• On-time or early project completion is more important than ever in today's mining projects because time delays cost contractors more money by lowering profit margins. • By using TBM, the manufacturer can achieve a faster overall construction time. Since acquiring a TBM will take up to 12-14 months, creating delays at the outset, it is preferable to pre-purchase TBMs for mining projects rather than waiting for the contract's full delivery period [17].

Conditions in the Environment

Areas where tunneling is done also face unique challenges for planning to predict the activities due to highly weathered conditions [17]. "Geology" between tunnel portals is one of the most important influences shaping tunnelling costs [18] [19] due to a lack of technology in the field of geotechnical imaging.

Situational factors

The size and usefulness of the construction site decide the TBM set. Heavy cranes provide additional space on-site to lift the TBM into and out of the launching and recovery shafts, which would directly demonstrate the scale of the individual TBM components that can be carried in [20] [17].

A low-gradient surface is favoured for crane and trailer transport. It is forbidden to use bent alignments. In hilly environments, a TBM with an 8-10 m shield body will weigh more than 130 tons, making entry to a site carrying such a heavy load impossible.

Disruption

Delays will render up to 73 percent of an excavation week ineffective [20]. TBM use is compounded by failures and repairs in more than half of the cases [7].

During mining, TBM cutting tools are exposed to wear. As a result of the extreme environmental conditions, mechanical and electrical equipment overheat, resulting in danger exposure [21].

Additional Delay Causes

TBM improvement and efficiency was limited by delay times caused by breakdowns in time set aside for mining [20]. One of the most common problems that affects costs, timeliness, quality, and safety is construction delays. Delays can be caused by clients, consumers, consultants, planners, managers, contractors, and suppliers. (#22)

Tunnel building equipment parameters

The scores of each TBM division (EPB or SPB) in each of these categories, as well as others, must be considered for each project.

Any of the most common places to think about are: -

- Overall site power requirements and required site and working area
- Use and availability of additives
- Capital cost of equipment
- Disposal of excavated material
- Speed of excavation
- Local experience

The supply of additives in terms of quantities and price, as well as the ability to use the additives, may limit the type of machine that can be chosen. [23]

3. Research Methodology

The strategy adopted to gather practical information from the undertaking site was systemized input from the questionnaires. The questionnaire was dispersed to the construction infrastructure development experts in various regions of India. The survey study was organized to give subtleties on the individual demographics, factors causing delays, and suggestions for mitigating the delays by utilization construction robots and advanced digital technologies. In the survey's initial feature, respondents' fundamental subtleties were inquired. Interestingly, in the following part, delay factors were analyzed on literature review were approached to be evaluated; lastly, in the last part, member's recommendations concerning the utilization of Robots and digital technologies in construction

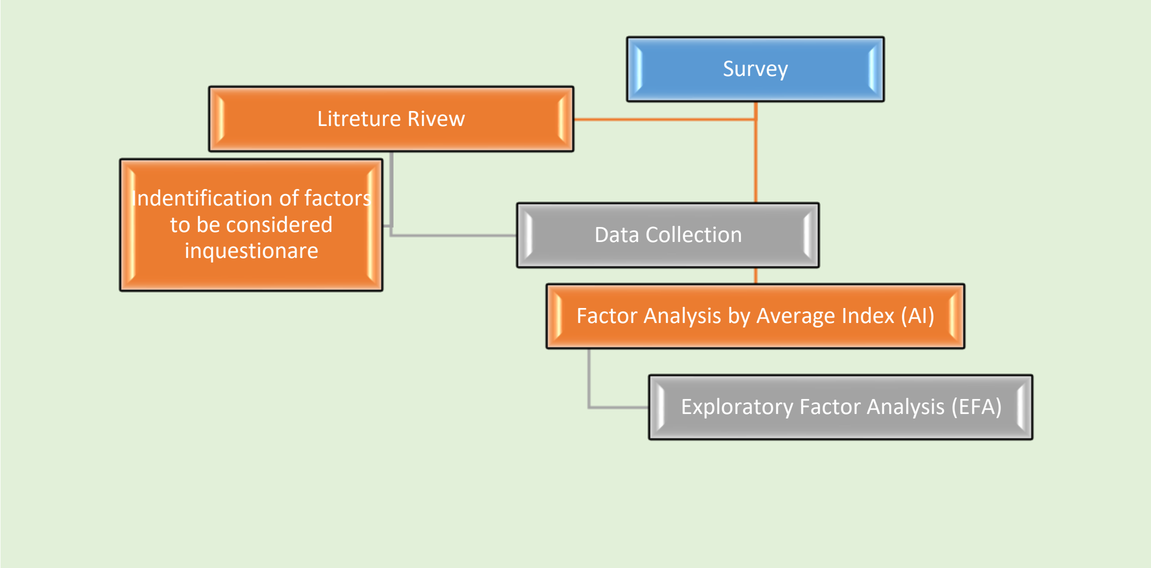

Diagram 1: Proposed framework of research methodology

Six main categories of delay factors were identified from 32 nos. of research articles, and seventy-eight factors causing construction delays. A total of 150 questionnaire survey forms were distributed to tunnel infrastructure professionals working on underground infrastructure projects, and only 120 nos of questionnaire forms were received from the respondent.

This study adopted a quantitative approach where the data was collected using a structured questionnaire survey. The questionnaire contained a list of delay factors together with 5 points Likert scale to capture the level of importance and its frequency of occurrence. For the level of importance, Likert scale 1 means very low and Likert 5 means very high while for the frequency, Likert scale 1 means never and Likert scale 5 means always. Regarding the sample size, this study used the following formula was used for the sample data collection:

Number of the sample, $n = \frac{N \times X}{(X+N-1)}$

Where N is the population size and $X = (Z_{\propto/2})^2 \times p \times \frac{(1-p)}{E^2}$

$Z\alpha/2$ is the normal distribution with a confidence level of 95% and

E is the error margin and lastly, p is sample proportion.

Based on formula 1, the calculated sample size for this study is 120. Hence the study selected 120 respondents who are having more than five (5) years of experience working in railway/metro construction projects. These respondents are professionals working on major underground infrastructure projects. The respondents were clustered into the client, consultant or contractor across the project. However, only 120 of the respondents responded where the collected data later were compiled for analysis.

The collected data was evaluated through statistical techniques known as Relative Importance Index (RII) used to analyze the data to get the desired result. The formula was suggested by (Ferdin & Fassa, 2019):

Relative Importance Index, $RII\% = (\frac{\sum W}{A} \times N) \times 100$

Where W = weight given to each factor (importance/frequency) by the respondents (1-5),

A = the highest weight (in this case is 5),

N = total number of respondents.

Demographics of Study

The demographic questions inquire about the respondent's education level, work experience, and role in the organization. The findings suggest that most of the respondents work as consultants, which is about 42%, while 22% are customers, and the remaining 36% are said to be contractors. Fig. 1-3 specifies the respondent's history of work in the industry; the results suggest over ten years of experience consists 74 per cent of respondents; the respondents had 5-10 years of experience consists in survey results was 22 per cent, and only 4 per cent have less than five years of experience. The data received on the qualification of respondents indicate that 74% have obtained a bachelor’s degree, while 18% have a master’s degree and only 8% have Diploma certification.

Figure 1: Experience of Participants

Figure 2: Qualifications of the participants

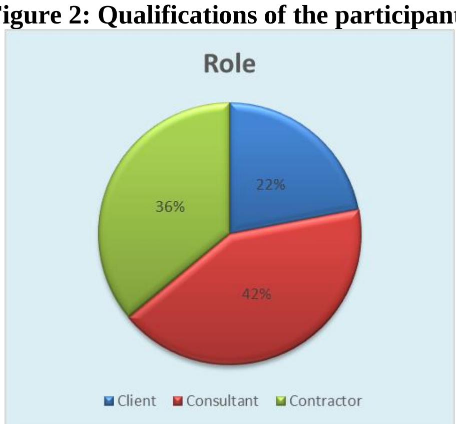

Figure 3: Role of the Participants

4. Ranking of Delay factors

Major identified delay factors are addressed in the survey and analyzed through the Relative importance Index (RII)

Delay Factors	Frequency of Cycle					Respondent	RII
	5	4	3	2	1	N	
Management Conditions	30	42	38	8	2	120	75%
Environmental Conditions	14	38	42	30	6	120	66%
Physical conditions	42	36	27	14	1	120	77%
Breakdown	12	40	47	18	3	120	67%
TBM Parameters in tunnel construction	18	22	66	10	4	120	67%

Table 1: Delay factors and their respective RII

Innovative factors	Frequency of Cycle					Respondent	RII
		4	3	2	1	N	
Construction Robots are future of infrastructure	55	43	12	10	0	120	84%
Digital Technology to improve efficiency	50	39	20	10	1	120	81%
Artificial Intelligence	54	40	20	5	1	120	84%

Table 2: Benefits of Construction Robots, Innovative Digital Technology & Artificial Intelligence

5. Discussion and Conclusion

The major factors causing delays in tunnel constructions in any infrastructure project discussed in this study are management decisions and site conditions, followed by breakdown and tunnel parameters, and construction robots, digital technology, and artificial intelligence support are the future of infrastructure projects to increase efficiency.

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