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Critical Factors Influencing the Performance of Highway Projects: An Empirical Evaluation

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Abstract: Highway construction projects have always suffered from cost overruns due to extended project delivery, causing a loss of public funds. Since highways are the backbone of a nation, the purpose of this study is to measure the criticality of the factors that influence the performance of highway projects. A survey instrument was prepared and distributed to 185 project managers. To achieve the aim of the study, exploratory factor analysis was used and the standard factor loading was the criteria to measure the criticality. From the analysis, it was identified that the factors were grouped under four categories: (a) Execution constraints (b) Operational factors, (c) Stakeholder and political constraints, (d) Design Constraints. Further, it was concluded that the complexity of the sub-contractor's performance, frequent modification in alignment, project design, loopholes in safety, and ambiguities in specifications are the main factors that impact the performance of highway projects. Therefore, it was recommended to develop an efficient project planning methodology which is a continuum of project management skills and tacit knowledge of managing a site which operates efficiently.

Keywords: highway projects; execution constraints; stakeholder management; construction projects

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1. Introduction

Highway projects are the backbone of and a significant contributor to the growth of a nation's economy by ensuring seamless transportation for all. In the present scenario, the government of India prefers to execute highway construction projects using PPP modes in which "Built operate and transfer (BOT)" and "Design-build finance operate and transfer (DBFOT)" are predominant approaches for the execution of various national highway projects [1]. Construction and infrastructure projects in India are vital components of the countries' productive capacity and efficiency. With the recent slowdown in economic activities, the pace of highway construction is also declining; in the current financial year, it has slowed down to 27 km per day as compared to the previous year's 30 km per day. This has resulted in a reduction in highway completion targets by the government to 6000 km for the current financial year.

Leigland [2] has stated that the private sector's interest in public–private partnerships (PPPs) has dramatically fallen since 2012. Losses incurred as a result of cost overruns, disputes, and claim settlements are the major cause of conflicts, and interruptions can be the reason for this [3]. This is due to a lack of correct information visibility, which contributes to the industry's tendency toward decreased profit margins and poorer productivity [4]. As a result, highway construction projects have been vulnerable to a variety of delay-causing issues such as pollution on the job site, supplier insolvency during construction, logistic failure, and community opposition, to name a few [5]. In addition, the lack of transparency and information exchange in this industry has had an impact on productivity [6–8].

According to the available research, highway projects have had unsatisfactory performance over the last three decades due to time and expense overruns. Also, prompt

completion, minimal cost overruns, no on-site dangers, and a sufficient quality standard have all been identified as indicators of a successful project [7,9]. The study, therefore, aims at measuring the criticality of the factors that lead to adverse performance outcomes in Indian highway construction projects. To achieve the aim of this study, a survey instrument will be developed from the factors that affect the performance of highway projects which were identified from the literature and RTIs. The study applies an unsupervised learning approach, so as an exploratory factor analysis approach will be used to group the factors under categories; then, literature was referred to again post-analysis to name the factor groups this helped in identifying the later variables that influence the performance of highway projects.

2. Theoretical Background

Overruns have been a regular and redundant phenomenon impacting the performance and overall project delivery of highway projects [10]. Currently, the major challenge in Indian road construction projects is an encroachment on the right of way, acquisition of land, and disputes between contracting parties, though the scope of such conflicts was limited to the maintenance and relaying of village road projects. The procurement selection for strategic construction, e.g., major highways and expressways, are handled through the use of the built, operate, and transfer method [5,11]. However, from the information received through the Right to Information Act, 2005 (RTI), over 35% of road/highway construction projects were delayed due to claims and counter claims, and approximately 10% were subjected to arbitration. Figure 1 provides a summary of disputes reported in various State Highway, Other District Roads (ODR) and Major District Roads (MDR) for the financial year 2015–2019; this information was obtained through RTI.

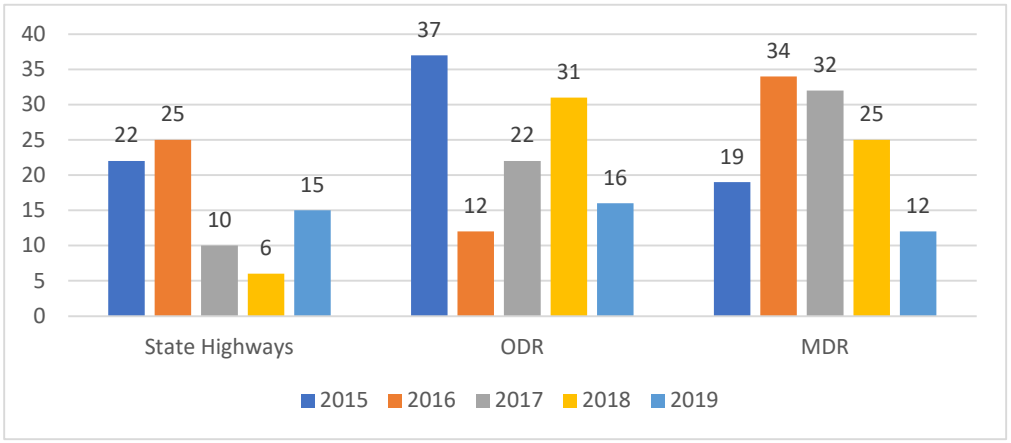

Figure 1. Delayed highway/road construction projects (Source: Information through RTI).

As per RTI application (information obtained through RTI application reference no MORTH/R/2019/50050 and CPWDN/R/2019/50005), the major reasons identified for causing delays are mentioned as follows:

- Incomplete works;
- Disruption due to encroachments in right of way;
- Socio-political reasons;
- Delayed payments;
- Work not conforming to the desired quality

The aforesaid identified reason creates risks that negatively impact project progression. Therefore, there was a need to explore the global scenario and identify the critical factors through the analysis of recent literature. The construction industry is mostly dependent on a several number of variables and participants, and because of this, to achieve the expected level of performance, an appropriate management technique for procurement planning and project execution is vital [12]. The selection of correct procurement has a direct influence

on project performance [13–18]. Fulfilling the end user's requirements, achieving optimal performance and sustainability are prime requirements of PPP projects because of their direct impact on public infrastructure projects. To achieve the objective above, a public–private–people partnership (4P) procurement strategy was proposed which integrated "people," with a target of improving value for money and to promote sustainability in infrastructure [19]. Furthermore, some of the common risks that prevail throughout the life cycle of a highway construction project are:

- Loophole in site safety leading to accidents and injuries [20,21];
- Constraints due to managing change orders [22,23];
- Unknown site conditions [22];
- Poorly written contracts [8];
- Unpredictable prices of raw materials [24];
- Seasonal shortage of laborers [25];
- Damage to or breakdown of equipment and tools [26,27];
- Disagreement with the sub-contractors [28];
- Lack of efficient project management skills [29]

Besides the aforesaid factors, the highway project in itself has a very complex nature, and lack of trust and coordination happens to impact productivity; hence, managing risks efficiently becomes a vital task [19,30–33]. The execution of the highway projects is a very exhaustive task when it comes to managing a project site located over a vast chunk of land. Efficient project management skills become vital, as they influence decision making it terms of procurement design and contractor selection [19,33]. In the current scenario, the Indian construction industry places a heavy emphasis on price-based supplier selection rather than trust-building measures such as early contractor involvement approaches, leading to the perception that favoritism and opportunism are still prevalent approaches to project awarding [34]. As a result, there are project delays to claims and counter claims due to dissatisfied subcontractors. This tendency is caused by a focus on project specific requirements, i.e., there is an ever-changing group of suppliers or subcontractors at the lower level of hierarchy varying through different projects, constraining the development of a cohesive and lasting relationship [35,36]. Furthermore, the observations from responses received in RTI application also indicated that the highway projects are also to a greater extent influenced by political favoritism specifically on the Indian subcontinent which indicates the impact of the current socio-political scenario, as indicated by researchers [37–40]. Furthermore, it was also observed that the local bodies tend to influence the contractors to lease their equipment which is ill maintained; however, this problem was limited to small scale works and mostly maintenance of the service roads, etc. However, the major problem that the contractors/subcontractors were concerned about was the theft of their equipment and the lack of a local availability of servicing facilities, ultimately resulting in the breakdown of machinery [26,28,29]. Thus, the exhaustive review leads to the identification of the following factors: delay from the clients; unprecedented price in raw materials; frequent modification from the client side; delay in land acquisition; inadequate and incomplete design; encroachment in the right of way; disputes between laborers; changing sequences in construction activity; change in quantities of work; adequate equipment; service for damaged equipment; impact of weather conditions on a project; pressure from any political party; local bodies compelling to use their resources; chances of sub-contractor walk out; delay in work execution of sub-contractor; revision of price. Hence, implications of these factors should be explored in the Indian Scenario.

3. Research Methodology

This study aimed at measuring the criticality of the factors that lead to adverse performance outcomes in Indian highway construction projects. In this context, the criticality of a factor can be defined as the importance of a factor from the perspective of a project manager and based on their perception of the impact of a factor on overall project performance. This achieved the purpose of this study, which was a survey instrument that is

developed from the literature. The survey was administered using Survey Monkey as a tool for storing a dataset and dissemination of the questionnaire. The rationale behind using a questionnaire-based approach was to derive knowledge and understand a project manager's perspective. The detailed research approach is shown in Figure 2. The respondents were required to rate the importance of the factors on a Likert Scale of 1 to 5 where 1 means "not important" and 5 means "extremely important" based on their experience with highway construction projects.

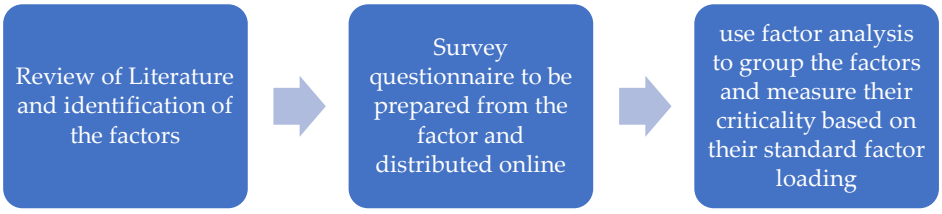

Figure 2. The research approach.

Simple random sampling was used in this study, and the participants were selected based on the years they have worked as project managers. It was further decided that the responses of only those project managers who have at least 5 years of experience as project managers for highway construction projects would be considered. Based on the selection criteria, the survey was distributed to 400 project management, and 185 responses were received. The demographic profile of the respondents is shown in Table 1. For analyzing the dataset, a staged approach was adopted. In the first step, Cronbach's alpha was used to demonstrate the reliability of the survey instrument. Then, exploratory factor analysis was used to identify the critical factors based on their standard factor load (SFL), and based on the recommendation of Hair, et al. [41], it was decided that factors whose SFL is below 0.5 would be rejected. The rationale behind using Exploratory Factor Analysis (EFA) was to investigate the relationship between various factors based on their factor loading, establishing the validity of the latent construction so identified [41].

Table 1. The demographic profile of respondents.

		Frequency	Percent
Years of working experience in Highway projects	5–10 years	147	79
	11–15 years	11	5.5
	16–20 years	14	7.0
	More than 20 years	13	6.5
Procurement Method Used	Design Build	46	23.0
	Engineering Procure and Construct (EPC)	55	27.5
	BOT and BOOT	9	4.5
	Public Private Partnerships	38	19.0
	Managing Contractor (ECI)	14	7.0
	Traditional Method	35	17.5
	Design Build	46	23.0

- Rationale for Using Exploratory Factor Analysis

As recommended by Hair, Black, Babin, and Anderson [41], when the relationships between variables are uncertain or ambiguous, Exploratory Factor Analysis (EFA) is commonly employed to investigate construct validity and to separate the measures into groups, as this is useful in defining the latent variable. As in this study, the factors were directly identified from the literature, and a survey questionnaire was prepared to evaluate the importance of the factors from the respondent's perspective. EFA was the most appropriate tool. Furthermore, in the case of validating a survey instrument, the EFA is a powerful

tool to explain the underlying structure of a larger set of variables, as it identifies the relationship between the measured items. The adequacy of the sample size was assessed by KMO and Bartlett's test for sphericity.

4. Results and Analysis

As discussed in the earlier section, a staged approach in the first step—the reliability of the data set—was evaluated using the Cronbach's alpha (CA) test. The test was performed based on the recommendation of Hair, Black, Babin, and Anderson [41], who stated that the acceptable value for the Cronbach's alpha is 0.7; post analysis, the CA value was 0.84, which was acceptable. In the next step, exploratory factor analysis was used. Following the recommendation of Hair, Black, Babin, and Anderson [41], data suitability was checked via Bartlett's test of sphericity, which was significant at 0.000. Also, the adequacy of sampling was tested by Kaiser–Meyer–Olkin (value of 0.645) to establish the sufficiency of sample size. According to these parameters, factor analysis had been justified as an appropriate tool for analyzing these data. The results of the analysis are shown in Tables 2 and 3, and it was observed that the factors identified were distributed into four groups. Factor 1 contains 8 items, including complexity of project design, improper specifications, disputes between laborers, delay from clients, service for damaged equipment, knowledge of equipment, impact of weather conditions on the project, and the chances of sub-contractor walkouts, which explained 35.38% of the total variance. Factor 2 contains 4 items, including delay in work execution of a sub-contractor, revision of price, changing sequences in construction activity and unprecedented price rise in raw materials, which explained 26.58% of the total variance. Factor 3 contains 3 items, including frequent modification from the client side, local bodies compelling to use their resources, and pressure from any political party, which explained 22.48% of the total variance. Factor 4 contains 2 items, including inadequate and incomplete design and change in quantities of work, which explained 15.55% of the total variance.

Table 2. Total variance is explained here by different factors.

	Risk Factor Description	Component			
		1	2	3	4
1	Encroachment in right of way	0.957	−0.057	0.167	0.230
2	Difficulty in land acquisition	0.942	0.220	−0.129	−0.219
3	Disputes between workers	0.881	−0.055	0.466	0.058
4	Delay from clients	0.832	0.445	0.192	0.269
5	Service for damaged equipments	0.813	0.233	0.421	0.327
6	Knowledge on equipments	0.697	0.458	0.392	0.389
7	Impact of weather condition on project	0.686	0.647	−0.107	−0.314
8	Chances of sub-contractor walk out	0.676	0.437	0.545	0.236
9	Delay in work execution of sub-contractor	−0.031	0.985	−0.125	0.111
10	Loophole in site safety leading to accidents and injuries	0.170	0.945	−0.144	0.239
11	Changing sequences in construction activity	0.450	0.783	0.022	0.429
12	Unprecedented price in raw materials	−0.355	−.746	−0.557	−0.084
13	Frequent modification from Client side	0.174	0.097	0.980	0.030
14	Local bodies compelling to use their resources	0.268	−0.205	0.879	0.336
15	Pressure from any political party	0.041	−0.310	0.800	0.511
16	Inadequate and incomplete design	−0.045	0.334	0.317	0.887
17	Change in quantities of work	0.451	0.316	0.250	0.796
	% of Variance	35.382	26.584	22.480	15.554
	Cumulative %	35.382	61.966	84.446	100.00
	Total	6.015	4.519	3.822	2.644

Table 3. Rotated Component matrix for categorization of factors.

	Factor's Description	Component			
		1	2	3	4
1	Encroachment in right of way	0.957			
2	Difficulty in land acquisition	0.942			
3	Disputes between labors	0.881			
4	Delay from clients	0.832			
5	Service for damaged equipment	0.813			
6	Knowledge of equipment	0.697			
7	Impact of weather condition on project	0.686			
8	Chances of sub-contractor walk out	0.676			
9	Delay in work execution of sub-contractor		0.985		
10	Loophole in site safety leading to accidents and injuries		0.945		
11	Changing sequences in construction activity		0.783		
12	Unprecedented price in raw materials		−0.746		
13	Frequent modification from Client side			0.980	
14	Local bodies compelling to use their resources			0.879	
15	Pressure from any political party			0.800	
16	Inadequate and incomplete design				0.887
17	Change in quantities of work				0.796

According to Table 4, there was a positive correlation between delays from clients with knowledge of equipment ($p \leq 0.01$), which signifies that a better understanding of equipment operation and access to maintenance records of the equipment is important to reduce the delays that result from a client's actions. For the service of damaged equipments and chances of a sub-contractor walking out ($p \leq 0.05$), in many road construction projects, major equipment are direct supply items from the contractor; additionally, sub-contractors generally walk out of the project when they are worried about their profit margins. The observation signifies that if well-maintained equipment is supplied to the sub-contractor, they will not suffer productivity losses. Also, the complexity of project design was positively correlated with disputes between laborers and service for damaged equipment ($p \leq 0.05$). Disputes between laborers were correlated positively with Service for damaged equipments ($p \leq 0.05$). Also, a positive correlation has been seen between knowledge of equipment with service for damaged equipments and chances of a sub-contractor's walk out ($p \leq 0.01$). If the equipment is properly maintained and operated by a skilled operator, this positively impacts the productivity of the sub-contractor, enhancing their project delivery. Interestingly, service for damaged equipment was correlated positively with the chances of a sub-contractor walking out ($p \leq 0.01$). There was a positive correlation between revision of price with changing sequences in construction activity ($p \leq 0.05$) and delay in work execution of a sub-contractor ($p \leq 0.01$). Local bodies compelling the use of their resources was correlated positively with frequent modification from the client side and pressure from any political party ($p \leq 0.05$). While there was no significant correlation among variables of factor4, surprisingly, the chances of a sub-contractor walking out was negatively correlated with the unprecedented price of raw materials ($p \leq 0.05$), which demonstrates a negative impact on a sub-contractor's profit, making them more vulnerable to opportunism and severe losses.

Table 4. The coefficient correlation between variables.

		DC	UPRM	FMCS	DLA	IID	ERW	DBL	CSCA	CQW	KE	SDE	IWCP	PPP	LBCR	CSW	DWEC	RP
Delay from clients	DC	1.000																
Unprecedented price of raw materials	UPRM	−0.758	1.000															
Frequent modification from Client side	FMCS	0.384	−0.682	1.000														
Difficulty in land acquisition	DLA	0.798	−0.409	0.052	1.000													
Inadequate and incomplete design	IID	0.410	−0.485	0.361	−0.203	1.000												
Encroachment in right of way	ERW	0.865	−0.410	0.332	0.817	0.195	1.000											
Disputes between labours	DBL	0.814	−0.537	0.606	0.745	0.141	0.938	1.000										
Changing sequences in construction activity	CSCA	0.842	−0.792	0.188	0.499	0.629	0.488	0.389	1.000									
Change in quantities of work	CQW	0.778	−0.602	0.377	0.288	0.870	0.639	0.543	0.797	1.000								
Knowledge on equipments	KE	0.964	−0.840	0.561	0.622	0.591	0.796	0.794	0.847	0.867	1.000							
Service for damaged equipments	SDE	0.949	−0.725	0.586	0.691	0.464	0.911	0.919	0.698	0.806	0.966	1.000						
Impact of weather condition on project	IWCP	0.755	−0.641	0.068	0.871	−0.127	0.530	0.501	0.678	0.237	0.611	0.562	1.000					
Pressure from any political party	PPP	0.188	−0.273	0.777	−0.245	0.601	0.309	0.456	0.013	0.528	0.399	0.466	−0.418	1.000				
Local bodies compelling to use their resources	LBCR	0.391	−0.461	0.898	0.020	0.496	0.493	0.677	0.124	0.543	0.568	0.650	−0.148	0.950	1.000			
Chances of sub-contractor walk out	CSW	0.925	−0.889	0.701	0.611	0.497	0.767	0.839	0.759	0.767	0.976	0.958	0.614	0.450	0.650	1.000		
Delay in work execution of sub-contractor	DWEC	0.418	−0.663	−0.030	0.180	0.389	−0.082	−0.134	0.802	0.354	0.423	0.188	0.595	−0.351	−0.284	0.367	1.000	
Revision of price	RP	0.599	−0.705	−0.013	0.335	0.474	0.140	0.045	0.916	0.529	0.588	0.376	0.669	−0.279	−0.195	0.505	0.971	1.000

5. Discussion

It was observed from the results of EFA that all the factors were grouped under four categories. So, it was decided that to investigate the theoretical causes behind the factor that group together, and for that purpose, an extensive review of the literature was performed. Based on an exhaustive exploration of the literature, it was identified that the following labels can be assigned to the groups:

- Execution constraints;
- Operational factors;
- Stakeholder and political constraints;
- Design Constraints.

These constraints are discussed in detail in the later sections.

5.1. Execution Constraints

The variables under this construct are those that have a direct influence on a project's vulnerability to delays and overruns that negatively impact project performance. Among the variable encroachment in right of way (sfl = 0.957) is dominant and influence project performance, as these complexities lead to several ambiguities which result in disputes [42–45]. The next factor was difficulty in land acquisition (sfl = 0.942), where it had been observed that major Indian construction projects face challenges due to constraints in land acquisition. In this context, the major reason cited for difficulty in land acquisition is due to illegal occupation in right of way and the purchase of land from the locals suffers poor implementation of resettlements and rehabilitation policies [46]. Next are disputes between laborers (sfl = 0.881). Most of the construction workers in India are migrant workers from a poor economic background and work in highly exposed conditions, which makes them most vulnerable, and conflicts have been observed due to interpersonal differences [22]. Delay from clients (sfl = 0.832) occur in the case of site handover and direct supply items. Servicing for damaged equipment (sfl = 0.813) and knowledge of the equipment (sfl = 0.697) are another other factor, as the owner of the equipment does not maintain proper maintenance records and spends less on its maintenance [29]. The forcing of major delays, e.g., the impact of weather conditions on a project (sfl= 0.686) was also grouped under this category, as the occurrence of force of nature events is difficult to predict, but it can heavily constrain the project [47,48]. Lastly, the chances of the subcontractors walking out of the project (sfl = 0.676) can have a critical impact on the performance and delivery of highway projects.

5.2. Operational Factors

Operational factors are numerous events which are beyond the control of decision makers, i.e., project managers, and impact the overall project operations. The first variable, i.e., a delay in work execution of a sub-contractor (sfl = 0.985), cannot be planned and is only resolved by switching the subcontractor [47,49–52]. It has been commonly observed that in all types of construction projects, opportunism has been a dominant phenomenon, and under its influence the parties involved in construction activities are concerned about their profit margins [48,53]. As a result, they tend to delay work execution by making frequent claims; thus, under such a situation, the project organization situation the project organisation should demonstrate a robust communication, claim-settlement, and conflict avoidance mechanism [49]. Next, it was observed that there are loopholes in site safety, leading to accidents and injuries (sfl = 0.945). This is a critical factor because work on-site may stop because of an accident on the site. Also, in the case of an accident, this may lead to a delay in the project [53,54]. In this context, it can be mentioned that accidents happen on road construction projects due to vehicular movement on-site and working with local traffic that leads to fatal injuries to the worker. These accidents can be prevented by demarking the site boundary and using a detour sign if possible. Also, during the process of laying bituminous concrete, workers are exposed to high temperatures, and workers are unaware of safety requirements and do not safeguard against burn injuries by

slipping on hot mix, or suffering heat stroke [25]. Additionally, it was also observed that changing sequences in construction activities (schedule variations (sfl = 0.783) leads to an increased lead time and shows that there is a lack of communication between the client and contractors. Furthermore, a changing of planned activities from the contractor's side occurs because of the unavailability of working capital required to arrange for the equipment needed for construction work [55]. Another important factor is the unprecedented price of raw materials (sfl = −0.746) and this has a severe negative impact on the overall project performance. The reason is that in the case of a road project, bitumen is a major raw material that is an international resource [56]. To manage the impact of unprecedented price rise, the contractors should develop a robust demand forecasting mechanism to secure additional supplies [14]. Furthermore, the negative value of an unprecedented price rise in the raw material demonstrates that this factor may severely influence the profit margin of both contractors and sub-contractors and proper contingency planning is important to minimize the impact of these.

5.3. Stakeholder and Political Constraints

These constraints are majorly due to frequent modification from the client side (sfl = 0.980) because of pressures either from stakeholder's end or due to the socio-political scenario of the country. Also, stakeholders frequent modification of work, or the constraints they introduce during the execution phase leads to several challenges for the contractors and other project participants [55,57,58]. For example, in the case of developing countries, there is a responsibility of the politicians to provide good connectivity to all the villages and cities, so in a planned project, the executing body is supposed to make many modifications to the alignment throughout the project lifecycle [59]. Next, it is observed that many times it so happens that local bodies are compelled to use their resources (sfl = 0.879) for a beneficial purpose and they resultingly try to create constraints in work progress on a construction site that leads to unnecessary delays in a project [53,54,60]. Also, it is necessary to obtain several permissions from local authorities, and sometimes they tend to push contractors and subcontractors to use their equipment, which is often obsolete [61–63]. Obsolete equipment is a common problem in developing countries, as the suppliers of these do not maintain proper maintenance records of the equipment [4]. Lastly, pressure from any political party (sfl = 0.800) demonstrates a socio-political scenario which plays a significant role in determining the prospects of highway construction projects, as in an attempt to please voters or satisfy the needs of their electorate, protests are staged on construction sites, affecting the execution of projects [64–66].

5.4. Design Constraints

Highway projects in developing nations, especially on the Indian subcontinent, suffer from severe design constraints. The highways themselves then suffer from severe maintenance issues and design errors that lead to severe time delays and cost overruns [67–72]. In the case of highway projects in developing countries, site investigation for designing pavement and facilities has been a major challenge [4]. Many times, the design is based on historical data, or a smaller number of samples are collected from the project location. Furthermore, widening or construction of a greenfield highway project leads to a rise in the prices of properties [73–78]; unplanned vehicular movement is observed in such areas due to rise in the number of unplanned settlements that results in design errors, and since the section lacks proper design, failure then leads to cost overruns [79–85].

Firstly, inadequate and incomplete design (sfl = 0.887) are due to frequent modifications in the drawings due to an increase in the number of settlements and sometimes because of the constraints created by the stakeholders that lead to modification in the alignment of the road. Next, a change in quantities of work (sfl = 0.796) is an observation that is a result of unplanned population expansion in the area where a highway expansion or greenfield projects are planned. A rise in the number of unplanned settlements in the vicinity of a road project creates several constraints, e.g., errant traffic assessment, design

errors in culverts and overpasses [86–89]. These errors further influence the alignment design, creating a variation in the quantities of work.

6. Conclusions

This study aimed at measuring the criticality of the factors that influence the performance of highway projects. A survey instrument was developed from literature and the factors identified were analysed using exploratory factor analysis. Among the results, it was observed that the factors were grouped into categories, e.g., execution constraints, operational factors, stakeholder and political constraints, and design constraints. Interestingly, it can be argued that the planners and decision makers should plan specifications in a proper manner, adhering to the project complexities and considering the impact of delays in the acquisition of land (sfl = 0.942) and encroachment in the right of way (sfl = 0 0.957). Another important observation made in this study was in the context of equipment that is used for the execution of projects. The factors, e.g., service for damaged equipment (sfl = 0.813) and knowledge of equipment (sfl = 0.697) indicates a gap in the body of knowledge in the domain of maintenance records of equipment and the lack of availability of skilled operators. Thus, it can be recommended that skilled operators must be recruited and that the equipment must be properly maintained.

The construction industry, irrespective of whether the project is highway construction or building, suffers opportunistic practices. Delays in work execution from the side of a sub-contractor (sfl = 0.985) represent their opportunism or a reaction to the opportunistic practices of the main contractor or the general contractor. In this context, it can be recommended that the clients should create a proper grievance redressal mechanism, and transparency in communication within the project organisation should be ensured. Next, important factors in the case of highway projects were loopholes in the safety at construction sites (sfl = 0.945), and this is a key area that requires more exploration, since injuries to the workers on highway projects are either due to burning, exposure to high temperatures, or moving traffic.

Moreover, on the basis of observations made from this study, the following practical recommendations can be made. The government should make strict policies for removing encroachment on the right of way. As in the present scenario, encroachment is only removed in the case of road expansion which leads to conflicts that result in delays while constructing roads. The maintenance records of the equipment should be a key component in the key selection criteria of a vendor. Also, a researcher can aim to develop a blockchain-based framework for monitoring the maintenance records of the equipment, as in that framework client, vendor and maintenance workshops should be connected. In the case of major projects, the sub-contractors can be involved in the early stages so that they can easily plan contingencies to deal with the project complexities.

Besides the previously mentioned oservations, there were certain additional limitations, and the first one is the limited availability of respondents. Another limitation was, as compared to building projects, literature in the case of highway projects is still emergent. Since the study followed an unsupervised learning approach and performance was an unobserved construct, a major limitation was predicting the relationship between the factors and performance. Since the scope of this study was to categorise the factors under groups, this limitation would be overcome in future studies by using structural equation modeling approaches. Therefore, it is recommended to develop an efficient project planning methodology which is a continuum of project management skills and tacit knowledge of managing site operation efficiently.

Additionally, future research should explore the factors that can influence the proper record keeping of equipment maintenance. Also, research can be carried out to explore the measures by which to control heat exposure and burn injuries inflicted on the workers on-site.

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