

A DYNAMIC MODEL OF CONTRACTOR INDUCED DELAYS IN INDIA

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Abstract: To understand delay in the Indian construction context, an exploratory survey was conducted as a precursor to the development of simulation models. System Dynamics (SD) was used to visualize the causal feedback relations that cause delay in order to evolve mechanisms to reduce it. A community development construction project in India serves as the case for modelling. Findings of the study suggest that there exist definite causal feedback relations among difficulty in financing the project, ineffective planning and scheduling, poor communication and coordination by the contractor, conflict between the contractor and other stakeholders, and use of inappropriate construction methods; and construction delay. However, the modelling efforts reveal that the use of best practices, such as, provision of adequate project finance and cash flow, effective planning and scheduling, adoption of appropriate construction methods and contingencies for rework in the schedule can reduce delay significantly.

Keywords: Construction, Delay, Project, System Dynamics, India

1. BACKGROUND

Several construction management scholars say the reasons for delays in projects could be classified under broad issues related to client, contractor, design, construction, materials, equipment and management (Alaghbari et al., 2007; Assaf, and Al-Hejji 2006; Chan and Kumaraswamy, 1997; Desai and Bhatt, 2013; Odeh and Battaineh 2002). However, out of these issues, contractor related issues play a major role in causing delay in developing countries (Doloi, 2009a; Odeh and Battaineh, 2002; Sambasivan and Soon, 2007). Scholars have also argued that contractors form important parts of construction projects. They are essentially responsible for the actual construction activities on project sites and as such challenges faced by contractors could cause significant delay in projects (Bon-Gang et al., 2015; Bon-Gang and Shimin, 2014; Bon Gang and Lay Peng, 2013; Ndekugri, Braimah and Gameson, 2008; Olawale and Sun, 2010). According to recent studies by Aswathi and Thomas (2013) in India, contractors rather than consultants and owners, were the most responsible party for the delays in construction projects. Similarly, according to Doloi, Sawhney, and Iyer (2012a, 2012b) more than 50% of Indian projects have both cost and time overruns and the major reasons are contractor related issues such as inefficient contractor lack of contractor commitment, and improper planning by contractors.

Plethora of studies has observed contractor related factors, and various methods of analyses of construction delay across the globe. But inquiries relating to development of policy interventions to resolve the challenges of delay in construction projects in relations to contractor aspects are limited. Therefore, the objectives of the study were to delineate the influential contractor related issues that leads to delay in India; evolve the causal feedback relations among the contractor related issues; and develop a model to estimate the reduction of delay under varied strategic interventions.

The next section of the paper presents the reviewed literature by highlighting the delay factors that are under the control of contractors. The research approach, which includes a survey and a modelling effort, follows the literature review section. The findings of the survey and the modelling efforts show the dynamics of the phenomenon and suggested policy implications were used to conclude the paper.

2. LITERATURE REVIEW

The sources of construction delay are varied, and to mention a few, they related to the performance of project actors, availability of resources, schedule delay, and contractual relations (Alaghbari et al, 2007; Odeh and Battaineh 2002; Pongpeng and Liston, 2003; Stumpf, 2000). In terms of causation by project actors, clients, contractors, designers, subcontractors and suppliers could make decisions to leads to delay. Of these actors, contractors have major impacts in India (Aswathi and Thomas, 2013; Doloi, Sawhney, and Iyer, 2012a).

The major contractor related factors, which are observed to be responsible for delay are: difficulties in financing project by contractor (Doloi, 2009a); delay in financing project by contractor (Sambasivan and Soon, 2007), rework due to errors during construction (Doloi, 2009a), conflicts between contractor and other parties (consultant and owner) (Al-Kharashi and Skitmore, 2009), poor site management and supervision (Chan and Kumaraswamy, 1997; Satyanarayana and Iyer, 1996), poor communication and coordination by contractor with other parties (Ahsan and Gunawan, 2010; El-Razek et al., 2008; Lo et al., 2006), ineffective planning and scheduling by the contractor (Ahsan and Gunawan, 2010; El-Razek et al., 2008; Lo et al., 2006), improper construction methods implemented by contractor (Chan and Kumaraswamy, 1997; Satyanarayana and Iyer, 1996), delay in site mobilization (Chan and Kumaraswamy, 1997; Satyanarayana and Iyer, 1996), and unavailability of incentives for contractor for finishing ahead of schedule (Aibinu and Odeyinka, 2006; Al-Kharashi and Skitmore, 2009).

It was however observed that although many of these factors have cause and effect relations (Assaf and Al-Hejji, 2006; Sambasivan and Soon, 2007), explicit studies relating to such feedback relations and their influence on construction delay are limited.

3. RESEARCH METHODS

The study used a survey research method for collection of primary data. Descriptive statistical analysis and Cronbach alpha test were conducted to check the reliability and suitability of the data set. The survey research method was employed to collect primary data from the various stakeholders in construction projects in India. A total of 120 questionnaires were administered, of which 100 were returned (85% response rate). Project managers, architects, engineers and designers, skilled technicians, specialist consultants, quantity surveyors, contractors and owners, were surveyed through semi-structured method. Various construction projects from which respondents were selected for survey include building, roads, bridges, railway, power plants, and industrial complex projects. The profile of sample and the projects is presented in Table 1.

“Please insert Table 1 Profile of respondents here”

In order to compile the survey questionnaire, the related literature was reviewed to identify the causes of contractor induced delay. Then a set of major delay factors were compiled and checked for their relevance in India. A pilot survey was initially conducted among the project actors with a sample size of 20 by using preliminary questionnaire in order to validate the selection of the factors to reflect the Indian construction industry. The questionnaire was modified and refined after the pilot survey based on the suggestions of the respondents and then the refined questionnaire was used for the survey for the data collection.

The respondents were asked to provide their opinions on the various parameters that cause delay and to rate the challenges in a scale of 1 to 5 from their experiences. A five point Likert scale (1= not influential, 2 = less influential, 3 = influential, 4 = significantly influential and 5 = most influential) was adopted for guiding the participants to provide their responses with varying degrees of influence of factors on construction delay.

Likert scale was employed to measure the relative influence of the variables in terms of a delay index (DI) causing delay. The DI is the mean score achieved from the responses of the respondents. The DI was then used to develop conceptual models by using SD modelling principles (Sterman, 2000). A construction project was considered as the system for developing the model. The influential factors, their positive and negative influences on the related factors and the causal relationships among them, were used to develop the SD models. The causal relationships among the variables within and across the major parameters were developed based on the evidences observed from the literature, and discussions and experiences of the professionals surveyed. Then a quantitative SD model was developed and simulated to compute the project duration and delay period under different scenarios and strategic interventions to reduce delay. While developing the models, discussions with the experts and professionals were conducted by using semi structured interviews (Day & Bobeva, 2005; Donohoe & Needham, 2009; Pandza, 2008). The discussions were conducted four times, such as (a) before developing the models to know the inter-linkage of parameters, (b) while developing the model to understand causal feedback relations, (c) to validate the causal feedback relations and conceptual

models and (d) while simulating under different strategic interventions. Modifications and amendments to the causal relations and model development and interpretation were made after every stage of the discussion.

4. MODELLING AND RESULTS

4.1 Major contractor related factors influencing construction delay

Parameterization is essential to identify the major influential contractor related factors, which significantly contribute to delay in Indian construction projects. This was done through evaluation of the relative impact of the factors by using Likert scale followed by discussion with the stakeholders. Table 2 presents the relative importance of the factors observed from the research. It was observed that difficulties in financing project by contractor, delay in financing project by contractor, rework due to errors during construction, conflicts between contractor and other parties (consultant and owner), ineffective planning and scheduling of project by contractor were perceived to be significantly influential in terms of construction delay. It is also notable that poor communication and coordination by contractor with other parties, improper construction methods implemented by contractor, and delay in site mobilization were seen as influential. However, lack of incentives for contractors to finish ahead of schedule does not appear to be influential. The findings more or less corroborate the findings of the other scholars in the literature.

"Please insert Table 2: Significance of various contractor related factors influencing delay in construction"

4.2 System Dynamics Modelling

4.2.1 SD modelling and justification of its application

A number of techniques have been developed to understand delay in the construction industry (Braumah, 2013). For instance, Paleneeswaran and Kumaraswamy (2008) developed an integrated DAS for delay analysis in construction projects, and Terry (2003) used network causal mapping and SD approach to study the impact of delays on a project. Some of the reviewed literature used Monte Carlo simulation to derive delay reduction interventions (Aswathi and Thomas, 2013) and Fuzzy logic for delay computations (Pandey, Dandotiya, Trivedi, Bhadoriya and Ramasesh, 2012). However, many of these methods do not explicitly consider the causal feedback relationships among the factors, which cause delay and specifically with regards to contractor related factors. The research was able to bridge this gap with SD modelling.

SD is a modelling technique in construction project management for improving the effectiveness of decision making process (Han et al., 2013; Lyneis and Ford, 2007). The use of SD is not limited to projects as unit of analysis. According to SD modelling scholars, this approach has potential to contribute to decision making in a complex system in which interconnectivity and complicated feedback process are rife. Given that the SD model could handle interconnectivities arising from complicated feedback processes, it is argued that it can help understand the inter-related factors at play in the industry and assist in developing plausible policy interventions to resolve the delay in construction projects. Under this premise, SD modelling is used to resolve delay at particular attribute level - the contractor level.

4.2.2 Conceptualisation of the model

As evident in Table 2, difficulties in financing project by contractor, delay in financing project by contractor, conflicts between contractor and other parties (consultant and owner), rework due to errors during construction, and ineffective planning and scheduling of project by contractor are the major contractor related causes of delay. The influence of poor communication and coordination by contractor with other parties, improper construction methods, and delay in site mobilization are however not significant. The causal relations among these contractor related factors causing delay are presented in Table 3. The causal feedback relationships among the factors and delay in the SD model (Figure 1) reveal that ineffective planning and scheduling has a direct linkage with construction delay through a feedback mechanism (balancing loop CB1). Ineffective planning essentially can happen because of poor communication. It can influence the construction activities through delay in site mobilization influenced by poor management of site and supervision and cause delay that disrupts the

effectiveness of the planning by feedback mechanism (CB1A). Similarly, difficulty in financing the project by contractor, which can lead to delay in financing the project, will cause construction delay. Conversely, once delay occurs, the contractor will face difficulty in financing the project because of the factors like cost escalation and mobilisation of funds. Thus, difficulty in financing the project cause delay and disrupts the project through feedback mechanism (balancing loop CB2). Also, delay can happen because of rework, if appropriate provisions are not in planning and schedule of the project. However, adoption of best practices of the industry such as planning for finance and budget ahead, provision of good communication and coordination, use of appropriate construction methods, and provision for rework and exigencies can reduce delay through the four reinforcing feedback mechanism with delay as envisaged in the Figure 1. First, planning for finance and budget ahead can lessen the burden of difficulty in financing; as a result the project will not be slowed down or disrupts because of lack of finance, thus reducing delay. As delay is reduced or avoided, the project will remain within the budget. This implies that planning for finance and budget ahead will reduce delay and vice versa through reinforcing feedback mechanism CR1A. Second, provision of good communication and coordination, can reduce ineffective planning and scheduling and consequently delay through reinforcing mechanism CR1B. Besides, it also will assist in proper site management and supervision and reduction in delay in site mobilisation, which in effect will reduce the negative effect of the disrupting mechanism CB1A. Third, rework needs to be considered as an essential element in the construction process. So, provision for rework and exigencies in the schedule can lessen the ineffectiveness of the planning and scheduling, thereby avoid any undue impedance in the project through the mechanism CR1C. Also, fourth, as rework, if necessitated by poor quality of work or use of inappropriate construction methods, then rework can be reduced by adopting appropriate construction methods through feedback mechanism CR1D, which in effect reduce delay in construction.

Therefore, it is envisaged that reduction of delay will occur through the actions of the reinforcing loop CR1 (constituting reinforcing sub loops CR1A, CR1B, CR1C, and CR1D) between adoption of best practices and construction delay. Thus, the disruptive mechanisms through CB1 and CB2 can be balanced or negated by reinforcing mechanism CR1. Therefore, causal feedback mechanism involving effective planning and scheduling, planning for finance and budget ahead, adoption of construction methods, contingencies in planning for rework and exigencies by the contractor, and construction delay is the dynamic hypothesis, which should be considered while developing policy interventions to reduce delay in construction.

"Insert Table 3 Cause and effect relationship among Contractor related factors here"

"Please insert Figure 1 Conceptual SD model of contractor related factors causing delay in India here"

4.2.3 Model building

Based on the explanations in section 4.2.2, a quantitative SD model was developed to observe the project duration and delay component in a construction project in India. Project duration is considered as a stock and there are three rate variables, which include normal construction rate (NCR), construction rate due to delay in financing, and construction rate due to ineffective planning. Availability of finance, good communication, provision for rework and use of appropriate technology and construction methods are the auxiliary variables, which influence the rate variables. Table 4 presents the various project attributes, project boundary and simulation variables used in developing and using the model. The maximum construction period of 36 months is considered as the model boundary and variables exogenous to the contractor related factors in construction, which include client, consultant and design related factors are kept out of the modelling. The model was built by using STELLA software, which employed algorithms developed based on the inter-relationship and dependence of the variables. The major algorithms used in the model building are given in the Equation (1 to 4). For example, project period under normal scenario is a function of initial project period and NCR (as shown in Eq.1); however project period in future scenarios of delay is a function of initial project period, NCR, AFDCR, AIPCR, CAFCR, CGCCR, CRWCR and CATCR and their relative influences (as shown in Eq.2).

The simulation time unit considered was one month up to a maximum period of 36 months because the maximum duration of the project under pessimistic conditions was three years from the day of project

'start'. Besides, a month was taken as the minimum time unit in simulation to easily comprehend the delay at different periods of construction. The Euler integration method with a time step of 0.03150 (for instance, in one month it integrates $1/0.03150=32$ times) was used for simulating the model.

$$\text{Project period (t)} = \text{Project period (t-dt)} + \int_{t_0}^t \text{Project period (t)} = \text{Project period (t-dt)} + 0.03150 = 32 \text{ times) ds of construction. cl} \dots\dots\dots (\text{Eq. 1})$$

$$\text{Project period normal scenario (t)} = \text{Project period (t-dt)} + \int_{t_0}^t \text{Project period (trmal scenar} \dots\dots\dots (\text{Eq. 2})$$

$$\text{Delay Normal scenario (D}_{tn}) = [\text{Project period (t)} - \text{Project period normal scenario}] / \text{Project period normal scenario} \dots\dots\dots (\text{Eq. 3})$$

$$\text{Delay original Estimate scenario (D}_{te}) = [\text{Project period (t)} - \text{Project period original estimate}] / \text{Project period original estimate} \dots\dots\dots (\text{Eq. 4})$$

Where

NCR= Normal construction rate

AFDCR= Addition to project period due to (reduction in construction rate) finance delay

AIPCR = Addition to project period due to (reduction in construction rate) ineffective planning

CAFRCR= Contribution to construction rate due to availability of finance

CGCCR= Contribution to construction rate due to good communication

CRWCR= Contribution to construction rate due to provision for rework in the schedule

CATCR= Contribution to construction rate due to use of appropriate technology and construction methods

w1, w2, w3, w4 are the weightages given to the respective variables as observed from historical data and expert discussion for sensitivity analysis

“Please insert Table 4 Project variables and simulated scenarios here”

“Please insert Figure 2 SD model (Stock flow diagram) based for analysing delay due to contractor related factors in construction projects”

4.2.4 Model validation

Once the model was established, and before it was used for simulation, it was tested to check if sufficient confidence in the model is attained. For this purpose, structure verification test, algorithm check and behavioural validity test were conducted. Structure verification and algorithm check were conducted by checking the causal feedback relationships and correctness of mathematical equations. For behavioural veracity of the model, the model was simulated for three completed projects having similar attributes in the same location and model results with the actual project periods were compared. The compared results (Figure 3) revealed that the model results vary marginally (from 3.5 to 7.8%) while showing behavioural validity of the model. In addition, experts were consulted to make adjustments and fine tune the model. The adjustments and fine tunings were done by adjusting the variable weights, checking the causal effects, verifying the influence of rates and results of auxiliary variables and behaviour of the model to provide results of measured variables such as project duration under different simulated conditions that should be close to real life scenarios (comparable to other similar projects).The validated model was simulated to compute the project period under different simulated scenarios.

“Please insert Figure 3 Comparison between model results and actual for validation of the model here”

4.3 Insights from the simulated SD models

The project duration and delay in construction project as obtained from the SD model was analysed under four categories (1) normal scenario (business as usual) (2) project period under important factors

causing delay scenarios; (3) project duration under strategic interventions to reduce delay and (4) comparative project duration under different scenarios. Figure 4 presents the project period and the trend of the delay under the scenarios, which cause delay. In this case two important scenarios, difficulty in financing the project with the contractor (which includes delay in financing, difficulty in obtaining the finance, budgeting and lack of communication among the stakeholders responsible for financing) and ineffective planning (which is a cause of lack of effective communication) are considered (Table 4). It was observed that under normal scenario the maximum project duration will rise to a maximum of 12.7% from the original estimate, which is quite marginal. However, the project period will be fairly high under the scenarios of finance delay (84.3%) and ineffective planning (114%). It is also seen that under the scenario of the combined effect of finance delay and ineffective planning, the delay in the project will be worst. The project period under such scenario will be exceeded by 206.3% from the original estimated duration. So, the simulated scenarios show that while difficulty in financing the project and ineffective planning autonomously will cause significant delay in the construction project, the combined effect is much worse. Therefore, policy interventions are needed to avoid such scenarios.

Figure 5 presents the project period and project behaviour under different strategic policy interventions. The simulations were conducted under four most significant scenarios as mentioned in Table 4. The scenarios which did not have significant impact either independently or in combination have been ignored for the simplicity of the analyses. While developing scenarios under different policy interventions, comparisons were made with the worst case scenarios as well as with the normal and original project duration. It was found that if good communication is effected, which essentially assists in obtaining effective planning, the project period will be reduced from the worst case scenarios of combined scenarios caused by ineffective planning and unavailability of finance, although it is still much higher than both original and normal scenario project period. This shows that policy interventions based on the combination of good communication and availability of finance alone will not reduce delay appreciably, although it will limit the delay to the certain extent. Under a combined scenario of good communication, availability of finance, provision for rework and use of appropriate technology and construction methods are effected the project period will be significantly reduced, i.e., it will be reduced by 59.8%, from the worst case scenario. In other words, the project period will be marginally higher (23%) than the original project period and close to (exceeds only by 9.2%) the project period under normal scenario.

"Please insert Figure 4 Project duration under different scenarios causing delay here"

"Please insert Figure 5 Project duration under different scenarios of policy interventions to reduce delay here"

5. CONCLUSION

This study addressed the various contractor related factors that are influencing project delays in construction. To realise the aim of the research, SD models were used to comprehend the amount of delay that can eventuate in project when individual or a combination of contractors related issues are at play in a project. Before the SD models were developed, an evaluation was conducted based on an index developed with exploratory survey in India. The simulated models reveal that delays that manifest through gaps in finance and project planning would substantially impact on the timely delivery of projects. This realisation therefore requires the use of policy interventions that could handle planning and finance issues in construction.

There are three policy implications that are generated from the findings of the study. First, planning for finance ahead can lessen the burden of difficulty in financing so that the project will not be slowed down or disrupted because of lack of funding. Moreover, the reduction of delay will enable the project to remain within the budget, which implies that planning for finance ahead will reduce delay and vice versa. Second, provision of good communication and coordination is essential as this could schedule clashes that contribute to delays. It will also aid in proper site mobilisation, management and supervision. Third, adoption of appropriate construction methods can reduce rework if produced by poor quality of work or use of inappropriate construction methods, which in effect reduce delay in construction. In particular, the combination of these policies in a project would reduce delay to a significant extent.

The paper has its limitation. Although, project actors were surveyed in India, the modelling effort only used a single project to provide insights into the dynamics of delays due to contractors' related matters. However, it is envisaged that the findings of the research should assist project actors (most especially contractors) to diagnose delay challenges and evolve mechanisms to address them on their projects. Also, the research offers a methodology to understand the influence of various contractor related factors causing delay in a project. The quantification of the extent of influences of these factors on projects amplifies the need to address them.

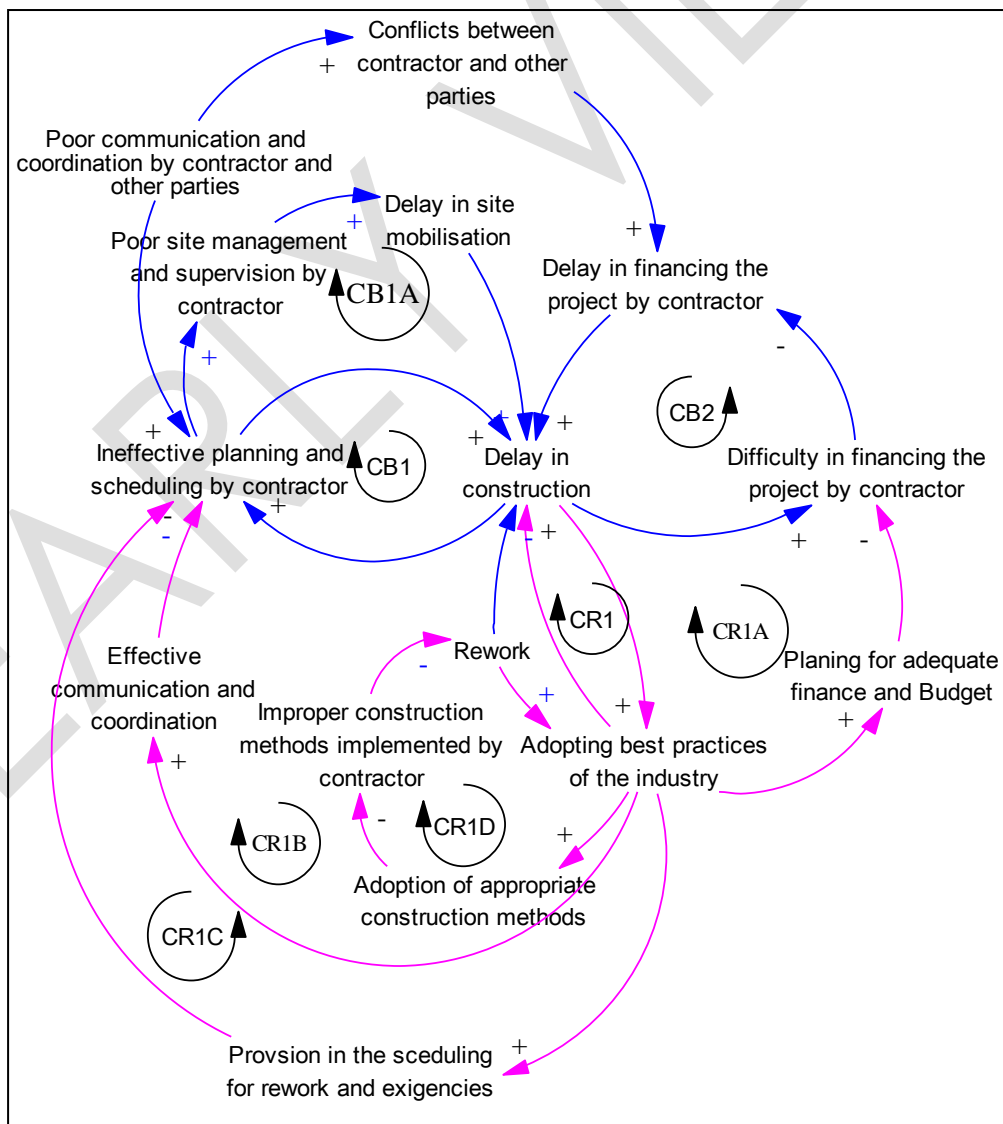
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Figure 1 Conceptual SD model of contractor related factors causing delay in India



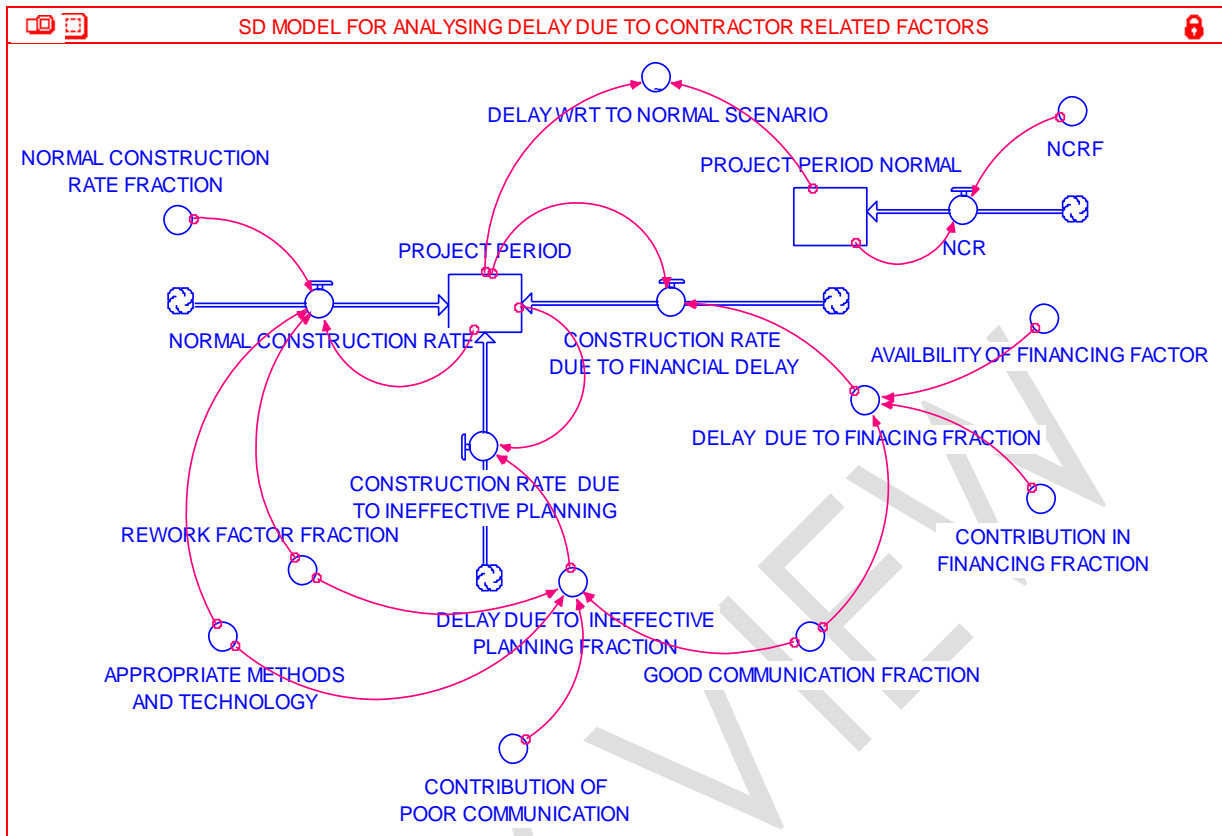
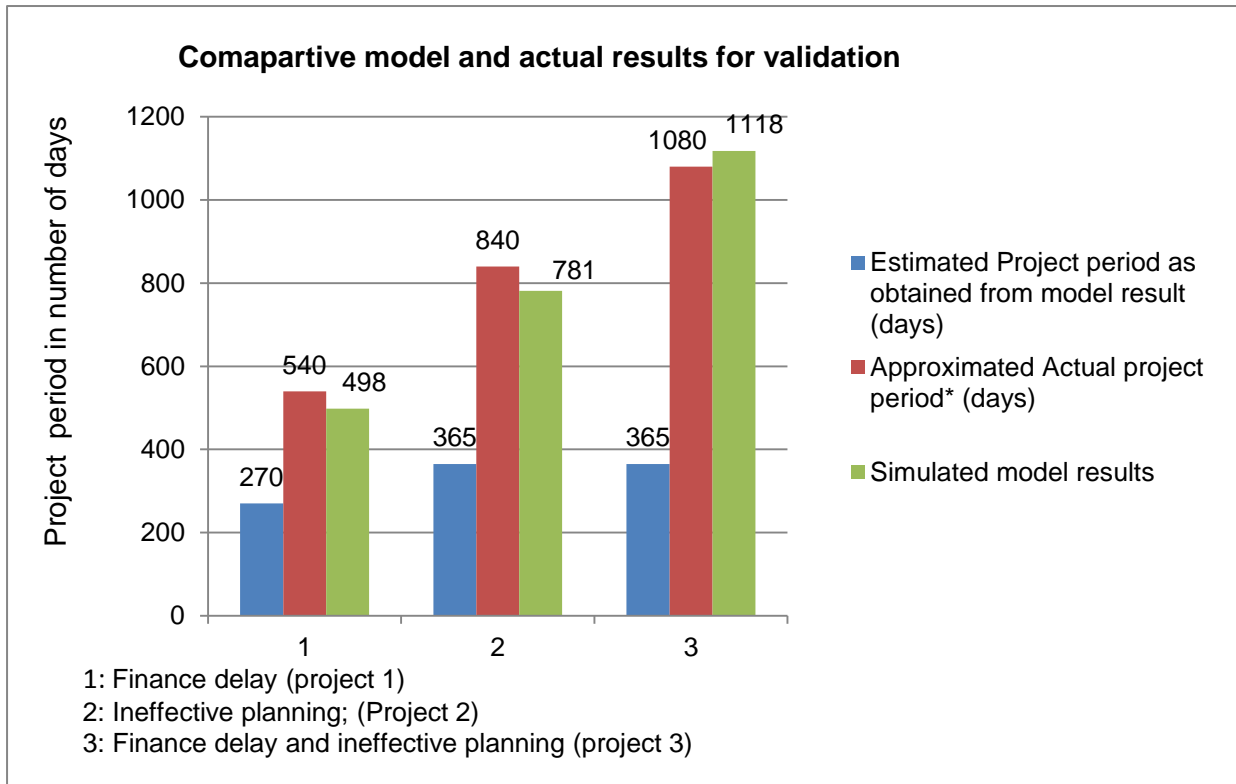


Figure 2 SD model (Stock flow diagram) based for analysing delay due to contractor related factors in construction projects

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(* Source: Projects are sourced from Odapada and Balipatna blocks in Odisha, India, 2009-2013)

Figure 3 Comparison between model results and actual for validation of the model

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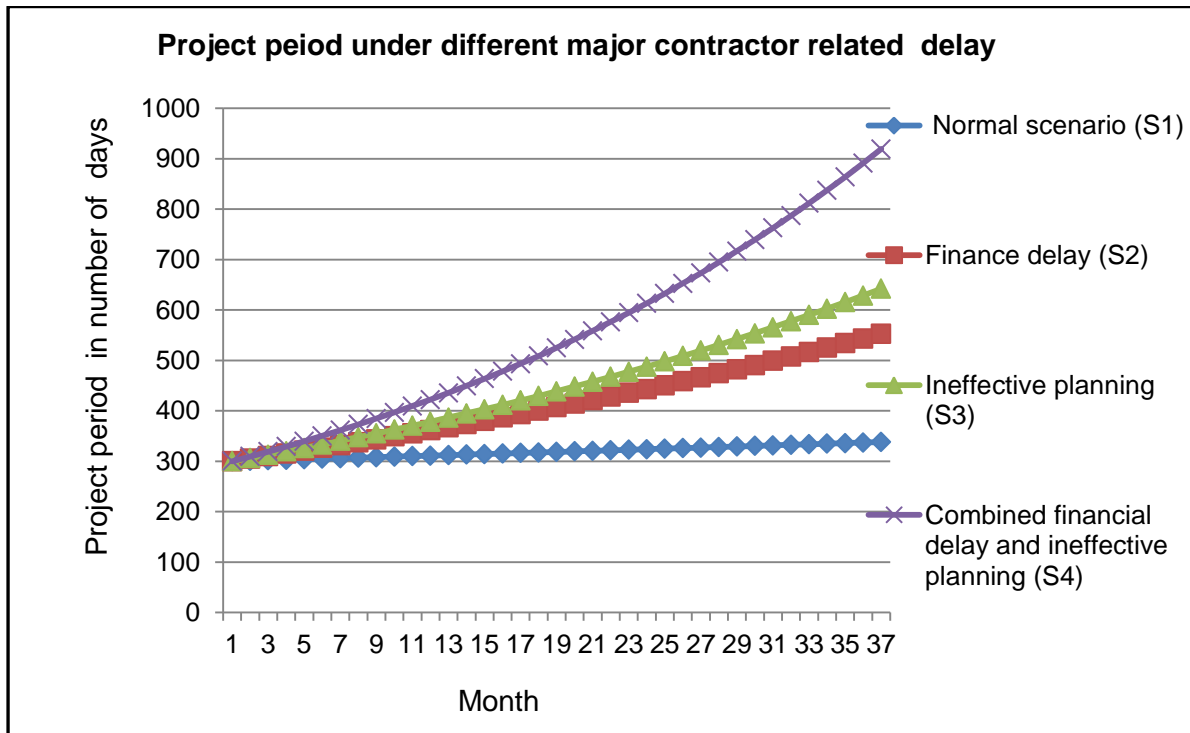


Figure 4 Project duration under different scenarios causing delay

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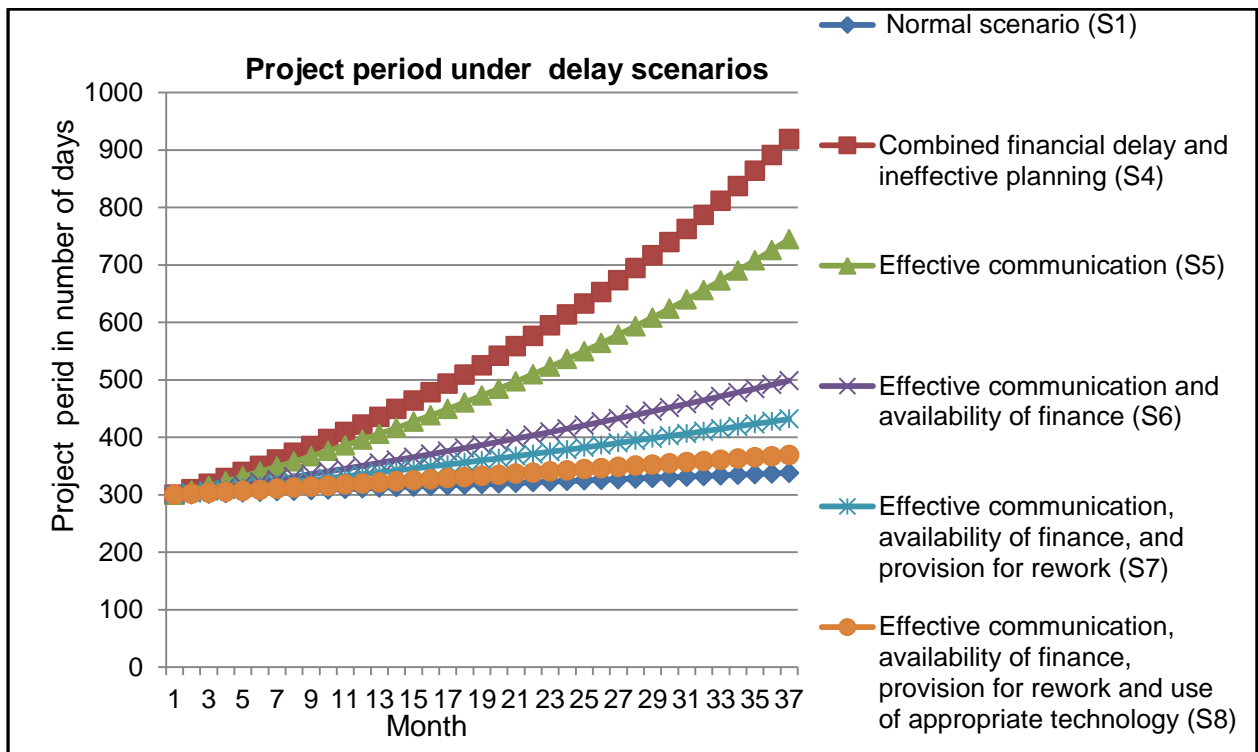


Figure 5 Project duration under different scenarios of policy interventions to reduce delay

Table 1 Profile of respondents

Project characteristics			Characteristics of Respondents	
Type of projects	Number	Per cent	Respondents	Number
				Industry time
Buildings	11	39.3	Owners/ Clients	13
				14-22
Roads	6	21.4	Project managers	17
				8-15
Bridges	4	14.2	Consultants	12
				7-18

Railway	2	7.2	Architects	11	6-15
Power plants	2	7.2	Engineers	14	13-20
Industrial complexes	3	10.7	Contractors	13	12-21
Total	28	100.0	Estimators	11	5-14
			Skilled Technicians	9	4-16
			Total	100	8.6-17.6

Table 2: Significance of various contractor related factors influencing delay in construction

Factors	Delay Index (DI)	SD	Cronbach'a	Rank
Difficulties in financing project by contractor	4.25	0.36	0.93	1
Delay in financing project by contractor	4.15	0.38		2
Rework due to errors during construction	4.10	0.32		3
Ineffective planning and scheduling of project by contractor	3.90	0.33		4
Conflicts between contractor and other parties (consultant and owner)	3.70	0.28		5
Improper construction methods implemented by contractor	3.65	0.26		6
Poor communication and coordination by contractor with	3.65	0.31		7

other parties

Delay in site mobilization	3.60	0.34	8
Poor site management and supervision by contractor	3.20	0.28	9
Unavailability of incentives for contractor for finishing ahead of schedule	2.85	0.26	10

(Note: External factors such as the weather condition have not been considered as they are beyond the control of project management)

Table 3 Cause and effect relationship among Contractor related factors

Cause	Effect	+/_	Source
Difficulties in financing project by contractor →	Delay in financing project by contractor	+	Doloi, H. (2009a); Odeh and Battaineh (2002); Sambasivan and Soon (2007); Satyanarayana and Iyer (1996)
Delay in financing project by contractor →	Delay in construction		
Poor communication and coordination by contractor with other parties →	Conflicts between contractor and other parties (consultant and owner)	+	Ahsan and Gunawan (2010); Assaf et al. (1995); El-Razek et al. (2008); Lo et al. (2006)
Conflicts between contractor and other parties (consultant and owner) →	Delay in financing project by contractor	+	Al-Khalil and Al-Ghafly, (1999); Al-Kharashi and Skitmore, (2009); Doloi (2009a)
Improper construction methods →	Rework due to error during construction	+	Chan and Kumaraswamy (1997); Satyanarayana and Iyer (1996)
Poor communication and coordination by contractor with other parties →		+	Aibinu and Odeyinka, (2006); Ahsan and Gunawan (2010); Assaf et al. (1995); El-Razek et al. (2008); Lo et al. (2006); Semple et al., 1994;
Rework due to errors during construction →	Ineffective		Chan and Kumaraswamy (1997); Doloi (2009a);

Delay in site mobilization	→	planning and scheduling of project by contractor		Doloi et al. (2012); Satyanarayana and Iyer (1996)
Poor site management and supervision by contractor	→	Delay in site mobilization	+	Chan and Kumaraswamy (1997); Satyanarayana and Iyer (1996)
Ineffective planning and scheduling of project by contractor	→	Delay in construction	+	Ahsan and Gunawan (2010); Assaf et al. (1995); BIS (2013); Doloi (2009a); El-Razek et al. (2008); Lo et al. (2006)
Adopting best practices	→	Planning for adequate budget	+	BIS (2013)
Delay in construction	→	Difficulty in financing the project by contractor	-	
Adopting best practices	→	Effective communication and coordination	+	
Effective communication and coordination	→	Ineffective planning and scheduling by contractor	-	Doloi (2009a); Doloi et al. (2012)b; Sambasivan and Soon (2007)
Adopting best practices	→	Provision for rework in scheduling and planning	+	BIS (2013)
Provision for rework in scheduling and planning	→	Rework due to errors in construction	-	Doloi (2009a); Doloi et al. (2012)b; Sambasivan and Soon (2007)
Adopting best practices	→	Adoption of appropriate construction methods	+	BIS (2013)
Adoption of appropriate construction methods	→	Improper construction methods adopted by contractor	-	Doloi et al. (2012)b
Reduction in improper construction methods adopted by contractor	→	Rework due to error during construction	-	Doloi et al. (2012)b

Table 4 Project variables and simulated scenarios

Project Variables	Variable attributes / values	Remarks
Type of project	Community development (Building)	Type of building: A school cum disaster management community shelter Location: Khurda district of Odisha state
Size of project	Two storeyed and about 800 sq. m	
Type of structure	Framed structure, isolated footing foundation, Flat RCC roof	
Maximum project period	3 years (36 months)	
Units of construction duration considered	in days	
Initial estimated construction duration	300 days	
Construction rate factions		
Normal rate of construction	0.0033 units/day	Obtained from the stakeholders discussion and historical data of projects
initial effective communication fraction	0.0.10	Obtained from Historical data of projects and discussion with engineering project execution personnel
initial rework factor fraction	0.0016	
initial financing factor fraction	0.0011	
	0.10	
w1	0.25-1.0	Based on experts and stakeholders discussion
w2	0.1-0.75	

w3 0.1-0.5

w4 0.1-0.5

Simulated scenarios		
Scenarios	Simulation variables	Combined effects considered
Normal scenario	S1 Business as usual (normal rate of construction as envisaged during project planning)	
Scenarios causing delay	S2 Non availability of finance	Difficulty in financing and delay in financing
	S3 Ineffective planning	Lack of effective communication and inadequate scheduling
	S4 Combination of ineffective planning and unavailability of finance	
Scenarios of reduction of delay under policy interventions	S5 Good communication	Good communication leads to effective planning
	S6 Good communication and availability of finance	
	S7 Good communication, availability of finance, provision for rework	
	S8 Good communication, availability of finance, provision of rework and use of appropriate technology in construction	