CSCE Annual Conference
Growing with youth – Croître avec les jeunes

Laval (Greater Montreal)
June 12 - 15, 2019

A SYSTEM DYNAMICS MODEL OF CLIENT LINKED DELAY IN CONSTRUCTION OF BUILDING PROJECTS IN INDIA

Das Dillip Kumar[1]
[1] Department of Civil Engineering, Central University of Technology, Free State, Bloemfontein, South Africa
ddas@cut.ac.za

Abstract: Clients are among the major stakeholders in construction projects and therefore play crucial roles in the completion of the projects. However, it is also argued that client induced factors contribute to cause delay in construction projects in India. Therefore, using the case study of building projects in the capital region of Odisha state of India, the objectives of the investigation are to identify the influential client related variables, which cause delay; to evolve the causal feedback relations among the most influential client linked variables and delay; and to develop a System Dynamics (SD) model to examine the scenarios of delay under varied strategic conditions. A survey research method and SD modelling approach were used for the study. Findings suggest that delay in progress of payments by owner, slowness in decision making process by clients, change orders by client during construction, late in approval of the revised design, delay in approving shop drawings and sample materials, and delay to furnish and deliver the site to the contractor by the clients are the major client related factors, which cause delay. However, the modelling effort revealed that effective communication among the various stakeholders and appropriate budgeting by the clients shall able to reduce construction delay in the building projects in India significantly.

1. INTRODUCTION

Construction industry ranks among the top five industries in India contributing significantly to the Gross Domestic Product (GDP) and employment generation. Building construction forms one of the most important segment of the construction industry and is contributing about 6% to 7% to the GDP of the country and generates millions of jobs (Ernst and Young, 2011; Gupta, Gupta, and Netzer, 2009). It is estimated that it has become the third largest contributor to the Gross Domestic Product (GDP) in the country. Moreover, the demand for 110 million houses by the year 2022, proposal to build 100 smart cities as declared by the Government of India, ease of rules and regulations for Foreign Direct Investment (FDI), and focus on affordable housing and housing for all by the year 2022, the sector is expected to grow further.

However, despite the socio-economic potential, the building construction projects are faced with the challenges of low productivity, and time and cost overruns, which range from 20% to 100% (Doloi, Sawhney, Iyer, and Rentala, 2012; KPMG and PMI, 2012). Also, in recent years, the challenge of delay in the project delivery to the customers has become enormously significant. Plenty of building projects all over the country, particularly in large and medium cities are observed to delayed. Consequent upon which reduction in sale of buildings, financial loss and legal litigation among the companies and clients have been observed.

According to the main stream literature in construction and project management, a number of investigations relating to occurrence of delay in construction including that of building projects has been conducted (Abd El-Razek, Bassioni, and Mobarak, 2008; Aiyetan and Das, 2016, Bon Gang and Lay Peng, 2013; Das, 2015). Literature suggests that delay in construction projects occurs because of the actions (inactions) and decisions (delay in decision making or poor decisions) of various stakeholders such as clients, contactors, consultants and designers, etc., (Abd El-Razek, et al., 2008; Bon Gang and Lay Peng, 2013). However, clients (in this case treated as synonym to owners of the projects) of the projects are among the major stakeholders in building construction projects and therefore play crucial roles in their completion. Since, research works on client (owner) linked delay particularly in the context of building construction projects in India are scarce, this investigation aims at examining the factors that engender client linked delay and evolve remedial interventions to alleviate the challenges. Therefore, the objectives of the investigation are to identify the influential client related variables, which cause delay; to evolve the causal feedback relations among the most influential client (owner) linked variables and delay; and to develop a System Dynamics (SD) model to examine the scenarios of delay under varied strategic conditions.

2. CHALLENGES OF DELAY IN CONSTRUCTION IN GENERAL AND BUILDING CONSTRUCTION

Delay in construction is the time overruns either beyond the contract date specified in a contract, or beyond the date that the parties agreed upon for delivery of a project (Stumpf, 2000). Delay is argued to be inevitable and an integral part in construction projects because construction activities are subjected to a number of variables and unpredictable factors despite the availability of advanced technology, and understanding of project management techniques (Bon Gang and Lay Peng, 2013; Das and Emuze, 2018; Stumpf, 2000).

Sources of delay are argued to be varied and context specific (Al-Momani, 2000). Some of the sources of delay include the performance and involvement of stakeholders such as clients (owners), contractors and consultants, resources availability, environmental conditions, contractual relations, and so on (Aiyetan and Das, 2015; Bon Gang and Lay Peng, 2013; Das, 2015; Das and Emuze, 2017,). Specifically, some of the most crucial factors responsible for time delay are design changes, poor labour productivity, inadequate planning, and resource shortages (Al-Momani, 2000). Further, lack of organizational support, poor health and safety, rework, extra work, external factors like unavailability of utilities, government law and regulations, etc., also contribute to delay (Aiyetan and Das, 2015; Iyer, Chaphalkar and Joshi, 2008). Also, client related factors such as decision-making and actions of clients contribute significantly to delay in construction projects (Das and Emuze, 2018).

Although, from the literature published over the past few decades, it is observed there is a high degree of similarity in the delay factors across many projects, the factors associated with the Indian construction industry do not necessarily follow suit (Ernst and Young, 2011). In the Indian context, although some scholars have established that inadequate design and planning coupled with scope creep and regulatory hurdles and contactors and consultant related factors are the primary reasons for time overruns, the role of owners in causing delay is no way meagre (Aswathi and Thomas, 2013; Doloi, Sawhne and Iyer, 2012; KPMG and PMI, 2012; Singh, 2010).

In Indian context, the ownership in the building construction sector is varied. Traditionally, it constitutes primarily of private entrepreneurs and family owned business houses. In recent years particularly in the last few decades since 1990s, large publicly held national or multinational companies and corporate sectors have participated in the sector (Bin, Musa and Ahmad, 2012; Chandrasekhar and Ghosh, 2018). The building construction industry is facing serious challenges because of the reduced demands in many cities of the country owing to the occurrence of delay in projects (Chandrasekhar and Ghosh, 2018). Building construction industry is highly complex and dependent on several variables and stakeholders. Although many of the factors are interlinked and have cause and effect relationships (Das, 2015; Das and Emuze, 2017; Sambasivan and Soon, 2007), explicit studies relating to causal feedback relations and their influence on construction delay are found to be limited. So, the importance of early identification of construction delays and development of causal interlinkage among the factors to engender delay-reducing remedies has been stressed (Sweis, Sweis, Hammad, and Abu, 2008). Moreover, quantification of delay or understanding of the behaviour of the building projects under different scenarios under the influence of client related factors based on their nonlinear and dynamic feedback relationship has argued to offer appropriate remedial intervention to reduce delay in building projects.

3. CASE STUDY CONTEXT AND METHODS

3.1 **Case study context**

Building projects in the capital region of Odisha state were used for the purpose of data collection. The capital region of the Odisha state (Province) constitutes two growing cities such as Cuttack and Bhubaneswar and their hinterland. Cuttack city is historically a commercial centre whereas Bhubaneswar is the capital city of the Province. The two cities are known as twin cities and are located at about 20 Kilometres apart and connected by a National Highway (NH42) and other arterial roads. The population of the region is around 2.0 million (Census, 2011). In the last two decades the region has attracted large scale population because of the location of economic activities such as large number of manufacturing industries, Information and Communication Technology (ICT) industries, business activities, and educational and governance activities in and around the region. The growth in population has created a significant demand for the development of building infrastructure such as commercial buildings and residential houses. As a result, a spurt in the building activities has been experienced in the region and the building construction sector is observed to be growing during the last two decades. However, in recent times, the sector is plagued by one of the most important challenges such as delay in the construction. Although, there are several reasons for the delay, it is alleged that clients or owners contribute significantly to the delay of the projects. Hence this case study area was chosen keeping the client/ owner liked challenges as the scope of the study.

3.2 Survey, data and data analysis

A survey was conducted to collect primary data regarding parameters that influence occurrence of client linked delay. Further, the data regarding details of project schedule was collected from a building project from one building construction company for the purpose of modelling. Statistical analyses- descriptive statistics and Cronbach alpha test were employed to check the reliability and suitability of the data set. Indices based on the Likert scale evaluation was used to parametrise and identify the influences of the variables causing delay which were used for the model building.

A questionnaire survey by use of the pretested questionnaire was conducted among the various stakeholders of the building projects in the study area. For this purpose, one hundred twenty (120) questionnaires were administered among the stakeholders belonging to 12 real estate companies engaged in building projects by following a random sampling process. The random sampling process was used because of the lack of availability of many stakeholders and their willingness to take part in the survey. However, while doing the sampling care was taken to check the diversity and relevancy of the stakeholders taking part in the survey. The projects from where the stakeholders were selected are High rise apartments, Group housing complex and Commercial buildings. The respondents include owners/ clients (13.26%), project managers (12.24%), engineers and designers (14.28%), skilled technicians (9.18%), consultants (10.20%), estimators (Quantity surveyors) (9.18%), contractors (15.31%) and supervisors (16.33%), who were surveyed through semi-structured interview method. From the survey, out of the 120 questionnaires administered 98 responses (approximately 81.67% response rate) were returned, which is seemed to be adequate. A five point Likert scale (1= not influential, 2 = less influential, 3 = somewhat influential, 4 = significantly influential and 5 = most influential) was adopted for guiding the participants to provide their objective responses with varying degrees of influence of client related factors on construction delay (Doloi, et al, 2012; Gravetter and Wallnau, 2008). The respondents were specifically asked to provide responses on the perceived influence of the measured attributes on delay based on their actual experiences in the projects they have worked on or involved in.

The reliability of the data collected was checked by use of Cronbach's alpha test. The consistency of the responses was checked by use of descriptive statistics such as Standard Deviation(σ). Likert scale evaluation was made to measure the relative influence of the variables in terms of a delay index (DI) (as obtained from the surveyed data) causing delay. The delay index is developed based on the mean score achieved from the responses of the respondents in the Likert scale.

By considering the most important client linked attributes and associated variables and their positive and negative influences on each other, causal feedback relations (loops) (CLDs) were developed by using System Dynamics (SD) modelling principles. While developing the CLDs the building project was considered as the system or environment (Forrester, 1968; Sterman, 2000). However, published literature, discussions with experts and experiences of the professionals were used as a precursor to establish causal relationships among the variables within and across the major parameters. Based on the CLDs, a quantitative SD model was developed and simulated to examine the trend/ behaviour of the project period and delay under different scenarios of cause of delay and strategic interventions.

4 MODELLING

Evidences from literature suggest that SD is a modelling technique that is based in the causal feedback relationships and delay, which are useful for understanding the complex socio-economic, business and to certain extent applied science and engineering problems (Sterman, 2000; Forrester, 1968; Senge, 1990). SD has also been applied in construction project management to understand the behaviour of different aspects such as rework, project delay, improving the effectiveness of the decision-making process, etc. (Aiyetan and Das, 2016; Das, 2015; Das and Emuze, 2016; Han, Love, Peña-Mora, 2013; Love, Edwards, Irani, 2008; Lyneis and Ford, 2007). According to Han et al., (2013) and Lyneis and Ford, (2007), the use of SD is not limited to projects as the unit of analysis but it can assist in examining the behaviour of the various phenomena in building construction and project management that may occur based on the causal feedback relationships among the influential variables. Since, delay occurs because of a combination of related factors and their interaction and feedback actions, SD is found to be suitable model for predicting the behaviour of the project in terms of project period or in other words occurrence of delay and thus used in this study. Based on this premise, SD modelling is used to resolve delays at a particular attribute level such as client linked delay in building projects.

4.1 Parameterisation (Evaluation of design linked factors influencing delay)

Table 1 presents the client related factors and their level of influence in construction delay. The high Cronbach's α values (0.74-0.83) indicate the reliability and acceptability of the data. The standard deviations (**σ**) of the perceptions of the respondents are also within the acceptable ranges indicating the consistency of the responses and therefore, the results are considered as acceptable and can be used for further analysis. It is found that delay in progress of payments by owner (DI=4.35), slowness in decision making process by owner (DI=4.20), change orders by owner during construction (DI=4.10), poor communication and coordination by owner and other parties (DI=4.05), late in revising and approving the design documents by owner (DI= 3.95), delay in approving shop drawings and sample materials by the owner (DI=3.85), and delay to deliver the developed site to the contractor by the owner (DI= 3.65) are the major client/owner related factors, which cause delay of the projects.

Table 1: Significance of attributes and factors influencing delay in construction

Factors	Delay Index (DI) (Likert scale Mean Score)	Standard deviation (σ)	Rank
Delay in progress payments by owner	4.35	0.34	1
Delay to furnish and deliver the site to the contractor by the owner	3.65	0.27	7
Change orders by owner during construction	4.10	0.32	3
Late in revising and approving design documents by owner	3.95	0.33	5
Delay in approving shop drawings and sample materials	3.85	0.38	6
Poor communication and coordination by owner and other parties	4.05	0.35	4
Slowness in decision making process by owner	4.20	0.32	2

Unavailability of incentives from the client to contractor for finishing ahead of schedule	2.85	0.26	9
Suspension of work by clients (because of lack of finance)	3.20	0.22	8

(Cronbach α=0.74-0.83)

4.2 Causal Loop diagrams (CLDs)

Causal Loop diagrams were developed based on the inter-relationship and causal feedback relationships among the variables causing delay (or influencing the project period). While developing the CLDs the project period is considered as the stock variable (as a proxy to occurrence of delay). The increase in project period compared to original schedule means occurrence of delay in the project. The causal feedback relations (loops), which essentially influence delay are identified by reinforcing loops (R) and the CLDs, which balance the project period or reduce delay, are identified by balancing loops (B). The interrelationship among the variables based on which the CLDs (presented in the Figure 1) are premised upon the evidences from literature and discussion with the stakeholders from the building construction industry.

Project period (or delay) is considered as a function of (1) decision-making by the clients/ owners with regards to construction and (2) progress in payment. The delay in approval of revised design, delay in approval of drawings and sample materials, delay in delivery of developed site to the contractors and change in orders cause delay in the decision making for construction. The delay in decision making for construction consequently lead to delay in construction, which essentially increase the project period (or delay in the project), through reinforcing feedback (CLD R1) (Figure 1). Further, slowness in decision-making to pay on account of lack of information on the project, and lack of availability of fund lead to delay in the progress of payment to the contractors, suppliers, labourers, etc. The delay in payment influences the progress of work negatively as materials, labourers, equipment, etc., might not be available. The phenomenon increases the project period and also strengths the CLD R1 caused by delay in decision making by the clients for construction. On the other hand, availability of fund and budget allocation along with the availability of appropriate information will assist in the progress of payment. The progress in payment will keep the project within the schedule or keep the delay under check through balancing loop B1. Besides, effective communication (through regular stakeholders' engagement and timely information transfer by using formal and fast communication systems) aided by coordination among the stakeholders will hasten the decision to pay and reduce the delay in decision-making regarding construction, which consequently will contribute to keep the project period under schedule. Thus, effect of CLD R1 and associated variables causing delay will be balanced by the CLD B1 and linked variables and keep the project under control.

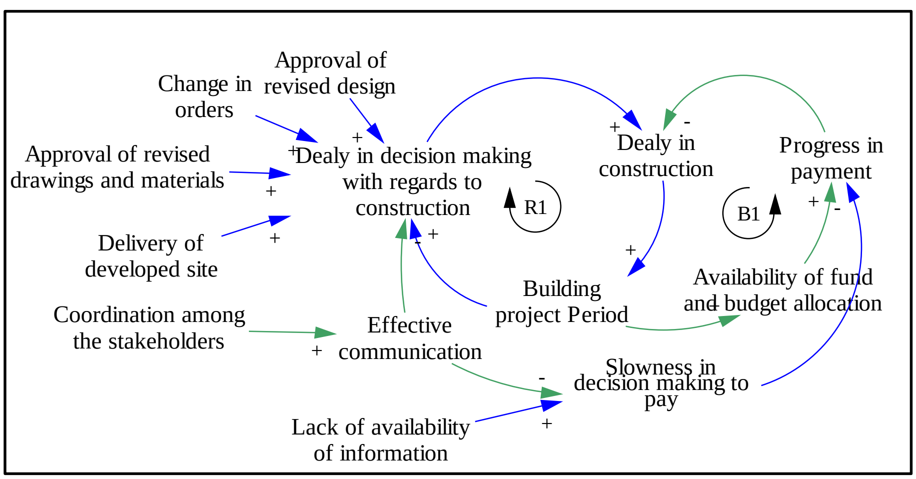

Figure 1: Causal feedback relations among the client/ owner related factors causing delay

4.3 Model building and simulation

A quantitative SD model was developed by using the CLDs and associated linkage between the variables influencing project period (client linked delay) in a building project in the study area. The model was then validated and simulated to observed the behaviour of the project in terms of project period or occurrence of delay under various scenarios of delay challenges and policy interventions to keep the occurrence of delay under control. Figure 2 presents the stock flow diagram or structure of the SD model. For this purpose, a residential complex building project comprising of residential apartments and associated infrastructure was used as the case study.

The structure of the model was developed by using SD modelling principles (Sterman, 2000). STELLA software was used to develop the model. Project period as the proxy for the delay (i.e. increase in project period with respect to scheduled project period) was considered as the stock variable. There are two rate variables, such as, normal construction rate, construction rate due to delay in construction. The normal construction is the rate of construction under business as usual scenario. However, delay in construction rate is a function of the various auxiliary variables such as delay in decision making and delay in progress in payment. The delay in decision making for construction is influenced by the variables such as delay in approval of revised design, delay in approval of approval of drawings and materials, change in orders during construction, and delay in providing developed site. Similarly, delay in progress in payment is influenced by the variables such as lack of information and unavailability of fund. So, the project period is influenced by normal construction rate under business as usual scenario and variables such as delay in decision making and progress in payment by clients and related variables and the feedback relationships between the project period and the variables. However, as envisaged, the dynamic hypotheses or policy interventions that could alleviate the delay or keep the project period under control are- effective communication between the client/ owner and other stakeholders, and appropriate budgeting by the client. In other words, the project period under policy intervention scenarios is influenced by the rate variables such as normal construction rate, challenges such as delay in decision making, and delay in progress in payment and their related variables and policy interventions of effective communication between stakeholders and availability of budget and their feedback relationship with the project period as shown in Figure 2. The values used for the initialising the variables were obtained from the historical data of the project and discussion with stakeholders. The maximum period of construction of the project was considered as 60 months over which the simulation was conducted, which was considered as one of the model boundary.

Once the model was built, it was validated through a three step process. Initially, a structure verification test was conducted, in other words, the causal logics among the variables were checked for their logicality and rationality. Further, the correctness of the algorithms, i.e., the mathematical equations were verified for their correctness. Finally, initial simulated results were discussed with experts in SD modelling and the building construction professionals to check if the behaviours generated from the model reflect the real conditions in the field. Based on the outcomes of the validation, required adjustments in the model were done. The validated model was then simulated to observe the behaviours of the project in terms pf project period and comparative occurrence of delay under different simulated scenarios.

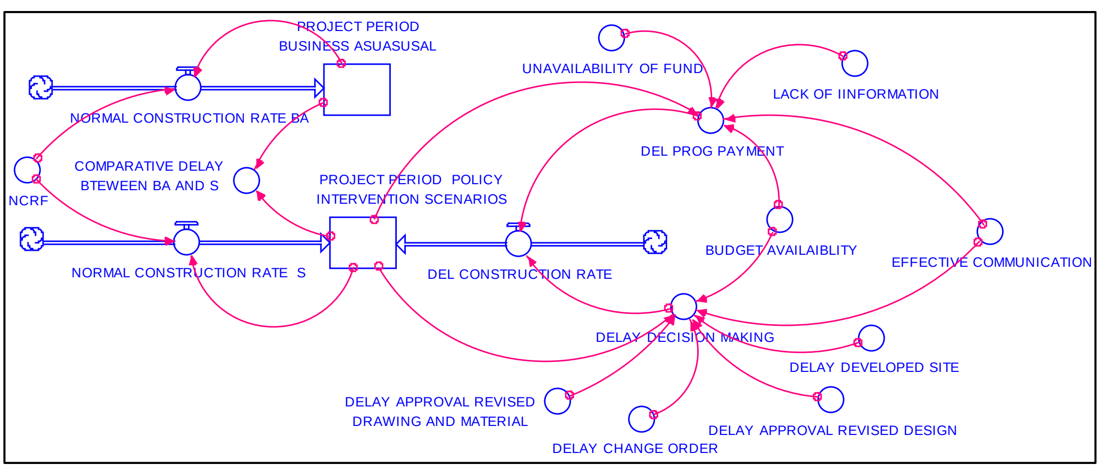

Figure 2: Stock Flow diagram (model) for client linked project delay

5. RESULTS AND DISCUSSIONS

Simulations were conducted by using the validated model to examine the behaviour of the project in terms of project period under the different scenarios. The scenarios considered were (a) business as usual (b) scenarios because of challenges of delay under individual and combined factors and their causal (feedback) relationships and (c) scenarios under policy/strategic interventions. For the purpose of analysing and examining the behaviour of the project, the following specific scenarios were depicted out of several simulated scenarios generated. They are (1) business as usual (S0) in which normal rate of construction as envisaged in project planning is followed, (2) delay in decision-making during construction period (S1), (3) delay in progress in payment (S2), (4) delay due to both decision-making and progress in payment (S3), (5) effective communication (stakeholders' engagement and formal and fast information transfer) (S4), (6) appropriate budgeting (S5) and (7) combination of appropriate budget and effective communication (S6).

Figure 3 presents the trend of project period under the business as usual and scenarios under the factors that cause delay. It is observed that under the business as usual scenario, the project period will be within control with marginal increase to maximum of 8.39% from the scheduled period. However, according to the stakeholders such a scenario is highly ideal, and does not happen often in the building projects in the cities of India. In the scenario 2, when delay in decision making occur because of delay in the approval of revised design, approval of revised drawings and materials, delay in providing developed sites and change in orders during construction, the project period increases at a significant rate rising up to more than 63% of the scheduled duration. Similarly, under the scenario of delay in progress of payment because of unavailability of fund and lack of information, the project period is likely increase by 59% of the original schedule. However, under the combination of the delay in decision making during construction and delay in progress in payment, the project period will rise sharply and it could likely to exceed the schedule period by about 117%. Thus, it is evident that the client related factors can cause significant amount of delay independently and in combination, which warrants policy/ strategic interventions.

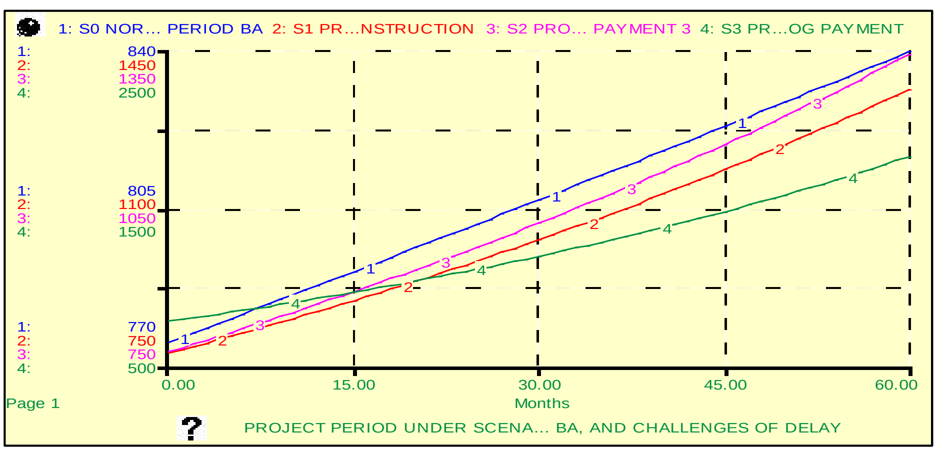

Figure 3: Project period under the scenarios of Business as usual and scenarios of challenges of delay

Figure 4 shows the trend of project period under the scenarios of policy/ strategic intervention. It is revealed that if effective communication between the stakeholders is realized (S4), it might assist in reducing the delay in the decision-making and the project period will increase at a relatively lower rate compared to the worst case scenario of delay under combination of challenges as mentioned in scenario S3. The project period is envisaged to exceed by about 51% from the original schedule. Although this increase is much leaser than the worst case scenario, it is still significant. So, effective communication cannot alone meet the challenges of delay in the building projects. Similarly, if appropriate budget is done without considering any other measures (S5), then the project period will show constant rise similar to the scenario S4 and likely exceed the schedule by about 50%, which is similar to the case of scenario of effective communication. However, it is also revealed that if a policy intervention is made by combining both having appropriate budget and effective communication (S6), the project period will be kept under significant control. Apparently, the project period is likely exceed the original schedule by about 17% only. Figure 5 presents the relative increase of project period of occurrence delay under the scenarios of the factors of client linked delay and policy/strategic interventions, Thus, although delay in building projects might happen because of the client linked factors both independently and in combination, appropriate policy interventions such as effective communication between the client and other stakeholders and making availability of appropriate budget by the client together are expected to keep the project period close to the original schedule by limiting the challenges of delay in decision making during construction and unavailability of funding. However, any policy interventions in isolation or independently might not able to meet the challenges caused by client linked factors and alleviate delay in the building projects in India.

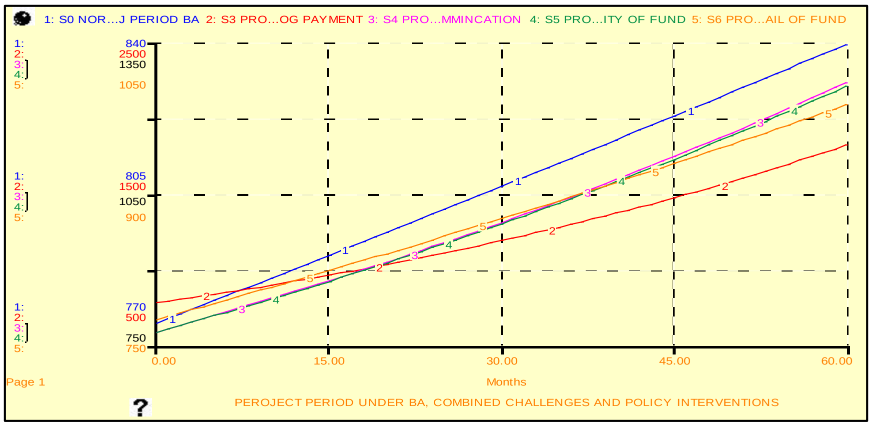

Figure 4: Project period under the scenarios of Business as usual and challenges of delay under combined scenario and policy interventions

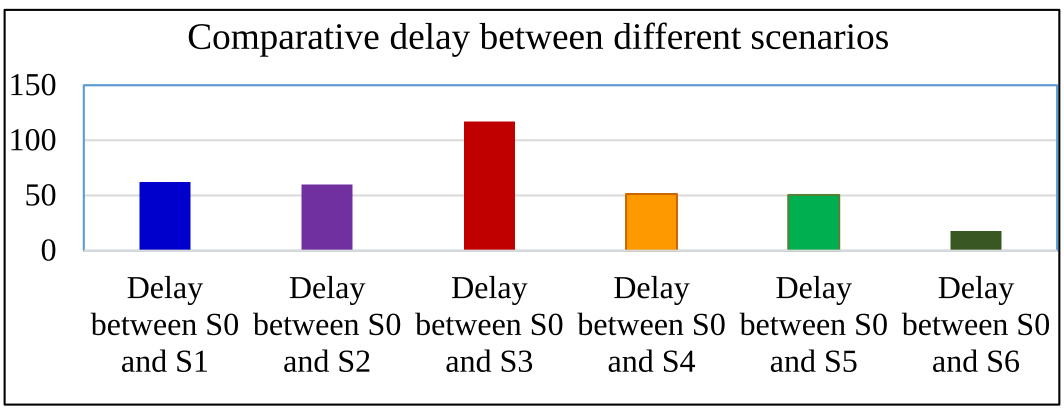

Figure 5: Comparative delay between the scenario of business as usual and challenges of delay and policy interventions

6. CONCLUSIONS

Clients or owners of the building projects play critical role in the successful completion of the projects. Like any other aspects of any projects such as consultants, contactors, design, materials, equipment, environment and weather, etc., clients also contribute to the occurrence of the delay. Evidently, all the aspects and associated parameters are interconnected to create a succession of events and actions which essentially cause delay in the projects. However, it is essential to understand what client linked factors- and how do they cause delay and to what extent before linking to them to other factors to understand the overall project delay. Moreover, there are not much study have been conducted on this aspect, specifically with respect to building projects in Indian context as evidenced from the main stream literature. Therefore, using the building projects in the capital region of Odisha State (province) of India, this study identified and examined the influential client related variables, which cause delay; evolved causal feedback relations among the most influential client linked variables and delay; and then developed a System Dynamics (SD) model to examine the scenarios of delay under different client linked factors of delay and strategic interventions to reduce delay. A survey research method and SD modelling method were used for the purpose of the study.

According to the survey results, slowness in decision making by clients, change orders, late in revising and approving the design documents by the clients, delay in approving shop drawings and sample materials by the clients, and delay to furnish and deliver the site to the contractor by the clients, progress of payments by clients, are the major client/owner related factors, which influence delay in building projects. These factors are envisaged to work in two critical mechanisms or dynamic hypotheses, one of which causes delay and the other keeps the project under control. In this regard, delay on the part of clients or owners with respect to approval of revised design, revised drawings and sample materials, delivery of developed site to the contractors and change in order cause delay in the decision making for construction. Further, slowness in decision-making to pay on account of lack of information, and lack of availability of fund cause delay in the progress of payment. These mechanisms together increase the project period through their causal feedback relations. On the other hand, the availability of fund through appropriate budget and effective communication aided by coordination among the stakeholders will hasten the decision to pay and reduce the delay in decision-making regarding construction, which essentially contribute to keep the time overrun of the project under control. The quantitative SD model apparently established these mechanisms. The SD model revealed that client linked factors such as delay in decision making during construction due to delay in approval of revised design, revised drawings, material, change in orders and delivery of sites; and delay in progress of payment cause delay appreciably independently. However, when these factors are combined the project period might rise sharply and delay become much more significant, i.e., the project period might become more than the double of the original schedule. The policy/strategic interventions of the effective communication (through regular stakeholders' engagement and formal ad fast information transfer) and appropriate budgeting independently might able to reduce to delay to certain extent and the project period could be lower than the worst case scenario, but may not be able to significantly control occurrence of delay. However, a combined effect of these two policy interventions would able to keep the delay or time overrun of the project under appreciable control.

The contributions of the study are that (1) it could assist the project stakeholders particularly the clients, contractors and project managers to diagnose the client linked challenges through the mechanisms that are created by the causal feedback relations; and (2) it also could enable the stakeholders to quantitatively estimate and foresee the impacts of policy interventions based on causal feedback relationships on the reduction of delay based on which appropriate actions to resolve the challenges of delay in construction projects in India can be taken. The SD model could perhaps provide higher insights to the construction delay challenges ensued on account of the clients/ owners both through qualitative causal feedback mechanisms and quantitative appreciations of the simulated scenarios. Since the model is developed by considering the context of a developing country- India, it can be adapted to analyse the project delay in construction projects in other developing counties having similar attributes related to construction projects. However, the study has certain limitations. First, the model is developed by using the data from one project located in one capital region of the country. Further, variables exogenous to the client/ owners related factors in construction, which include consultant, contractor, materials and equipment, weather, and environment related factors are the other model boundary and were kept out of the scope of modelling.

REFERENCES

Abd El-Razek, M. E., Bassioni, H. A. and Mobarak, A. M. 2008. Causes of delay in building construction projects in Egypt. *Journal of Construction Engineering and Management*, **134**: 831–841.

Aiyetan, O. A. and Das, D. 2015. Using system dynamics modelling principles to resolve problems of rework in construction projects in Nigeria. *Journal of Construction Project Management and Innovation*, **5(2)**: 1266–1295.

Aiyetan, O. A. and Das, D. 2016. Resolving contractor commitment challenges in project delivery by using conceptual system dynamics models. *Journal of Construction Project Management and Innovation*, **6(1):** 1563-1582.

Al-Momani, A. H. 2000. Construction delay: A quantitative analysis. *International Journal of Project Management*, **18(1)**: 51–59.

Aswathi, R. and Thomas, C. 2013. Development of a delay analysis system for a railway construction project. *International Journal of Innovative Research in Science, Engineering and Technology*, **2(1)**: 531–541.

Bin, M. Mohd, F. and Ahmad, Z. 2012. Corporate Real Estate (CRE): Public Institution of Higher Learning in Malaysia. *Procedia - Social and Behavioral Sciences*, **36**: 273–279.

Bon Gang, H. and Lay Peng, L. 2013. Comparison of schedule delay and causal factors between traditional and green construction projects. *Technological and Economic Development of Economy*, **19(2)**: 310-330, DOI: 10.3846/20294913.2013.798596.

Chandrasekhar C. P. and Ghosh, J. 2018. A crisis is building up in India's real estate sector, https://www.thehindubusinessline.com/opinion/columns/c-p-chandrasekhar/a-crisis-is-building-up-in-indias-real-estate-sector/article9872650.ece, accessed on 27/3/2018.

Das, D. 2015. Development of mechanisms by using conceptual system dynamics models to resolve delay in construction projects. *Proceedings of the 5th International Construction Specialty Conference of the Canadian Society for Civil Engineering (ICSC)*. 8–10 June. Vancouver, Canada. pp. 279-1–279-10.

Das, D. and Emuze, F. 2017. A dynamic model of contractor induced delays in India. *Journal of Construction in Developing Countries*, **22(1)**: 21–39. Available at: http://web.usm.my/jcdc/vol22_1_2017/JCDC%2022(1)%20Art%202_early%20view.pdf

Doloi, H., Sawhney, A., Iyer, K. C. and Rentala, S. 2012. Analysing factors affecting delays in Indian construction projects. *International Journal of Project Management*, **30(4)**: 479–489.

Ernst a Young. 2011. *Engineering, procurement and construction (EPC): Driving growth efficiently*. New Delhi: Ernst & Young.

Forrester, J. W. 1968. *Principles of systems*. Cambridge, MA: Productivity Press.

Gravetter, F. J. and Wallnau, L. B. 2009. *Statistics for the behavioral sciences*. 8th ed. Belmont, CA: Wadsworth Cengage Learning.

Gupta, P., Gupta, R. and Netzer, T. 2009. *Building India: Accelerating infrastructure projects*. Report prepared by McKinsey & Company Inc., Mumbai, India.

Han, Sangwon, Love Peter, Peña-Mora, Feniosky. 2013. A system dynamics model for assessing the impacts of design errors in construction projects. *Mathematical and Computer Modelling*, **57**: 2044–2053.

Iyer, K. C., Chaphalkar, N. B. and Joshi, G. A. 2008. Understanding time delay disputes in construction contracts. *International Journal of Project Management*, **26(2)**: 174–184.

KPMG and PMI. 2012. *PMI-KPMG study on drivers for success in infrastructure projects 2010 – Managing for change*. Available at: http://bit.ly/Q6y88X

Love, P.E.D., Edwards D. Irani, J., Z. (2008). Forensic project management: an exploratory examination of the causal behaviour of design-induced error. *IEEE Transactions in Engineering Management,* **55 (2)**: 234–248.

Lyneis, J. M. and Ford D. N. 2007. System Dynamics Applied to Project Management. *System Dynamics Review*, **23**: 157-189.

Ndekugri, I., Braimah, N. and Gameson, R. 2007. Delay analysis within construction contracting organizations. *Journal of Construction Engineering and Management*, **134(9)**: 692–700.

Odeh, A. M. and Battaineh, H. T. 2002. Causes of construction delay: Traditional contracts. *International Journal of Project Management*, **20(1)**: 67–73.

Sambasivan, M. and Soon, Y. W. 200). Causes and effects of delays in Malaysian construction industry. *International Journal of Project Management*, **25(5)**: 517–526.

Senge, P. M. 1990. The Fifth Discipline: The Art and Practice of the Learning Organization. Doubleday/Currency.

Singh, R. 2010. Delays and cost overruns in infrastructure projects: Extent, causes and remedies. *Economic & Political Weekly*, **45(21)**: 43–54.

Sterman, J. D. 2000. *Business dynamics: Systems thinking and modelling for a complex world*. Boston: Irwin/McGraw-Hill.

Stumpf, G. R. 2000. Schedule delay analysis. *Cost Engineering*, **42(7)**: 32–43.

Sweis, G., Sweis, R., Abu Hammad, A., Shboul, A. (2008). Delays in construction projects: The case of Jordan. *International Journal of Project Management*, **26(6)**: 665–674.