# Applicability of System Dynamics Approach in Construction Project Control

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***Abstract*—Construction projects are usually difficult to execute due to the involvement of several different systems which are interacting cross functionally, which makes construction project complex. But system dynamics methodology gives us an effective way of understanding the construction project in a realistic manner. Difficulties of construction projects from the viewpoint of system dynamics are analyzed. Rules of system dynamics causal loop diagram are described and construction project control loop is explained. At last need of system dynamics in construction industry is discussed.**

**Keywords: System dynamics, Construction project, Construction industry.**

## I. INTRODUCTION

Construction industry is one of the major industries that represent the growth of the nation, so better understanding over construction projects is very much necessary for smooth and effective run of the construction industry. But in construction industry delays and cost overruns are common, here cost overruns of 100-200% are common and delays are sometimes till such point that the market conditions for which it is designed have changed [4]. These delays, cost overruns are due to the fact that construction projects are more complex and dynamic. So we need a methodology like system dynamics which can help us for better understanding over projects to avoid these cost overruns and delays.

Currently construction industry is using techniques like Critical path method (CPM), PERT and Gantt charts for construction project planning and control. These techniques are useful for scheduling and to get the activity sequence, but they don't consider the feedback effect of activities [4]. So system dynamic methodology has to use with other techniques like CPM, PERT and Gantt charts so that these techniques are used to overcome from complexities of multiple parallel and sequential activities and system dynamic methodology will take care of dynamic complexities created by interdependencies, feedbacks, time delays and nonlinearities of construction projects.

## II. OVERVIEW SYSTEM DYNAMICS

System dynamics is a kind of methodology that considers all interrelations, feedback and dynamic nature of the components of the system which is under study [5]. As construction industry environment is so wide and complex because of its components and interrelationships, system dynamics methodology gives us scientific way of modeling these components and interrelationships by establishing the causal relations and causal loops which is the main part of system dynamics model.

In system dynamics methodology simulation was one of the important step, simulation is done with the help of computer which is also called system simulation. Main parts of system simulation are System, Models and Computer [1]. System dynamics models are made with the help of modeler experience or by discussing with group of people who involved in that work in system by converting their mental models in to System dynamic models which can be evaluated and improved.

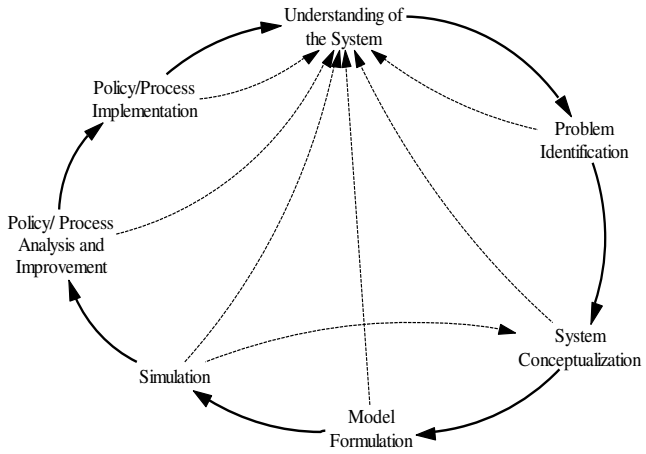


Fig. 1. Overview of system dynamics methodology [6]

In system dynamics methodology first we have to understand the system which is under study to find out the problems of the system which is to be solved then we have to create the model of the problem situation then we have to formulate that model for simulation in computer using simulation software's like Vensim, Stella, iThink etc. then we can analyze those process or policies which we are using earlier is best or what and we can improve those process or policies in scientific manner [6].

## III. DIFFICULTY OF CONSTRUCTION PROJECTS FROM THE VIEW POINT OF SYSTEM DYNAMICS

### *A. Consists of large number of interdependent components*

Project success depends on numbers of factors like Project procedures, Project related factors, Human related factors, Project management actions and External environment factors all these factors are interrelated which is difficult to analyze with traditional tools [3]. For example, change in lift installation location may lead to civil engineering, mechanical and other design changes. These kinds of changes will delay the actual progress of the work which results in postponement of progress of work. Such causal relationships make it difficult to make out the interactions of these components in mind, since the analysis of this kind of problem is beyond the capacity of the mental model. These multiple correlations will be effectively described by system dynamics.

### *B. Highly dynamic*

Dynamic because construction project performance outcome depends upon both present action and previous action taken. Its outcome will not be same as time passes even if input is constant. For example, increase working hours of employees to finish projects quickly without thinking employees fatigue level it may increase the chance of quality problems which may intern increase project duration or if we hire more workers to complete the project quickly it may help in long run but in short run first the existing experienced employees has to spend their time in training the new employees which intern increase the

cost and time of the project. These kinds of dynamic situations cannot be handled by traditional methods. It can be properly represented, handled and explained by system dynamics methodology.

*C. Involve nonlinear relationships*

In construction projects there are complex nonlinear relationships whose cause and effect relationships are not simply directly proportional. For example, consider relationship between working hours and progress, to increase the progress of project working hours of employees is increased, first it will seems like increased working hours of the employees will reduce project duration but in long run increased working hours of the employees will reduce their efficiency that means there is increased risk of quality problems that can finally increase the project duration. Causal feedback of system dynamics can trace these nonlinear relationships and evaluate their impact.

*D.* Involves multiple feedback processes

Construction projects consists of multiple reinforcing and balancing feedback processes which is also called as feedback loops. Reinforcing loop is also called as positive loop shows that system behavior is away from the goal, where as balancing loop also called as negative loop shows that system behavior is towards the goal. For example during construction progress project may delay due to factors like material shortage, quality issues etc. to cope up with delay employer forces the employees to do overtime thus balancing loop is produced but in the other end overtime may increase fatigue level in employees which leads in reduction of production rate and work quality and thus have a reverse impact on progress of the work thus this effect will generate reinforcing loop in system.

*E. Involves both hard and soft data*

Construction project performance depends on both hard and soft data. Hard data represent the engineering properties such as drawings, reinforced concrete, materials and equipments. While soft data represents organizational properties such as organization structure, organization goals and managerial decision rules. System dynamics methodology will consider both soft and hard data and specify there relation in model.

## IV. CONSTRUCTION PROJECT CONTROL LOOP

*A. Basics of Causal Loop Diagram*

Causal loop diagram is a main diagram which describes the basic structure of the system to draw causal loop diagram we have to first know some basic rules of causal loop diagram. If we consider the variables ‘A’and ‘B ‘if ‘ B ‘is increasing due to effect of ‘A’ on ‘B’ means ‘B’will get positive polarity in the same manner if ‘B’ is decreasing due to effect of ‘A’ on ‘B’ means ‘B’will get negative polarity, apart from polarity two types of loops are there one is ‘Balancing Loop’ and another one is ‘Reinforcing Loop’. If a loop behavior tending towards the goal then loop is balancing loop which is also called as negative loop. If a loop behavior tending away from the goal then loop is called reinforcing loop which is also called as positive loop.

As a rule of thumb, if the number of negative polarity in the loop is zero or even then the loop is considered as reinforcing or positive loop and if the number of negative polarity in the loop is odd then the loop is considered as balancing or negative loop [6].

*B. Control loop of construction project*

With the help of system dynamics causal loop diagram construction project control loop is discussed. Construction project duration will changes mainly due to design changes and rework. Due to design change rework will be more and also planning changes will occur due to this, deviation in the estimated project duration will be more so project duration will get increase. In situation like this management of

the company will think about two thinks one to increase working hours of the existing employees, another one is to hire new employees to increase the work rate to balance the deviated project duration, which create the balancing effect.

But in reality, if management increases the working hours of the employees, seems like it the deviation time of the project can be get back in track with estimated time of project but in long run, due to increased working hour's employees will get more tired so their work efficiency will be less this will increase quality issues in construction project which will leads to rework that means finally this effect will create reinforcing effect, or if management hire the new employees then existing employees has to spend time in training the employees here training requires time for training the new employees existing employees has to deviate from their work to train new employees. If they didn't train the new employees to suits Company style of working then rework will be more, so finally this effect will also create reinforcing effect. Here both decisions in long run deviates project from the track.

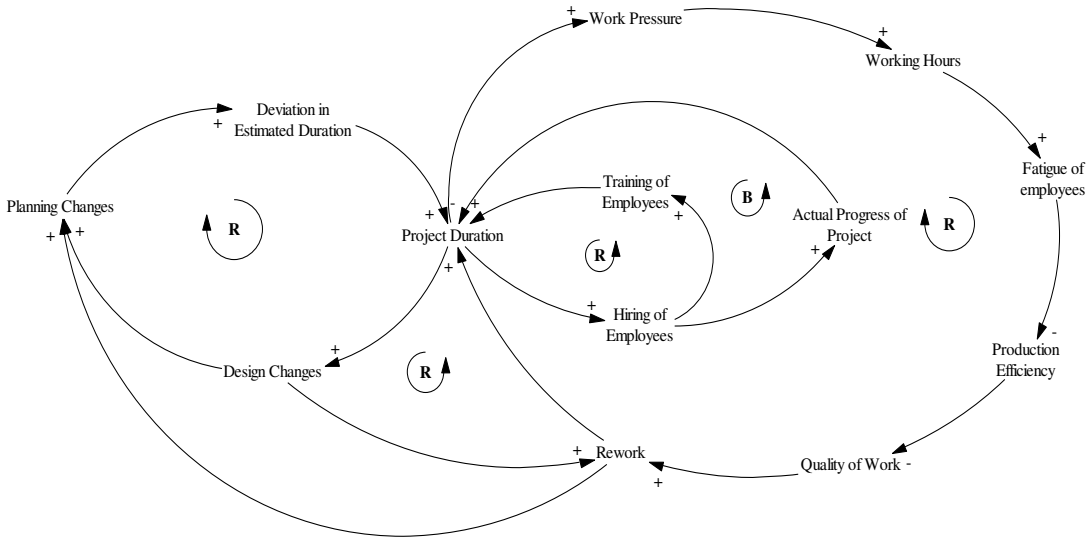


Fig. 2. Control loop of construction project.

## V. APPLICABILITY OF SYSTEM DYNAMICS IN CONSTRUCTION INDUSTRY

Construction project control loop shows that there is a complex causal relationship exists between various elements of system of construction projects. These complex relationships cannot be handled by mental models of humans alone because bounded rationality of human mind cannot analyze the complex causal relationships effectively, because human brain is bounded by various limitations like attention, memory, information processing capability or the decision may biased depending on his emotions. When solving complex problems, analysis of problem and solving those problems is big when compared to the capacity of human brain capability

Mental models are very good in establishing first order relationships because human mind can gather lot of information but it is weak in generating higher order consequence's and mainly another thing in mental model is it cannot be examined by others means it is difficult to exchange these information, as it is difficult to examine by others it may be biased.

We need system dynamics methodology because, this methodology gives us a way to overcome from these difficulties and complexities as computer models can be easily examine by others and it gives us opportunity to review these models and here we are able to interrelate as many relations simultaneously and also group of experts can interrelate their models at a time to get a best solution for a problem situation. But here we have to carefully monitor because computer models can be manipulated as here good and bad practice can be found.

## VI. CONCLUSION

Managers while facing the complex situation in project their decision is a kind of sudden decision making process depending on their experience, knowledge, emotions. Emotion play a very important role here so bias in decision making can happen, then decision making is not realistic so system dynamics methodology gives us an effective scientific manner in process of decision making in complex situations. By combining formal techniques with system dynamics methodology through qualitative and quantitative analysis we can build the models which represent the actual real system and with the use of system dynamics simulation software we can test the models through simulation, simulation will consider both system structure and function into consideration so that decision process will be in scientific manner.

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