Scientia Iranica A (2017) 24(6), 2684–2695

SCIENTIA IRANICA

Sharif University of Technology
Scientia Iranica
Transactions A: Civil Engineering
www.scientiairanica.com

Assessment of labor productivity in construction projects using system dynamic approach

M. Khanzadi[a,*], A. Kaveh[b], M. Alipour[a] and R. Khan Mohammadi[a]

a. *Department of Civil Engineering, Iran University of Science and Technology, Narmak, Tehran, P.O. Box 16846-13114, Iran.*
b. *Centre of Excellence for Fundamental Studies in Structural Engineering, School of Civil Engineering, Iran University of Science and Technology, Narmak, Tehran-16, Iran.*

Received 8 August 2015; received in revised form 16 April 2016; accepted 17 October 2016

KEYWORDS
Labor productivity;
Contractors;
System dynamic;
Construction projects;
Simulation;
Total productivity.

Abstract. Labor productivity is one of the most important factors in achieving project success at different stages of a project. In this research, a new method is presented to model labor productivity for different types of contractors based on System Dynamic (SD) simulation. Using cause and effect feedback loops, a qualitative model is constructed. The relationships between different parameters are then determined by expert's judgment and real data obtained from several real projects, and the quantitative model is built. The labor productivity is simulated by the proposed SD model, considering all affecting factors. For higher accuracy, the model is examined on two types of contractors and two models are constructed. The total productivity of each contractor is obtained, and the effect of different parameters on the labor productivity is investigated.

1. Introduction

Labor productivity at each stage of a project is one of the most important factors in achieving a project's success. Productivity estimate is an essential element to obtain the duration and cost of a construction operation [1]. Site workers account for up to 40% of the direct capital cost of large construction projects, and there is a need to maximize the productivity of labor resources [2]. Improving construction productivity can go toward eliminating time and cost overruns [3]. The loss of construction productivity is usually attributed to various factors rather than a single one. In addition, the factors affecting construction labor productivity are rarely independent of the others; some factors may be the result of the same cause, or one factor may trigger the occurrence of others [4-7]. Knowledge and understanding of various factors affecting construction labor productivity is needed to determine the focus of the necessary steps in an effort to reduce project cost overrun and project completion delay, thereby increasing productivity and overall project performance [8]. Productivity increase problem has long been a concern of researchers. Based on previous studies, key factors that can affect labor productivity in construction have been obtained from studies by Lim and Alum [9], Olomolaiye et al. [10], Ibbs [11], Nepal et al. [12], Enshassi et al. [13], Alinaitwe et al. [14], and Hanna et al. [15], among many others. Most researchers work on the factors affecting the labor productivity; however, there are some other studies on productivity. As an example, Nasirzadeh and Nojedehi [7] proposed a model that the labor productivity is simulated, considering the effects of all influencing factors. The effect of labor productivity on different project performance measures is also assessed in terms of time and cost [16]. Using the proposed model, the project manager may find the

*. *Corresponding author. Tel.: +98 21 77240540-3164*
E-mail addresses: khanzadi@iust.a.ir (M. Khanzadi); Alikaveh@iust.ac.ir (A. Kaveh); malipour@iust.ac.ir (M. Alipour); reza.khanmohammadi@yahoo.com (R. Khan Mohammadi)

doi: 10.24200/sci.2017.4164

main causes of a decrease in productivity. Alzraiee et al. [17] presented a new method that integrates Discrete Event Simulation (DES) and SD models to address the operational and soft/strategic variables on a single computation platform. The expected outcomes are realistic project schedule networks and enhanced understanding of the interactions of the project's factors. Mohamed and Srinavin [18] introduced a fourth model where productivity can be predicted as a function of the thermal comfort index. The latter paper then presents a comparative analysis between all proposed models with emphasis on their sensitivity to air temperature. Field data collected from different construction sites demonstrate that the observed productivity data agree well with those predicted by the thermal comfort index model. Moselhi et al. [19] explored the impact of changing orders on construction productivity and proposed a new neural network model for quantifying this impact.

Although several research studies have been conducted to determine the effects of different factors on labor productivity, these studies have faced some major defects. In the previous studies, most of the researchers have focused on the parameters affecting the labor productivity, without considering their inter-relationships. In these studies, the parameters were selected and then ranked. After that, they analyzed and arranged. However, it is obvious that most of the mentioned parameters have complex inter-relation with each other, which may be affected by the other ones. There are also a few studies in which the interrelations between parameters are considered [5], the different personnel job is not considered, and only the labors in the construction project are the focus of study. Furthermore, in the previous studies, the effect of the labor productivity on the time of the projects was not elaborated. Goodrum et al. [20] conducted a study through analysis of variance (ANOVA) and regression analysis, and found that activities experiencing significant changes in material technology have also experienced substantially greater long-term improvements in both their labor and partial factor productivity.

This paper presents an SD-based method to model labor productivity. System dynamics, introduced by Forrester [21], enables any user to model complex systems, considering all the influencing factors.

SD is utilized to consider the complex interaction of different factors affecting labor productivity. The qualitative model of labor productivity is constructed employing cause and effect feedback loops, considering the influencing factors. Then, the quantitative model is built by determining the relationships between different factors. Using the proposed simulation approach, all the influencing factors affecting different jobs in the construction project are simulated, and the labor productivity and amount of time needed to complete an activity are found. Therefore, the project manager can improve the productivity of the project and, consequently, reduce the time and cost of the project by selecting a proper strategy.

The structure of the paper is as follows: In Section 2, research methodology is described briefly. In Section 3, the proposed model structure is explained in detail and the dynamic simulation of the labor productivity is elaborated. Section 4 shows the model application for three case studies, and finally, some concluding remarks are provided in Section 5.

2. Research methodology

2.1. System dynamics models

System dynamics is a method to enhance learning in complex systems. Just as an airline uses flight simulators to help pilots to learn, SD is a method to develop management flight simulators, often computer simulation models, to help us learn about dynamic complexity, understand the sources of policy resistance, and design policies that are more effective [22]. SD introduced by Forrester [21] is an object-oriented simulation methodology enabling us to model the complex inter-related structure of different factors affecting a construction project. SD modeling is useful for managing and simulating processes with two major characteristics: (a) Changes are involved over time; (b) Feedback of the transmission and receipt of information are allowed [23,24]. Much of the art of SD modeling is in discovering and representing the feedback processes which (along with stock and flow structures, time delays and nonlinearities) determine the dynamics of the system [22]. Several diagramming tools are used in SD to capture the structure of systems, including causal loop diagrams and stock and flows. Each causal link is assigned a polarity, either positive or negative, to indicate how the dependent variable changes when the independent variable changes. The important loops are highlighted by a loop identifier which shows whether the loop is a positive (reinforcing) or negative (balancing) feedback [5,22].

Positive feedback: Positive loops are self-reinforcing. For example, more chickens lay more eggs, which hatch and add to the chicken population, leading to still more eggs and so on. A causal loop diagram captures the feedback dependency of chickens and eggs (Figure 1(a)). The arrows indicate the causal relationships. + signs at the arrowheads indicate that the effect is positively related to the cause, i.e. An increase in the chicken population causes the number of eggs laid each day to rise above what it would have been expected (and vice versa, a decrease in the chicken population causes egg-laying rate to fall below what it would have been). The loop is self-reinforcing, hence

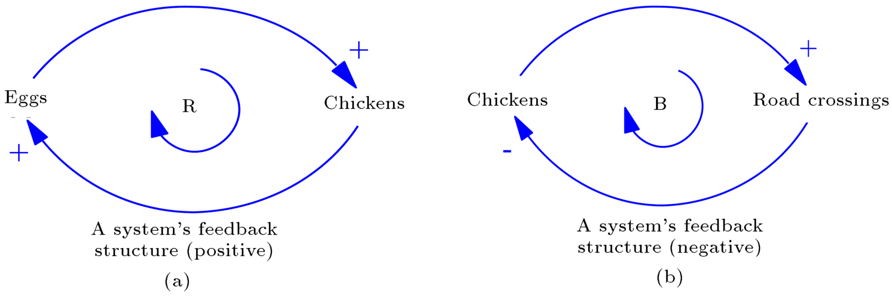

Figure 1. Positive (a) and negative (b) feedback loops (extracted from [22]).

the loop polarity identifier, R. If this loop was the only one operating, the chicken and egg populations would both grow exponentially. Of course, no real quantity can grow forever. There must be some limits to growth. These limits are created by negative feedbacks.

Negative feedback: Negative loops are self-correcting. They counteract change. As the chicken population grows, various negative loops will act to balance the chicken population with its carrying capacity. One classic feedback is shown here: the more chickens, the more road crossings they will attempt. If there is any traffic, more road crossings will lead to fewer chickens (hence, the negative polarity for the link from road crossings to chickens). An increase in the chicken population causes more risky road crossings, which then brings the chicken population back down. B in the center of a loop denotes a balancing feedback (Figure 1(b)). If the road-crossing loop was the only one operating (say, because the farmer sells all the eggs), the number of chickens would gradually decline until a constant value of chickens remained. All systems consist of networks of positive and negative feedbacks, and all dynamics arise from the interaction of these loops with one another [22].

3. Model structure

A flowchart representing different stages of the labor productivity simulation by the proposed SD model is shown in Figure 2. As it can be seen in this figure, all influencing factors affecting labor productivity and their interrelationships can be considered simultaneously. For this purpose, first, different factors that may have effect on the labor productivity are identified as a qualitative model. This can be done by doing interviews with experts and observing the real projects. The factors are indeed many and some of them have partial effect on labor productivity. Thus, the model boundary should be cleared and, according to the boundary, some parameters should be deleted from the list. The factors are completely identified by the two methods explained in the subsequent section. These are evaluated from the real data collected from several projects and interviews with several experts. After providing all the factors, these are sorted according to their effects on the labor productivity, and hence some of them with low severity are deleted. This procedure is repeated for the other models as well. After that, the qualitative model will be constructed. This stage can be executed by interviews and observation of the real projects as detailed in Section 3.1. All the interrelationships and cause and effect feedback loops should be

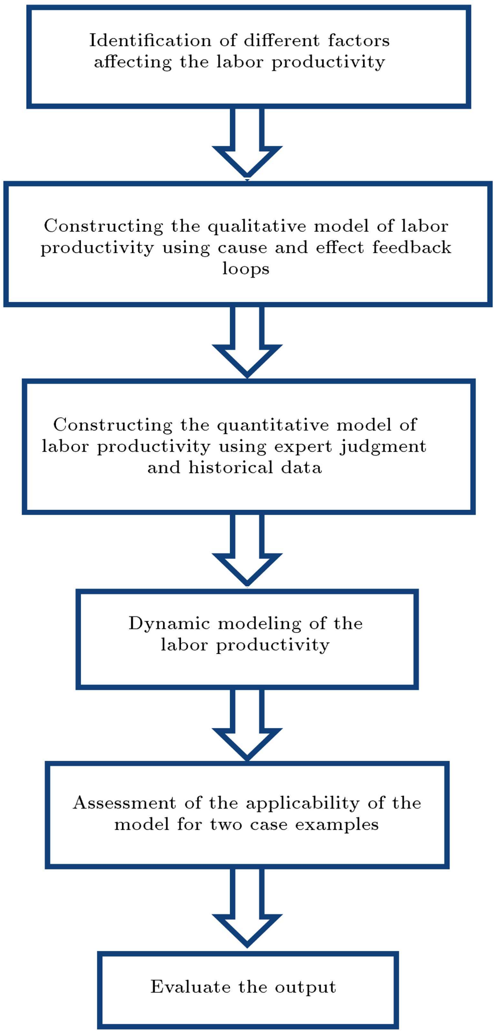

Figure 2. Flowchart of different stages of labor productivity simulation by the proposed SD model.

constructed in this stage. Next, the quantitative model is completed using expert judgment and historical data that are explained in Section 3.2 in detail. All the existing formulas between different parameters should be determined to make a simulation. At the next stage, dynamic modeling is performed and the outputs of the model are checked. Finally, the model is applied to two real projects and the model is assessed.

3.1. Qualitative modeling of labor productivity

There are several factors affecting the labor productivity, and these factors may vary from one contractor to another. These factors have complex interactions with each other. In order to determine the labor productivity properly, it is necessary to account for these influencing factors. In this paper, three types of contractors are studied: (a) Plasterer; (b) Form worker; and (c) Excavation team productivity.

It is clear that there are several subcontractors in construction projects and all of them are influenced by several factors that may be identical or different. In this paper, three different kinds of contractors are considered. The first one is a plasterer that is a kind of contractor done by people with no specific instrument. The second is a formworker that needs mold and some other tools. The last one is an excavation team that work with several construction machinery and contractors; their productivity is severely affected by machines. Other types of contractors can be considered by industry or researchers according to their projects using the methods presented in this paper.

For constructing the qualitative model, two methods are available: the first one is based on the evaluation of the real projects, and the second one is based on the interviews with experts. In the first method, some projects about each of this contractor are studied and parameters that can affect the amount of work done by a contractor have been identified. For this purpose, for example, a plasterer in a construction industry is monitored daily and the amount of his record is noted. In addition, the parameters that may affect his work causing rise or fall in his productivity should be recorded.

As another side, interviews with experts can be helpful to recognize the different factors affecting the labor productivity. Experts can be selected from a group of contractors, engineers, workers, and so on. All factors affecting the three mentioned contractors' productivity will be explained in detail. Interviews can also be conducted by some helpful methods such as Delphi technique, brain storming, or other methods. In this section, experts are asked to provide their opinion about the parameters that may affect the productivity of a specific contractor. In addition, one can use a questionnaire to get the opinion of the experts. Then, the researcher should collect all the questionnaires and extract the findings.

To make the model more realistic, measurable model variables can be quantified using the questionnaire survey [25].

Because of the variety of construction projects and changing the risk from one kind of project to another in this research, three building construction projects, with each containing at least 10 stories in height, are studied. It is clear that there are several project types in construction management field such as buildings, bridges, tunnels, harbors, dams, and so on; each of these is exposed to several distinct risks and uncertainties. Therefore, we selected similar projects (building with at least 10 stories in height) in order to compare them. In addition, more than 20 experts are selected for interview while each with at least 10 years of experience in construction industry. This model is written for sub-contractors, and the number of persons and their experiences are assumed effective factors in the model.

Experts are asked to give their opinion about parameters affecting the contractor productivity and the qualitative relationships between these parameters.

The conceptual diagram of plasterer productivity is presented in Figure 3. There are several factors affecting the plasterer productivity. As an example, motivation, working hours, climate conditions, and skill and training are the most important factors affecting the plasterer productivity. Each of these factors is interrelated with other factors.

Having determined the influencing factors, the relationship existing between these factors has been depicted by cause and effect feedback loops [26]. As an example, increasing plasterer productivity will bring about the employer's satisfaction; in this way, the employer pays reward to his contractor, which causes an increase in motivation. Finally, increasing motivation will lead to raising the plasterer productivity. On the other hand, increasing plasterer productivity will cause an increase in workers fatigue, and this will lead to a decrease in working hours; finally, the amount of plasterer productivity will fall down. The second feedback loop that is a negative loop will cause the growth of the plasterer productivity to be harnessed and become constant during some iteration.

The factors affecting the formworker productivity are shown in Figure 4. It can be seen that the amount of a formworker productivity is determined by six factors consisting of motivation, rework, availability of mold, number of skillful teams, daily working hours, and standard ability. These six factors are influenced by other factors shown in Figure 4. Once the influencing factors are determined, the existing relationships among these factors are identified by the cause and effect feedback loops. As an example, an increase in

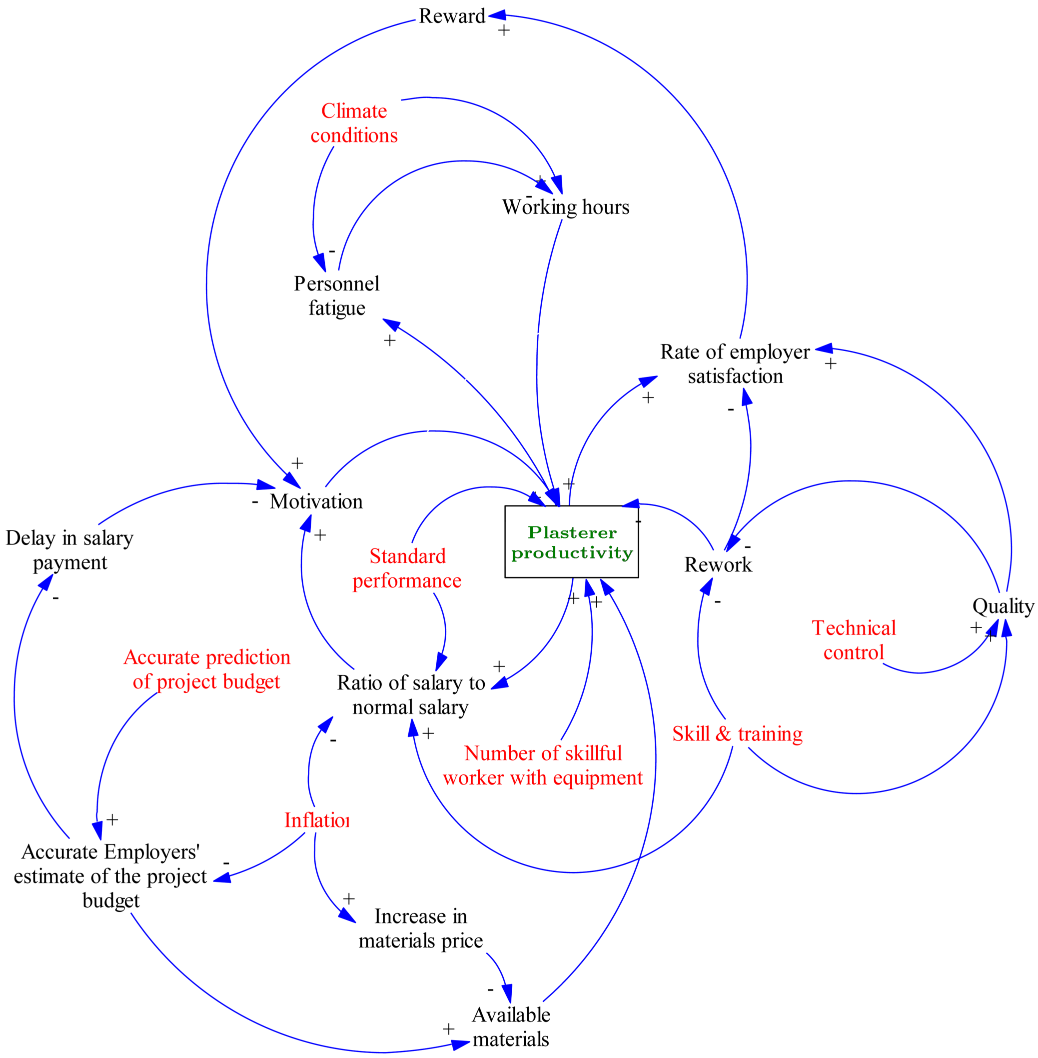

Figure 3. Factors affecting the plasterer productivity.

the form worker productivity will cause an increase in client satisfaction. As a result, the client will pay reward to the workers, and this will lead to a rise in the workers motivation. In this way, they will do more work and their productivity will grow, and vice versa. This means that a decrease in the formworker productivity will decrease client's satisfaction. As a result, the client will not pay a reward to the workers, leading to a decline of the workers' motivation, and consequently their productivity will fall down. As another aspect, an increase in the formworker's productivity will cause personal fatigue, and hence the working hours will decrease; consequently, the form worker productivity will decrease. Therefore, a balancing loop is constructed.

Similarly, the factors affecting the excavation team productivity are shown in Figure 5. As shown in the figure, seven factors affect the excavation team productivity, consisting of the number of drivers with their machines, depreciation of the machines, working hours, truck's loading value, motivation, proportion of machinery with project dimension, and normal productivity. As can be seen in the figure, there are many factors affecting the excavation team's productivity. Having determined the influencing factors, the existing relationships among these factors are identified by cause and effect feedback loops.

The main advantage of the system dynamic modeling is that one can follow up the effects of changes in the input parameters on the outputs.

3.2. Quantitative modeling of labor productivity

Having determined the qualitative model of labor productivity, the existing relationships between different factors are determined and the quantitative model of the labor productivity is built. Depending on the type of factors and availability of data, to find the relationships, two methods can be utilized: a) historical data, and b) expert's judgment using inference mechanism. In a case where historical data

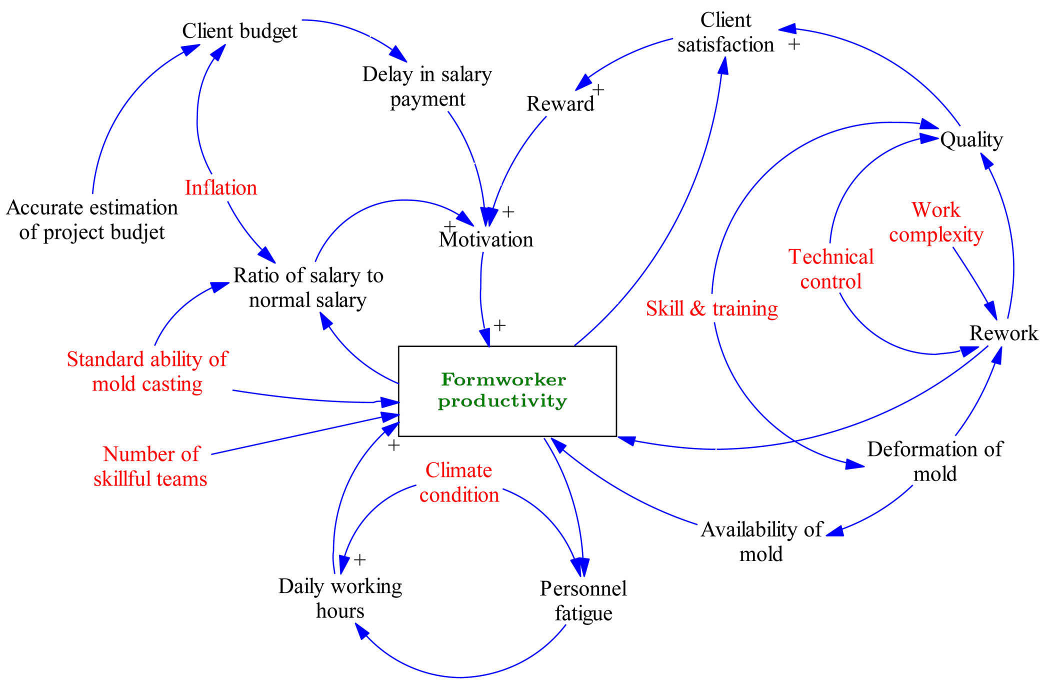

Figure 4. Factors affecting the formworker productivity.

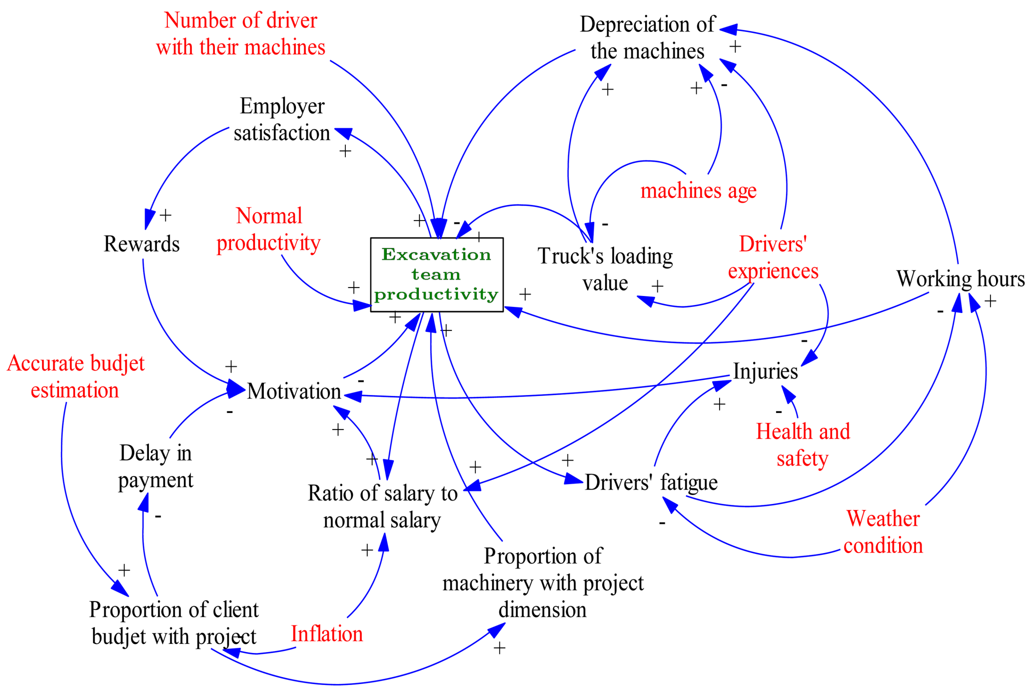

Figure 5. Factors affecting the excavation team productivity.

are available, the relationships can be determined by extrapolation. For this purpose, real data are gathered from several projects, and then analyzed by available software and the relationships of the factors are determined by regression [23]. When the historical data are not available or the parameters are qualitative variables (or linguistic variables), the relationships will be determined by experts' judgment using the inference mechanism [26], explained in Section 3.2.2.

3.2.1. Determination of relationships using historical data

In this research, three real construction projects are studied and the historical data are collected for these sample projects. The data are collected by gathering data from the site. As an example, As it can be seen from Figure 4, the deformation of the mole is affected by skill and training. Hence, we should collect several real data in several projects to find the interrelation between these two parameters. Table 1 shows the data gathered from three projects in 6 periods of time for workers' skill and training and deformation of mold.

By using the interpolation procedure for these data, the relation between experience and deformation of mold is obtained. To find the mathematical relation between the parameters using collected data, one can use several available software products, such as Matlab or Excel.

For example, in this case example, the obtained relationship is:

$$y = -2.1578x + 48.142, \tag{1}$$

where y is the deformation of mold (%) and x is the workers' skill and training (year).

R^2 value (coefficient of variation) for the formula between these parameters is more than 0.95, and because of that, a linear trend line is selected for these parameters. However, several types of relationships are often modelled through non-linear relationships.

Similarly, other existing equations between the factors should be determined as the quantitative model is constructed.

Table 1. The data gathered for plasterer productivity from 3 real projects in 6 periods of time.

	Item explanation		Deformation of mold (%)	Skill and training (years)
Gathered data from 3 projects and 6 visits	Project no 1	1	35	5
		2	25	10
		3	30	8
		4	20	12
		5	25	10
		6	30	7
	Project no 2	1	10	17
		2	10	15
		3	15	18
		4	5	20
		5	15	15
		6	10	17
	Project no 3	1	30	10
		2	35	8
		3	40	3
		4	35	7
		5	35	8
		6	30	10

3.2.2. Determination of relationships using inference mechanism

When the historical data are not available or the factors are introduced by linguistic variables, then the relationship between factors should be determined by inference mechanism. The if-then rule performs approximate reasoning with imprecise or vague dependencies or commands [26]. The Mamdani-style inference mechanism as one of the most famous types of fuzzy controllers is employed in this research [27]. The main idea of the "Mamdani" controller is to describe process state by means of linguistic variables and to use these variables as inputs to control rules [27,28].

Inference is a set of if-then rules that operates on linguistic variables and encodes the control knowledge of the system [27]. The rules connect the input variables with the output variables and are based on the fuzzy state description obtained by the definition of the linguistic variables. The definition of linguistic variables and rules is the main design step when implementing a Mamdani controller [28].

Formally, the rules used in the inference mechanism can be written as follows [28]:

$$\text{Ruler}: \text{ if } X_1 \text{ is } A_1^{j1} \text{ and } X_2 \text{ is } A_2^{j2} \text{ and...and}$$
$$X_n \text{ is } A_n^{jn} \text{, then "}u\text{" is } A^j, \tag{2}$$

where A_i^{j1} is the jth term of linguistic variable i corresponding to membership function $\mu_i^{j1}(x)$ and A^j corresponds to membership function $\mu^j(u)$, representing a term of the control action variable.

As an example, the relation between workers' motivation, ratio of salary to normal salary, delay in salary payment and reward has been determined based on the inference mechanism. As it can be seen in Figure 2, three parameters can have influence on the motivation. If each of them could get 3 linguistic variables, 27 conditional rules will be constructed. For example, if the ratio of salary to normal salary is more, delay in salary payment is negative and reward is high, then the motivation will be high. The complete "*If-Then Rules*" for this case example is shown in the Appendix.

Similarly, other relationships are determined, and finally the quantitative model will be constructed.

4. Model application

The proposed SD model is employed in two types of contractors in a real project to evaluate their performances. This project case example consists of 2000 m^2 plastering and 1500 m^2 formworker. The input

Table 2. Input parameters used in the plasterer simulation model.

Description	Linguistic variable	Value
Skill & training		10 years
Rework		10-15%
Technical control	Moderate	
Accurate prediction of project budget	Moderate	
Quality	Moderate	
Rate of employer satisfaction	Low	
Working hours		9 hours
Climate condition	Moderate	
Available materials		90-100%
Increase in materials price	Moderate	
Personnel fatigue	Moderate	
Number of skillful teams with equipment		1 team
Motivation		0.9
Reward	High	
Inflation		10-15%
Accurate Employers' estimate of the project budget	Moderate	
Ratio of salary to normal salary	Low	
Delay in salary payment	Moderate	
Standard performance		30 m^2

parameters used in the simulation model are as shown in Table 2.

Using the above input parameters, the SD model has been run by a laptop computer (CPU: 2.5 GHz, Intel core 2 Duo. Ram 4 GB. Graphic card 1 GB). The software that is utilized in this modeling was Vensim 5.9.

The input values from Table 2 have been entered in the software and it has been run. After a moment, the modeling is finished and the outputs are ready. As it can be seen in Figure 6, the outcomes show that the plasterer's productivity is raised due to the inputs during the first stage of the period. After that, the model uses a balancing loop, the rises will be controlled, and the output will fall. This will happen several times during time steps to become constant in the next time steps. The model has been run for 20 time steps, and the results are shown in Figure 6. Each time step may be selected as a day or other time scales. In this research, each time step is assumed a day. It is clear that if the input parameters change, the output will change and may decrease or increase the initial values. As it can be seen, in this figure, the plasterer's productivity will start by 30 m^2; however, as a result of the effect of other parameters, this value is raised until about 32 m^2.

Thus, the time needed for plastering the project is:

$$T = \frac{2000}{32} = 62.5 \quad \text{days}.$$

As another example, a formworker contractor is evaluated. For this purpose, the input parameters are collected in Table 3.

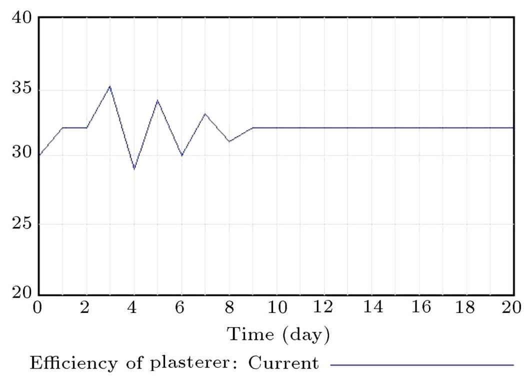

Figure 6. Plasterer productivity.

The input values from Table 3 have been entered into the software and it has been run. As it can be seen in Figure 7, the input parameters have affected the formworker's productivity and changed it from the standard value to more than 105 m^2 per day because of positive loops in the first time step. After that, negative loop has reduced the formworker's productivity up to 93 m^2 per day. This fluctuation will happen several times during time steps to become constant in the next time steps. This value will be fixed and can be selected as the formworker productivity for this project. Figure 7 shows the formworker productivity during a period of time as a result of the affecting parameters. The final value of the formworker productivity obtained by these input parameters is about 108 m^2 per day.

In the above example, it is noteworthy that each

Table 3. Input parameters used in the formworkers simulation model.

Description	Linguistic variable	Value
Skill & training		12 years
Rework		10-15%
Deformation of mold		10-20%
Technical control	Moderate	
Quality	Moderate	
Availability of mold	High	
Accurate estimation of project budget	Moderate	
Client satisfaction	Moderate	
Daily working hours		9 hours
Climate condition	Moderate	
Personnel fatigue	Low	
Number of skillful teams		1 team
Motivation		0.9
Reward	Moderate	
Inflation		10-15%
Client budget	High	
Ratio of salary to normal salary	Moderate	
Delay in salary payment	Moderate	
Work complexity	Low	
Standard productivity		100 m^2

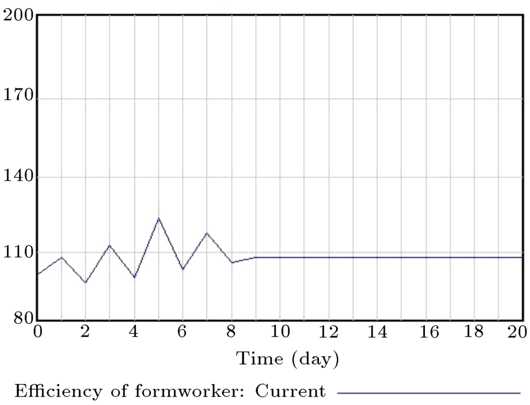

Figure 7. Form worker productivity during a period of time.

factor has negative or positive effect on the productivity depending on the situation. As an example, favorable weather condition with a positive effect on the productivity and level productivity will be raised. On the other hand, a bad weather condition may have a negative effect, decrease the productivity, and result in the shutdown of the activity. As seen from Figure 4, the increase in formworker's productivity will lead to an increase in the ratio of salary to normal salary and will result in an increase in motivation; finally, this will terminate with an increase in formworker productivity. However, the increase in the form worker's productivity will lead to an increase in personnel fatigue and a decrease in daily working hours, thus decreasing the formworker productivity. This will lead to the balance of the first loop in the next run. The effect of this parameter has been considered in many studies alone; however, in this research, the effects of these parameters and other parameters are considered simultaneously.

Tables 2 and 3 show the input parameters for two types of contractors. These values have been adopted from a real construction project. These are initial values; however, some of them are not normal since they are gathered from the middle of a project.

The model is run for two case studies, assuming the input parameters as constants. However, the model has the capability of being run for parameters that change during different periods. Moreover, in this case study, the model is run until the output is fixed. The result shows that 20 time steps are sufficient for this case study. However, in the project where the input parameters are not constant, the model should be run more than 20 time steps.

It is clear that this amount of contractor's productivity is obtained for the proposed case example and the input data shown in Tables 2 and 3. If each of the input parameters varies from this case example, the output will be different. Therefore, for providing a successful scheduling plan for a project, the scheduler should obtain the contractors' productivity with their project limitations. This research is performed for only three contractors and should be completed for other sections of the projects.

When the qualitative and quantitative models are constructed according to Section 3.2, the model can be run for any case example and output will be obtained. In this model, the input parameters that are given for two case studies are shown in Tables 2 and 3, which are constant values. Thus, the output will be fixed after some time steps. Therefore, 20 time steps are selected here because of not changing in the output after 20 time steps. The SD model can be used in two cases: first, the models that are changing during periods; the ones that include several factors affecting each other. In these case examples, it is assumed that the input, like motivation, is constant during a period of time. It is obvious that if the input parameters vary during the time, the output will change by passing the time.

5. Concluding and remarks

One of the most important parameters in formulating a project scheduling is the period of activities. For this purpose, many methods are available and one of these is parametric method. In this method, for finding the time of an activity, the activity volume is divided into the contractor productivity. Many researchers have attempted to find the parameters that affect the productivity and find the productivity with higher accuracy. However, almost none of them has considered the entire affecting parameters simultaneously. In this paper, the SD model is adopted considering all the influencing factors concurrently.

In this paper, three types of contractors are studied: (a) plasterer; (b) form worker and (c) excavation team productivity. First of all, the qualitative model of SD is constructed using the cause and effect feedback loops. Then, the quantitative model of SD is constructed utilizing the historical data and expert's judgment. Finally, the modeling is performed and run for two real case studies. For both case studies, positive and negative loops are working simultaneously, and when a positive loop causes a raise in the output, negative loops will neutralize the positive effects in the next time steps and lead to a decrease the outputs. The result is that the output becomes constant after some time steps. The output shows that the presented model is an applicable one and can be used in real projects. Results show that this model can consider all influencing factors affecting the labor productivity simultaneously and also the influence of each parameter individually.

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Appendix

A case example of if then rules for plasterer productivity is shown in Table A.1.

Table A.1. A case example of if then rules for plasterer productivity.

Motivation =
IF THEN ELSE("Ratio of (wages to normal wages)"=1:AND:Bonus=1:AND:Delay in wage payment<2, 10,
IF THEN ELSE("Ratio of (wages to normal wages)"=1:AND:Bonus=2:AND:Delay in wage payment <2, 10,
IF THEN ELSE("Ratio of (wages to normal wages)"=1:AND:Bonus=3:AND:Delay in wage payment<2, 10,
IF THEN ELSE("Ratio of (wages to normal wages)">1:AND:Bonus=1:AND:Delay in wage payment<2, 10,
IF THEN ELSE("Ratio of (wages to normal wages)">1:AND:Bonus=2:AND:Delay in wage payment<2, 10,
IF THEN ELSE("Ratio of (wages to normal wages)">1:AND:Bonus=3:AND:Delay in wage payment<2, 10,
IF THEN ELSE("Ratio of (wages to normal wages)"<1:AND:Bonus=1:AND:Delay in wage payment<2, 10,
IF THEN ELSE("Ratio of (wages to normal wages)">1:AND:Bonus=2:AND:Delay in wage payment<2, 10,
IF THEN ELSE("Ratio of (wages to normal wages)"<1:AND:Bonus=3:AND:Delay in wage payment<2, 10,
IF THEN ELSE("Ratio of (wages to normal wages)"=1:AND:Bonus=1:AND:Delay in wage payment=2, 7,
IF THEN ELSE("Ratio of (wages to normal wages)"=1:AND:Bonus=2:AND:Delay in wage payment=2, 8,
IF THEN ELSE("Ratio of (wages to normal wages)"=1:AND:Bonus=3:AND:Delay in wage payment=2, 9,
IF THEN ELSE("Ratio of (wages to normal wages)">1:AND:Bonus=1:AND:Delay in wage payment=2, 7,
IF THEN ELSE("Ratio of (wages to normal wages)">1:AND:Bonus=2:AND:Delay in wage payment=2, 8,
IF THEN ELSE("Ratio of (wages to normal wages)">1:AND:Bonus=3:AND:Delay in wage payment=2, 9,
IF THEN ELSE("Ratio of (wages to normal wages)"<1:AND:Bonus=1:AND:Delay in wage payment=2, 7,
IF THEN ELSE("Ratio of (wages to normal wages)">1:AND:Bonus=2:AND:Delay in wage payment=2, 8,
IF THEN ELSE("Ratio of (wages to normal wages)"<1:AND:Bonus=3:AND:Delay in wage payment=2, 8,
IF THEN ELSE("Ratio of (wages to normal wages)"=1:AND:Bonus=1:AND:Delay in wage payment>2, 6,
IF THEN ELSE("Ratio of (wages to normal wages)"=1:AND:Bonus=2:AND:Delay in wage payment>2, 7,
IF THEN ELSE("Ratio of (wages to normal wages)"=1:AND:Bonus=3:AND:Delay in wage payment>2, 8,
IF THEN ELSE("Ratio of (wages to normal wages)">1:AND:Bonus=1:AND:Delay in wage payment>2, 6,
IF THEN ELSE("Ratio of (wages to normal wages)">1:AND:Bonus=2:AND:Delay in wage payment>2, 7,
IF THEN ELSE("Ratio of (wages to normal wages)">1:AND:Bonus=3:AND:Delay in wage payment>2, 8,
IF THEN ELSE("Ratio of (wages to normal wages)"<1:AND:Bonus=1:AND:Delay in wage payment>2, 5,
IF THEN ELSE("Ratio of (wages to normal wages)">1:AND:Bonus=2:AND:Delay in wage payment>2, 6,
IF THEN ELSE("Ratio of (wages to normal wages)"<1:AND:Bonus=3:AND:Delay in wage payment>2, 7, 10

Biographies

Mostafa Khanzadi is an Assistant Professor of Civil Engineering with over 25 years of professional experience in civil and structural engineering. His main expertise and experience is in the fields of structural analysis, concrete technology, and construction management.

Ali Kaveh was born in 1948 in Tabriz, Iran. After graduation from the Department of Civil Engineering at the University of Tabriz in 1969, he continued his studies on Structures at Imperial College of Science and Technology at London University and received his MSc, DIC, and PhD degrees in 1970 and 1974, respectively. He then joined the Iran University of Science and Technology. Professor Kaveh is the author of 525 papers published in international journals and 145 papers presented at national and international conferences. He has authored 23 books in Farsi and 7 books in English published by Wiley, RSP, American Mechanical Society and Springer.

Majid Alipour is a PhD graduate in Civil Engineering, Construction Engineering and Management field. He received his BSc, MSc, and PhD degrees in 2009, 2011, and 2016, respectively. He won the best young researcher award from the Iran Project Management Institute in 2001. His main expertise and experience is in the field of construction management, labor productivity and project scheduling.

Reza Khan Mohammadi is an MSc graduate in Civil Engineering, Construction Engineering and Management field. His main interest and experience is in the field of construction management and labor productivity.