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Simulation of delay factors in dam construction projects with a system dynamics approach

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ABSTRACT: Delays are among the causes for financial loss in construction projects. Extensive research has thus been carried out on how to confront it, or reduce its consequences. The effect on dam construction projects is highly pronounced as a consequence of their high operation magnitude, and long initial execution duration. Numerous papers have thus far studied the causes of delay in projects from a dynamic systems' approach, in such sectors as construction, railways and highways. However, a simple comprehensive exploration of literature on the study of construction delay through the dynamic systems method reveals a gap of research around dam construction. As this is the largest class of projects in the nation, numerous factors are involved in project delays. To investigate the causes of delay in these projects the Vensim software package has proven useful and imperative in carrying out dynamic system analyses. The present paper, involves a case study of the Marvak dam in Lorestan province. Based on previous studies and former practical experience in construction, a set of 10 common causes of delay was compiled into a questionnaire, for 20 dam construction experts who were asked to rate the causes from 1 to 10, depending on how much each factor actually causes delay in the project, with a rating of 1 and 10, signifying the highest, and lowest weight. Among the factors, the effect of four variables, namely human resources, machinery and equipment, financial resources of the contractor, and deficiency in technical blueprints, were selected as the most effective factors. The Vensim software package was then used to simulate the model based on project specifications. Results involved the project's "overall predictable delay" with the share of each factor specified in a breakdown.

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1- Introduction

Every year, a large portion of the national wealth is spent on investment into construction projects for developing water, structural and industrial resources. Resource limitations during execution often cause prolonged execution and significant delay in finalization. Time management and project scheduling involve procedures needed to manage the completion of projects on time. This type of management is based on a reference schedule showing when each product, service or project results indicated in project specifications will be delivered; and what delays with what reasons can occur. This serves as a basis of communications, managing expectations and reporting achievements. The dynamic systems' method and system dynamics are methodologies for quantitative and qualitative analysis of system behavior through time. System dynamics is considered an effective approach to analyzing dynamic systems in such various areas as management, economy, biology, engineering, etc. The present research has thus used the dynamic systems' analysis to attain a better understanding of the model, as it is both able to identify the relationship between each of the factors in the presented model, and to show how the system changes in response to a modification in each of its components, and how each component is affected through time and in response to a change in other factors. The method can thus provide a tool for policy makers and executives to identify the factors most effective in project delays, and to reduce delay by modifying these factors. As delays are among the major causes of an increase in the duration and expenses of a construction project.

Delays are among the major causes of increase in a project's time and cost around the world, incurring severe harm both to contractors and employers. As such, estimation of factors causing delay using project time management during execution (while taking initial resources into account) can significantly help the execution avoid delay, extra cost, and attrition. This has been a focus of a wide array of research carried out around the world. The breadth of variety of operations involved in dam construction projects (hydraulics, structre, surrounding buildings, instruments, etc.) and how they directly and indirectly affect each other as well as the project in its entirety, requires a comprehensive

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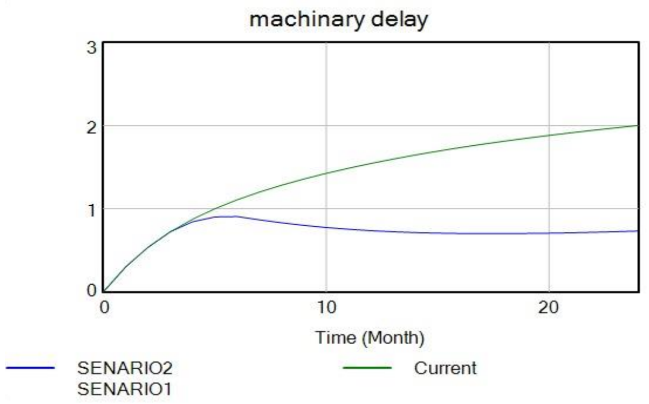

Fig. 1. Diagram of the impact of scenario 2 on the delays related to the lack of machines resources

Table 1. The effect of applying scenario 1 on delays related to human

Time (Month)	Senario1	Current situation	Time (Month)	Senario1	Current situation
0	0	0	13	0.32899	1.5628
1	0.41666	0.5	14	0.31012	1.5751
2	0.67885	0.854533	15	0.29608	1.5873
3	0.75513	1.09298	16	0.28618	1.5995
4	0.75173	1.24802	17	0.2798	1.6118
5	0.70746	1.34738	18	0.2764	1.6241
6	0.64646	1.41139	19	0.27554	1.6365
7	0.58228	1.4537	20	0.27682	1.649
8	0.052183	1.48302	21	0.27991	1.6615
9	0.46821	1.50469	22	0.28453	1.6742
10	0.4224	1.52196	23	0.29046	1.6867
11	0.38434	1.53673	24	0.29748	1.69979
12	0.353468	1.55013			

analysis of delay where all professional relationships between project procedures are taken into account. In this regard, a comprehensive system is needed. So far, many studies have analyzed dam construction. However, none have used system dynamics to investigate the causes of delay. For example, Kamalan et al. in their 2020 paper titled "Fundamental analysis of reasons for delay in dam construction, a case study of the Karun 3 dam" and Alameri et al. in their 2017 paper titled "Statistical analysis in determining the causes of delay in dam construction in Amman" have used a hierarchical analysis. No use of dynamic system analysis had been found in this field [1, 2].

2- Methodology

Human societies and organizations face ever-growing challenges requiring new thinking. In so many fields, the efforts of managers and officials to solve a problem have only led to temporary alleviation, leading to the same problems in previous situations, or in some cases, exacerbated conditions. Despite progress in project management, execution cost and time overflow, have endured for decades. In 19511, static modeling approaches, such as program evaluation and review technique (PERT), or critical path method (CPM) were developed. Most dynamic system models are designed to control and analyze system behavior. Scenario definition is an inextricable part of such methods. It is used to apply modifications to the method (A set of such modifications with a specific purpose is called a scenario), allowing assumptions to be tested, causalities to be discovered and revisited, and the best scenario to be selected and executed in the real system [3].

The present research identified the causes for delay. To do so, a questionnaire was designed with a list of 10 common causes of delay The list was extracted from previous relevant studies and compiled into a questionnaire. 20 dam construction experts were asked to fill the questionnaire, by rating the effectiveness of each factor from 1 to 10 (where a rating of 10 signified the highest effectiveness).

3- Results and discussion

Based on the results, four factors with the highest impact in terms of delay in dam construction were selected. The four primary factors of delay in dam construction projects (human resources, machinery and equipment, financial resources of the contractor, and deficiency in technical blueprints) were analyzed as flow variables and their effect on overall project delay, as well as the breakdown of each factor's share in the delay was analyzed using the Vensim software package. To achieve this goal, regarding the four variables, all inputs and outputs from daily, monthly, and seasonal reports, human resources, machinery and equipment tables, and contractor turnover were obtained:

Human resources: based on daily contractor reports, the workforce count involved in the project was 100. On average, during 24 months, each two months, one worker has quit the project.

Machinery and equipment: Machinery and equipment statistics during 24 months are presented in Table 1. The project has begun with 70 machines, 2 of which have gone out of service during 12 months.

Deficiency in technical blueprints: The project has started with 100 blueprints, with an estimate of a further 10 technical blueprints lacking during 12 months.

Financial resources: Based on the contractor's financial bills, the project has encountered 600 million rials in financial shortfall during 12 months. The initial investment was 3 billion rials.

3- 1- Scenario 1

As the gap in human resources in the first four months has caused the most delay, two methods (alone or in combination) can be used to remedy the situation: First, Increasing the workforce (from 100 to 125 workers in this scenario); and second, increasing the workforce recovery rate (from 0.15 to 0.2 in this scenario). (Table 1)

3- 2- Scenario 2

Following the preceding analysis, considering the gap machinery count, an increase in the recovery rate of machinery from 0.03 to 0.04 between the 2nd to 6th month can reduce the delays.

The effect of the second scenario on overall project delay is a delay reduction of 5.9078 to 5.35498 months. In addition, applying the necessary modifications will reduce the delay caused by a lack of machinery from 2 to 0.73 months. (Figure 1) Moreover, a comparison of delay caused by workforce vs machinery shows that a lack of machinery contributes more to the overall delay.

4- Conclusion

The project studied herein (Marvak dam) was expected to finish in 2 years when it started. However, considering the current trend, the project is predicted to run into 5.97 months of delay. The share of the aforementioned four factors (selected by experts from a pool of 10 factors) in the overall predicted delay was determined as follows: First, a lack of financial resources is expected to delay the project by 2.53 months; Next, a lack of machinery may add 2 months to the delay; and last, a lack of technical blueprints (a negative-signed factor) had almost no effect on the overall delay. By analyzing the aforementioned four factors responsible for delays in the studied project, the most severe delays were attributed to the first 4 months of the project, when financial shortfall, lack of machinery, and workforce deficiency comprise %40, %33 and %27 of the delay, respectively. Various scenarios considered to manage these four factors involved the increase of initial financial resources, workforce, or machinery which remedied delay factors, causing the overall delay to decrease significantly. For example, reinforcing human resources reduces relevant delays from 1.70 to 0.30 months. Likewise, replenishing financial resources reduces the corresponding delay from 2.54 to 0.89 months. Overall, we have concluded that project management in the first 4 months of execution, plays a critical role in reducing delays in this project.

References

[1] H. Kamalan, A. Abedin Maghanaki, Root Cause Analysis of Delays in Dam Construction (Case Studies: Karun-3, Marun, Shafaroud and Jamishan Dams), Journal of Hydraulic Structures, 6(3) (2020) 45-58.

[2] N. Alamri, O. Amoudi, G. Njie, Analysis of construction delay causes in Dams projects in Oman, European Journal of Business and Social Sciences, 6(2) (2017) 19-42.

[3] Sterman's business dynamics book, translated by Korosh Brarpour and Parisa Mousavi, (in persian).

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