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ENHANCING PLANNING, MONITORING AND CONTROLLING OF ROAD CONSTRUCTION PROJECTS IN EGYPT

Amer, N.[1], Okasha, A.[2], Arafa, A.[3]
[1] Ph. D., Arab Academy for Science and Technology, Cairo, Egypt.
nabil_amer63@yahoo.com
[2] Lecturer Assistant, Military Technical College, Cairo, Egypt.
ahmed.okasha.rady@gmail.com
[3] Ph. D., Administrative Control Authority, Cairo, Egypt.
amir.arafa@gmail.com

Abstract: In this research, system dynamics methodology is applied to model road construction project in Egypt and represents the effect of changes in time schedule by application of VENSIM software. System dynamics uses stocks, flows, internal feedback loops, table functions and time delay to understand the nonlinear behavior of complex systems over time. It aims to help project managers taking decisions in the highly dynamic environment and assess the performance of project. Also, help in minimizing the changes impact on projects. The introduced model consists of subsystems interacting with each other. Each sub-system contains other small cycles. Factors and cycles integrate with each other to show the project behavior. Also, this model takes into account the effects of schedule pressure, morale, communication congestion, overtime, and experience on the defect rate and productivity. The model is validated by panel of experts in the construction of roads sector. Also, a questionnaire is used for data gathering to feed the model with values of factors and limitation of variables. The results show that system dynamics is better than traditional techniques in planning and controlling the project performance. Integration of system dynamics with the traditional techniques creates advantages for the project manager. In addition, workload is simulated in two cases: first simulated as one company will do all the work with the limited time but with no limitation in sources; second it simulated by dividing workload and assign the parts to different companies. To simulate the real world, this division is done according to the real project division. This division of workload and required operation capacity will increase the productivity of the project and also increase project complexity. In total, the productivity increased by average 22.23 % along the whole project with elongation in schedule by 8.3 % to overcome the complexity. Finally, Modeling and simulation using system dynamics enables project manager to powerfully estimate the required operation capacity and number of working crews. Hence, the delays in construction projects could be eliminated by good controlling of project using system dynamics methodology.

1 INTRODUCTION

In recent years, projects became more complex. This complexity makes projects suffer from failure, overruns, and cancellation before completion. Hence, the need for quick and effective responses from project managers and decision makers increases [1]. Today, large part of the investments in the country is spent on implementation of development projects in various parts [2]. Road construction projects are like other projects that suffer from schedule slippage and cost overruns in addition to the numerous quality problems. Several studies have identified the need for a more strategic approach such as Systems dynamics (SD). SD assumes a holistic view of the projects and their relation with managerial strategies and deals with the time-dependent behavior of managed systems [3]. It also offers better scheduling estimates and better visibility of project status [4]. The aim of this paper is to use literature review, and proposed model to present the benefits for project manager from using SD in planning. A case study is applied, in order to provide its contribution in road construction project improvement. In addition, highlights the weak points of traditional techniques and approaches in the planning process.

2 LITERATURE

In today's dynamic and changing world, organizations facing a variety of changes and instabilities that make projects suffer from challenges in planning and managing [2]. There are arguments about the lack of suitable and effective project management practice for construction projects, and that SD can be a suitable conceptual framework to provide better theory and practice [5] and [6]. The literature on system dynamics models of projects varies widely in the level of detail, especially in modeling projects, from complete model to almost none. The persistent underestimation of projects provides the opportunity for SD to improve projects [3]. These projects have lower levels of technological uncertainty and novelty, but higher levels of complexity because they deal with different types of users and markets. These facts influence the organization of project activities [5]. Many different types of models have been developed to improve project management. These models include some of the system features and characteristics addressed by SD [4] and [5]. One of the most successful areas for the application of SD is project management. A lot of models and applications have been developed to enhance management of projects. Delays in construction industry are global symptom in Saudi Arabia, Nigeria, Thailand, Jordan, Ghana, and Hong Kong. The performance of construction industry in these countries is observed to be poor. Failure to achieve targeted time, budgeted cost and specified quality result in various unexpected negative effects on the projects [1]. It is not easy to maintain project success because every mega complex project has variety of effects of stakeholders arise in different project phases in the entire project [2]. In order to have a successful executed mega complex construction project, project managers and owners should apply best practices [3]. To apply these practices it must first capture the properties of a complex projects (represented as complex system). Not only qualitatively but also quantitatively analysis should be applied to understand the system behavior and the interactions between subsystems and parts that integrate in that system [4, 5]. System dynamics simulation helps in learning the dynamics of system behavior that impact planning and innovation of new strategies that can help in improving the performance of system. The main characteristic of this approach is the complex system existence, the closed loop feedback existence, and the behavior change of the system [6]. As mentioned, it necessary to view the construction projects not only as a monolithic system, which are “a set of different elements connected to perform a unique function that not performable by any element alone”, but as a system of systems. Where, changes in one part of any system or subsystem affects the other linked subsystems or parts with changes in them [7].

3 CASE STUDY PARAMETERS

A double free road with a total length of 26 km and a width of 94 meters (5 traffic lane as the main road + 3 traffic lane as service road in each direction and two islands between the main road and service road, in addition to central island between the two directions (Figure 1: . The project has total digging in rocky soil for about 12 million m^3. And total landfill works was 22 million m^3. Also, the estimated project value is 3000 million Egyptian pounds. The start date was 01/07/2016 and finish date is 31/12/2018. In addition, the management team uses the following methods in managing the project: work break down structure, critical path method, responsibility matrix, activities overlapping, and using mental model in taking decisions.

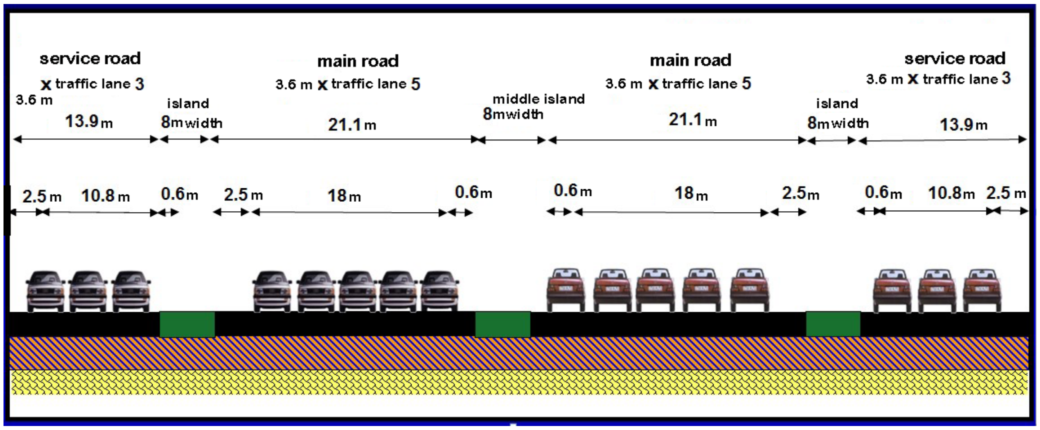


Figure 1: Cross section of the studied road

4 BUILDING MODEL

Using the refinement of Love model [7], Lyneis model [3], and Rodrigues model [8], a system dynamics model is built based on the application of rework cycle to help in improving projects performance. The model is built for two execution phases of road construction projects that are divided into Excavation and Filling works as a first phase and Base and Asphalt for the second phase. The model started by getting information about the road project to be done as shown in Figure (2).

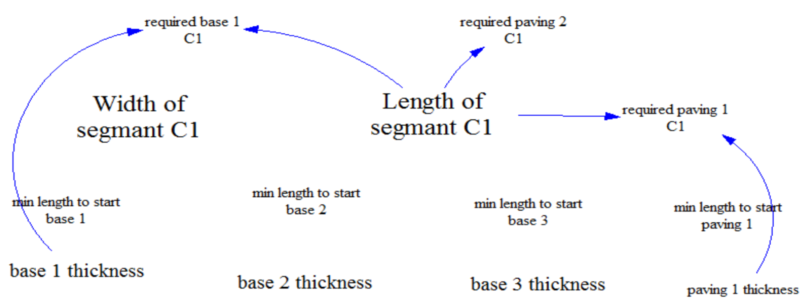


Figure 2: Collecting project data

This required data (Figure 2) defines the project by its length and width of segments and the required amounts of excavation and filling. Also, the thickness for each layer of base and asphalt are required to completely define the required work. The relations between the tasks of project are defined by the minimum amount of tasks required to be correctly done to start the dependent task. Work on site starts with excavation or filling soil, this is modeled as shown in (Figure 3).

The digging load first assigned to “Assigned Digging” as its initial value. The digging rate is depending on the crew available and its productivity in addition to the equipment available. The productivity of crew in digging depends on machines and operating time. If the operating time increases, the equipment requires maintenance (i.e. additional cost) and its productivity will be decreased if the maintenance not done. Then, the digging soil is checked by the as built team. If the as built digging report mention that the work is okay then it`s accepted and if not it will be added to the assigned digging to be worked again.

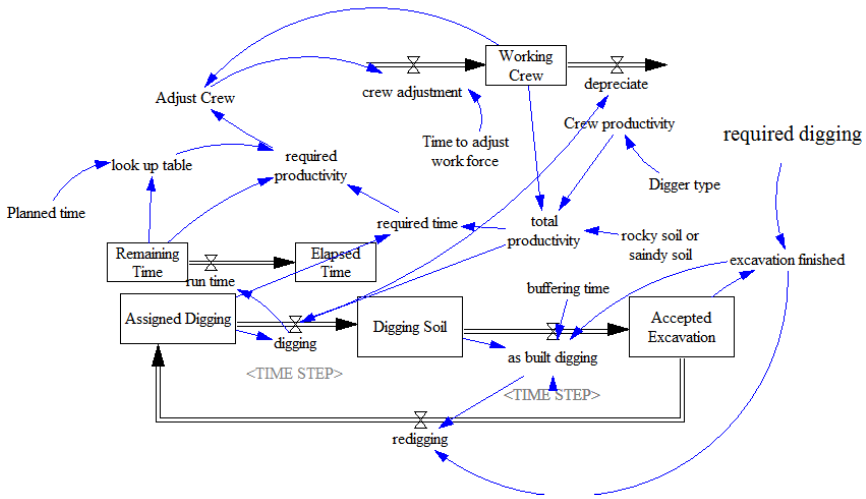


Figure 3: Excavation and filling works

The total productivity is determined by the multiplication of the productivity of crew multiplied by the number of working crew as follows:

$Pt = Cp \times Nc$

Where:

Pt: is the total productivity.

Cp: is the productivity of crew.

Nc: is the total number of working crew.

The work done by productivity vary as mentioned according to crew number which varies depending on the time available that increase or decrease the required productivity. The flow of work depends on the rework cycle which means that part of the work done is not done correctly at the first time and requires to be done more than one time. The percent of work not done correctly depends on the quality of work. It is not shown as an explicit variable but it is embedded in the rate equation. This cycle of work is repeated in all subsystems and then all subsystems are integrated together to build the model.

Subsystems of the model are depending on each other's state in work. That mean the work of the next subsystem will not operate unless the minimum amount of work required to initiate this subsystem is done correctly as shown in Figure (4). The subsystem of base 2 will not operate unless the minimum amount to start base 2 "minimum length to start base 2" is equal or less than the "Equal finished length base 1". This logic is repeated for all subsystems.

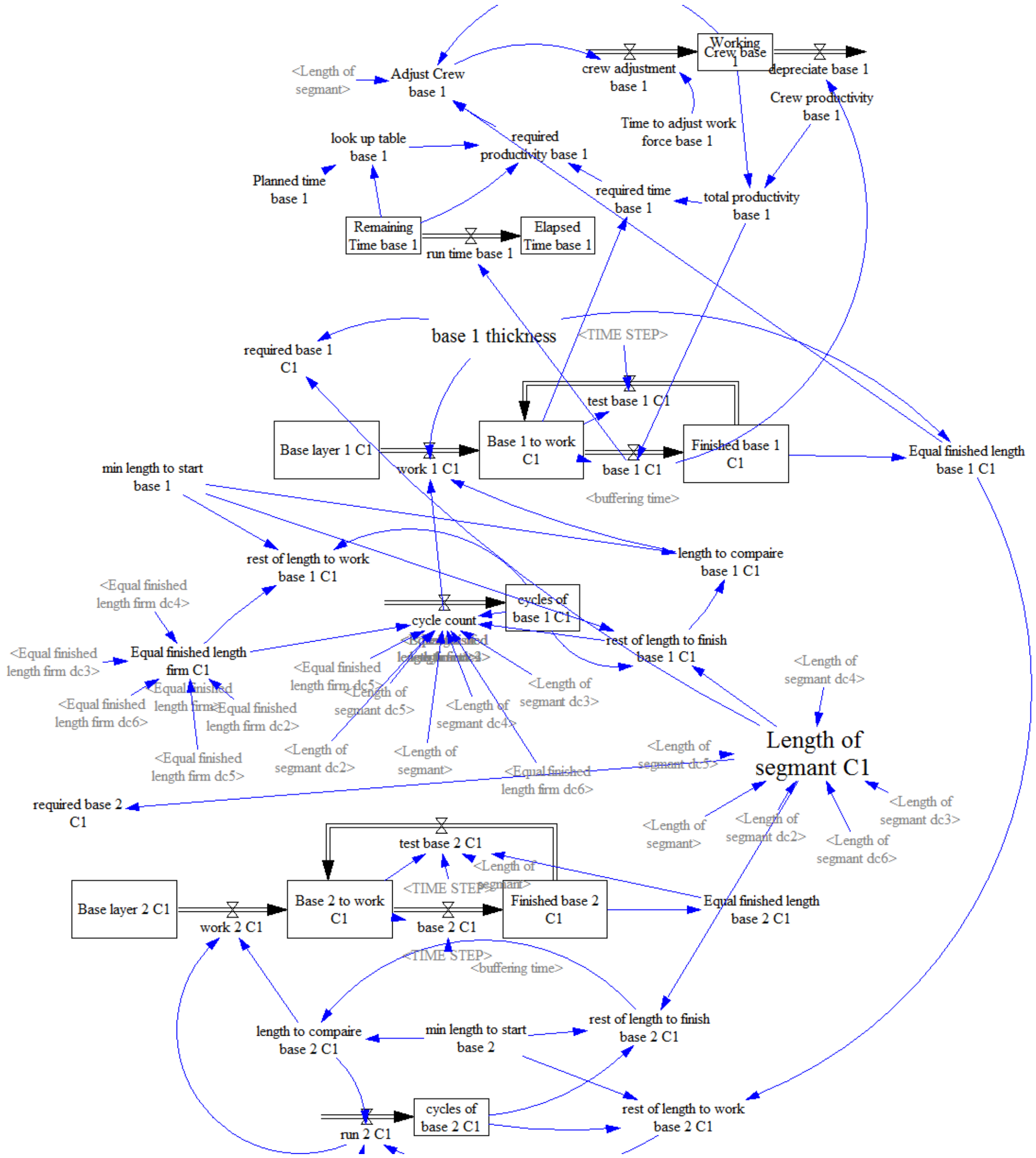


Figure 4: Work dependency

5 DISCUSSION

Assessing the management method used in the case study, it is found that management team used traditional methods in managing the project (WBS, CPM, as mentioned before). These approaches are unable to fully address the holistic view of the project management process. This was obvious in monitoring and controlling the project. While rates of working required from the contractors does not consider neither complexity nor dynamics, the rates are simple as quantity required over the available time. And this simple rate (traditional tools) fails with the first obstacle facing it. So, project manager recalculates the required rate by the same manner (the rest of quantity over the rest of time) to overcome the slippage in schedule. Table (1) shows the actual and planned percentage of work. It is clear that project suffer from delays in the schedule. Some of these delays are due to inaccurate planning and some due to obstacles facing the project.

Table 1 the detailed operational position at the end of March 2018

Item (km)	Total in two directions	Finished in the east direction	Finished in the west direction	Percent finished (%)	Planned percent (%)
Firm	22.975	10.650	12.325	49	59.23
Base 1	20.350	8.650	11.700	42	58.82
Base 2	18.300	6.975	11.325	38	57.35
Base 3	14.325	4.550	9.775	30	52.94
MC	14.325	4.550	9.775	30	42.85
Asphalt	11.800	3.800	8.000	25	41.38

On the other hand, SD can focus on information feedback and offer a method for modeling and analyzing complex project systems [8]. Its structure in modeling projects describes project features, rework cycle, project control, and ripple effects which are the fundamental explanations for many adverse behaviors [9].

Planning using traditional techniques

The process of estimating the duration of activities in a project network analysis provides an example of the relationship between the strategic and operational analyses. The estimated duration of project activities is based on the assumption that the staff employed will work at a certain productivity level. In this estimation, the project manager naturally considers subjective factors like workforce motivation, schedule pressure, workforce experience, and possible errors. However, if in practice this informal analysis fails, all the effort employed in the development of the work schedule plan will be wasted. A good experienced project manager may make adequate allowance for all the factors, but the traditional techniques do not encourage their consideration by any explicit analysis. Another typical case relates to project monitoring: the project control process is based on human perceptions of the project status. In the real world, errors tend to remain unperceived and, as a consequence, the real progress differs from the perceived progress. Detailed plans based on these misleading perceptions can result in ineffective or even counterproductive efforts. These same arguments support the idea that an appropriate analysis should require a strategic perspective [11].

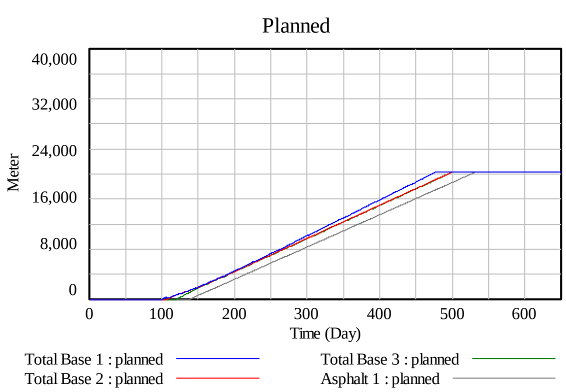
The planning using traditional method doesn’t consider the factors mentioned above. Hence, its schedule is not flexible in facing the obstacles and emergency situations. This in turn puts project manager under pressure, and hardens the process of controlling the project.

Table (2) shows the required quantities and its durations in the schedule, and the last column represents the rates required to finish these quantities according to schedule and the relations between activities as given from the project manager. These rates are constant and does not consider any of project factors that makes the dynamics of project.

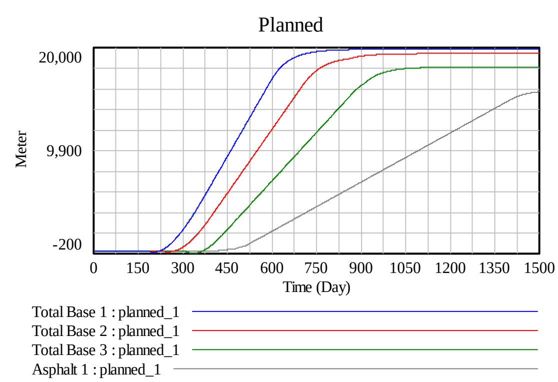
Table 2: Planning using traditional technique

Item	Quantity	Duration (Day)	Rate
Excavation	12,000,000 m3	477	25157.23 m3/day
Filling	22,000,000 m3	484	45454.55 m3/day
Base 1	24 km	344	69.76 m/day
Base 2	24 km	351	68.37 m/day
Base 3	24 km	236	101.69 m/day
Asphalt 1	24 km	229	104.8 m/day

In addition, figure (5) shows difference in planning between traditional and system dynamics approach. Figure (5-a) represent the accumulation of rates in the linear manner using critical path method. And in (5-b) the same rates of work are applied to the system dynamic model. The model is taking into accounts the factors mentioned above. It is obvious that required quantity differ from the two methods. The final project time is different in two approaches. The time of project will be elongated to 1500 Day. SD model shows that it`s hard to finish with these rates the project at the required time. It will exhibit sever delays in the schedule. The traditional method doesn`t consider changes in productivity, moral, complexity, and other factors.



(5-a) using CPM with required rates



(5-b) using SD with the same required rates and considering the factors

Figure 5: Planned Schedule

5.1 Planning using system dynamics approach

Planning using traditional management methods with constant rates get the required schedule to be 600 Days as required. But it is not a real schedule. Because when monitoring and controlling project, these rates and quantities are not actually done. In addition, when the project manager found the project late in schedule, the schedule of the project is changed but with another linear one, that does not capture the dynamics of the project. By taking into account the complexity, feedback relations and making the rates of the traditional method not constant, but depend on time and working crew. The new schedule is shown in Figure (6).

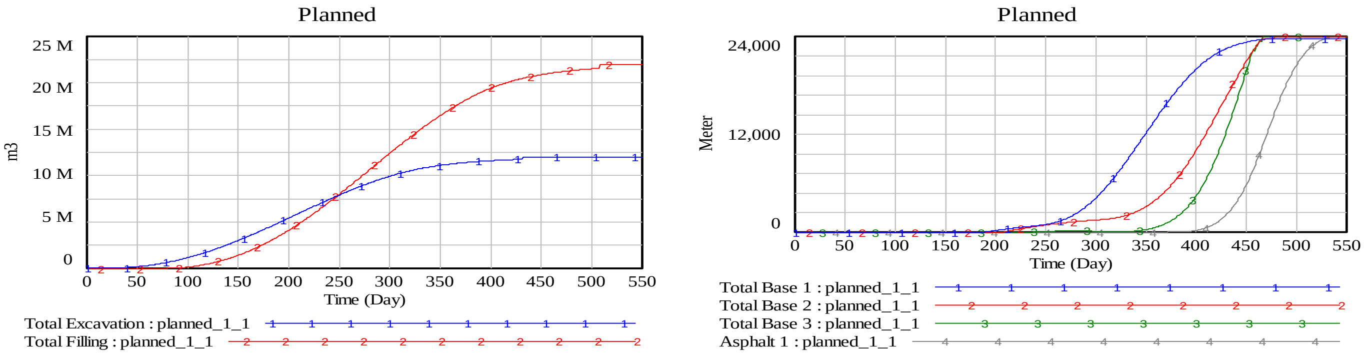


Figure 6: Estimated schedule according to system dynamics

The application of system dynamics modeling, rework cycle, and the time boxing and feedback effects, the completion of a project task may be flawed, resulting in a need for further tasks in a recursive cycle that can extend project duration and work load far beyond what is originally conceived. In the absence of the rework cycle, project completion is a function of the number and scope of tasks, the available resources and their productivity (case of traditional techniques). By considering defects, quality and testing through rework cycle, many path-dependent reinforcing loops are generated that critically impact the fate of projects. In this research, the model is subjected to the conditions done by mental model as:

1- When time is limited and productivity is not capable to finish the required work in the required time, hence productivity can be enhanced by increasing the number of crew working i.e. hire more crews.
2- The dependent activity doesn`t start until the minimum allowable quantity of the independent activity is available to be done.
3- The time delay required for hiring new crew or preparing the new task and the time delay required in taking decision is also considered in the model.
4- Logical expressions are used to avoid negative quantities.

By the application of the rework cycle, the planned schedule shows that this project could be finished less than 600 days. But, the project cannot be finished at this time without applying the estimated quantities. These quantities represent the operating capacity required which is more than the capabilities of the organizations. So, this load of work will be divided to more than one organization.

It is better to divide the work load but this division will increase number of organizations (contractors) in the project. This leads to increase in project complexity. In the following figures, the modified schedule planning according to the division of the operating capacity (OC). This division of the OC (as shown in figures) does not change the number of crews or the estimated required quantities. It is approximately the same. This division will help the contractors in managing its part of the whole project.

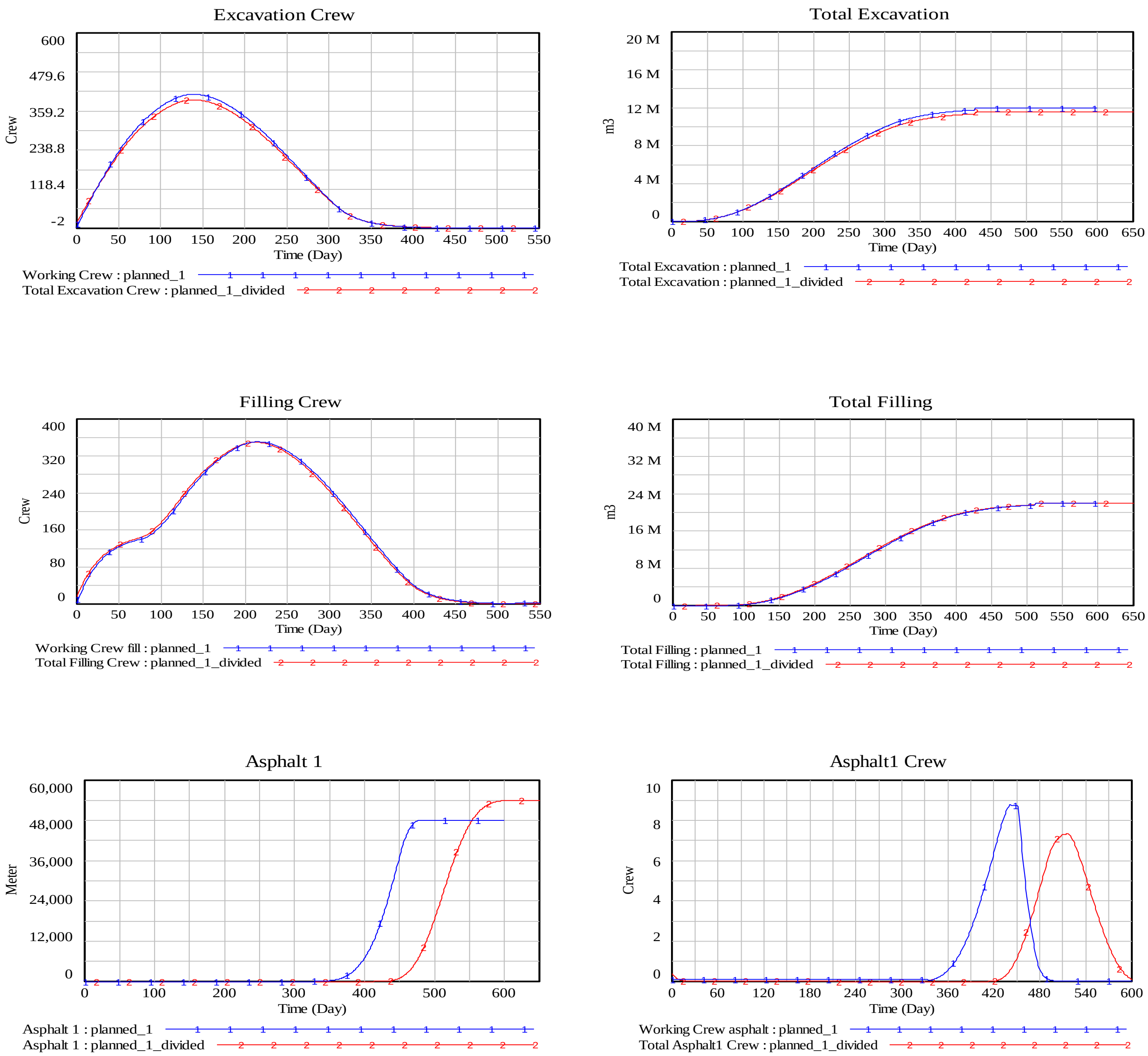


Figure 7: Work load and estimated crew number for the excavation, filling, and asphalt work

Figure (7) shows the difference between estimated schedule and crew working in the two cases of dividing work to four contractors and the undivided one. The divided plan shows some delay in starting the work. This is because the specified zone of work not ready to the next phase i.e. the start of the task is dependent on the previous task with minimum quantity to start this task. This delay decreases the allowable time to complete the task. As a consequence, the crew exhibits small increase to overcome this delay as shown in Figure (7).This illustrates the small variation between the curves in the two cases.

6 CONCLUSION

Using system dynamics in planning is more realistic than the traditional techniques. In addition, integration of system dynamics with the traditional techniques creates advantages for the project manager that enriches the control of the project. On the productivity side, the division of operation capacity increases the productivity of the project and increases complexity of the project too. In summary, the productivity increased by average 22.23 % along the whole project with elongation in schedule by 8.3 % to overcome the complexity.

Managing projects using system dynamics help project managers in taking right decisions. I.e. With modeling and simulation project manager could manage project powerfully by estimating the required operation capacity and number of working crews. Also, delays in construction projects could be overcome by increasing the crew working i.e. increasing productivity of work. So, planning using system dynamics approach increases organization efficiency.

Furthermore, this model has limitations could be eliminated in the future work:

- It does not consider the two phases of design and construction.
- It does not consider the effect of multiple defects per task.
- It does not consider the probability of missing rework in testing.

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