

STEERING PROJECTS THROUGH SIMULATION: AN INNOVATIVE TOOL TO IMPROVE PROJECTS GUIDANCE EFFICIENCY

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ABSTRACT

A project plan hardly reflects what actually happens during the project mainly because it tends to be static, while nowadays projects are extremely dynamic. Moreover, the strong integration between the executing and the planning phases makes the projects guidance very hard, especially under strict time boundaries. The existing project management techniques are quite inadequate to handle these features. For this reason, the paper proposes an innovative tool able to guarantee an improvement of projects guidance efficiency by introducing the simulation into the time-cost trade-off analysis. The model on the basis of which the tool has been developed uses in an integrated manner different operational software: Microsoft's Project, Visual Basic for Application and Rockwell's Arena. The tool has been tested on a construction project in progress and has already proved its usefulness in the planning as well as in the executing phases.

Keywords: project management, project control process, stochastic network project, uncertainty management

1. INTRODUCTION AND LITERARY REVIEW

The flexibility required to coordinate the multiple feedback processes between the project variables during the execution phase makes nowadays projects highly dynamic and complex. Moreover, the lack of knowledge about the project, especially at the beginning stage (as the *learning curve* teaches), make necessary a systematic management of the project factors and variables since project success principally depends on it, both in terms of reliability of the results and time respect.

Technical, schedule, cost and political changes as well as mistakes that naturally occur during project execution make aleatory the duration of the activities in which the project has been subdivided.

The deep analysis of the existing project planning and control techniques has underlined their inadequacy in managing the present challenges (de Falco et al.

2008). These techniques have not been modified for several years and, therefore, are not able to manage the new critical aspects in actual projects.

Particularly, the deterministic assumptions of the Critical Path Method (CPM) (Kelley and Walker 1959, Kelley 1961) ignore the complexity associated to the uncertainty of the network activities. Except for specific cases, the decisions taken during the project execution on the bases of deterministic analyses do not guarantee high probabilities to complete the project respecting the project plan specifics. This because the conditions in which the project develops are intrinsically probabilistic.

On the contrary, the Program Evaluation and Review Technique (PERT) (Malcom et al. 1959, Elmaghraby 1977), even if based on a probabilistic procedure, is nevertheless limited since it reduces the solution space to a single critical path through the network, ignoring the effects of the complex interactions existing between the dependent sub-path. Except for singular cases, ongoing decisions taken through a PERT analysis do not assure the selection of the best project alternatives (Mummolo 1997).

During the execution phase, project plans have to be periodically re-evaluated and updated as soon new information are available. This creates a complex dynamic probabilistic problem whose final solution is a series of partially implemented plans, each one based on the best available information at the moment of the related evaluation (Conde 2009).

The simplifying hypotheses on which all the probabilistic approaches are based often compromise their reliability degree in representing the real problem. In these cases, turning to a simulative approach may accomplish interesting results for both time and cost management (Dawson 1995, Elkjaer 2000).

The use of simulation models to represent projects guarantees different advantages:

- Virtual models are explicit and the assumptions are available for the analysis.

- The simulation models are able to unfailingly evaluate the logical consequences of an hypothesis.
- Innumerable factors may be simultaneously correlated.
- Virtual models can be simulated under controlled conditions, and, therefore, allow the analysts to obtain previsions about possible alternative choices.

Moreover, adopting a simulative approach in project management consents to consider different characteristics which can not be differently evaluated, such as: the dependencies between the activities durations; the possibility to decide the best project alternative in function of significant events occurring during project execution; the time-cost links for each activity of the network (Salvendy 2001).

In spite of that, simulation tools have found many applications in project planning and scheduling while their use as support to the control process, excluding some recent cases (Bowman 2006), is still very scarcely diffused (Arto et al. 2001).

The stated observations summarize the motivations of the present research work which proposes a simulative approach to guide projects with more effectiveness.

After a brief description of the methodology, which has been already presented in a previous paper (de Falco and Falivene 2009), the tool which has been ad hoc developed to implement the procedure will be illustrated in detail.

2. THE PROPOSED METHODOLOGY

The innovative methodology to guide projects proposed in the present paper is graphically represented in the figure that follows (Figure 1).

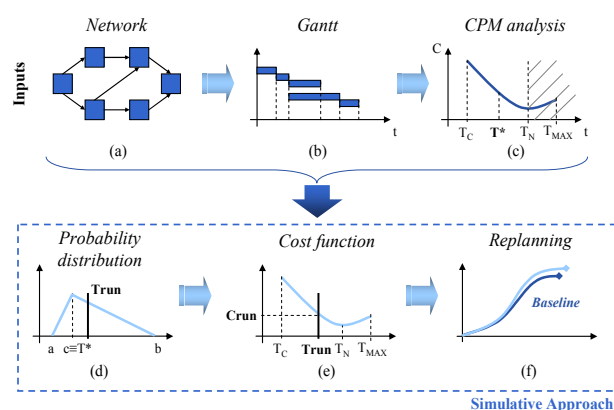


Figure 1: The simulative methodology to guide projects

The approach starts from different inputs coming from the classical project management tools.

Once the network diagram (a) and the related Gantt chart (b) have been built, the specific durations for each activity of the network (T^* in the figure) which minimises the total cost of the whole project (c) can be determined through a classical CPM analysis. The

network which derives from these durations allows the determination of a project baseline of reference.

At this point the simulative approach can start by introducing a variability to each duration T^* through a specific probability distribution in order to consider the natural uncertainty of the activities duration.

At each iteration, for each activity, a duration value is sampled from the probability distribution function (d) and the relative cost value is updated (e). On the basis of these values the critical path and the whole project duration can be identified (f). After a sufficient number of repetitions a “baseline pencil”, which represents the variation field of the project time-cost binomial, can be obtained.

The baseline pencil enables the determination of a probability distribution for the whole project duration and, therefore, the estimation of the probability of exceeding prefixed contractual due dates.

The proposed approach allows different advantages both in the planning and in the execution phase of a project. Particularly, during the execution phase, the data related to the completely performed activities are considered as deterministic inputs for the simulation model with the consequential reduction of the uncertainty associated to the project duration estimation.

3. THE TOOL

The logical model on the basis on which the tool has been built consists of three characteristic elements (Figure 2): the Input Module, the Simulation Model and the Output Module.

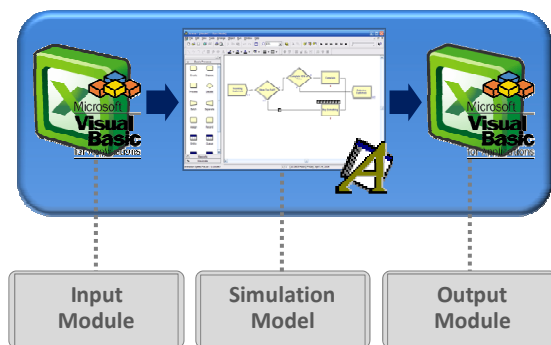


Figure 2: Graphical schematization of the logical model

These elements have been developed through the combination of different management software.

The Input Module allows the link with the project management software (Microsoft’s Project) and has been developed through Visual Basic for Application in Excel. It consents to convert the data coming from the project management software into data readable for the Simulation Model.

The Simulation Model has been instead developed through the Rockwell Software’s Arena. Particularly, a specific program code developed through Visual Basic for Application allows the automatic transfer of the information coming from the Input Module to the

Simulation Model which automatically builds the network diagram to start the simulation process.

Lastly, the simulation results are transferred to the Output Module which, in its turn, is able to convert in automatic the input data into information comprehensible for the user. The Output Module has been developed through VBA in Excel.

The following sub-paragraphs will illustrate the graphical aspect of the tool as well as its operation logic in implementing the proposed approach to manage projects.

3.1. The Input Module

The Input Module is the element that interacts with the project management software. The information coming from the project plan realized during the planning phase through Microsoft Project, are converted into data understandable for the Simulation Model as the button “Update” is activated.

Figure 3 shows the main table of the Input Module. Each of the column in the Excel sheet is dedicated to one of the project activity. In particular, the data of the project plan are stored into the yellow cells, whereas the white cells contain the values of the characteristic parameters calculated through the Excel sheet.

Particularly, among the data coming from the project plan there are:

- The total number of the activities in which the project has been split during the planning phase, “ N° Activities”.
- The duration “ T^* ” identified through the preliminary CPM analysis for each activity of the project.
- The value chosen for the shape parameter k , which allows the definition of the time variation range Δ for each project activity, “ k ” (for the analytical expressions of Δ and k see (2) and (3) formulas).
- The characteristic parameters for the definition of the cost function for each of the project activity, “ T_L ”=Limit or Crash Time, “ T_N ”=Normal Time, “ T_{max} ”=Max Time, “ C_L ”=Limit Cost, “ C_N ”=Normal Cost, “ C_{max} ”=Max Cost.

The Input Module elaborates these data and evaluates, for each one of the project activities, a series of characteristic parameters necessary to realize the simulative process. Specifically they are:

- The acceleration cost, “ C_a ”, which is automatically calculated by the Input Module through the following formula:

$$C_a = \frac{C_L - C_N}{T_N - T_L} \quad (1)$$

- The time variation range for each activity duration, “ Δ ”, which has been defined through the following expression:

$$\Delta = \frac{T_N - T_L}{e^{k \cdot \frac{C_a}{C_L}}} \quad (2)$$

in which:

$$k = k_1 \cdot \frac{C_L - C_N}{C_N} \quad (3)$$

where k_1 is a positive constant and $(C_L - C_N)/C_N$ is the cost proportional increase of a generic project activity (de Falco and Falivene 2009).

- The characteristic parameters for the definition of the triangular probability distribution, “ a ”, “ b ” and “ c ” (see Figure 1d) which are automatically calculated by the Input Module, on the basis of specific hypothesis, through the formulas:

$$\begin{cases} a = c - \Delta / 3 \\ b = c + 2 / 3 \Delta \end{cases} \quad (4)$$

The condition (4) reflects the choice to consider for each activity the pessimistic event more likely than the optimistic event with a two to one ratio (de Falco and Falivene 2009).

Besides the mentioned data, the project management software has to transmit to the Input Module the information related to the logical links between the network activities in order to realize the subsequent simulation. Figure 4 shows how the Input Module presents the sheet in which the table summarizing the relations between the activities is reported.

These data in their original format cannot be read by the Simulation Model and, for this reason, have to be converted into information compatible with this model. To this aim, by activating the “Update” button (on the left side in the figure), the Input Module is able to transform the “relations table” into a “relations matrix”. The column on the right of the matrix reports the

Figure 3: Input Module - Data related to the project activities

number of predecessors for each activity, and the row under the matrix reports the number of activities which succeed each network activity. The delays of each network activity (column) in relation to the specific preceding activities (row) are reported in the matrix, if they are present.

At this point, all the information necessary to start the simulative process are available.

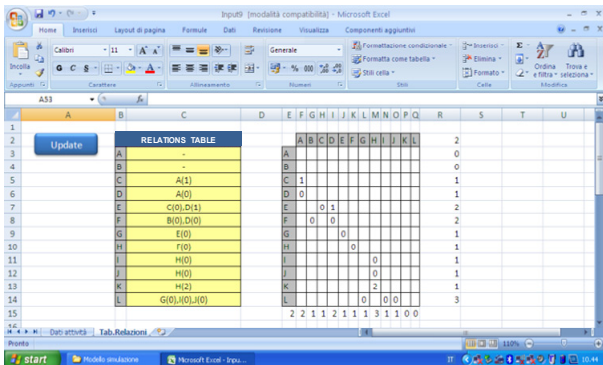


Figure 4: Conversion of the “relations table” into the “relations matrix”

3.2. The Simulation Model

The figure that follows (Figure 5) shows the main window of the Simulation Model.

In particular, the figure illustrates the screenshot of the tool in execution. The user can interface with a control panel that presents specific fields in which it is possible to insert the information needed to start the simulation.

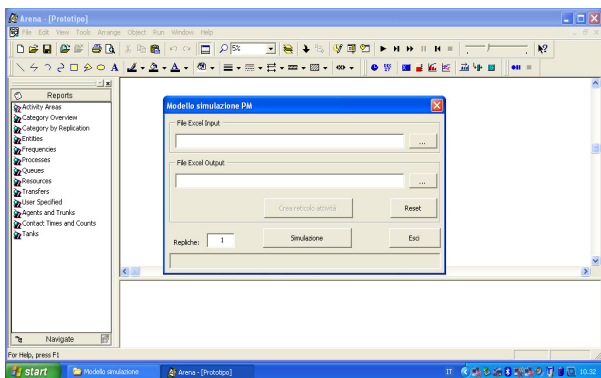


Figure 5: Main window of the tool

The first field, “File Excel Input”, allows the loading of the Excel file in which the input data are contained, that is the above described Input Module (Figure 6).

The “File Excel Output” field, in its turn, permits the loading of the output file, the Output Module, on which the results of the simulation will be written at the end of the run (Figure 7).

Once the two fields have been filled in, the activation of the button “Create activity network” allows the Simulation Model to automatically create the network related to the project (Figure 8).

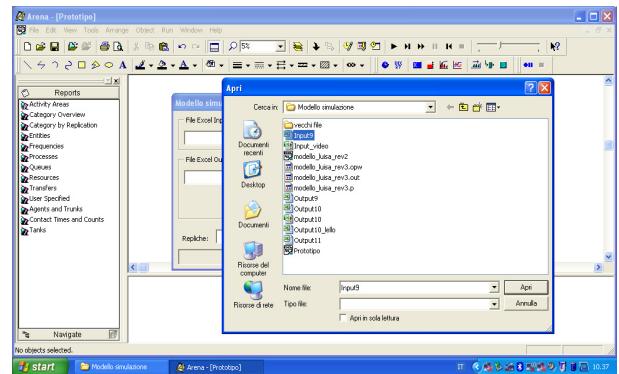


Figure 6: Loading of the input data into the Simulation Model

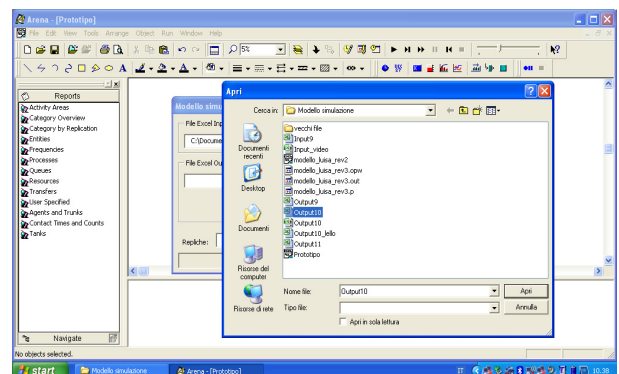


Figure 7: Loading of the file where the simulation results will be written

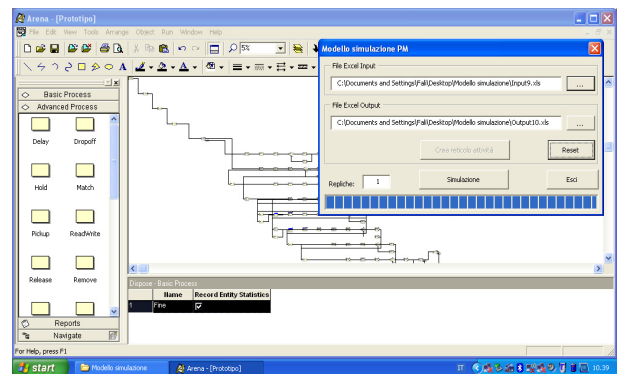


Figure 8: Creation of the project network through the Simulation Model

Particularly, the flow chart of Figure 9 illustrates the logical scheme that the Simulation Model follows in order to build the project network through the Arena Software. The figure shows the different Arena blocks used to represent the initial and the final nodes of the network, which are built once, as well as the project activities.

Moreover, the specific parameters coming from the Input Module (through the Readwrite 1 and Readwrite 2 blocks), generated (through the Delay, the Process and the Assign blocks) or transferred to the Output Module from the Simulation Model (through the Readwrite 3 block), are indicated under each Arena element.

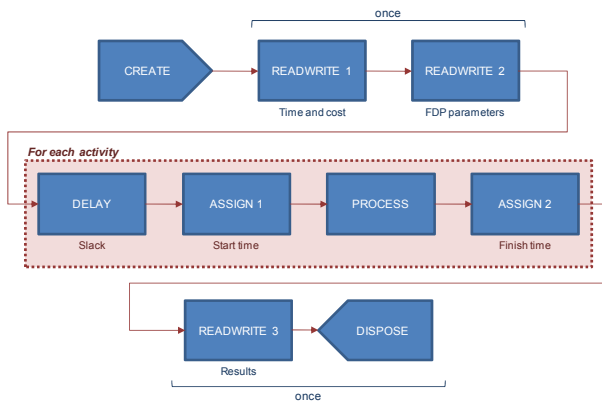


Figure 9: Logical scheme for the construction of the project network

At this point, the user has to choose and consequently write into the field “Replications” the number of simulation replications that wants to perform and, therefore, activate the button “Simulation” in order to start the simulation runs (Figure 10).

In the window of the figure it is possible to note the presence of a blue bar which allows the user to control the time advancement of the simulation in order to guarantee him a precise idea of the time to the completion of the process.

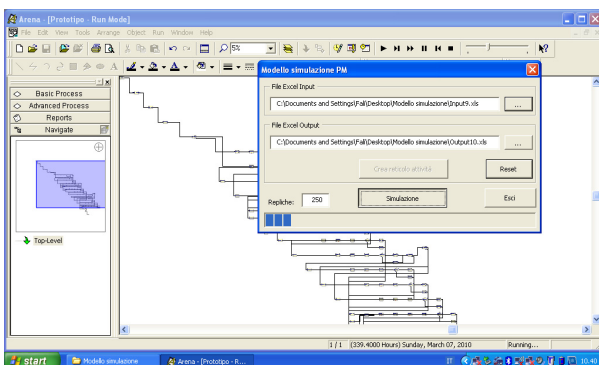


Figure 10: Choice of the number of replications and starting of the simulation process

3.3. The output module

As previously mentioned, the results of the simulation are automatically transferred to the Output Module, which has been developed through VBA under Excel.

The data coming from the Simulation Model are stored into an Excel sheet in the form of a matrix which columns represent the project activities and which rows report the data of each simulation run (Figure 11). Particularly, for each activity, the start times (T_{start}), the finish times (T_{finish}) and the costs ($Cost$) associated to the estimated duration at each iteration are loaded in the Output Module.

These data are reorganized by the Output Module and, for each activity and for each simulation replication, the unit cost is calculated (Figure 12).

For each simulation run, the unit cost for an activity has been determined by spreading on the time

range ($T_{finish}-T_{start}$) the total cost associated to the duration estimated through the Simulation Model.

Iteration	T_start	T_finish	Cost
0	180		53000,00
0	172,3027622		54924,31
0	192,8618196		50214,28
0	177,752217		53561,95
0	200,9433848		52223,61
0	184,7859079		51803,52
0	190,1622543		50459,44
0	190,3163577		50420,91
0	179,0176713		53245,58
0	176,5567982		53860,80
0	178,4107908		53397,30
0	173,7934343		54551,64

Figure 11: Simulation results in the Output Module

Activity	T_start	T_finish	Cost	Unit Cost
Attività 1	0	180	53000,00	294,4444444
Attività 2	0	187,2	86000,00	459,4017094
Attività 3	181	339,4	372000,00	234,8484848
Attività 4	180	228	60000,00	125,1723
Attività 5	339,4	627,4	220000,00	76,3888889

Figure 12: Estimation of the unit costs for the project activities

Also in this case, the data coming from the Simulation Model must be converted into data comprehensible for the users. For this reason, the Output Module provides the possibility to manage the available data in order to construct a Gantt diagram for each simulation replication (Figure 13).

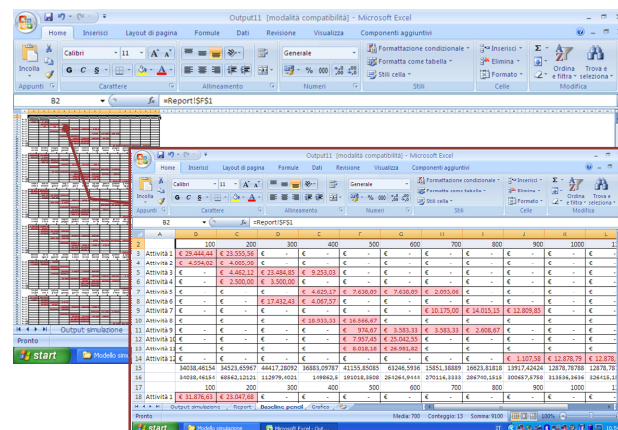


Figure 13: The Gantt diagrams related to the different simulation replications

The Figure 13 shows the different Gantt diagrams in the Excel sheet and a zoom on one of them in order to make their peculiar characteristics more evident. As it is possible to see in the figure, under each Gantt chart

there are two rows which quote respectively the total costs and the cumulated costs of the project.

Through the cumulated costs, by activating the button “Create Baseline”, the Output Module is able to graphically represent a “baseline pencil” (de Falco and Falivene 2009) which portrays the variation field of the project time-cost binomial (Figure 14) and a related probability distribution function of the project completion time.

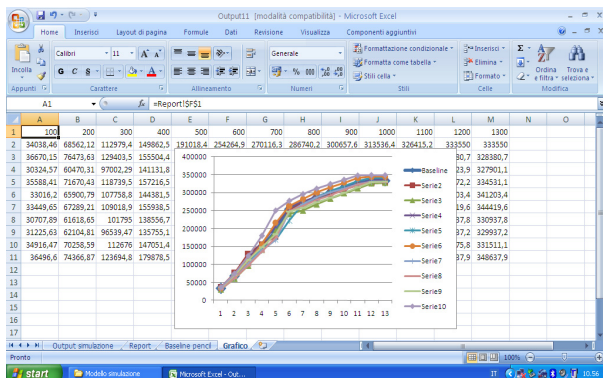


Figure 14: The baseline pencil

4. CONCLUSIONS AND FUTURE RESEARCH

The proposed approach to manage projects is a sort of probabilistic CPM that, by introducing simulation, consents the introduction into the classical analysis of the intrinsic aleatory of the network activities durations. This allows the increasing of the efficiency both of the planning phase and the execution phase thanks to the possibility of updating in real-time the data.

Particularly, during the project planning phase turning to the present methodology consents a series of interesting advantages:

- the generation of the baseline pencil and the related probability distribution function guarantees more confident estimations;
- the use of simulation allows managers an higher consciousness when submitting proposals or negotiating contracts with the clients;
- the approach determines a stronger consciousness of both real and perceived potentials of the chosen project proposal.

At the same time, the use of the methodology during the execution phase consents a more efficient control process since:

- it allows the real-time updating of the data after the control;
- it allows the identification, the testing and the evaluation of potential improvement strategies with project is in progress.

The ad hoc developed tool, thanks to its particular characteristics, gives users the effective total visibility of the project information heritage during its execution.

The real-time monitoring of the tendencies of particular relevant phenomena allows the efficient representation of the project dynamics and the production of interesting indicators for the ongoing monitoring, ex-post evaluations and impact evaluations.

Moreover, the goodness of this tool is more evident since it guarantees managers the availability of always updating data and the possibility of realizing continuous analyses on the tendency of relevant phenomena, such as analyses which give a complete and timely informative vision useful to make decisive choices and consequently evaluate their effects.

The simulative approach together with the developed tool are characterized by a great flexibility since the Input Module, the Simulation Model and the Output Module can be fitted on all kind of project.

The advantages of the proposed tool with respect to apparently similar systems such as spreadsheet model supported by simulation packages (i.e. Crystal Ball) can be resumed in the two following points:

1. easy management of the precedence rules among the activities;
2. quick realization of the simulation model reproducing the project activity network.

The simulation model is in fact automatically created by the tool, completely avoiding in this way the complex and time consuming phases of design, implementation and validation of the model. In addition, any variation on the activity durations is automatically managed, with the shifting of all the connected activities, making an effective real-time control of the project advancing possible.

The strength points evidenced by the proposed project management approach are several but the potential interesting extensions of the research are also numerous.

First of all, the cost functions associated to each project activity have been considered deterministic but in practice it is likely that the cost value related to a particular activity duration is considered variable according to a specific probability distribution, as for the time.

Finally, the tool has been tested on a construction project in progress and has already shown its potentialities but it would be opportune to follow a project from the drafting of the project plan to its completion in order to demonstrate its real degree of effectiveness in leading to a higher performing project management.

ACKNOWLEDGMENTS

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