# Using Simulation Approach in an Assembly Line Implementation Project: a General and Qualitative Feedback

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In companies, the simulation has been used for over thirty years through analytical support and has improved production, handling and logistics. Simulation tools are very frequent and support the analysis process for the design and control of operations management and distribution. With the recent development of supply chain management, firms are part of more complex supply chains. The modelization and the evaluation of the links of these chains are vital for overall performance and to reveal strategic and inter-organizational issues that may appear. The work described in this paper is the result of a study that was conducted as part of a project to establish a new assembly line in an existing plant. The main objective of this paper is to present a summary review of the simulation potential in the design and the management of an industrial process through feedback. The paper also attempts to highlight mistakes that can be made in such projects.
**Keywords:** assembly line, complex problems, industrial logistics, project, simulation.

## 1. INTRODUCTION

In companies, the simulation has been used for thirty years for analytical support and has improved the production, handling and logistics business [21]. Simulation tools supporting the analysis process for the design and management of production activities (including procurement and manufacturing) and distribution (for storage and transportation) are quite common. We can name the most famous tools such as ARENA [8] or WITNESS, but also more recently PROMODEL.

In addition, firms are now part of more complex supply chains involving a large number of national and international players. The evaluation of these networks is essential to achieve improvements in performance [2], [4] but also to reveal strategic and inter-organizational issues [5], [9]. Thus, for example, suppliers of the automotive industry have inevitably been impacted by the strong pressure on costs and deadlines that govern this business. Especially when managers apprehended the fact that the strength of a firm depends on the links of supply chains in which it is itself built. It is almost natural that companies in this sector are among the major users of simulation tools used in order to improve the overall performance of their supply chains.

The work presented in this paper is the result of a study that was conducted as part of a project to establish a new assembly line within an existing industrial site. We have not tried to expose the results but the process of modelling and simulation that has been beneficial for the company. We have also tried to take stock of synthetic potential of the simulation tool in the design and piloting of an industrial process through a real feedback experience. This case study also helps put into perspective the errors in steering the project and the team management, mistakes that are always potential lessons to be learned [3].

## 2. BACK TO TRADITIONAL SOLVING PROBLEM ACTIONS

Existing problems and business methods that require resolution seeking an optimal solution (a maximum or minimum) are numerous and varied. There is a plethora of approaches and tools, rather different in nature, to problem-solving. Methods of problem solving can then be formalized, empirical, mathematic, etc. Regarding the decision-making process, many models of problem solving have been proposed over the last fifty years. As an example we can cite the famous Intelligence-Modelization-Choice (IMC), a model proposed by Simon [18] or the ones of Mintzberg et *al.* [13] and more recently Tsoukias [20]. The last two must also be seen as extensions of the Simon model.

Regarding the simulation, it represents an additive possibility in addition to the full panoply of tools available to decision makers. To compare the simulation with other methods, we propose a simple first diagram of the problem solving process, looking for an optimal or at least an acceptable solution.

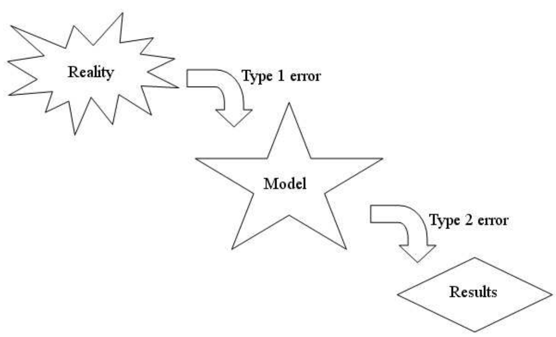


Figure 1. The error process in the study of a complex problem

Complex problems can be solved by methods that are "exact" or "heuristics" [15]. If the methods chosen are exact, the model will likely be relatively far from reality because these methods can hardly be used on large complex problems. Thus the amplitude of the type 1 error will be relatively important. However, once the model is established, results will be the best possible and therefore, the type 2 error will probably be less or zero. But let us not forget that the results are not directly associated with a reality but a model associated with this reality. In contrast, if the method chosen is a heuristic type, the model can be relatively close to reality and therefore the type 1 error can be relatively low. However, type 2 errors are likely to be more consistent. Indeed, the heuristics cannot give a guarantee of suitability or quality of results [7]. We integrate the simulation in the heuristic category because the results don't guarantee the optimality of the best solutions found. On the other hand, the simulation is probably the approach that allows the designing of models closer to reality. Thus, with simulation it is possible to create models with type 1 errors among the lowest possible. It is also true that type 2 errors may be substantial. It is often recommended to combine other methods to ensure that the simulation uses correctly and efficiently the portfolio of potential solutions.

## 3. DIFFERENT KINDS OF SIMULATION TOOLS

In any event, the decision maker must take stock of skills and tools available to it before starting a process of studying a complex problem [1]. Obviously, the skills required are sometimes identified externally but they often represent a considerable cost. And in terms of resources, it is necessary to include the time that represents both a resource and a constraint. We shall return to this point later particularly when examining the statement of the case study presented.

For simulation tools, we can perform an initial classification, with two large families: the continuous-time simulators and those with discrete time. The first work mainly on continuous equations that attempt to explain the system behavior. These tools are not included in the scope of our study. We will develop analytical tools only with regards to discrete time. It is interesting to note that in general the methods of solving problems based on mathematical algorithms are generally either discrete type or continuous type. In fact, mathematics offer two worldviews. The one where it is possible to count the objects representing the world and the one where it is possible to measure them. Problems with continuous variables are fairly obvious to identify. Defining the mass, the volume, the duration, are examples of problems in a continuous perspective. In contrast, problems trying to identify a quantity or trying to find a good or a better solution from a limited number of opportunities are often covered by discrete modelling. The discrete simulation or more precisely the discrete-time simulation considers that the time may be modelled by a discrete variable. Thus, the time “jumps” from one moment to another usually depending on important events which occur while operating the modelled process. Consequently, the approach of discrete event simulation is perfectly consistent with the modelling process. The latter one is very current and corresponds to the supply chain management philosophy. Figure 2 provides a fairly conventional process. The same representation can be used for modelling in the case of a simulation.

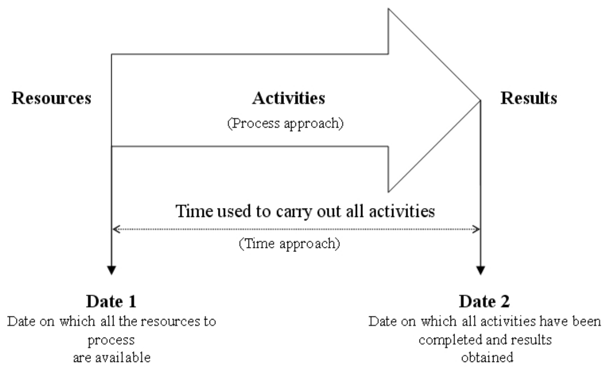


Figure 2. Connection between the process approach and modelization for a simulation

The contribution of simulation is the integration of the time variable in the process approach. Dynamic systems, that is to say that evolve over time and involve a probabilistic approach, are better adapted to the principles and objectives of the simulation. As mentioned before, the simulation is particularly useful in design projects including implementation problems but also the management of production and logistics systems.

## 4. THE USE OF THE DISCRETE SIMULATION BY INDUSTRIAL COMPANIES

For control activities, the simulation can be used for the Sales and Operations Planning (SOP) referring to a long term view, for the Master Production Schedule (MPS) in a medium term view, or for short term operational manufacturing activities. Given its ability to process a large number of variables, the simulation tool is particularly useful to control short term activities. For long-term activities, it will be preferable to translate the problems on the basis of linear equations. Thus, linear programming is probably more appropriate for the particular difficulties encountered in developing a Sales and Operations Planning. In addition, from the point of view of the constraints met and from the objective, a spreadsheet tool is often enough to support the decision making process.

To assist operational activities, the simulation model includes all production resources (operators, machines, etc.), piloting rules, and all the constraints and inputs (products, orders manufacturing, etc.). The model must reflect a complex reality in a detailed manner and accurately. It is true that the simulation tools are often used to create models in which technology, which generally does not evolve on a short term basis, remains stable. For more volatile data (inventory levels or production orders for example) they may be captured easily. Also for the simulation of a short term reality, to assist the decision making process, it is sometimes beneficial to use experimental designs to establish a set of simulations that give to the decider, a general but relatively accurate view of how effectively control its production system.

For sizing problems, the simulation can be used in an analysis prior to the implementation of new technology, or for the reorganization of existing technology. It is for this latter type of application that we propose a presentation of the approach to our study.

## 5. THE SIMULATION IN THE CONTEXT OF AN ASSEMBLY LINE PROJECT

The creation of a new assembly line is a major strategic project with important consequences for an industrial company. A new line, under or oversized, may jeopardize the very existence of the plant. So it is a very sensitive and vital project because it involves the top management and all employees. In our case, the time horizon of such a project is about three years. Three teams of engineers are mainly allocated to the project because different operations must be undertaken simultaneously. A team consists of two to four engineers accompanied by one or two external consultants and possibly some persons from related departments such as procurement or production. Confidentiality does not allow us to present the accurate role of each team, but it is easy to imagine that some people will work on technologies and others directly on infrastructures. Obviously, the organizational aspect must be well integrated throughout the project.

One of the team's missions is to study how the production process must run in its entirety. Some examples of issues raised by the team are presented below.

- For a given operation, should you choose a large-capacity machine or two machines with a relatively lower capacity?
- What is the best size of buffer stocks that should be adopted to deal with failures?
- What type of system should be used to supply the line and the various workstations?

Necessarily, the working teams are both independent and interrelated. The choice of a technology directly impacts the organization and the organization itself impacts the manufacturing process. And of course, a global coordination is needed. It is provided by the production manager of the plant. It is well known that an efficient administration and a strong cost control are essential in project management [11]. Integrating four main steps called "feasibility", "conception" (or "design"), "execution" and "start-up" (Figure 3), the project happens to be particularly costly for the firm. Over a period of three years, incurred expenses and effective expenses reveal a huge gap. Indeed, the feasibility study and design are conceived as a substantial portion of the project. At the end of this last step, effective expenses are relatively low, but incurred expenses remain quite significant.

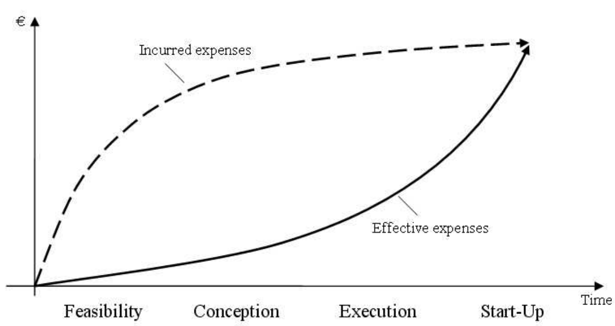


Figure 3. Incurred and effective expenses during an assembly line project

To control expenses, the feasibility analysis should be conducted with utmost care. Thus, it was decided to integrate early modelling and simulation in the pre-project studies.

Material flows, human resources and information in a plant shall be designed to ensure a lean production [19], [10]. There are several factors that influence the movement of materials and men. Important factors include delivery schedules, availability of production resources and material handling equipment, circulation spaces and the width of aisles, etc. The simulation is the best tool to capture the dynamic nature of these operations.

Without an efficient layout especially focused on the vision of the production, facilities may be unable to supply a production system connected to the market needs. The philosophy of just-in-time [22] and lean manufacturing [14], [17] can be implemented more easily if the facilities are built for this purpose. Efficient production facilities cause some immediate benefits such as reduced costs, less damage to products, better utilization of space and equipment and a more secure work environment. Once the benefits are there, a general flow of more efficient production and better productivity naturally ensues. The facility design is an iterative process where many improvements are generated before obtaining the final design. Because of the fact that the flow of materials and human resources are key factors in designing a production unit, adequate analyzes of flows are required in many iterations of the design cycle facilities.

To understand the relationships between laying out and the flows, the movement of materials from receiving to production and all points of consumption as well as between production and storage areas, it is absolutely necessary to perform an analysis taking into account the processes, distances and volumes. By analyzing the frequency of arrivals, the production time and travel time, a quantitative assessment can be made, directly linked to material flows and use of various resources. An analysis of those times and an evaluation of the use of different resources, but also storage and waiting points, can permit to determine the best scenarios. Software tools can do the analysis. However, it is important to remember that relying entirely on static analysis can be misleading when establishing an effective management. Production schedules, changes in product mix, availability of technical resources and unplanned stop of assembly line, can create variable costs that affect all the system. Accordingly, a final analysis of material flows can be done using the simulation and taking into account all these different variables.

## 6. A PROPOSED METHODOLOGICAL APPROACH TO APPLY SIMULATION

In this fifth part, we propose to present a framework for the use of simulation in the case of setting up an assembly line. This is to present a methodological approach in eight basic points.

**The description of the problem.** It involves identifying the controllable and uncontrollable inputs but also to define the performance measurement system and an objective-function. It claims in this case to develop a preliminary model structure for inter-connect inputs and measure the performance.

**Data collection and analysis.** Whatever the method of data collection used, the decision regarding the quantity of data to be collected is a compromise between cost and accuracy.

**The development of the simulation model.** This task is done to ensure sufficient understanding of the system to develop a conceptual appropriate and logical model. The development of the simulation model is undoubtedly one of the most difficult tasks.

**Model validation, verification and calibration.** In general, the model validation helps the correspondence between the model and reality. Its verification and calibration are based on the consistency of the model. The term validation is applied to the process to determine if the simulation matches the real system. It should be noted that discussions with engineers and / or production managers are required during the implementation of these first four steps.

**The analysis of inputs / outputs.** Simulation models of events generally have stochastic components that limit the nature of probabilities of the system studied. For a successful modelization of inputs, it is necessary to be able to associate inputs as closely as possible to the real mechanisms of probability of the system. In the analysis of inputs, it is important to modelize an element (e.g., arrival process, service time) in the simulation of an event based on data on the element of interest. At this step, it performs intensive error detection on inputs, including external variables, industrial policy and other variables. The experimentation of the simulation system consent, step-by-step, an understanding of its behavior.

**The performance evaluation and the analysis of hypotheses.** The analysis of hypotheses is at the heart of simulation models. The estimate of sensitivity is the means to provide users with analytical techniques available so they can understand what are the important interrelationships in complex models [12]. Again, it is important to involve engineers during this step.

**Optimization**. The traditional techniques of optimization have required a variable estimate. As for sensitivity analysis, the approach to achieve the optimization requires an intensive simulation to construct a response-function. We consider it essential to add variable estimation techniques to convergent algorithms such as Robbins-Monro [16] in order to achieve optimization.

**The production of written reports.** Reporting is a fundamental and critical link in the communication process between the model and the end user. This last step should certainly not be neglected.

One remark deserves to be highlighted here. If the project did not reach the stage of construction and use, the mere fact of defining variables, of expounding the hypotheses about their relationships and expressing these relationships in terms of equations, gives a high value added. Indeed, this will force the top management to think more carefully about the problems in order to achieve more efficient and sustainable solutions.

## 7. THE LESSONS LEARNED FROM THE USE OF SIMULATION

Depending on this experimental research, we would like, in this sixth part, to talk about the flow of the simulation by answering the main questions often asked by those considering its use in industrial development projects. Here, we are trying to answer very succinctly “why”, “how” and “when” to use simulation models.

**Why use simulation models?** It is safer and much cheaper to simulate than test in reality. It is for this reason that models are used in industry, commerce and in the healthcare sector. It is often very costly, dangerous and sometimes impossible to do experiments with real systems.

**In what kind of context can simulation be used?** The use of simulation is interesting for dynamic systems involving probabilities. However, the modelization of such complex systems requires too many simplifications and the resulting models often may not be valid.

**How to simulate?** Suppose we want to simulate a picking process in a distribution platform. It would be possible to describe the behavior of the system graphically by plotting the number of resources included in the activity of gathering. On the graph, a percentage increase in the use of resources could be observed. In this case, it would appear possible to see the peak for a given day. This chart is an overview of the results observed in an actual operation of collection, but could also be fictionally constructed, leading consequently to a simulation.

**When must you use the simulation?** This is probably the question that is most difficult to answer. If we refer to Figure 3, the reflex would be to use the simulation as soon as possible, early in the feasibility project step. This reflex appears when the stakes are very high. Our experience on a large industrial project refutes this indication. Indeed, the simulation approach becomes interesting when a number of parameters has already been established. In the project, for the first analysis of volume and rate, it seems wiser to use a lighter and simpler tool. Energy spending devoted to precise simulations (but often questioned because the choices are too open), make the work unproductive and impact negatively on the team motivation in charge of modelling. Thus, for projects to design or create a new organization, we advocate the use of simulation only after the main technical choices have been made. The arrival of the simulation in our opinion should be held in mid-design stage. In the experience presented in this article, it seems that simulation should be used to further refine the parameters of the chosen technologies but not necessarily to choose them directly.

## 8. CONCLUSION

The design of an assembly line is a major project. The fact that each such project contains some uncertainty often generates more or less expensive and difficult mistakes to adjust for top management. The feedback that we propose in this paper highlighted two key lessons. Each major step in creating the simulation uses the adapted tools and methods. Anticipating their use can be counterproductive. Delaying them may obviously jeopardize project deadlines. Regarding the simulation, a major risk is characterized by the desire to anticipate its use. If the structure and the main technologies are not chosen and selected, a model is just a big waste of time and energy and thus resources too. The simulation is useful only when the need for a model is really necessary. The error gives rise to a second lesson characterized by the need for a better and true integration inside and between the teams. In this example, some redundancy was observed between the work done by the group of employees in charge of modelling and those in charge of the feasibility study. A better coordination could get the group in charge for modelling understands the real needs of the project in terms of settings and scaling. A project is always a unique experience. Although they are difficult to generalize, the lessons learned from this experience are full of different perspectives and more particularly regarding one aspect. The human, technical and financial resources are in constant interaction. These interactions sometimes create a particularly distressing and difficult experience for all project resources [6]. In conclusion, this article allows the reader to get the benefit of an interesting feed-back on an empirical use of the simulation in industry. The resulting conclusions should guide future and exciting research on this topic with numerous new opportunities for analysis.

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