Dynamic behavior of NPD

Yolanda Álvarez Castaño
University of Oviedo
Dpto. Administación deEmpresas y Contabilidad
Avda. del Cristo s/n 30071 Oviedo (Spain)
Telephone: 34 985104858 Fax: 34 985103708
yalvarez@econo.uniovi.es

1. Abstract

The purpose of this work is to increase knowledge and understanding of the dynamics of development projects in order to improve their performance. System dynamics models provide a useful tool for analyzing the scope of the effect that the policies adopted is going to have on the performance of R&D projects. In this way, it is possible to evaluate possible alternatives in order to choose the decision, which will improve the process, and thus facilitate organizational learning.

2. Introduction

By carrying out innovative projects, the company seeks not only to obtain a profitable innovation —with a threefold aim: speed, quality and efficiency—, but also to increase the organization's technological capabilities —in order to guarantee its profitability, and survival in the medium to long term— and augment its knowledge about how to manage these projects.

The dynamism and globalization of today's competitive setting have made the New Product Development (NPD) process one of the most important sources of competitive advantages for the firm. However, it is these same characteristics of the setting which make it difficult to manage this kind of project. R&D projects cannot be efficiently managed without comprehending the dynamic characteristics of their structure: feedback systems, delays and non–linear causal relations, among the different components of the process. It is precisely the combination of these three elements, which causes certain measures adopted in order to improve the performance to generate unexpected effects, and even aggravate the initially detected problem. In addition, this combination makes it difficult to transfer the experience and knowledge obtained thanks to the previous developments of new products, towards improving the management of future innovation projects.

For this reason, if it is taken into account that system dynamics:

1. Aims to show how the problem detected occurred (Schroeder III, 1977; 246). Then, it is possible to identify causal explanations for phenomena, which have been detected in diverse empirical studies, because the structure of the dynamic model elaborated includes the causal relations existing between the most relevant factors involved in the project, which cause its dynamic behavior.

2. Enables factors concerning the technical, human and organizational aspects to be included in the analysis of the problem; the latter two aspects being incorporated thanks to the information provided by the people working in the

system. Their mental models provide rich and accurate information about the problem and how they interact in order to make decisions to solve this problem. This information is used to configure the system structure(1) (Eden, 1994).

3. The dynamic model can be used as a learning laboratory (Senge and Sterman, 1992). In this way, it is possible to evaluate a priori, the repercussions that certain policies or behaviors are going to have on the project. The use of a learning laboratory facilitates organizational learning, and establishes a flexible and dynamic procedure, which aids in the management of this type of activity (Pawson et al. 1995).

4. Enables the involvement of the individuals, who are going to be affected by the decisions in the decision —making process— which thus facilitates their acceptance (Jones and Deckro, 1993). In this way, the people involved in the project are given the option of refuting the merits of one another's ideas and assumptions, at the same time as they are provided with a tool helping them to understand why a certain decision was made, and to identify the rules of the game (Kim and Mauborgne, 1977).

5. Finally, adapting the generic model to each specific project, and performing different simulations, it is possible to establish specific recommendations, which favor the management of the process and, consequently, the commercial success of its outcome. Thus, system dynamics contributes towards promoting the link between organizational theory and practice.

Applying this methodology to the planning and management of R&D projects provides a strategic alternative, assuming a holistic view of the organization —as required by Gupta and Wilemon (1990)—, with emphasis on the behavioral aspects of the project and its relations with managerial strategies (Rodrigues and Bowers, 1996).

In this way, it is possible that the members of the development team are faced with a "reality test", which forces them to think the project through in sufficient detail in order to devise some way to complete the project satisfactorily (Rosenau and Moran, 1992; 99). From this perspective, it is considered that the use of system dynamics in R&D project management enables three fundamental objectives to be obtained (Pawson et al.1995):

1. Reducing the "Time to Market"; that is to say, the time needed to design, develop and market the new product.

2. Helping to adapt new products to individual customer requirements; thus contributing to their commercial success.

3. Increasing the flexibility of the operational process, when faced with unforeseen events.

3. Causal Diagram

If it is taken into account, that the companies considered as most innovative, attained success, not by using of the most widespread and accepted management practice, but thanks to the simultaneous and effective application of the combination of those organizational practices considered the most adequate, and which best fits their specific context (Takeuchi and Nonaka, 1987; Griffin, 1997), the need for a causal analysis is obvious.

A causal diagram compiles the different factors intervening in the development process of a new product, as well as the causal relations existing between them —performance attained by the development team, precedence relations, etc—. These determine the structure of the system, and also its overall behavior. However, the use of system dynamics in building this model allows not only the development of a model capable of revealing causal explanations for empirically detected facts, but it will also, be able to provide the firm with a tool for analyzing and even quantifying —a priori— the effect that the policies and decisions adopted is going to have on the evolution of the project.

It is therefore possible to anticipate —before the application of these policies in the real system— the scope of their consequences and thus prevent the implementation of those policies that have proved to be destabilizing.

Based on the extensive qualitative information collected, of a theoretical as well as an empirical nature —various in–depth interviews were conducted from July 1996 to February 1998 with the people in charge of the innovation activities of various companies belonging to diverse sectors of the Spanish economy— a causal diagram —Figure 1— was drawn up. This compiles the different factors intervening in the development process of a new product, as well as the causal relations existing between them. These relations determine the structure of the system as well as its overall behavior, in the face of different events and the policies implanted in order to correct unfavorable processes, and favor the most beneficial courses of action.

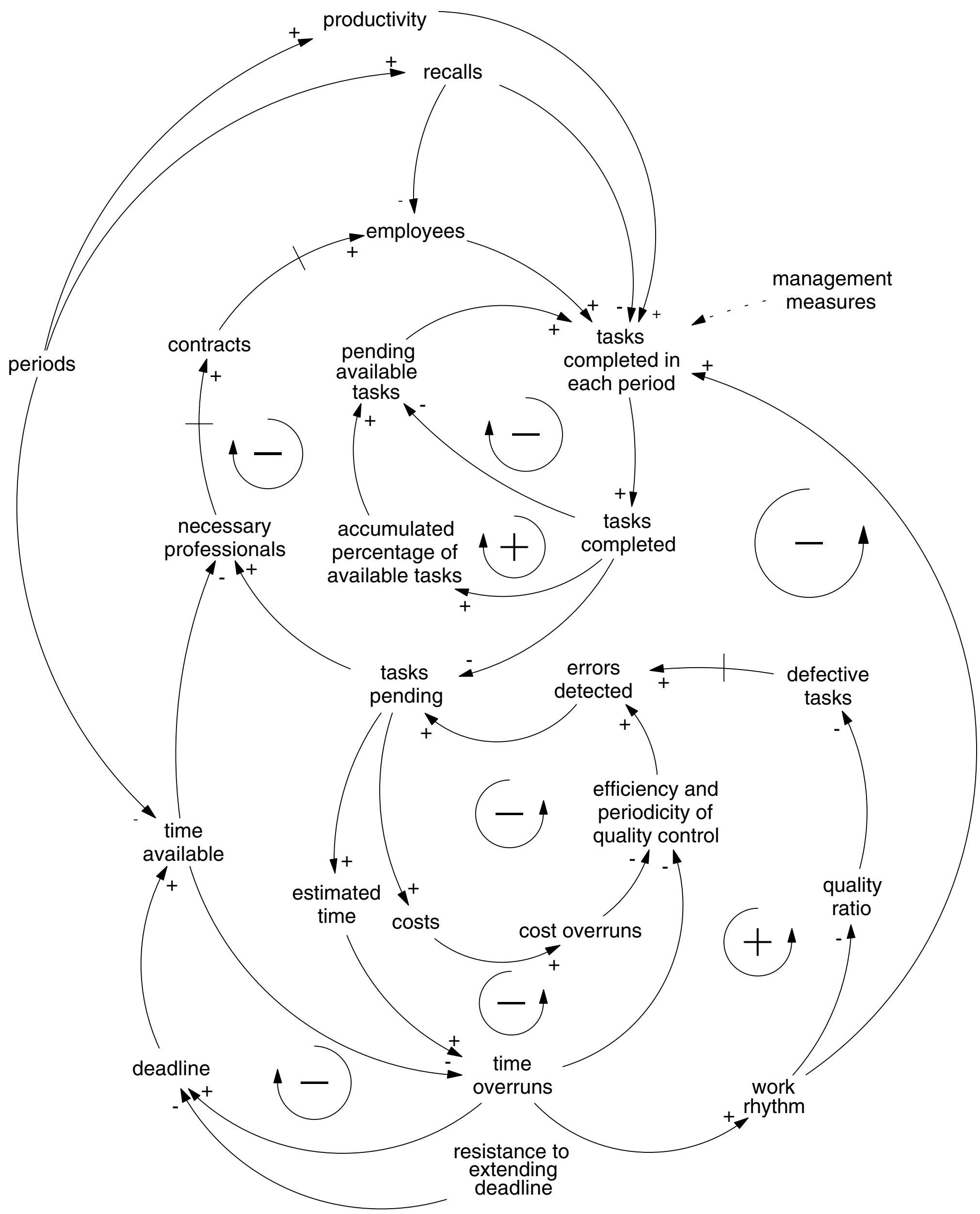

Figure 1: Causal diagram
Source: Own

4. Validity

This set of causal relations —Figure 1—, was transferred to a system of differential equations, using the software program VENSIM 3.0A.

The model compiles the evolution followed by a project made up of 26,000 tasks, which has an estimated completion time of 65 weeks, and is carried out by a team of 10 professionals, organized according to the structure known as a matrix team. The model was validated, because it satisfactorily overcame the structural validity tests —these check whether the structure of the model is an adequate representation of the real structure— and behavior validity tests —checking if the model is capable of producing an acceptable output behavior—to which it was submitted (Barlas, 1989).

Furthermore, the generic model designed was adapted to a project performed by a firm specialized in the engineering, construction and installation of electromotive centers, which is recognized in the international environment as a innovative and prestigious firm. This company has a process divided in 14 phases, in order to generate ideas, develop and introduce a new product.

The project was carried out from October 1994 to March 1997, by six people working part–time. These professionals belong to the R&D, Marketing, Supply, Process and Production Unit departments. The total resources invested in the project amounted to 107 million pesetas, 47.7 million of which were direct investments in the project. Forecasted duration and cost were 19 months and 83.7 million, respectively.

A significant financial and time overrun was observed, but the ISO 9001 norm and Quality Function Deployment (QFD) guaranteed quality, by means of "the house of quality".

Table 1 shows the numerical results obtained by comparing the evolution of the real project and that simulated by the model. The Behavior Reproduction test is more than comparing the correspondence of simulated and actual data on a point–by–point basis. The test focuses on the character of the simulated data: does it exhibit the same modes, phase relationships, relative amplitudes, and variability as the real data? (Sterman, 1984).

Results of statistical test	
Number of periods	30 months
Coefficient of Determination R^2	0.99931
Mean Absolute Percent Error (MAPE)	0.00727
Mean Square Error (MSE)	25.96696
Root Mean Square Error (RMSE)	5.09578
Bias (U^M)	0.00002
Variation (U^S)	0.00000
Covariation (U^C)	0.99998

Table 1: Summary statistics(2)
Source: Own

These results demonstrate that the total error is small. Nevertheless, it is interesting to know the sources of the error detected. Discrepancies observed between historical and simulated data can be due to model errors or to a high degree of randomness in the historical data evolution (Sterman, 1984). Hence, the usefulness of distinguishing between different sources of error. With this aim, the statistics obtained from dividing the MSE into three components as proposed by Theil (1966) are applied.

In this case, almost total error is caused by the third component —U^C—. This indicates that the point–by–point values of the simulated and actual series do not match even though the model captures the average value and dominant trends in the actual data well. This implies that the error is small and unsystematic with the purpose of the model, and the model is able to endogenously generate the behavior of any project (Sterman, 1984).

5. Analysis of some results

Formal control is defined as those written rules and procedures, which determine both the behavior and performance expected of workers (Bart, 1991), and the informal control has its essence in face–to–face communication or some form of interpersonal interaction, being more flexible than formal control, and given a feedback, which provides a richer, more complex and sometimes more subtle opportunity for gaining understanding about the innovator's work. Therefore, the reduction of the degree of formal control exercised over new product R&D projects (Bart, 1993) —it is not applicable to the subtle and tricky process of creativity (Judge, et al. 1997)—, by a high level of informal procedures, allows to be quickly identified any disagreements between the performance of new product development and the initial plans. Thus, corrective measures are immediately adopted. In addition, the frequency of adjustments to new product R&D projects can be made with timeliness and finesse, by means of informal control methods, which help to reduce delays in manger–worker communications (Bart, 1993).

For this reason, the following hypothesis was formulated:

H: Project flexibility improves performance speed.

In order to test this affirmation, the sensitivity of the model's behavior faced with delays in decision–making was checked —from 0 to 16 weeks—, as well as the time period acting as a base to smooth the values concerning the performance of the team and the information on the possible overruns(3) —from 1 to 16 weeks—.

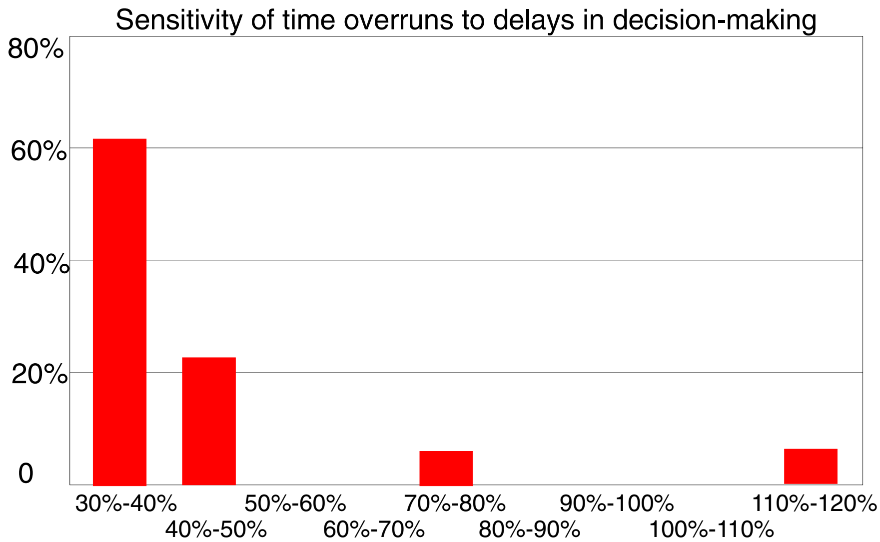

Figure 2: Graph of sensitivity to delays in decision–making
Source: Own

The time overrun shows a significant sensitivity to speed in decision–making. These variables can therefore be considered as leverage points of the system —factors for which modifications in their values have significant repercussions on the behavior of the system (Senge, 1993)—.

Therefore, in view of the results obtained, it is possible to conclude that a great part of the origin of the dysfunctions perceived is found in the delays in decision–making. These decisions are going to enable the initial plans to be adapted to the changes, which unavoidably arise, throughout the carrying out of the R&D project.

However, some studies affirm that the total absence of control is as dangerous as a tight control. In this work, the technology known as Reality–Check, was used to test this statement.

Reality Check gives a straightforward way of validating and defending the models built. A model is useful if it addresses problems. As the model is built, various checks take place, which may be implicit mental simulation and our own understanding of models and the modeling process. These checks are highly important in ensuring that the models developed can adequately address the problems they are being applied to.

Reality Checks provide a language, in which the specifications made are not tied to a version of a model. They are separate from the normal model equations and do not interfere with the normal function of the model, but let us know whether or not the model is in violation of the constraints imposed by reality imposes.

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Starting testing of Constraint NO CONTROL
Test inputs :
   permission for contracts=1
   time pressure=1
   time extension=MAX(estimated deadline-deadline,0)
Starting to test the constraint NO CONTROL at time 1
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Starting testing of Constraint TIGHT CONTROL
Test inputs :
   time extension=0
   permission for contracts=0
Starting to test the constraint TIGHT CONTROL at time 1
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There were 0 failures testing 2 constraints
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Figure 3: Results of the Reality–Check
Source: Own

Figure 3 shows that if no–control —NO CONTROL—, or tight control—TIGHT CONTROL: no more human or financial factors can be incorporated in the project, nor can the deadline be extended—, are established over the project, the results will be worse than if an informal control is applied. In this way, the assumption established is validated.

6. Reflections

This paper has attempted to outline a result of the application of system dynamics to the planning and management of R&D projects.

The construction of a dynamic model and the later simulations made with this have enabled us to state how certain measures adopted in order to favor the innovative process cause, however, unexpected and even counterproductive effects, in this aim.

The computing application designed —of which only a couple of results have been summarized in this work—, enables different simulations to be made in order to check the scope and consequences of different organizational practices and behaviors.

In this way, it is possible to know (Kleinmuntz, 193), whether a particular failure is due to (a) some unpredictable chance event in the external environment, (b) inconsistency in the application of the decision, or (c) deficiencies in the decision itself.

Therefore, in view of the results obtained, it is possible to conclude that a great part of the origin of the dysfunctions of many R&D is found in the delays in decision–making. These are going to enable the initial plans to be adapted to the changes, which unavoidably arise, throughout the carrying out of the R&D project.

7. Notes

(1) However, mental models, despite being very rich in content (Radzicki and Seville, 1993) have little capacity for accurately tracing the dynamic behavior inherent in their structure, as the system presents circular and accumulative behavior patterns, which are counterintuitive; hence, it is necessary to perform a simulation process.

(2) Where MAPE = 1/n ∑ [(St –At)/ At] and MSE = 1/n ∑(St –At)2; and St is the value of the variable in the period t, and At is the value of the variable in that period. This measure has a double advantage, because it gives more weight to high bias, than low ones, avoiding opposite signs from being neutralised. Value of the RMSE can only be analysed taking into account the mean value of the variable (Pindyck and Rubinfield, 1980); in this case A= 393.3.

(3) The longer this period, the lower the importance of the specific deviations produced.

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