Strategic Evaluation of Flexible Assembly Systems
- Combining Hard and Soft Decision Criteria -

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Abstract

The evaluation of investments in flexible assembly systems lacks of an appropriate methodology. First a brief review of decision making processes regarding complex investments is given. Such decisions have to be made in the tension of hard and soft decision criteria which often produce a dilemma for the decision maker: Considering only short-term effects in terms of hard criteria will usually kill investment proposals. In contrast managers feel the need for the investment but have difficulties to justify their intuitive insights. As a possible solution a Systems Dynamics based approach is proposed to bridge the gap between rational and intuitive judgement. The approach combines qualitative and quantitative criteria by using a computer-aided step-by-step modelling concept.

Introduction

The evaluation of complex investment objects is not an easy task. We are dealing with interventions into complex socio-economic systems. Here decision makers have to consider:
- hard and soft decision criteria,
- interdependent aspects,
- high capital investments,
- time-consuming implementation,
- long time horizons,
- often significant organizational change, and
- important impacts on the competitiveness.

All in all such decisions can be considered as strategic. They must be submitted to a comprehensive economic evaluation. However, up to now there are no methods available which permit this evaluation in a satisfactory way.

Available Approaches for Evaluating Complex Investments

Conventional methods of investment evaluation differ primarily in whether the time aspect of expenses and earnings of an investment is taken into account or not. Static calculation methods ignore differences in the time structure of the series of payments. Dynamic methods take into consideration the values of the payments which are due at different times. Both types of procedures, however, presuppose clearly defined expectations with regard to the development of the payments concerning a particular investment. These procedures evaluate individual investment projects that are not interconnected according to one goal criterion and are limited to quantifiable aspects. Interdependencies between different investment projects are neglected. Besides, additional premises have to be fulfilled if the respective methods are to be applied successfully. This results in further limitations.

Conventional methods can be used at best to estimate the expenses of an investment. The consideration of the benefits is possible only in a limited way. These methods, although widely used in practice, thus often result in a "killing calculation" of an altogether advantageous investment. One also speaks of a so-called "brake effect" which appears when these methods are applied exclusively (Lüder 1993).

In the case of soft decision criteria the gap between the existing procedures and the desirable ones is even greater. Figure 1 shows three examples. The respective effects that an investment produces are presented by means of lists of impacts (Horváth e.a. 1987). Balance sheets of arguments are also used to structure qualitative criteria - in this case pro and con arguments are listed side by side in a structured balance (Wildemann 1986). The most widely used method still is the scoring model (e.g. Blohm and Lüder 1991).

- **Lists of Impacts**
- **Balance Sheets of Arguments**
- **Scoring Model**

  Purpose: Structured evaluation of decision alternatives based upon the preferences of the decision makers (concerning multi-dimensional objectives)

  Procedure: (1) Formulation of decision criteria concerning the alternatives
  (2) (subjective) estimation of the importance of the criteria
  (3) (subjective) evaluation of reaching the objectives of each alternative

  Example: Choosing between alternative plant location

Criteria / Alternatives	Time Saving	Traffic Security	Availvabilty of Personal Resources	Scores
	Importance of Criteria (g)			Aggregation Rule
	g(1) = 0,3	g(2) = 0,4	g(3) = 0,3	N = n(i1)*g(1) + n(i2)*g(2) + n(i3)*g(3)
Location C	n(11) = 8	n(12) = 7	n(13) = 9	N = 7,9
Location D	n(21) = 6	n(22) = 8	n(23) = 8	N = 7,4

Figure 1: Scoring Model

The advantage of the scoring model lies in the fact that investment alternatives can be organized with regard to a multidimensional goal system. However, interdependent effects are neglected here as well. Besides, this model leads to a certain pretense of objectivity which contains the danger of deceiving the decision maker from the real subjectivity of the estimates and evaluations. Apart from this, there exist a number of different procedures and methods. All in all, however, they have the following disadvantages:

- The integration of so-called hard and soft decision criteria in a comprehensive model remains to be solved.

- The processing of information about the conditions of the market and the competition is mostly not satisfactory.
- The long-term effects of an investment are only considered in isolation.
- There is no support provided when information of long-term effects about an investment is needed.

Intuition as an Element of Real Decision Processes

Since there do not exist any suitable methods for the evaluation of investments, decisions are often made on the basis of intuition and of previous experiences. Although the weaknesses of this kind of evaluation of investments are evident, real life often requires decisions on this basis because there are no better methods available.

Intuitive knowledge about complex issues is stored in various ways in so-called mental models by the decision makers. Senge (1990) notes three categories of knowledge as shown in Figure 2:

- Knowledge of facts is noted first when dealing with complex systems. It comprises knowledge about the state of the system, perhaps about skills for mastering problems in a reactive way. This encompasses e.g. knowledge about financial aspects such as profits, costs, revenues, etc.
- Behavioral knowledge about systems is more far-reaching. It deals with statements about trends and developments in the past which may possibly continue into the future in terms of trend extrapolations, e.g. the development of demands, business cycles, etc. The consideration of such knowledge permits a certain future-oriented or proactive decision-making.
- The development can only be influenced generatively or organized if structural knowledge is available. This is knowledge about feedback loops, policies, delays, and gains.

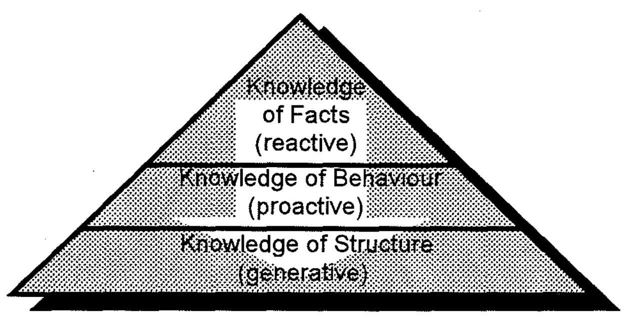

Figure 2: Knowledge about Complex Systems

The problem is that the decision maker has stored these types of knowledge mentally in a relatively unstructured way. Furthermore, the difficulties of a purely intuition-based approach increase the more in detail this pyramid is regarded. In real life intuition-based decisions are seldom founded on correct and verified structural knowledge.

Especially in the case of investments in flexible assembly systems one deals with complex socio-economic systems. And complex systems possess two basic characteristics which make them extremely difficult to handle, and which present themselves as a basic evil for the decision maker: Complex systems contain feedbacks and delays (Sterman 1989).

This severely inhibits the formation of structural knowledge through intuition. By now there exist a number of scientific studies which prove that human decision makers tend to commit the same errors over and over again when dealing with complex systems without the support of any instruments (e.g. Dörner 1983, 1989; Vester 1985; Sterman 1989, 1994). E.g. delays in socio-economic systems are often underestimated. One simple example are delays in the process of training people. New employees become productive only after a certain period of time. Until then they may even inhibit the productivity of the present team of employees. The employment of new people can thus - contrary to the intended effect - reduce the output of the company for a certain time. Only in the long run do the intended positive effects become manifest. The time gap between cause and intended effect often makes it difficult to bring them together and connect cause an effect correctly. An exemplary collection of such basic errors in human's reasoning with regard to complex systems is shown in Figure 3.

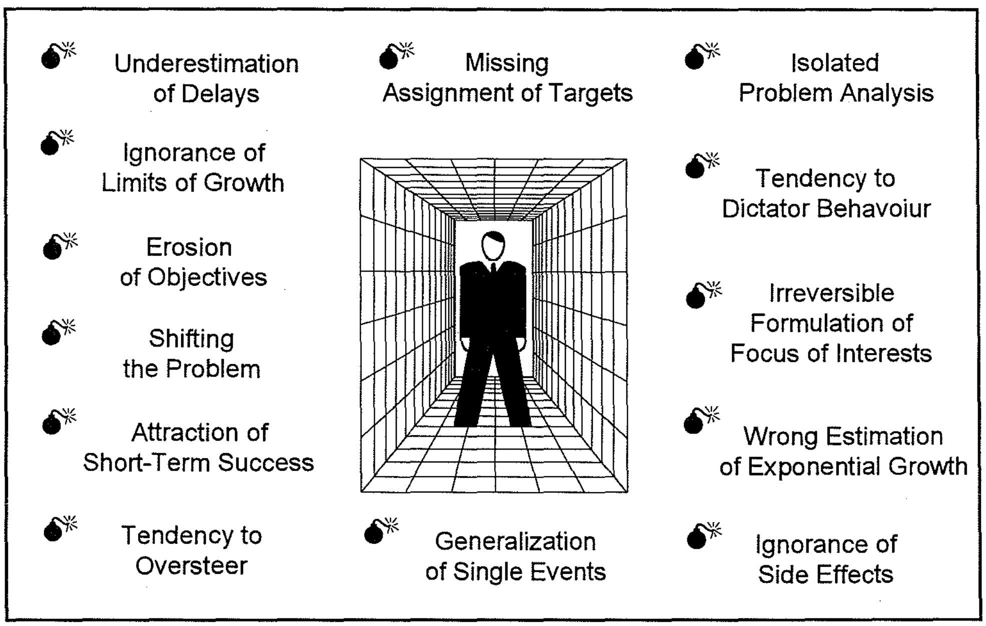

Figure 3: The Manager as Prisoner of his/her Own Errors of Reasoning.

Nevertheless, the mental models resp. the experience of experts and decision makers contain a large amount of valuable knowledge that should be considered when a decision is made. After all, this it is already done in real life. However, there it takes place mostly in an unstructured way and is purely based on intuition, under the hazard of committing the errors described. Up to now, unfortunately there aren't any methods or procedures available, or not even ideas concerned with these, which could provide substantial support for the solution of this problem.

Figure 4 counterposes once more the two diametrically opposed methods which are used in real life. The evaluation of investments on the basis of hard decision criteria, such as e.g. costs, rentability, etc., and the application of conventional investment procedures are not sufficient if one desires an overall evaluation. These procedures can be useful in evaluating the cost- and payment-aspects, but the benefits and profits of an investment can hardly be analyzed properly. The inconsistency in the consideration of flexibility costs and flexibility benefits easily leads to a "killing calculation" of necessary investments.

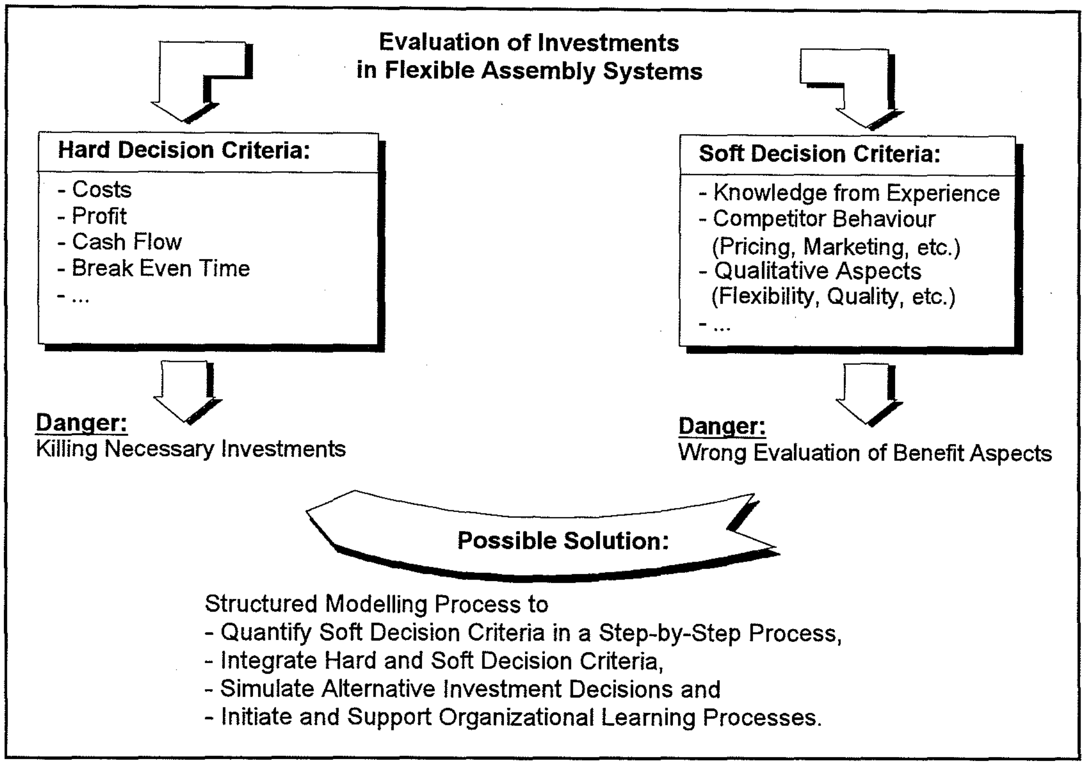

Figure 4: Evaluation of Investments in Flexible Assembly Systems

This is contrasted with the sole use of soft decision criteria. Here a suitable evaluation of an investment is not possible either. The estimation based on intuition of the effects of qualitative benefit factors, as e.g. improvements in flexibility and quality, easily results in their overestimation. Because of the dynamic long-term effects only seldom decision makers can build up knowledge from experience that can immediately be transferred to future projects.

Because of the differing foci of analysis the simultaneous application of hard and soft decision criteria in separate studies may lead to conflicting results. Often the investment does not seem desirable when considering the hard criteria. The application of the soft criteria, however, leads to the insight that the investment is desirable, perhaps even absolutely essential. Therefore it appears useful and important to attempt a better integration of the two types of decision criteria in a more comprehensive procedure. The intention is to achieve the following:

- to quantify soft decision criteria step by step,
- to integrate hard and soft decision criteria,
- to achieve a dynamic simulation of the interconnected effects of investments in flexible assembly systems, and
- to initiate and support collective learning processes with regard to understanding the effects of such investment programs.

Integrating Hard and Soft Decision Criteria Step by Step

Figure 5 shows a step by step modelling concept for evaluating investment decisions (Zahn and Greschner 1993). It aims to make a simulation model available in which the investment project is shown in its economic network. This should make the evaluation of the effects of an investment possible in relation to time. This simulation model can eventually be converted into a learning model that is designed to distribute the knowledge generated in the modelling process among all the employees of a company. The basic idea behind this is that it is not the scenario of effects that is produced by means of such prognostic models but it is rather the process of modelling itself which permits essential insights (Vennix and Scheper 1990).

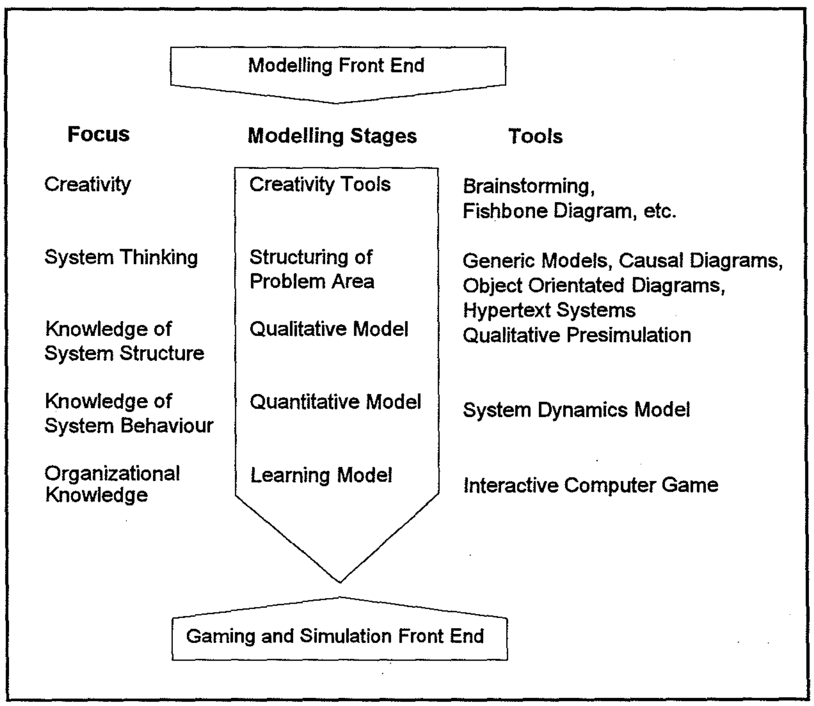

Figure 5: Step by Step Modelling Concept

The generation of the simulation model is realized in computer-aided sessions. A previously formed group of decision makers is asked to participate actively in the process of modelling. This so-called modelling group gradually uncovers the relationships of cause and effect that underlie the investment project in a structured way. In this process hard, quantifiable decision criteria are applied as well as soft criteria that are difficult to quantify. The aim is to uncover and describe the problem while taking into account the intuitive experiences of the experts and decision makers.

In a first step the modelling group can fall back on a general or generic model. This generic model is based on a large number of empirical studies and theoretical insights. In the generic model the basic structures of the field under investigation are shown - in our case investments in flexible assembly systems. The generic model presents the basic cause - effect relationships in the form of diagrams and of a hypertext system in which knowledge about the model is stored. This knowledge can then be made available to all users.

When structuring and delimiting the problem the concrete model is deduced from this generic level with the help of creativity tools. This step provides a graphic presentation of the specific cause-effect relationships in the form of causal diagrams and of an expanded hypertext system. The following step encompasses the qualitative specification of the model - that is the description of the cause-effect relationships as shown in Figure 6.

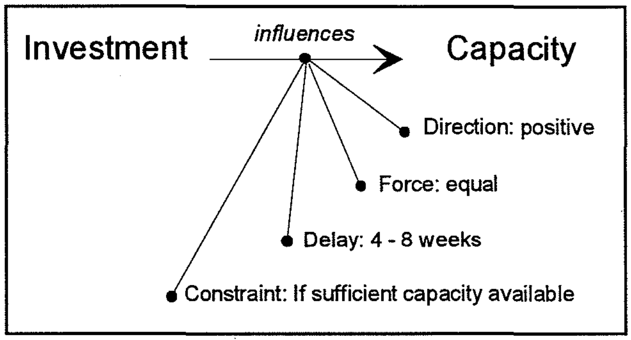

Figure 6: Qualitative Specification.

This qualitative specification permits a preliminary qualitative simulation which contributes to a primary examination of the model structure and eventually leads to the later dynamic simulation. On the basis of this qualitative view the behavior of the model of the later dynamic simulation should become more easily imaginable and understandable for the users.

It has not been possible so far to analyse the dynamic phenomena of the investment because of the lack of a simulation that takes into account the time factor. Nevertheless, this structured discussion of a problem results in qualitatively better decisions than an analysis that is purely based on intuition.

All qualitative causal chains between two elements, i.e. all possibilities for inter-connectedness in the interrelated system between these two elements, can be generated and examined. Problems can be discussed, as e.g.:
"What effects do investments have on market share ?"
"Which causal chains exist between these two elements?"
The next step on the way from soft to hard decision criteria comprises a quantitative specification of the model in the form of mathematical equations. Thus a System Dynamics simulation model is created that can then be employed to examine the dynamic phenomena of the investment project. On the basis of the information generated through simulation the available investment alternatives can be evaluated. Finally, this simulation model can be transferred into a learning model with an appropriate user interface. With the help of this learning model the knowledge that the modelling group has acquired in the process of modelling can be distributed in the company as a whole. The aim is to initiate and support processes of organizational learning.

A Learning Model to Initiate Organizational Learning

By means of System Dynamics simulation studies a large amount of important and relevant knowledge is created. However, frequently only the modelling group has this knowledge at its disposal, and therefore only this group among all managers of a firm can make use of this knowledge. In the case of complex investment projects other decision makers need to be convinced that organizational measures based on this knowledge are necessary. Decisive premises for parallel and uniform action toward the same goal by all managers involved in an investment project are an understanding of the necessity of the changes which this investment will cause, and of the formation of common expectations with regard to the economic causalities affected.

In workshops the learning model is used as an instrument to facilitate the development of such common ideas and insights in a collective process for the people that are involved in the decision about an investment - that is to construct a common mental model. For those involved the learning model provides the opportunity to work out essential insights on their own (e.g. Kim and Senge 1994).

Figure 7 shows the user interface of a learning model. The users have the option to make various decisions. They can

- realize investments,
- fix prices,
- give orders for overtime work,
- order material, and
- hire or fire people.

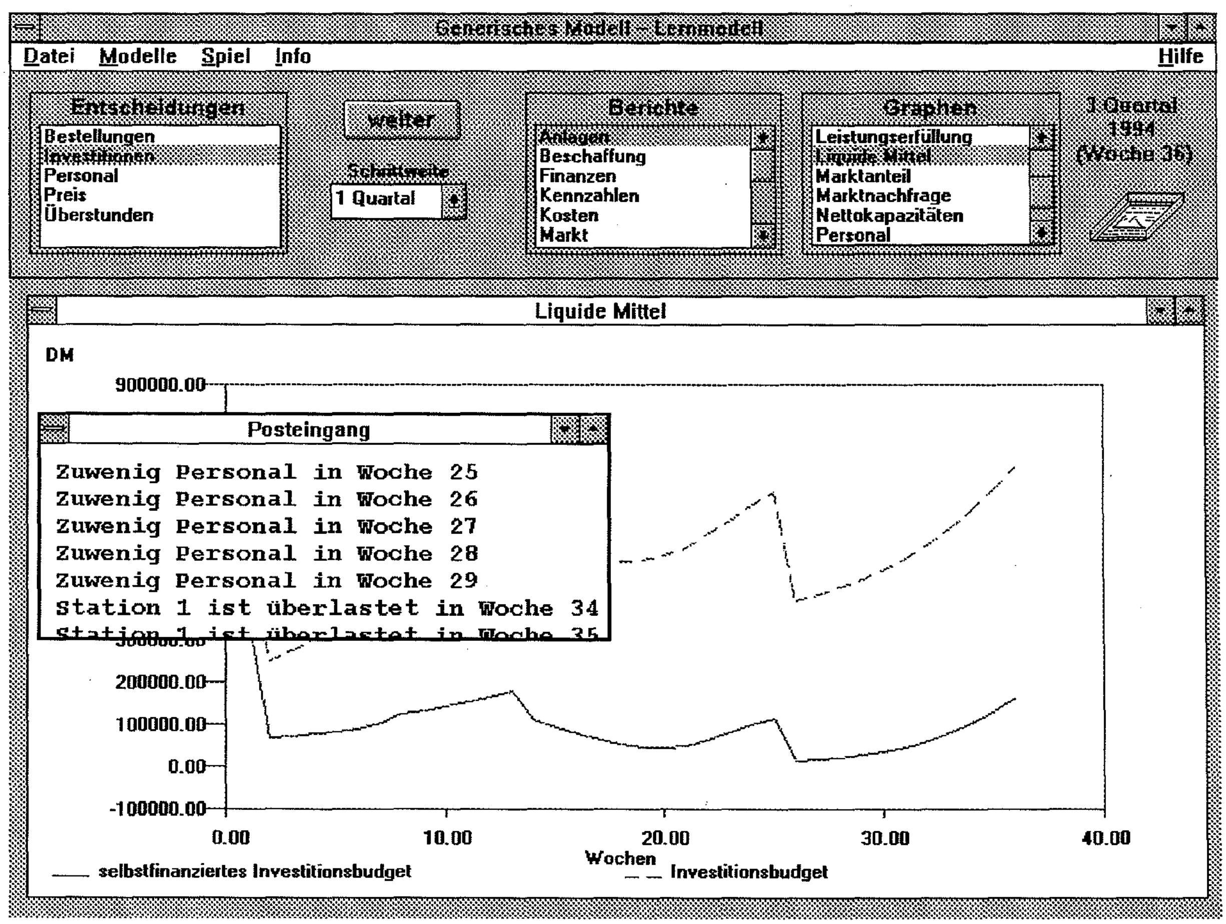

Figure 7: User Interface of a Learning Model

Once the users have made their decision they start the simulation of 12 weeks = 1 quarter by a mouse-click on the button "continue". After the program has run through the users can read the information about the consequences of their decisions in reports, diagrams and charts. These include data about business aspects such as revenue, profit, cash flow, etc., but also information about capacity, flows of material, personal resources, etc. The diagram as shown in Figure 7 shows the curve of liquidity during the first quarter simulated. In real life the liquidity is a decisive aspect with regard to the success of an operation. In the model this is the case as well. Does the curve move below zero the company is insolvent. This virtual bankrupcy can also be caused if something goes wrong with the second existential aspect, that is the equity of the company. If there do not exist any more equity this will also cause a premature end of the game.

Furthermore, we have installed a "mailbox" which notifies the state of critical aspects of the assembly system. In this case the lack of manpower and the overload of station 1 is pointed out.

As has been said before, working with the learning model aims at users who intend to acquire the knowledge of the modelling group for themselves in an interactive way. For this reason the program provides them with access to all the tools that have briefly been presented here, that is the causal diagrams as well as the hypertext system, and the qualitative methods of analysis.

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