The importance of simulation as a mode of analysis

Theoretical and practical implications and considerations

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1. INTRODUCTION

The number of scientists incidentally or permanently engaged in the simulation and gaming of social systems has grown tremendously the last twenty years. The 'simulation boom' comes at a moment when the social sciences, the policy-makers and the public in general are confronted with the increasing complexity of society.[1]

It is not our intention to go into the complex mathematical details of game theory.

We will, however, try to clarify the importance of simulation and game theory for social sciences.

Its significance for practical research and educational value will be emphasized as well.

The word simulation comes from the Latin verb 'simulare' and means 'to imitate, to simulate'.

The term simulation has been used in a variety of ways. To define a simulation we should recognize the fact that:

> "A Simulation involves the experience of functioning in a bona fide role and encountering the consequence of one's actions as one makes decisions in the execution of that role. The participants address the issues and problems seriously and conscientiously in a professional manner".[2]

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1. Cf. for instance the scientific journal *"Simulation and Games"*.
2. M. Gredler, *"Designing and evaluating games and simulations. A process Approach"*, London, 1992, p. 14.

For M. Shubik the purpose of simulation is the availability of a rapid user-friendly way of analysis.[3]

F. Martin focuses on the importance of conceptualization and organization.[4] For R.E. Shannon simulation is very important since it enables us to understand the behavior of a system and to evaluate different strategies within a given structure[5], with the real system meaning reality.

Indeed, simulation basically means one creates a model of reality by means of quantification of notions and actions. This model will evolve by means of algoritms or personal decisions. In this way one constructs an artificial reality that should be able to evolve in a *similar* way to the reality it represents. This gives us the opportunity to *investigate* alternatives without actually really undertaking them. In mathematics, a model is generally conceived as an abstract theory (that can 'replace' reality).

In simulation literature, a system is mostly defined as an entity, i.e. a constantly changing formation.

Game theory, the theoretical basis of simulation, was first developed by J. Von Neumann and O. Morgenstern in 1944.[6]

Scientists such as Pascal (1654)[7] and mathematicians such as Gournot (1838), Bernouilli, Borel[8] and Zermelo (1912) had developed already some forms of probability calculations. Von Neumann and Morgenstern actually followed in their footsteps and elaborated modern game theory.

Defining the elements of game theory, however, is not an easy matter. Kontopoulos tends to interpret game theories in general (metagames, supergames and differential games) as complex systems of interaction.[9]

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3. M. Shubik *"Games for Society, Business and War. Towards a theory of games"*, Cambridge, MIT press, I, 1984, p. 12.

4. F. Martin *"Computer modelling and simulation"* New York, 1967, p. 13.

5. R.E. Shannon *"System Simulation"* Englewood, 1975, p. 7.

6. J. Von Neumann & O. Morgenstern *"Theory of Games and Economic behavior"* Princeton, 1944. Von Neumann (1903-1957) wrote in 1927 his *"Zur Theorie der Gesellschaftspiele"* at the University of Berlin. Associated with Morgenstern at Princeton University in the 1930s, they developed the first electronic computer ENIAC. Von Neumann also collaborated with Oppenheimer who was constructing the atomic bomb.

7. A. Colman *"Game theory and experimental games"* Oxford, 1982, p.6.

8. J. Eatwell, M. Milgate & P. Newman *"Game Theory"* London, 1989.

9. K. Kontopoulos *"The logics of social structure"* Cambridge University Press, 1993, p. 142-150. Yet by constructing a three-level game as a model whereby constitutive factors are in a regular interaction or interdependence, and wherein every object has its own possibilities and goals, and is yet constrained by a limited set of overall options (a platform of structures with several strategies), one gets close to his notion of heterarchy.

2. THE NOTION OF GAME THEORY

The very word 'game' tends to evoke some sort of socially unimportant waste of time and is commonly associated with children. Therefore R. Luce and H. Raiffa share the opinion[10] that the word is not very well chosen in a scientific context, since the reference is somehow pejorative.[11] Yet there are some reasons to maintain the word 'game'. Many games are performed in a social context. Children and young animals play intensively, not because they can't preoccupy themselves with complex matters, but because it enables them to simulate (conflict)situations before they actually occur in reality (when it may be too late to figure out what to do). Many adults enjoy to participate in games because they represent all kinds of (conflict)situations that may happen in everyday life or represent everyday life; of course then the emphasis is on recreation, which blurs the link with reality. Hence only the game element remains. But a game is always a form of conflictsituation. This has to be interpreted in a broad manner: Theatre is also a 'play' and can be called a game, referring to the imitation of human behavior.[12] A game can be defined as

> "a situation wherein several decisionmakers, each trying to achieve the best outcome, have to make a choice between a limited number of options while the consequences of each decision and action are influenced by the decisions of the others."[13]

Other authors such as J. Nichol[14] and M. Shubik[15] perceive the distinction between game and simulation as a degree of technology:

> "a game is an interaction between people or between people and a computer while a simulation can be fully informatized".

Both focus on the didactical elements, although Nichol perceives a game as something less complicated than simulation, since a game can be an interaction

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10. R.D. Luce & Raiffa *"Games and Decisions"* New York, 1967, p. 2.

11. Some attempt to find another name for 'gaming' since they are concerned the name 'game' would induce a government department to deny financial support: H.A. Becker & H.M. Goudappel (eds.) *"Developments in simulation and gaming"* Sociologisch Instituut te Utrecht, 1972, p. 158.

12. In German the word Spiele and in Dutch the word spel are both synonyms for 'theatre' and 'game'.

13. G. Bruyneel *"Een algemeen overzicht van de Speltheorie"* Simon Stevin, vol. 54, Universiteit Gent, 1980, p. 5.

14. J. Nichol & D. Birt *"Games and Simulations in History"* London, 1975, p. 5.

15. M. Shubik, ibid., p. 13.

in a fictional system while a simulation refers to an existant or plausible functional system. But both words 'game' and 'simulation' are frequently used to indicate the same mode of analysis, although the latter is generally conceived somehow superior in the sense that very complex models are defined as simulations, and less complex models as games. As stated above, 'computerized' models are often described as simulations, while 'man operated' models are called games. Last but not least, simulations are more used for analytical purposes, while games focus on educational or instructional objectives.[16]

Basically, a game has to consist of 5 elements:

A number of players, a number of rules ('laws'), a limited number of possible strategies[17], a limited number of possible combinations of strategies and an outcome. In the case were a strategy consists of multiple steps, one can represent the game in the form of a tree.[18] One starts at the first level where the first decision is made, enters level 2, and so on until one has created the entire strategy. Multiple players can be represented in one tree. This 'decision' tree gives a better picture of how the game occurred then a matrix does, although the latter are still frequently used. Of course there is a tremendous difference between games with complete information (such as chess) or incomplete information (such as card games). The latter produce a high degree of probability influx. Another type of games are coalition games or cooperative games. Multiple players are then capable of alying themselves vis-a-vis others. The main strategy becomes to choose a partner and then construct a cooperative strategy. Within the latter individual strategies are still possible, because after a period of time the coalition can end, whereupon a new coalition can be formed.[19]

Thus one has to realize that a game can be quite complex indeed. Nobel prize laureate M. Eigen[20] even claims that a game can represent all parts of reality and gives as an example the formation of snow crystals that are being shaped

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16. H.A. Becker & H.M. Goudappel, id., p. 10.

17. A strategy is a finite sequence of a finite number of actions of one player in every game. Strategies of several players can sometimes not be combined in a coalition strategy. E.g. in chess player 1 can attempt in 30 moves to defeat his opponent. Therefore his opponent has only a limited amount of strategies that can be coherent with these 'moves' if he acts on a rational basis.

18. M. Shubik (ed.) *"Game Theory and related approaches to social behavior"* Thomas J. Watson Research Center, New York, 1964, p. 19-23.

19. E.g. E. Kalai "Bounded rationality and strategic complexity in repeated games" in T. Ichiishi, A. Neyman & Y. Tauman (eds.) *"Game Theory and Applications"* San Diego, Academic Press, 1990, p. 134-136.

20. M. Eigen & R. Winkler *"Das Spiel"*, München, R. Piper Co.Verlag, 1975.

by multiple 'laws'.[21] This brings us quite close to the notion of artificial intelligence.[22]

Game theory enables us to represent the result of strategies during a simulation. The decisions that were made can be analyzed and one can investigate whether better options were available or preferable within the given 'constraints' of a certain structure.

Let us give a concrete example to illustrate this point clearly and at the same time relate game theory to historical processes.

"Fire in the East"[23] and *"Advanced Third Reich"*[24] are simulations based on game theories whereby one can investigate the outcome of historical events. In these particular simulations one is capable of examining whether Nazi Germany could have defeated the Soviet Union – given the de facto resources at the time – in the Second World War if it would have started the invasion in early March instead of late June 1941. Or, whether it would have been possible at any given moment in the 1940s.

In order to answer this question, economic factors, industrial output, military components, morale, intelligence collection and dissemination, logistics, geographical, climatological and political elements are all taken into account.

The whole research is then implemented in the model and 'Operation Barbarossa' is reconstructed in a detailed way: not only micro-analysis (e.g. firepower of artillery brigades or economic output of a small region) but also macro-analysis (e.g. possible Japanese invasion of Siberia or Soviet economic productivity) is taken into account. Several strategies can be formed (e.g. main thrust of German invasion in Ukraine, a general economic development plan and/or cultivating diplomatic relations with certain countries). Several desicions can be made (e.g. ordering encirclements or defining policies towards civilians in invaded territory) within a given strategy. These microlevels interact

a) with one another (e.g. lines of supply) and
b) influence the intermediary level (i.e. in our example game results [a quan-

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21. A. Rapoport, J. Kahan, S. Funk & A. Horowitz "Coalition Formation by Sophisticated Players" in M. Beckmann & H.P. Kunzi (eds.) *"Lecture Notes in Economics and Mathematical Systems"* nr. 169, Heidelberg, 1979, p. 16-33.

22. cf. the many publications of the Massachusetts Institute of Technology (MIT).

23. *Fire in the East*: by Game Research/Design-Europa Game Designers' Workshop, 1984 Design by J. Astell, P. Banner, F. Chadwick & M. Miller.

24. *Advanced Third Reich* by Avalon Hill Game Company, Baltimore, MD, 1992. Project Director: Bruce Harper. Cf. also P. Perla *"The Art of Wargaming"* Annapolis, Naval Institute Press, 1990, p. 206.

tified analysis of casualties versus conquered territory] that is linked to the level of overall morale of troops in a given area.

This level of morale (intermediary level) influences in its turn:

a) the microlevel (e.g. efficiency/performance in combat of troops in a given area which can spread to another area: this demonstrates the interlinkeage of microlevels).

b) the macrolevel (e.g. German successes on the microlevel and intermediary level increase the possibility of a Russo-Japanese war on the macrolevel). If this occurs, all above-mentioned factors are again taken into account (economy, population, industrial capacity and so on) and the process starts all over again since these macrolevels influence

a) one another (e.g. entrance of Japan in the War may prevent early Finish capitulation to Russia).

b) the intermediary level (e.g. morale of all troops or population involved).

c) the microlevel (military units of a country just entering the war [and altering given strategies] can cooperate with other units dependant on certain circumstances (e.g. Rumanian and Hungarian military units, both German allies, may start waging war among each other on the Russian battlefield because of historical reasons).

The macrolevel and the microlevel may both have their own internal logic (e.g. 'general rule' that Japan will paricipate more easily in the war vs. the USSR than Turkey according to historical research, although the policy of both countries can be modified due to lower levels as was illustrated; e.g. specialization of specific military units and combined armor with various degrees of direct or indirect interdependence).

The more countries that are actively involved and have a 'seperate player' (and thus beyound doubt 'seperate interests'), the more complex the game becomes.[25] Naturally, the different strategies and options can have direct and indirect effect upon all three 'levels'. E.g. the decision to invest a considerable part of German production in submarines to defeat Great Britain in 1941, will not only have an impact upon the war against Britain, but also on the battlefield in Russia, since the focus on submarine building goes along with a relative decrease in armaments that can be directed to the Eastern Front.[26]

The overall result of this model of World War II, however, clearly demonstrates that Germany (and its allies) could not have won the war if the invasion would have started earlier (due to the impact of industrial output, population resources, the given terrain etc.). Several different strategies however, would

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25. Von Neumann and Morgenstern, 1944, ibid., p. 403.

26. This is the case in the computer-simulation model of "Third Reich" created by Avalon Hill Game Company 45959 IBM CD-ROM.

undoubtedly have *prolonged or shortened* the war considerably (1 to 3 years). So far one example of what a simulation can offer to analyze a world historical 'event'.

The creation of a operationable simulation and an adequate game-theory is far from evident[27]: one has to

1) formulate precisely the problematic topic of research and from there on investigate which models to choose/construct. Specific questions about the agenda of research is vital for the construction of a succesful model and subsystem. (e.g. what does the researcher want to learn from the model or from the players?).

2) collect and analyze data with regard to the above mentioned topic of research. The knowledge and previous experience of the researcher is quite important [28] (e.g. what information is to be conveyed to the players?).

3) determine the time-scale ratio.

4) develop the game system that form the components of the model. (conceptualization of interaction of all levels).

5) verify the model and validate it.

6) experiment with and optimalize models (the more these are tested, the more the model results can be refined[29]).

7) analyze, interpret and document the results of the effort.

Thus, the goal is not to mimic reality (as in theatre) but to capture the essence of a real system without including unnecessary details. Number 4 is vital to the research. When collecting the necessary data, one usually perceives important relations. Yet quantifying them, while fitting it all neatly in the entire game theory of the model, is quite difficult. Therefore it is always useful to look at existing models (and codifications) and then consider their validity or adjustability for your purposes.[30] First of all, one has to code data and set up a logical model of laws that form the simulation. All kind of variables have to be taken into account. Certain variables such as trust, threats and interpretations can only be partially incorporated in a computerized simulation: that is why human 'players' are quite important to the outcome of the simulation.

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27. For a short review of methodologies cf. S.V. Hoover & R.F. Perry *"Simulation. A Problem Solving Approach"* Reading, Addison Wesley Publishing Company Incorporated, 1989, p. 14.

28. S.V. Hoover & R.F. Perry, id., p. 205 mention 'the art' of collectioning data.

29. S.V. Hoover & R.F. Perry, id., p. 299.

30. H.A. Becker *"Simulatie in de sociale wetenschappen"* Alphen aan de Rijn, Samson uitg., 1976, p. 54.

Variables that are *not* part of logical laws in the model can be implemented to have an 'external' influence on these very laws. These variables are called 'random generation numbers'.

Number 5, the verification and validation of the model, is equally important. A considerable amount of scepticism is required to analyze whether the chosen 'modus operandi' is adequate. Verification means looking if mathematical formulae are correctly implemented; validation means whether the model as a whole is indeed capable of producing a realistic 'reconstruction'.[31] Each simplification in the model must be verified in terms of its impact on the performance.

3. ORIGINS OF SIMULATION

The first appearances of simulation can be traced in military planning of Sumerians and Egyptians when they used miniature statues representing soldiers to predict the outcome of a possible battle. It resembles chess wherein planning and laws are essential.[32] But credit of the invention of the first real 'wargame' can probably be attributed to the Chinese general and military philosopher Sun Tzu[33] who created the game known as 'Wei Hai' (meaning encirclement) about 5000 years ago.which is probably the original version of the Japanese game "Go".

About the same time in India, a four-sided board game known as Chaturanga came into existence. Chess is assumed to have evolved out of the latter. As introductions to military thinking, these games required the players to focus on a well-defined objective and to evaluate the abilities of their own and their opponent's capabilities.[34] From the 17th century onward, the military value of a wargame, became acknowledged, especially in Germany were it was called a Königspiel. In the late 18th century the techniques and models became more complicated and spread out all over Europe. In some ways they had the same complexity relationship to later war games as 'Monopoly' bears to current business games.[35]

In 1797, a scholar and military author by the name of Georg Venturini designed a new game that was based on his publication *"A Mathematical System of Applied Tactics and the Science of War Proper"*.[36]

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31. S.V. Hoover & R.F. Perry, ibid., p. 281.
32. M. Eigen & R. Winkler, ibid., p. 90.
33. Sun Tzu *"The Art of War"* translated by Yuan Shibing, Wordsworth Editions, 1993.
34. P.P. Perla, ibid., p. 15-16.
35. F.J. McHugh *"Fundamentals of Wargaming"* Newport, 1966, p. 2-5.
36. P.P. Perla, ibid, p. 21-22.

In 1828 H. von Moltke started with simulation and the ensuent Prussian victories introduced wargames in other countries' defense ministeries. In 1913 the historian H.G. Wells describes in his book *"Little Wars"* a model with lead figures that represent military units. In the 20th century all great powers became thoroughly familiar with the 'art' of wargaming. The chief of the German general staff, count Alfred von Schlieffen (1833-1913) predicted on the basis of simulations an early victory in the west in case of a world war, but his results were too optimistic and the resistance of the Belgian army was underestimated.[37] During the whole Great War military authorities continued to use wargames and prepare battles such as Tannenberg (1914) and the Kaiser-schlacht (1918) although the simulation did inform the Germans that the offensive had little chance to success.[38] During World War II, simulation as a form of wargaming became a very commonplace thing indeed: when Operation Barbarossa, the German onslaught on the Soviet Union, was prepared, it became clear that a backlash was to be expected at the end of 1941.[39]

The Japanese army, for instance, used several models to prepare their offensives of South East Asia.

The attack of Midway was simulated intensively and predicted Japanese defeat. Yet Japanese HQ cheated with results. The model, however, predicted the right outcome. Even the Soviet Union used the principles of simulation. In January 1940 Marshal S. Timosjenko simulated a German attack upon the Soviet Union. Chief of Staff Meretskov was even fired when the outcome seemed to indicate a German victory.[40]

The commander of the British Army in North Africa, B. Montgomery simulated wargames at the time critical desicions had to be made during on the battlefield itself. A very remarkable event occured the evening of the landing in Normandy by the Allied forces in June 1944. All major German commanders were absent because they were conducting a simulation of the iminent Allied landing on the French coast. General Marcks, in the role of General Eisenhower, conducted a succesfull landing in Normandy!

After the second world war, the first computer, the Electronic Numerical Integrator and Computer (ENIAC) was used to analyze the data of the explosions on Nagasaki and Hiroshima.[41] Henceforth the computer became a instrument to develop more and more complex models. The Pentagon created during the Eisenhower Administration the Studies Analysis and Gaming Agency (SAGA). As recently as April 1996, a wargame simulation was organized by

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37. T. Allen *"War Games"* London, 1987, p. 122.
38. P.P. Perla, ibid., p. 41.
39. T. Allen, ibid., p. 128.
40. A. Bullock *"Hitler and Stalin. Parallel Lives"* New York, 1992, p. 709.
41. T. Allen, ibid., p. 133.

the US Army to improve their combat skills, whereby US Army forces located in Virginia observed the tactics of a a dozen Wall Street brokers who were invited to participate voluntarily in this exercise. This simulation enabled the military to compare the brokers' tactics and skills (learned at the stock-market) with those of the US infantry.[42]

But not only military organizations have recognized the values of simulation.

Several applications of game theory with regard to economics became over time also more significant.[43] Indeed, in 1994 the Noble Prize for Economy was rewarded to J. Nash, J. Harsanyi and R. Selten for their life-long work on game theory.[44]

The two major applications of game theory to economics have been to the study of various aspects of oligopolistic competition and collusion and to the study of the emergence of prices in a closed economic system[45], studies using stochastic simulations attempted to evaluate the EMS and EMU, and predict wage regimes within a unified European Union.[46]

More and more companies and multinational organizations invest in the research of simulations.

Naylor differentiates the following different models being sponsored:

- financial and management planning models (such as research sponsered by AT&T)
- Industrial planning models (used and made by XEROX and EXXON)
- Banking planning models: focused on econometric research (e.g. used in the North Carolina National Bank)
- Electronic models: used for hydraulic and central thermo-electrical planning
- Railway models (e.g. used by Canadian National Railways).[47]

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42. For an interesting analogy cf. E.M. Christopher & L.E. Smith *"Leadership training through gaming: power, people and problem-solving"* New York, 1987.

43. E.g. T. Ichiishi, A. Neyman & Y. Tauman, ibid., 1990 and S.J. Brams, A. Schotter & G. Schwodiauer (eds.) *"Applied Game Theory" Proceedings of a conference at the Institute for Advanced Studies"*, Vienna, 1979, p. 187-369.

44. J. Harsanyi *"Rational Behaviour and Bargaining Equilibrium in Games and Social Situations"* Cambridge University Press, 1977.

45. M. Shubik in his *"Game Theory in the Social Sciences. Concepts and Solutions"*, MIT press, 1982, gives a splendid overview of several applications. With regard to economy cf. p. 370-385; cf. also M. Shubik *"A Game-Theoretic Approach to Political Economy"* MIT Press, Cambridge, 1984.

46. R. Barrell & J. Whitley (eds.) *"Macroeconomic policy coordination in Europe: the ERM and Monetary Union"* London, National Institute of Economic and Social Research, 1992.

47. Th. Naylor *"Simulation in corporate planning"* London, 1978, p. 5.

Recently, more and more applied research is based on simulations and virtual reality.[48]

Social and public administrations can gain a lot of flexibility by using simulation models.[49]

More recently, simulation studies have been constructed to analyze and implement governmental programs concerning income distribution of public welfare[50], urban programs (community development).[51] Concerning governmental (and related defence) policies the RAND Corporation has published an immense amount of studies.[52]

But also social sciences are using game theory and simulation.[53] For instance, in political science[54] the possible topics of interest concerned are voting/elections[55], power, diplomacy[56] (which is related to negotiation and bargaining

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48. K. Carr & R. England (eds.) *"Simulated and virtual realities: elements of perception"* London, 1995.

49. B. Hollinshead and M. Yorke (eds.) *"Perspectives on Academic Gaming & Simulation 6"* London, 1981, p. 21-55.

50. J. Falkingham & John Hills (eds.) *"The dynamic of welfare: the welfare state and the life cycle"* New York, 1995.

51. J.F. Kain & W.C. Apgar Jr. *"Housing and neighboorhood dynamics: a simulation study"* Harvard University Press, 1985.

52. E.g. Ku Shin *"The effects of the changing policy envronment on the global economy: a small scale model approach"* Santa Monica, RAND, 1992 (this model is especially focused on US-foreign economic relations with Japan).

53. Cf. the quarterly review *"Simulation & Gaming"* from March 1990 onwards and previously *"Simulation & games"* (covering the period 1970-1989) Sage Publications. For earlier references cf. L. Collins (ed.) *"The Use of Models in the Social Sciences"* London, 1976; M. Inbar & C.S. Stoll *"Simulation and gaming in Social Science"* The Free Press, New York, 1972.

54. E.g. W.D. Coplin *"Simulation in the study of politics"* Chicago, 1968.

55. S.J. Brams *"The presidential election game"* Yale University Press, 1978; E. Buyst, L. Lauwers & P. Uytterhoeven "A Game-Theoretical Approach to the results of Parliamentary Elections in Belgium between the Wars" *Social Science History*, 1989, vol. 13, 3, pp. 237-254; R. Rapoport & L.R. Atkeson & W. Stone "A simulation model of presidential nomination choice" in *American Journal of Political Science*, vol. 39, Feb. 1995, p. 135-161.

56. Michael Don Ward (ed.) *"Theories, models and simulations in international relations"* Westview Press, 1985; From the mid fifties international relations simulations began to appear. H. Guetzkow and his colleagues at Northwestern University developed 'inter-Nation simulation' as a valuable tool to comprehend structural and dynamic features of the international system. A more recently published interesting study is that of Th. R. Cusack & R.J. Stoll *"Exploring realpolitik: probing international relations theory with computer simulation"* Boulder, 1990. R.E. Quandt "On the Use of Game Models in Theories of International Relations", *World Politics*, XIV, 1, 10/1961.

behavior), ideology[57], coalition formation among political groups[58], logrolling[59] and conflict management.[60]

Furthermore, in sociology, anthropology[61] biology, law and ethics[62], game theory is being used as well.[63] Even in archeology[64] and psychology[65] has simulation proven to be a fascinating methodology.

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57. J. Elster "Marxism, Functionalism and Game Theory" *Theory and Society*, 11, 1982, pp. 453-482. and "Further Thoughts on Marxism, Functionalism and Game Theory" in B. Chavanche (ed.) *"Marx en Perspective"* Actes du Colloque organisé par l'Ecole des Hautes Etudes en Sciences Sociales à Paris decembre 1983, Editions de l'Ecole des Hautes Etudes en Sciences Sociales, Paris, 1985.

58. In January 1996, a political megasimulation was created on-line on the Internet. The simulation can currently be found on the Website http://www.President96.com and is a very good way to investigate how political parties interrelate with one another, primaries are being held, propaganda is constructed during the elections, opinions polls tend to shift in favor of certain (fictious) candidates and so on, this through the participation of thousands of players all over the United States. An analogous simulation about the operation of American congressional politics, 'Reinventing America' was on line on the Internet from November 1995 through May 1996. Both programs are made by Crossover Technologies Inc. and The John and Mary R. Marble Foundation.

59. Cf. M. Shubik (ed.) "Does the fittest necessarily survive?" in *"Readings in Game Theory and Political behavior"*, New York, 1954; M. Shubik (ed.) "Game Theory and the study of social behavior: An introductory exposition" in *"Game Theory and Related Approaches to Social Behavior"*; M. Shubik *"The uses and Methods of gaming"* New York, 1975; M. Shubik, id. 1982, p. 385-394 for an overview. Cf. also S.J. Brams *"Game Theory and Politics"* New York, 1975.

60. J.L. Rasmussen & R.B. Oakley *"Conflict resolution in the Middle East: simulating a diplomatic negotiation between Israel and Syria"* Washington DC, United States Institute of Peace Press, 1992; Han-Jyun Hou *"A simulation model of political conflict: a system dynamics approach"* Phd, Dept. of Political Science at SUNY-Binghamton, 1993.

61. R. Sokal & N. Oden & G. Barbujani "Indo-European origins: a computer-simulation test of five hypotheses" *American Journal of Physical Anthropology*, vol. 96, Feb. 1995, p. 109-132.

62. A. Goldman "Simulation and interpersonal utility" in *Ethics*, vol. 105, July 1995, p. 709-726.

63. Again, see M. Shubik, ibid., for a nice overview p. 409-414. Cf. also I.R. Buchler and H.G. Nutini *"Game Theory in the Behavioral Sciences"* University of Pittsburgh Press, 1968.

64. Cf. Ian Hodder (ed.) *"Simulation studies in archeology"* Cambridge University Press, 1978 and Jeremy A. Sabloff (ed.) *"Simulations in archeology"* University of New Mexico Press, Albuquerque, 1981 and more recently S.J. Mithen *"Thoughtful foragers: a study of prehistoric decision making"* Cambridge University Press, 1990 (covering hunting and gathering societies in the Paleolithic and Mesolithic periods. The publication is based on the author's doctoral thesis).

65. D.H. Olson (et.al.) *"Families, what makes them work"* Sage Publications, 1983; K. Opwis "The Flexible use of multiple mental domain representations" in D.M. Towne, T. de Jong & H. Spada (eds.) *"Simulation-based Eperiental Learning"* Proceedings of the NATO Advanced Research Workshop on The Use of Computer Models for Explication, Analysis and Experiential Learning, Oct. 12-14 1992, Berlin, Springer-Verlag, 1993, p. 77-89; Stone & M. Davies (eds.), *"Mental simulation: evaluations and applications"* Oxford, 1995.

In climatology simulation models are being used more and more for in depth research.[66]

They are also proven to be useful for ecological research.[67] Moreover, simulation models and artificial intelligence are crucial in cybernetics.[68] In nursing, simulation models are increasingly used as well (for instance to train students in diagnosing patients accurately and rapidly).[69]

What history is concerned, H.G. Wells made - as mentioned above - several models. The group of New Economic history (with the famous models of yet another Noble Prize winner R. Fogel) also recognized its value. In the history department, the usage of simulation to interpret historical conflicts was advocated.[70] An interesting politic-historical study was made by Welsh on the Hungarian Revolt.[71]

In historical demography simulation models are used to reconstruct mortality rates.[72] The use of computer simulations, to test, for instance, a model of balance between peasant labor supply and food supply needs in Ancient Greece by applying it ot household life-cycles, proves to be a fascinating way of opening up new methods of inquiry.[73] Also for the analysis of certain migration patterns can simulation turn out to be an illuminating methodology.[74]

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66. E. Corcoran "Calculating reality" *Scientific American*, vol. 264, nr. 1, jan. 1991, pp. 74-83.

67. Bernard C. Patten (ed.) *"Complex ecology: the part-whole relation in ecosystems"* Englewood Cliffs, NJ, 1995.

68. R. Trappl *"Cybernetics and System Research '92'"*, vol. 2, Proceedings of 11th European Meeting on Cybernetics and System Research, University of Vienna, april 1992.

69. Margaret S. Wolf *"Simulations/games: a training for nursing education"* National League for Nursing, New York, 1979 and Mieger (S.) & Rodgers-Sheller (R.) *"Radiation therapy. Simulation Workbook"*, Pergamon Press, 1986.

70. S.P. Glick & L.I. Charters "War, Games and Military History" *Journal of Contemporary History*, 1983, Vol. 18, pp. 567-582 (cf. especially p. 580); another interesting perspective is that of M. Thaller *"Data Base Expert Systems as complementary tools for historical research"* in 'Historical Information Systems' Studies in Social and Economic History: Congress Proceedings B 12b, Leuven University Press, 1990, pp. 21-32.

71. W.A. Welsh *"A Game-Theoretic Conceptualization of the Hungarian Revolt: Towards an Inductive Theory of Games"* in F.J. Fleron Jr. (ed.) "Communist Studies and the Social Sciences: Essays on Methodology and EmpiricalTheory" Rand McNally & Co., Chicago, 1971, pp. 420-465.

72. Th. Whitmore *"Disease and death in early colonial Mexico: simulating Amerindian depopulation"* Westview Press, 1992 (based on the author's doctoral thesis at Clark University).

73. Th. Gallant *"Risk and Survival in Ancient Greece. Restructuring the rural domestic economy"* Oxford, 1991

74. Ch. Duley & Ph. Rees *"Incorporating migration into simulation models"* University of Leeds, 1990.

In conclusion, we can say that simulation is more and more becoming an *interdisciplinary methodology* that with the increasing importance of the computer will enable scientists to simulate different models more rapidly and accurately.

4. THE PURPOSES OF SIMULATION

Thus a succesful simulation enables us to:

- evaluate behavior and decisions of actors and elements within a given system.
- evaluate logical models and criteria.
- look at alternative elements and strategies.
- predict the result of certain decisions.
- represent a total of propabilities within certain strategies.
- optimalize the possible combinations 3 of elements in a given system and indicate the best outcome.
- reveal certain relational patterns that otherwise would have been overlooked.

Furthermore, the practical educational value of gaming and simulation can certainly not be underestimated.

As Max Weber points out in one of his classic essays:

> "Certainty in our understanding of actions may either take a rational form (in which case it may be either logical or mathematical) or the form of empathetically re-living the experience in question. (...)
> Rational certainty is achieved above all in the case of an action in which the intended complex of meanings can be intellectually understood in its entirety and with complete clarity. Empathetic certainty is achieved when an action and the complex of feelings experienced by the agent is completely re-lived".[75]

The importance of recognizing the educational values of simulation through the experiences of empathy that go along with the actual process of simulation

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[75]. W. Runciman (ed.) *"Max Weber: selections in translation"* Cambridge University Press, 1978, p. 8; cf. also p. 22 on his statements about 'laws'. In advocating his 'ideal type model' Weber gives the example of the 1866 campaign and says that historian may want to explain the war as if the actors at the time had full knowledge of their own and the enemy's situation and if they had been ideally rational in pursuit of their purposes: (p. 24). However, by introducing 'fog of war' and the aid of man-machine simulations one can try to overcome these problems.

itself is evident if one has a brief look at the contemporary simulation literature.[76]

5. SIMULATION AS EDUCATIONAL INNOVATION

Not only do participants in simulations and complex games *gain knowledge* about the relationship between agency and structure through the empathic experience, they also tend to increase their insight on the issues (facts and principles) that the simulation covers. Moreover, a favorable *learning environment* is created which is non-authoritarian (and non-ex-cathedra), that goes along with a more realistic and relevant presentation of learning experiences and, in general, an increase in student motivation and interest. Participants learn to train decision-making and acquire analytical skills as the simulation goes on.[77]

Not surprisingly, many perceive simulation as an adequate alternative of providing knowledge to students in high schools. "If educational techniques were used according to their merits, simulations would be commonplace in schools and colleges" wrote Ken Jones back in 1980.[78] Unfortunately, the penetration of simulation/models in the 'defences of educational establishments' proved to be quite slow indeed. Even today, a considerable bias exists towards the very word 'gaming'. The general picture is one of 'don't know, don't want to know, too busy'.[79]

Simulation however, has undoubtedly its merits in schools: it is oriented towards activity in the classroom, represents a corporate approach to the understanding of a situation, is problem-based and therefore helpful in the development of inter-disciplinary approaches to learning and social skills (simulation games can help players learn about group dynamics such as group leadership, group membership, group processes and individual relations to the group[80]). Many

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76. E.g. W.R. Heitzmann *"Educational games and simulations"* Washington D.C., National Education Association, 1983 (revised ed.) (with an emphasis on educational games) and M.E. Gredler *"Designing and evaluating games and simulations: a process approach"* London, 1992, p. 129-140 on empathy; P.J. Bambrough *"Simulations in English teaching"* Philadelphia, Open University Press, 1994.

77. R. Maidment & R.H. Bronstein *"Simulation games: design and implementation"* Columbus, Ohio, 1973, p. 19-28

78. Ken Jones *"Simulations. A handbook for teachers"* New York, 1980, p. 105.

79. Jones, ibid., p. 107.

80. D. Adams, ibid., p. 21.

educators feel that too much emphasis is placed on the analytical and not enough on the spontaneously creative, intuitive side of scientific thinking[81] since engaging in simualtion can offer students in classes exactly those possibilities of creativity that are so often lacking in dull and ex-cathedra style of teaching. Unlike drill, or memory-developing exercises, games and simulations encourage an active experimentation on the system of knowledge.[82]

Last but not least it is a technique which is fundamentally dynamic: it deals with situations that change, and which demand flexibility in thinking, and responsive adaption to circumstances as they alter.[83] All this makes it a very fruitful autotelic exercise.[84]

Since *"it becomes increasingly evident that learning styles and media which suit one person do not necessarily accommodate another"*[85] one should look for educational alternatives such as simulation.

The media and the educational authorities should do more to inform and enlighten teachers and parents about the nature and potentiality of simulations in the educational field. It is clear that for many reasons simulations have the potential of being helpful as an instructional tool.[86] Games and simulations induce individual skills or traits that are not obtained through conventional teaching methods, e.g. decision-making, sense of efficacy, attitudes reflecting realism-cynicism. In class they can be especially valuable for the under-achiever, the nonverbal or the cognitively deprived student.[87]

By highlighting the word 'potentiality' one should be aware of the dangers of using simulation as well.

6. CRITIQUE AND LIMITATIONS OF SIMULATION

The mathematical models of a game theory universally assume opponents to be rational. In real situations this is often not the case, and a player may benefit from the 'irrationality' of his co-players by systematic deviations from his own 'rationally' prescribed course of action. In such situations, the a piori pre-

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81. G.E. De Boer *"A History of Ideas in Science Education"* Teachers College, Columbia University, New York, 1991, p.196.
82. M. Inbar & C. Stoll, ibid., p. 260.
83. J.L. Taylor & R. Walford *"Simulation in the classroom"* Penguin books, Middlesex, 1972, p. 33-43; D.M. Adams *"Simulation Games: An approach to learning"* Belmont, CA, 1973, p. 7-14.
84. Simulations have the reward for engaging in them built in the activity itself: M. Inbar & C. Stoll, ibid., p. 262
85. R. Lock "A cocktail of delights for OFSTED?" in *School Science Review*, June 1997, volume 78, nr. 285, pp. 30
86. Adams, ibid., p. 99
87. M. Inbar & C. Stoll, ibid., p. 262

scription for rational behavior becomes meaningless, a fact which poses no problem for the theory but which complicates experimental operationalization of tests of a theory.[88]

This to illustrate that every model has its flaws and dangers.

For instance, poorly designed simulation games can make things seem what they are not. Simulation games, by their very nature, are simplified or single aspects of a much more complex reality. Furthermore, anyone may use a particular set of prejudices by disguising them as concepts and principles.[89]

Increasing the complexity of a model does not necessarily increase its realism; constructing a model of a real system that is neither oversimplified and hence trivial nor too detailed and hence clumsy and prohibitevely expensive to operate, is extremely difficult.[90] The usual argument for a complex model is the need for exact results. However, the increased run-time for more complex models may lead to fewer replications, which in its turn produce wider confidence intervals on the performance measures.

Hence, a more detailed model may actually produce less precise results. A large and complex model is also more likely to contain undetected bugs that can introduce errors of a much lager magnitude than would be introduced with a more simple model.[91] Related to this is the time factor: simulations, however attractive, can be extremely time-demanding activities (in constructing and using them) and need to prove of high value to justify their use (and cost).[92]

This evaluation is available for existing models and can be consulted in professional media.[93] Self-constructed models can only be evaluated during research and after (play)testing.

Another disadvantage of the use of detailed, complex models is often a severe slowing down of the simulation, at least the more one is dependable on human participation.[94]

Sometimes people just expect too much of a simulation: an exact prediction of an outcome in the future is quite rare. A relatively correct indication of what might happen and why is the main thrust of this 'auxiliary' science. But

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88. A. Rapoport, J. Kahan, S. Funk & A. Horowitz "Coalition formation by sophisticated players" in M. Beckmann & H.P. Kunzi (eds.) *"Lecture Notes in Economics and Mathematical Systems"* nr. 169, New York, 1979, p. 6.

89. D. Adams, ibid., p. 15.

90. C.P. Pegden & R. Shannon & R. Sadowski *"Introduction to Simulation using SIMAN"* McGraw-Hill INc., 1990, p. 34.

91. C. Pegden & R. Shannon & R. Sadowski, ibid., p. 36.

92. J. Taylor & R. Walford, ibid., p. 44.

93. The magazines *Vae Victis* and *Fire and Movement* and the Internet site http:/www.Grognard.com give comments and previews on historical simulations.

94. P. Perla, ibid., p. 217.

some of the sharpest attacks on 'behavioural simulations' are usually related to competition: the desire to win to the exclusion of anything else and often materialistic values have to be taken into account. Educational games can create tensions, show-downs and fierce competition.[95]

Special attention to the ethical aspects is always necessary.[96] Simulations create the illusion of reality and good ones succeed. This illusion can be a powerful and sometimes insidious influence, especially on those who have limited operational experience. Participants in gaming and simulations should be encouraged to be wary and sceptical and to question the validity of insights derived from them until the sources of those insights are adequately explained.[97] The latter may be one of the most valuable attitudes that one can acquire while constructing or participating in a simulation.

7. CONCLUSIONS

Since constructing simulation models requires a lot of research and intensive work regarding the implementation of different data, the testing and retesting of the model, as well as the validation and optimalization, one should consider in advance whether the whole enterprise will be worthwile undertaking. Simulation may provide an in-depth analysis about the development of certain strategies and the likelihood of probabilities, but this does not mean it counterbalances the costs and the efforts involved. The specific goal of the analysis has to be carefully examined so one can see if a simulation will provide the requested information. Too often designers try to reproduce realism by designing models that explicitly account for everything that could physically affect a situation. This is an admirable goal, but only up to a point.

The critical point is reached when making the system work demands too much artificial behavior from the participants involved because each added artificiality distorts perceptions and psychological reactions to the very reality that the simulation/game is trying to re-create.[98] True, computers and artificial intelligence, the so-called 'inhuman component', can expand certain time-constraining limits that were initially imposed on human beings.

Yet artificial automaticized opponents in the shape of computer programs have the danger replacing human actions too much.[99] Factors such as stress and intuition can not be dismissed or 'incorporated' in computer programs.

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95. Jones, ibid., p. 102-103.
96. H.A. Becker & H.M. Goudappel, ibid., p. 15.
97. P. Perla, ibid., p. 182.
98. P. Perla, ibid., p. 302.
99. P. Perla, ibid., p. 305.

Historical reality is made by human interaction and competing wills. Exploring human behavior, the role and potential effects of human decisions within specific constraints and a limited set of choices is fascinating. Computers will help, but can not entirely replace active human beings. Again, one of the most crucial mistakes regarding simulation in the social sciences in particular, is that one expects too much from it. A detailed and exact prediction of future events based on models or simulations is unlikely to occur. One has to remain realistic with what one wants to achieve.

The processes under investigation, whether they are institutions, wars, political actions, can all be simulated. Up to a point. The better one fully comprehends the exact goal of the research, the data involved and the limited use that certain (albeit sometimes impressive) models can offer, the better the outcome of the simulation will be and the more success it will have to highlight specific impacts and specific interrelated processes.

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FIGURE 1: FROM R. MAIDMENT & R.H. BRONSTEIN "SIMULATION GAMES: DESIGN AND IMPLEMENTATION" COLUMBUS, OHIO, 1973, P. 57

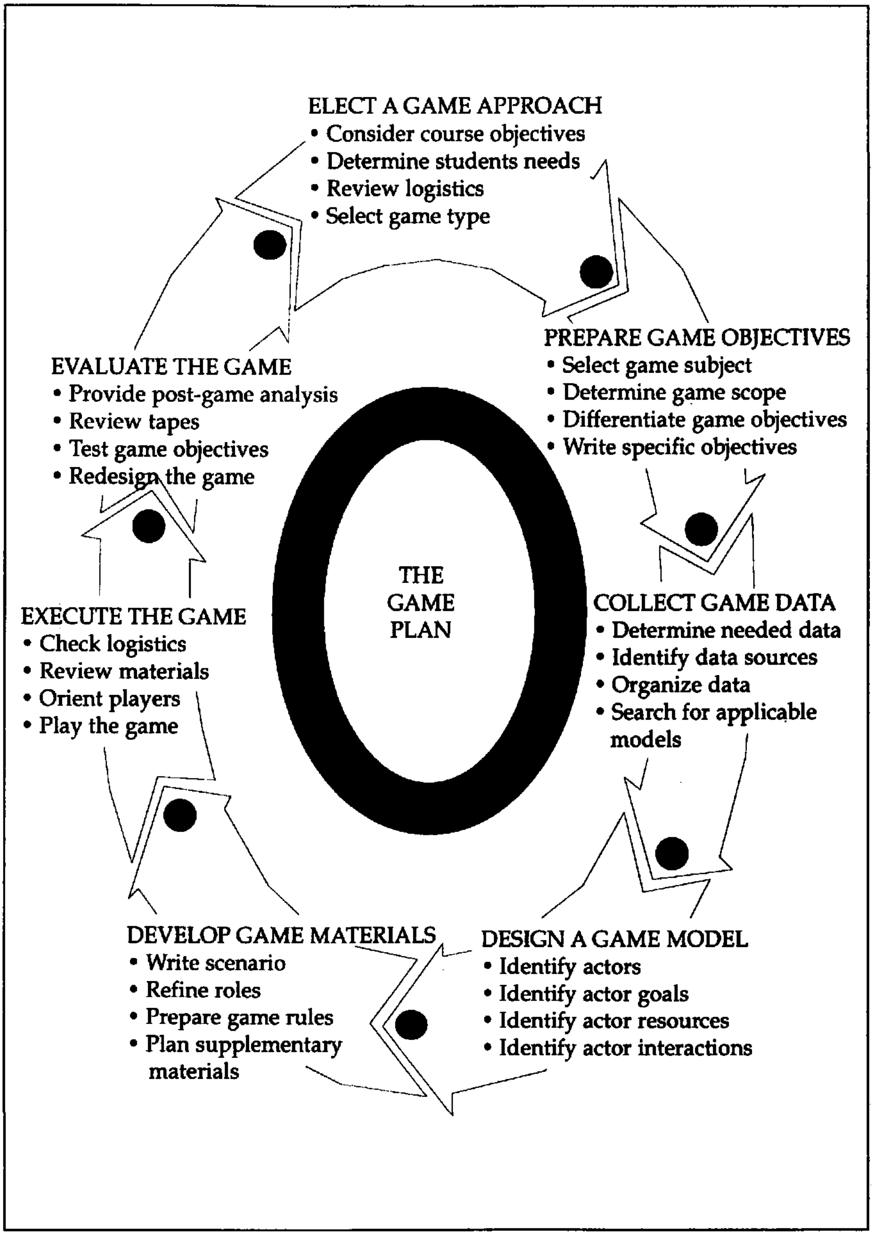


FIGURE 2: M. INBAR & C. STOLL "SIMULATION AND GAMING IN SOCIAL SCIENCE" THE FREE PRESS, NEW YORK, 1972, P. 267

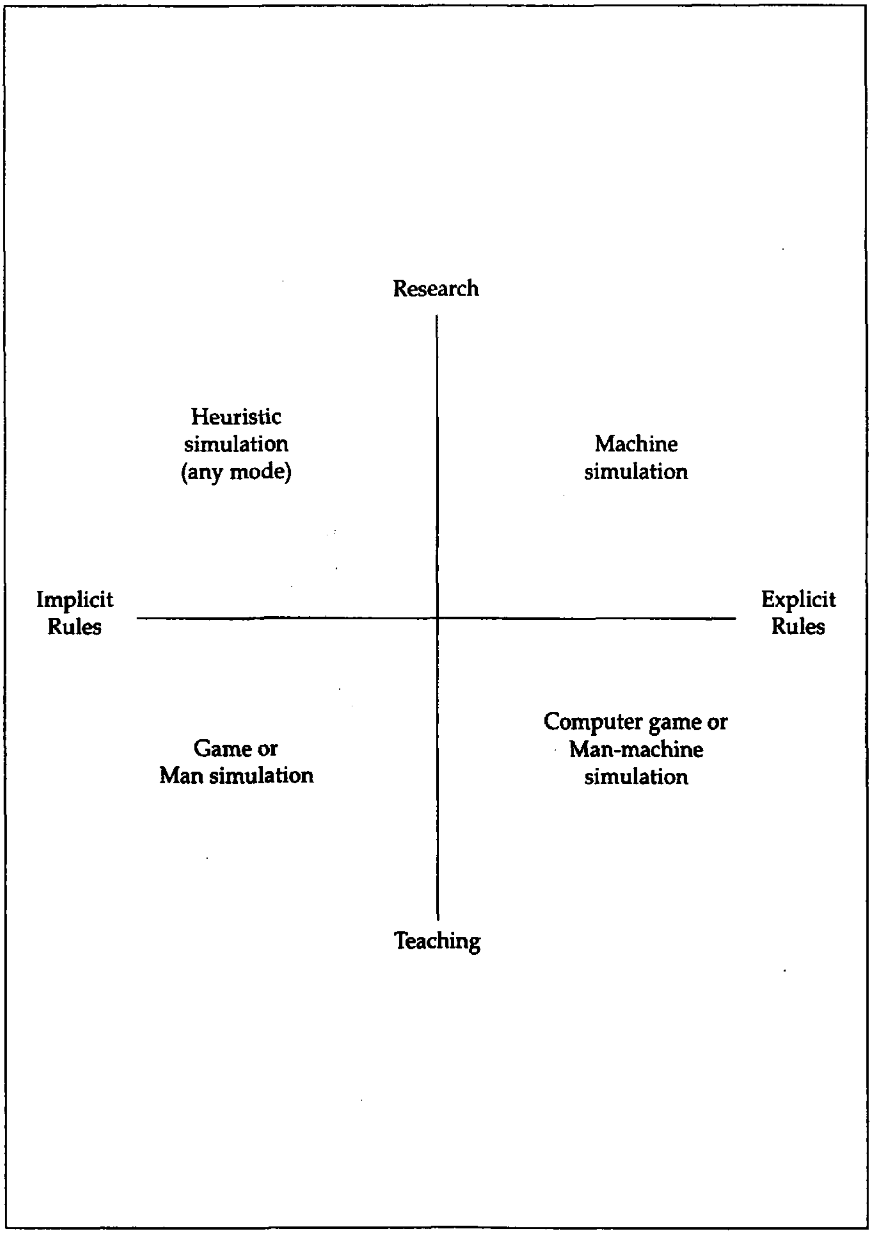


FIGURE 3: H.A. BECKER & H.M. GOUDSAPPEL (EDS.) "DEVELOPMENTS IN SIMULATION AND GAMING" SOCIOLOGISCH INSTITUUT UTRECHT, 1972, P. 80

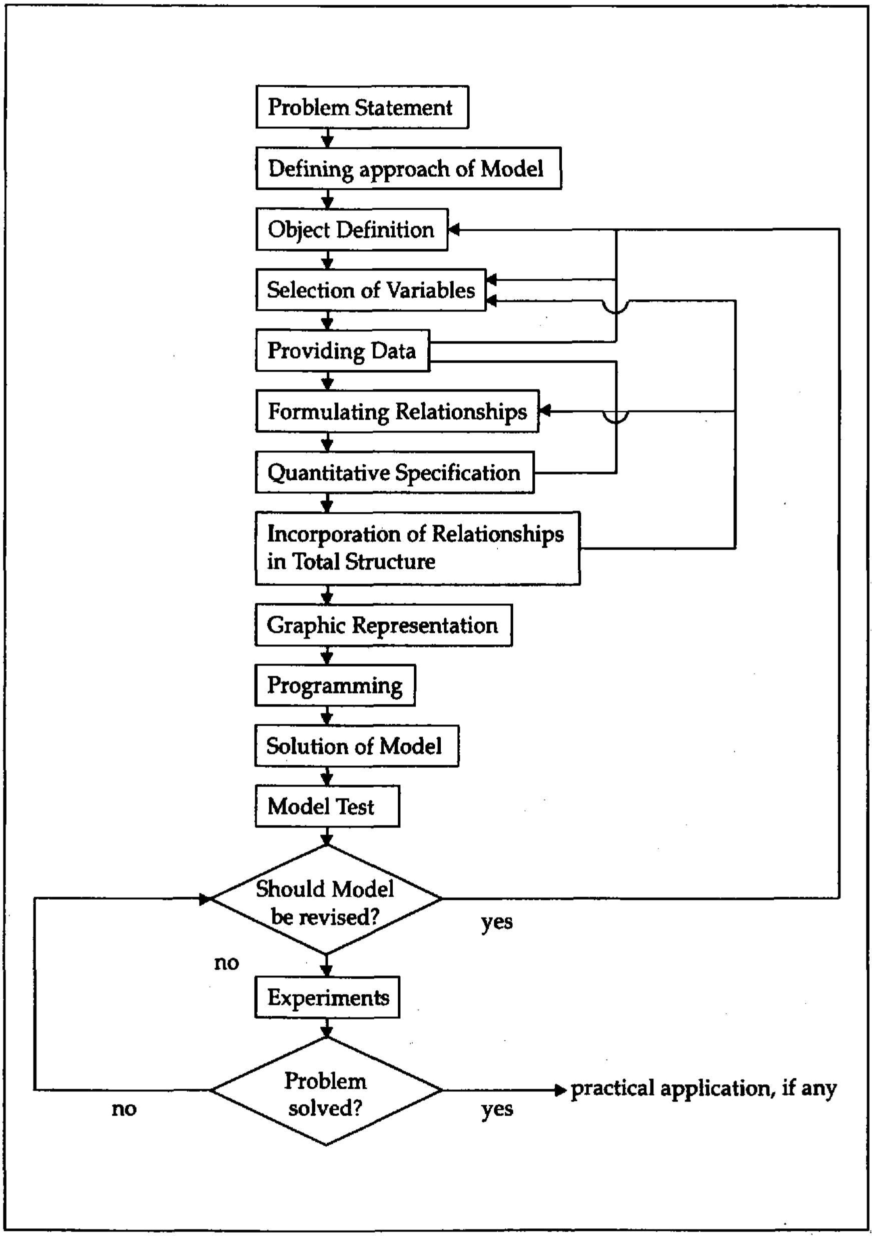
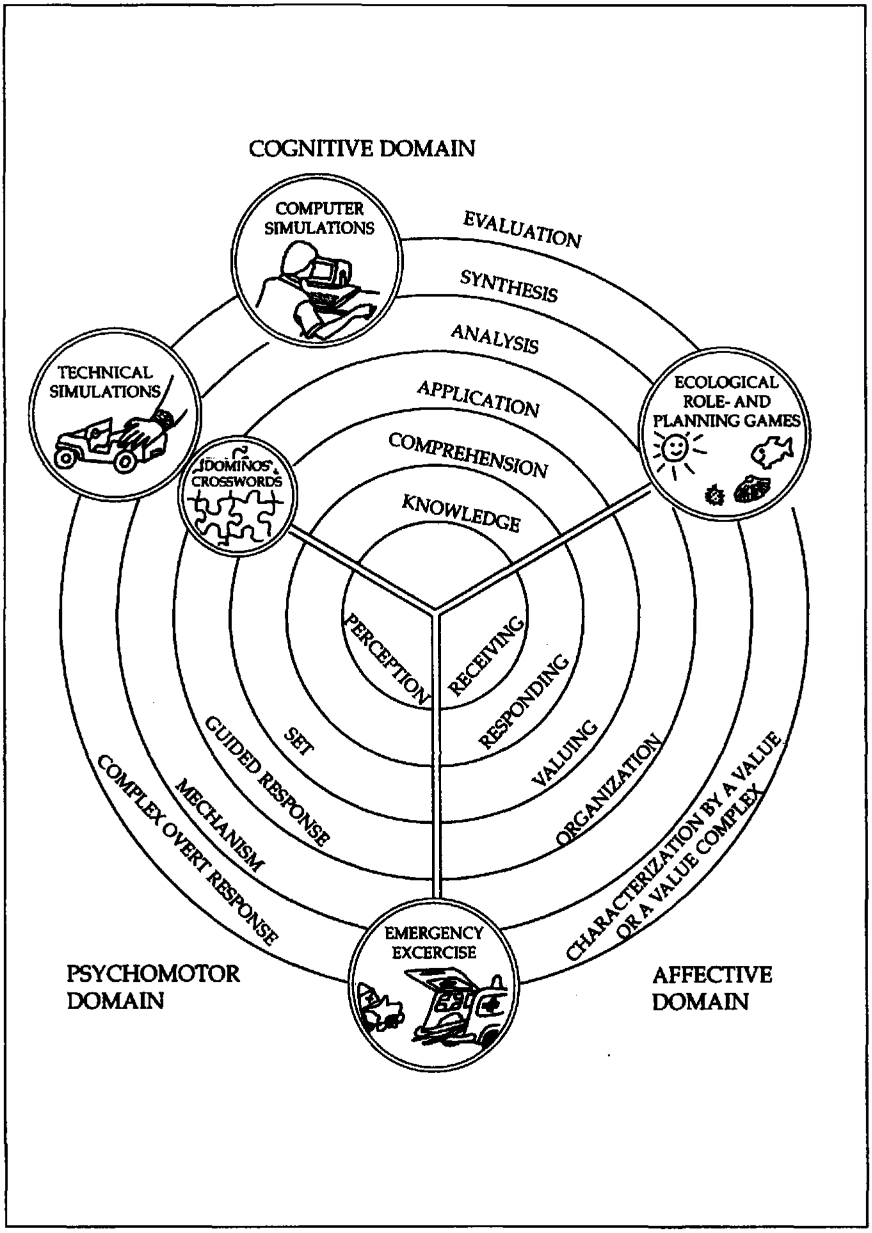


FIGURE 4: B. HOLLINSHEAD & M. YORKE (EDS.) "PERSPECTIVES ON ACADEMIC GAMING & SIMULATION 6" THE PROCEEDINGS OF THE 1980 CONFERENCE OF SAGSET, THE SOCIETY FOR ACADEMIC GAMING AND SIMULATION IN EDUCATION AND TRAINING, LONDON, 1981, P. 147



Het belang van simulatie als analysemethode
Theoretische en praktische implicaties en bedenkingen

HANS MIELANTS EN ERIC MIELANTS

SAMENVATTING

Simulatie wordt in toenemende mate gebruikt in sociaal wetenschappelijk onderzoek om via deze methode een antwoord te vinden op de complexe structuur van de maatschappij. De term simulatie komt van het Latijnse *simulare* en betekent 'nadoen'. Dit houdt in dat men een model van de realiteit opmaakt door middel van kwantificeren van het menselijk gedrag en waarbij, door middel van variabelen, een evolutie kan geschetst worden volgens algoritmen of beslissingen. Dit geeft de mogelijkheid die realiteit te onderzoeken zonder deze te wijzigen. De theoretische basis werd gelegd door Von Neumann en Morgenstern in 1944 met de ontwikkeling van de speltheorie (die alle elementen van een spel weergeeft).

Dankzij simulatie kunnen we antwoorden geven op een aantal (historische) vragen: had Duitsland de USSR kunnen verslaan in 1941 door vroeger aan te vallen? Uit simulatieonderzoek blijkt dat het geen verschil had uitgemaakt.

Bij het opstellen van een simulatiemodel moeten eerst data (van de realiteit)) verzameld worden en daarna de relaties binnen deze data vastgesteld worden. Daarnaast worden alle mogelijke variabelen met telkens een specifieke grootte en invloed bepaald waarna het geheel getest wordt op de validiteit ten opzichte van de realiteit waarnaar het refereert.

Het gebruik van simulatie gaat terug naar het oude China (500 v.C.) waar Sun Tzu de eerste oorlogssimulatie maakte. Hieruit ontwikkelde zich Schaak dat evolueerde tot het *Königspiel* uit Duitsland waaruit de moderne *wargames* zich ontwikkelden. Deze werden sinds begin 19de eeuw officieel gebruikt bij militaire instanties en hadden niet zelden een ingrijpende of voorspellende rol in de acties. Sinds de Tweede Wereldoorlog wordt simulatie ook gebruikt door bedrijven, overheden en universiteiten.

Een simulatie laat toe gedrag te bestuderen, alternatieve strategieën uit te werken, probabiliteiten weer te geven en verbanden te leggen binnen een logisch kader.

Het spreekt dan ook voor zich dat het goed gebruikt kan worden als didactische werkvorm: het geeft een hoge graad van empathie, brengt verschillende inzichten tot stand, verhoogt het probleemoplossend vermogen en zorgt voor een positieve leeromgeving die zeer motiverend werkt.

Dit betekent niet dat simulatie zonder gevaren en beperkingen zou zijn. De techniek is zeer tijdrovend, zeker als men zelf een model moet construeren, en is niet altijd kosteloos. Daarnaast kan een slecht gevormd model foutieve

resultaten weergeven waaruit verkeerde conclusies worden getrokken.

Simulatie is dus een zeer diepgaande analysemethode die ons toelaat variaties van de realiteit na te gaan. De techniek heeft een lange traditie en veel toepassingsvelden maar ze dient kritisch benaderd te worden en de beperkingen moeten gekend zijn.

L'importance de la simulation comme méthode analytique. Considérations et implications théoriques et pratiques

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RÉSUMÉ

La simulation est de plus en plus utilisée dans les sciences sociales, afin de trouver une solution à la complexité de la société. Le terme dérive du verbe latin *simulare*, qui signifie "faire paraître comme". Il implique que l'on utilise un modèle de la réalité, construit par quantification de la condition humaine, grâce à des variables. De la sorte, on peut reconstruire une évolution de cette réalité par rapport à des algorithmes ou décisions humaines, ce qui permet de rechercher cette réalité sans la changer. La base théorique de simulation a été posée en 1944 par Von Neumann et Morgenstern par le développement de la théorie des jeux (contenant tous les éléments d'un jeu déterminé).

En ce qui concerne l'évolution historique, la simulation peut aider à apporter des réponses à certaines questions. Ainsi, l'Allemagne aurait-elle pu vaincre l'URSS en 1941, en attaquant celle-ci quelques mois plus tôt? En l'occurrence, les résultats des simulations montrent que le cours des évènements n'aurait pas été modifié.

Pour construire un modèle de simulation, il faut d'abord rassembler les faits constitutifs de la réalité et tracer les relations entre ces éléments. Ensuite, chaque variable possible doit être mesurée, avec son importance intrinsèque et son influence. Enfin, la validité du tout doit être testée par rapport à la réalité concernée.

L'utilisation de la simulation commence en Chine (500 avant J.-C.), où Sun Tzu construit la première simulation de guerre. Suit le jeu d'échecs, qui sert de base à la *Königspiel* en Allemagne. A son tour, celle-ci mène au *wargames* modernes. Les simulations ont été utilisées par les institutions militaires, dès le début du XIXe siècle, avec beaucoup de succès. Depuis la Seconde Guerre Mondiale, elles sont pratiquées par des entreprises, des gouvernements et des universités.

La simulation permet d'étudier la conduite humaine, d'inventer des stratégies alternatives, de présenter des probabilités, en rattachant le tout à un cadre logique. Il est clair qu'une telle méthode est utile dans l'enseignement sous l'angle didactique: elle induit une grande empathie, fournit des éléments de compréhension, augmente la capacité de résolution des problèmes et aide à motiver les élèves.

La simulation n'est pas pour autant sans dangers, ni sans défauts. Pareille méthode exige beaucoup de temps, surtout à qui doit développer son propre modèle, et peut occasionner des frais. De plus, il existe sur le marché tant de

mauvais modèles, qui peuvent conduire à des conclusions incorrectes.

La simulation est donc une méthode analytique qui permet d'étudier tous les éléments de la réalité. Elle repose sur une longue tradition et propose de nombreux cas d'application, mais il convient de l'approcher avec un grand sens critique, ainsi qu'avec une connaissance de ses limites.