Methodological issues based on the ideas of chaos theory for the consequences of sustainable development

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Abstract
Reflecting sustainable development, and the role the universities should have in it is reflected in this paper as part of dealing with complexity. It is the task of the university to teach and do research on complexity in order to be able to understand the diverse, complex issue of sustainable development. Sustainable development can be considered as a complex societal issue. The relation between the diverse phenomena and the role of the different actors in it is dynamic. Because of this interaction the outcome of the process is unpredictable. It is the task of the university to play a role in understanding and teaching this complex issue. This paper shows how difficult and sometimes impossible it is to predict outcomes of an (aspect of) complex societal issue such as sustainability. In order to illustrate this one of the aspects of sustainability, in casu the technological development and its economical consequences, is selected.

The idea that on the long run economical processes can be seen as transitions between chaos and order is a starting point for the question we like to discuss concerning some aspects of the technological development in society. Technological development can not be considered without its historical background. Technological development is implemented in context, time and environment, and not only based on rational analyses of prizes of labor and capital. In consequence technological development sometimes is concentrated in clusters. Factors that influences technological development can be found in all parts of society. Therefore technological development can be considered as a complex interdisciplinary societal phenomenon.

Scientific concepts and theories are developed to describe phenomena in reality. These concepts and theories enable us sometimes to observe things we were not aware of before. Chaos theory is a relatively new theory which focuses especially on moments of unpredictable processes. Concepts of chaos theory are fruitfully applied in many scientific disciplines such as physics, mathematics, meteorology, biology and humanities. There is found unpredictability in the weather (Lorenz, 1989), in the spreading of infectious diseases (Metz, 1990) and in observed heating of fluid. Realizing this, one could wonder whether concepts of chaos theory can also be used to describe processes of technological development.

Leading economist have shown that technological development can be considered as an aspect of economical development. Most economists believe that economical development can be described with linear equations. Some scientists think that this linear development view in some cases has to be changed for a non-linear view. Theoretical notions and concepts coming from the chaos theory gives scientists the opportunity to describe the non-linear processes. Non-linear processes of technology development can be sometimes non predictable. In these non-linear processes there can be a development towards patterns (Besselaar & Leydesdorff, 1993). Concepts of chaos theory like attractors, entropy and self-organization can be used to express these patterns of development.

For analyzing technological development and/or predicting future developments we encounter many methodological problems. We will discuss some of these methodological problems of non-linear technological development in relation with the concepts from the chaos theory and complex problems, in which we will give some answers and ask many questions.

1 Non-Linear development
Leading economist have shown that technological development can be considered as an aspect of economical development. Most economists believe that economical development can be described with linear equations. Believing this the search for determinant variables is understandable. If the determinant variables are known and the relations between the variable are known then it would be relatively easy to predict future economical and technological developments. Comparing the scientific assumption of linear economical development with reality we see that predicting future technological developments is not so easy as the theory would suggest. Technological development is not only based on linear analysis of prizes of labor and capital and rational decision making. Some scientists have the opinion that the linear development view in some cases has to be changed for a non-linear view.

In a recent article Besselaar and Leydesdorff (Besselaar et al., 1993) show that in these non-linear processes there can be a development towards patterns and clusters in stead of a linear move of the production function towards labor or capital or both. One of the explaining factors of this phenomenon is that the technological development is retarded by already done investment in human knowledge and in technology.

Non-linear processes of technology development can be sometimes non predictable. In order to describe some of the development of these phenomena theoretical concepts of the chaos theory can be used. Concepts of the chaos theory can describe moment of non-linear development and emphasize uncertainty and non-predictability. Which moment in the technological development are uncertain and/or unpredictable, and what the factors are that influences this process must be found out step by step in carefully designed research.

In their book ‘Am Steuerrad der Wirtschaft’ show Bruckmann and Fleissner that in the long run in economical models of Austria order and chaos can be alternated. In the long run one can see moments of predictability and unpredictability. The amount of predictability and unpredictability will depend on the scope of the issue. By focussing on a small time scope and on only a one or some technological developments the amount of predictability will be larger that a broader technological view and longer time scope. In periods of stability the predictability will be larger than in periods of instability.

2 Technological development as a complex interdisciplinary societal problem

Looking at society as a whole, like in the European, western or world economy, technological development seems unpredictable. Technological development not only has non-linear moments it also is influences by more than two factors, labor and capital. In fact technological development is influenced by many factors, this makes the prediction of technological development very hard to do. Technological development as a result of economical development can be considered as a complex interdisciplinary societal problem. How the technological development will be in the future and why it is developed the way it is in the past, should be approached as a complex interdisciplinary societal problem. In the development of complex interdisciplinary societal problems like technological development is play uncertainties, coincidence, irrational decisions and moments of non-linear development a role. In what way and how they play a role should be carefully analyzed in a multi-disciplinair team of researchers.

3 What are complex interdisciplinary societal problems?
Although each complex interdisciplinary societal problem has its own characteristics there are some shared characteristics that most of the complex interdisciplinary problems have. Some of these characteristics are:

1. There is uncertainty about the starting point, the development and the end of the problem.
2. Knowledge and data about the problem are incomplete or not directly available.
3. Many problems are only vaguely defined or not defined at all.
   Botkin says (1979, p. 7):
   ‘We are not certain whether the issues we identify are complete, correct, or correctly stated.’
4. The problems create often unique and sometimes unexpected situation.
5. There are often many people involved.
6. They are hard to get grip on, let alone solve.

It is difficult to say what a solution of a complex interdisciplinary problem is: a definite solution is hard and often impossible to find. Solutions are not at hand or seem politically not possible at this moment. Moreover for many of these problems it seems not to be possible to agree what an optimal solution is.

Complex societal interdisciplinary problems are often imbedded in a dynamic context which makes the problem continually changing, this combined with the unpredictability of the effects of interventions makes it hard to handle the problem.

Many problems can not be solved or at most can only be temporarily solved or only a part of the problem can be solved. This is the reason why we prefer to use word 'handling' instead of the word 'solving'. Solving could suggest that the problem is solvable. With the word 'handling' we indicate the entire process which includes problem analyzing, problem defining, reflecting interventions, perform interventions and evaluate them.

Technological development is a result of the complex economical development.

To illustrate this we like to give some examples of how different phenomena influences the development of economy and technology. Some historical examples:

A well-known example for phenomena that influence directly the economic development of a country are the presidential elections in the USA. The results of the elections is directly apparent in the stock-market, which in turn influences the economical development. A similar phenomena is the (positive) reaction of the Japanese stock-market on the marriage of the Japanese prince in the beginning of the 90th. In the next example the relation between technological development and phenomena that influences it is more complicated. In England the technological development of computers is indirectly influenced by the sexual prevalence of a scientific researcher and the hypocritical reaction of society on it. In the forties of this century the development of computers hard- and software was highly positive influenced by Alan Turing. He developed, together with his female colleague a program that could break the code of the German submarines during war time (World War II). Turing had very creative ideas about the potentials of the computers and inspired other researchers in thinking and applying creative ideas about this. But an collision with the hypocritical Victorian sexual ideas of that time that regarded homosexual activities as a crime, made him end up in prison. This humiliation broke his spirit and influenced him for committed suicide. The lost of a creative scientist on computers was the beginning of the declination of England from a number one country on technological development of computer to the state it is now in. A country that does not play an important role in computers any more. The relation between technological development and war industry is many times shown. In their competition for being number one in the space both the western
world and the former soviet-union invested large amounts of money and human capital in technological development of space shuttles and other space mobiles. The relation between technological development and war industry is often influenced by irrational things like 'believes'. Some America politicians and army generals liked to believe that the air protection of USA as defined in the so-called 'Star-wars' project was a sufficient shield to protect the USA. Therefore they set-up a large scientific research program which should develop technological things like rackets? guided by computer programs based on artificial intelligence. As is clear now the whole project failed. Already in the beginning, it was clear to some scientists that was far too ambiguous, too expensive and not possible, at least not at this moment. The same irrational things influenced technological development in Germany before the second world-war by forbidding all Jewish and communist technological scientists too execute their profession. This retarded, among many other things the development of the atomic bomb. Other things that negatively influenced technological development is ignoring, dismissing and forbid women to participate in technological development. This shows that technological development is depended on more factors that only the well-known factors like labor and capital. Often is also suggested that technological development is based on rational decisions, but large amount of research (Rosenthal, 1984; Crombag, 1984) showed that many decision are made on non-rational decisions like on emotional, personal benefit, hidden agendas. Next to this also coincidence plays a role. From these examples we can learn that in order to study the technological developments carefully, knowledge and know-how of different disciplines are necessary.

4 How can these problems be studied?

For analyzing and defining complex interdisciplinary societal problems knowledge of different disciplines and domains are needed. These disciplines have theoretical concepts or hypotheses about the effect of problem on the phenomena it influences, about the causes of the problem, and on how the variables are related with each other. The knowledge of these different domains can be found, to a certain extend, in persons who studied these domains. The knowledge about a problem is, as far as it is known, spread in the mind of different experts and in documents. Each expert has knowledge about a part of the problem. Together this knowledge is necessary for analyzing and defining the problem. This knowledge should be combined to one overview in which the problem can be carefully analyzed, defined and when necessary guided. An important question now is how to collect and to co-ordinate and to combine the knowledge?

5 A method for analyzing complex interdisciplinary societal problems: the Compram method

The method Compram supports the process of co-operative problem modeling for analyzing and defining complex interdisciplinary societal problems. It is an interactive method for modeling a problem. The method can be categorized under group communication support method. The method is specially developed for exchanging information of participants which have a different background and are of a different disciplines, who should work in cooperation which each other. The method supports defining a problem by making a model of the relevant aspects and variables of the problem. It also can supports interventions and creating scenario's. The method can be applied for societal and organizational problems,

1 Compram means complex problem analyzing method (DeTombe, 1994).
which can be analyzed in cause-event loops. The method is specially developed for analyzing dynamically problems that can be analyzed in cause-event loops. The method is based on cognitive psychology, computer science, theory about group-processions and system dynamic modeling. The method can be used for co-operative problem analyzing. The method can be applied on the moment in the problem handling process when policy makers is aware that there is a problem that should be handled.

For analyzing a complex problem like technological development one need experts of different disciplines. depending on the mental idea one has about what fields influences the technological development one can invite experts of those fields. At the start of the process of problem defining each participant often has a detailed view of that part of the problem of his or her expertise and a vague mental idea of the whole problem. This idea is colored by his or her domain view, political point of view, cultural background and temporarily situation. The mental ideas of the problem of the participants will most certainly differ among them. The detailed view of all the participants should be completed and combined in a overall conceptual model of the problem. An intensive information exchange by discussing and data gathering is needed for this. The method combines social science methods for information exchange with technological support. In order to ease the exchange of information discussions, (small) lectures, and explanation of the participants will be taken place. This will be combined with specific social science methods like brain storming, and making semantic networks. Technological support like overheads, and computer tools simulation software, brain-storming software, databases, text-writers and HyperCard combined with projection facilities like a LCD -screen, or laser-canon. The discussion of the participants will be supported by descriptions in HyperCard and a model made in system dynamic software Ithink. System dynamic modeling can also be used to make scenario's. At several moments of the process can be supported by the computer with groupware for brainstorming, MCDA (Multiple Criteria Decision Analysis) and voting instruments. The problem handling process will be supported by a facilitator who handles also the software.

Problem handling phases
In handling a problem one can distinguish two sub-cycles. The first cycle, the cycle of defining, starts with awareness of a problem and ends with a conceptual model of the problem by which the problem is defined. The first cycle of the problem handling process: defining the problem
1.1 awareness of problem
1.2 a (vague) mental idea
1.3 putting the problem on the (political) agenda
1.4 forming a problem handling team and data gathering
1.5 hypotheses
1.6 conceptual model: defining the problem

The second sub-cycle, the cycle of changing the problem, starts with making a model of the relevant aspects and relations between the aspects of the problem, based on the conceptual model of the problem, followed by suggesting interventions, and a describing scenario's.
2.1 empirical model of the problem, and desired goals
2.2. defining the handling space
2.3 constructing scenario's
2.4 suggesting interventions
2.5 implementation interventions
2.6 evaluating the effect

The problem can be described in a seven-layer model:

1. description in words of the problem
2. definition of the concepts, and phenomena of the problem
3. verbal description of the theory on which these relations are based (theory, experience, intuition)
4. knowledge islands (what do we know and what don't we know)
5. semantic network: a picture of relations between the objects
6. causal network of the problem
7. system dynamic model of the problem

Problem handling process
In order to handle the problem different groups of persons are selected. First a group (knowledge) experts with knowledge about the phenomena and of the actors involved. Then the main actors. All the groups describe the problem in the same manner in the seven-layer model. This kind of complex societal problems have knowledge aspects, power and emotional aspects. All these aspects together play a role in the problem handling process.

The method combines individual preparation session with group sessions. First the knowledge experts are invited to analyze and define the problem, describe the empirical model, the desired goals (of others) and the handling space. Then the actors are invited to do the same. Each actor is invited to give its own view of the problem in the same way the knowledge experts did, also filling the seven-layer model: sub-cycle one and the first two phases of sub-cycle two. Then in cooperation the actors and knowledge experts try to come to an acceptable intervention in the problem. Before implementing the interventions time is taken to reflect on the societal reactions. Is the intervention sustainable? Will the interventions be accepted? Then the interventions are implemented and evaluated. Often the problem then has changed or parts of the problem have changed, so that the problem handling process can start again, although know with the knowledge of the first handling process.

The amount of group sessions depends on the complexity of the problem and the time available of the participants. The first sub-cycle should at least be done twice, but it can be repeated several times. After ending the last sub-cycle the circumstances can be changed so much that the problem handling process again must start again now with the changed problem with re-defining the problem.

6 Chaos theoretical concepts

Chaos theory offers new concepts, a new theoretical paradigm to describe phenomena. In this it influences our view on everyday life. Chaos theory principally changed our way of thinking toward predictability and control (DeTombe, 1992). In this way chaos theory changed our scientific way of thinking towards many phenomena. In this we follow the constructivistic point of view (Brouwer, 1981; Van Dijkum, 1991). In stead of a clock-wise universe of Laplace we have to realize that some phenomena, some developments are principally unpredictable, no matter our efforts. That is shown by Lorenz (1989) and Tennekens in the weather prediction. No matter how large computers are, how refined our data collection is, and how precise our models are, the weather is principally unpredictable, in many areas, after more than seven days.
The same kind of unpredictability can be seen in technological development. In technological development there are moments of linear and moments of non-linear development. In both these moments technological development is hard to predict. In moments of linear development the unpredictability is due to the missing variables, the white spots in the model, the unexpected things that can happen in these kind of dynamically processes and due to coincidences. In the non-linear moments, there comes the moments of principally unpredictability to it. Concluding we can say that predicting technological development is not so easy as it looks like. It depends on many factors of which some are known, and some are not known. And of many uncertainties. It would be interesting to study technologically development from the point of view of a complex interdisciplinary societal problem. And constructing with a multi-disciplinair team a system dynamic model in which there are linear and non-linear connections. To describe this model concepts of the chaos theory can be useful. This can be a challenging starting point for a new approach in studying technological development in reflection to sustainable development.

References:


Dijkum van, Cor, Dorien DeTombe, & Etzel van Kuijck (Eds) (1999) *Validation of simulation models*. Amsterdam: Siswo
