The general applicability of the consumat approach

In the previous chapters, many discussion points about to the various simulation experiments have been addressed. This concluding chapter will draw a more general picture of the applicability of the consumat approach. First the advantages and disadvantages of the consumat approach will be discussed. Second, we will sketch a general perspective concerning the validation of simulation research using the consumat approach. Third, we will discuss for what types of issues and for which users the consumat approach may be a suitable research tool.

The advantages and disadvantages of the consumat approach

The advantages of the consumat approach reside in several matters. First of all, the conceptual meta-model of human behaviour on which the simulation approach is based, provides a valuable tool to analyse various practical issues. Much applied psychological research has and still is focussing on attitudes of people and on strategies to change attitudes, thereby assuming that an attitude change affects the related behaviour. The meta-model provides a much broader, multi-theoretical and more dynamical perspective on behaviour and behavioural change. This may lead to a better understanding of, e.g., the dynamics of habit-formation and how undesired (e.g., environmentally harmful) habits can be changed.

Second, the consumat simulation approach offers a tool that allows for the introduction of more realistic behavioural dynamics in simulation research. This makes it possible to experiment with micro-macro dynamics and to explore dynamical (feedback) effects of individual behaviours. Especially when simulation research is used in combination with empirical social-psychological experiments, it would be possible to obtain a better understanding of the dynamics behind certain social phenomena. The operation of more realistic behavioural dynamics in integrated models leads to a better modelling of processes of social change. Moreover, it permits the use of indicators of people's quality-of-life, based upon changing levels of need satisfaction for a variety of human needs.

The disadvantages of the consumat approach mirror its advantages. Because the consumat approach is rather complex, its formalisation for a specific domain requires more effort and deliberate choices than a (much simpler) rational actor approach would. Especially when the issue being modelled becomes more complex it will be a lot of work to formalise the full consumat model. Here, the need-satisfying capacities and resource demands of many different opportunities may have to be assessed, if one wishes to include these in the simulation model. The researcher who is willing to take this effort must be convinced of the relevance of sophisticated behavioural dynamics in the system to be modelled. However, in many cases one may well use a simplified ('necessary and sufficient') version of the consumat
model. When the researcher is interested in a particular process within a given system, such as adding habitual behaviour to a consumers’ optimisation strategy, it may already be worthwhile to incorporate only certain elements from the consumat approach in existing models.

Incorporating the full consumat approach in integrated ecological-economic models may yield outcomes that are less transparent with respect to the precise behavioural processes underlying these outcomes. Here, the issue of validity comes into question, because it has to be estimated to what extent the outcomes of a model are relevant, realistic and hence applicable. The next section will therefore discuss the issue of empirical validation of the consumat approach from a generic perspective.

**Prospects for validating the consumat approach**

The issue of validity has been discussed in chapters 7, 8 and 9. It was concluded that it is difficult to validate results from simulation experiments because often the necessary empirical data are not available. For example, despite the fact that there exists an abundance of empirical research on the management of a common resource, no data are available regarding the cognitive processes that people employ in deciding how much to harvest. As a consequence, the behavioural dynamics found to affect the harvesting behaviour of consumats, have not been demonstrated in real people. To do so, it would be necessary to try and replicate the most relevant versions of the simulation experiment using real people. Here, a particular perspective on the relation between empirical and simulation research becomes clear. First, simulation research makes it possible to run many experiments, thereby offering a tool to explore the dynamics of behaviour in a way that would be very costly and hard to do with real people. If some interesting dynamical process has been identified to occur under certain conditions, it is worthwhile to investigate the magnitude and robustness of such an effect in various empirical settings. Simulation here functions as an explorative tool to search for issues that are promising for empirical study. An example would be the empirical study of the imitation-effect that has been discussed in Chapter 7.

The other way around, questions emerging from empirical research can sometimes be placed on the agenda of simulation research. For example, often effects have been found in empirical studies, which are hard to explain unambiguously because of the behavioural complexities of interacting people. An example would be the manifestation of aggression in large crowds, which has been documented quite well, but without systematically exploring the underlying behavioural dynamics. In such cases simulation models may be developed to unravel the behavioural dynamics underlying such effects, providing suggestions for further empirical study. Simulation research and empirical study can thus be considered as tools that can be mutually stimulating in exploring behavioural dynamics.

Regarding experimental research, the integrated use of empirical studies and simulation studies is feasible because empirical experiments are replicable, and thus the simulation results can be validated against real world data using correlational techniques such as regression analysis. Whereas in this dissertation no empirical work has been done to validate the behavioural dynamics that have been demonstrated especially in Chapter 7 and 8, it is imaginable and strongly recommended that such work be done.
The consumat approach also allows for experimentation with behavioural dynamics that are less susceptible to empirical study. As was concluded in Chapter 2, on the limitations of experimental games research, many real-world commons dilemmas involve longer time-series, more people involved, and more serious outcomes than can be feasibly captured in empirical research. Moreover, as concluded in Chapter 1, there is a demand for incorporating behavioural dynamics in integrated ecological-economic models. Empirical research reduces real-world systems to an extent that replication of experimental findings is possible. This amounts to using the strict falsification principle of Popper (1963), to test hypotheses concerning behavioural effects. Modelling the dynamics of real-world systems, such as an ecological-economic system, confronts the researcher with a complex system with corresponding varied behaviours. The complexity of a real-world system implies that very different courses of development can originate from the same starting point, making it impossible to formulate confident predictions about system developments. This uncertainty bears a fundamental character, as the Laplacian universe has ceased to exist (see Chapter 2 on metaphors as modelling paradigms). As a consequence, the validation of the outcomes of model runs against historical data is of limited value because these data could well have been very different. This implies that a badly formalised model may yield results that mirror empirical data, whereas a conscientiously formalised model may yield outcomes that differ from empirical data. This implies that Popper's (1963) falsification principle of is less suitable for validating models of more complex systems. The replication of real-world time-series of some complex system thus may reflect only a superficial validity.

The question now becomes: "how can models of complex systems be validated if empirical replication is not conclusive?". The bedrock of this validation resides in the capacity of a model to convince peers in the scientific community that the model adequately captures the processes that determine real-world developments. This validation does not require an empirical replication of the outcomes, but it involves questions about the extent to which the model constitutes an unificational metaphor (see Chapter 3 on modelling as a metaphor). This holds that researchers must search for agreement on the conviction that the same processes guide the developments in the real world and in the model. Van Dijkum and Van Kuijk (1999, p. 15) state that validation procedures should be aimed at both the level of theory and the level of facts (outcomes).

At the level of theory, the validation procedure should be aimed at hypotheses that can be derived from the theoretical basis of the model and the associated structure of the relations between the variables included in the model. The questions that appear to be relevant in determining this theoretical validity are (based on Dijkum and Van Kuijk (1999, p. 15):

- Are all the variables relevant for the system being modelled included in the model?
- Are the relevant feedback-loops of the real-world system included in the model?
- Are the feedback-loops that are included in the model relevant, and do they actually exist in the real-world system being modelled?
- Do the (difference) equations and rules of the model make sense?
- Are the parameters used in the equations and rules meaningful, and do they relate to values that have been empirically observed in the real-world system?

At the level of outcomes, the validation procedure should be aimed at questioning the realism of the observed behaviour (outcomes) of the model. The relevant questions here are:
- Is the sequence of developments of a real-world system being replicated in the model outcomes?
- Does the model yield outcomes (e.g., dynamical processes) that help to understand the real-world system and that can be recognised in the real-world system?
- Is the model free from anomalies such that outcomes are not too extreme to be imaginable to happen in the real-world system?
- Is the model ‘sparse’ in the sense that all variables and feedback-loops are necessary to produce the dynamics that are typical for the real-world system?
- Do changes of critical model parameters (e.g., simulated policy measures) result in changing outcomes that can be related to corresponding changes in the real-world system?
- Are processes of change (e.g., societal transitions) relatively insensitive to small plausible changes of parameter values of the model variables? Here the reader must bear in mind that we focus on processes rather than outcomes, as the same process may lead to very different outcomes, as the lock-in dynamics (Chapter 8) demonstrate.

Whereas the criteria mentioned above are not ‘hard’ in the sense that they are conclusive, the rules constituting our consumat (cf. Especially Chapter 6) appear to meet these criteria better than ‘rational-actor’ agents and agent rules that are currently being used in game theory. This is not to say that the consumat approach passes all the above criteria. For example, it can be seriously questioned if all the variables relevant for human behaviour are included in the consumat model (e.g., explicit group norms and values have been omitted) and if the selected values of ‘minimal level of need satisfaction’ and ‘uncertainty tolerance’ make sense. Within the context of these criteria, the reader may conclude that the consumat approach is still in its childhood, and that much work has to be done to raise it to the status of a mature scientific tool. The criteria mentioned above therefore, are also valuable in setting a research agenda for the further development of the consumat approach.

The simulation experiments presented in this monograph demonstrate that validation can be based on different approaches simultaneously. In a series of simple simulation experiments it is possible to test and develop behavioural rules. Here, the replication of empirical (experimental) results serves as a guiding principle in the development of consumat rules. Next, applying these consumat rules in more complex simulation models requires that a full model is validated on a more theoretical and outcome-oriented basis. This combination has been used here to validate the consumat approach, and despite the fact that the empirical basis for replicative validity was weak, a first indication of the validity of the consumat approach has been found, because the simulated effects appear to be in accordance with empirical phenomena.

The overall conclusion is that the more realistic a model is, the more complex it will be, the more unpredictably and opaquely the model will behave, and the harder it will be to validate the model empirically. The best procedure is to work on various fronts simultaneously; validating parts of the model using empirical studies, and applying the validated model parts in more complex models.
Possible applications of the consumat approach

The consumat approach appears to be applicable to three main issues, namely: (1) the study of fundamental behavioural dynamics in itself, (2) integrated modelling of complex systems involving human behaviour, and (3) studying how policy makers manage complex systems that involve human behaviour.

Fundamental behavioural dynamics

Regarding fundamental behavioural dynamics, the consumat approach appears to be a promising tool to be used in combination with empirical studies. Whenever an empirically established effect or process is affected by personal factors, and the behaviour of people is highly susceptible to what other people do, it may be very difficult to attribute an observed effect to a certain combination of variables. Especially where process-effects emerge from interactions between individual and group factors (e.g., uncertainty and network-size), the consumat approach may be suitable for studying underlying behavioural dynamics. The consumat approach allows one to control for all the unwanted variance, and to check under what precise conditions an effect may occur and how the dynamics evolve over time. A subsequent empirical study may be performed to validate the results of the simulation. Simulations thus help to identify effects that are hard to perceive in reality, but which may play important roles nevertheless.

Several fundamental issues that involve behavioural dynamics can be thought of for applying the consumat approach. An interesting issue on which some preliminary experiments have been done is the introduction of social value-orientations, such as individualism, cooperativeness and competition (see Chapter 2 on individual factors), in the resource dilemma described in Chapter 7. These social value orientations reflect the preferences people have for the distribution of outcomes for themselves in relation to the outcomes for an interdependent other (McClintock, 1978). Simulation experiments can be designed to study how the management of a common resource develops when social value-orientations are distributed differently over a given population of consumats. A further perspective would be to allow the consumats to form networks on the basis of mutual cooperation. This would allow for formalising an institutional level with associated group norms and values in the consumat approach.

A second possible application is to try to formalise the consumat approach for ‘give-some’ games. Whereas the experiments presented in Chapter 7 and 9 involve consumats that are harvesting from a collective resource, thus reflecting a ‘take-some’ game, in a ‘give-some’ game the decision concerns the level of individual contribution to a public good. Practical examples of such ‘give-some’ issues are tax-paying, recycling behaviour (contribution of effort) and volunteering as a blood donor. Whereas the basic structure of these situations mirrors ‘take-some’ games, the psychological context is quite different. It would be worthwhile to test if these differences in some way can be replicated in simulation studies employing the consumat approach.

A third issue is the modelling of different markets in relation to dominating needs and social processes. Some preliminary results indicate that very different markets may emerge...
from different settings of ‘level of need-satisfaction’ and ‘uncertainty tolerance’. These results are interpretable in terms of, e.g., locked-in markets, fashion markets and competitive markets. Here, much work has to been done to formalise product development and marketing strategies that could be followed in introducing new products on a consumer market.

The dynamics of large crowds is a fourth issue that appears to be accessible for research using the consumat approach. Although this issue marked the onset of social psychology, in later years the attention for it has decreased because of the difficulty in performing realistic experiments on large crowds. However, several authors have developed theories explaining various phenomena manifested in large crowds. According to several modern authors (e.g. Reicher; 1987; McPhail, 1991), a main problem of these studies is that the process is studied from the macro-level, for example postulating a ‘group-spirit’. However, the dynamics of behaviour in crowds have important determinants at the individual level (and vice versa). It would therefore be worthwhile to study the micro-macro dynamics in order to understand the relevant phenomena. Such an approach would not only sharpen our view of the micro-level determinants of crowd behaviour, it would also offer a more dynamical perspective to help us interpreting empirical data on crowd behaviour.

**Integrated modelling of complex systems**

To study processes of environmental degradation, and to assess how policy strategies may affect these processes, several integrated models have been and are being developed (see Chapter 1). Many processes of environmental degradation involve human behaviours. As was stated in Chapter 1, up to now, however, integrated models exclude many behavioural processes relevant for understanding the driving factors behind environmental degradation. Because human behaviour is being modelled in a rather implicit manner, these models also do not offer indicators for assessing social issues that are related to environmental degradation, such as quality-of-life, poverty and income distribution. Here, the consumat approach seems to offer points of application, as it includes behavioural processes and indicators for integrated assessment. However, as stated before, the formalisation of the consumat approach for a real-world issue is usually laborious without guaranteeing sufficient transparency of outcomes. Therefore, the consumat approach can also be used as a toolbox for introducing relatively simple behavioural dynamics into integrated models. In this way, the consumat approach can be used to implement, e.g., habitual behaviour, or to model the spreading of technological innovation via social processes. An example of this use of the consumat approach is the inclusion of habitual behaviour in modelling the choice behaviour of farmers in Rangelands (Janssen, Walker, Langridge and Abel, in press).

Regarding some well-defined issues the researcher’s goal may be to study the behavioural dynamics that underlie a problem, and to explore which policy measures may be successful in changing relevant behaviours. In such cases it is recommended to formalise the full consumat approach, at least with respect to the cognitive processes and the most important human needs involved. For example, for the issue of domestic energy consumption (see, e.g., Giovanni and Baranzini, 1997; Jager, Janssen and Vlek, 2000), many empirical data are available, which are often analysed with the statistical technique of regression analysis to identify stable behaviour-determining factors. Regression analysis is also used to develop projections of possible scenarios of future household behaviours. On the basis of scenarios it
is possible to forecast the effect of changes in major behaviour-determining factors on consumption volumes, thereby identifying possible unfavourable trends. These scenarios can thus be used to investigate possible future situations, and thus can be regarded as some sort of guiding map that sets targets for the future of household consumption and attends us on possible futures that should be avoided.

However, knowledge concerning the preferred direction of developments does not automatically yield knowledge about the process of getting there. This is because household energy consumption is part of a complex dynamic system, where consumers develop preferences for certain appliances (e.g., giant refrigerators, jet-stream baths, waterbeds) and their use, partly on the basis of what other people in their environment do. This complexity is further enhanced because of the relation between the household consumption system and various other systems, such as the production system, the political system and the physical environment. Acknowledging this complex dynamic character of household energy use implies that policy making has to be focussed more strongly on understanding the total dynamics incorporating the household system. To explore the dynamics of this system, it would be worthwhile to formalise the various cognitive processes into a model of household energy use. On the basis of a more generic understanding of the household system dynamics it is possible to diagnose unforeseen and unwanted developments in an early stage, and to develop appropriate policy measures.

Managing complex systems involving human behaviour

Policy makers usually have a certain representation of the important dynamics of the system they are managing, and policy measures are developed on the basis of this representation. Often, the latter is partly constructed on the basis of scenarios and predictions that have been formulated on the basis of multiple regression models. For example, developments in consumption volumes are frequently being predicted using such models, and the effects of policy measures estimated. However, policy domains in which consumer behaviour plays an important role are usually so complex that it is hard to acquire a representation of the relevant system. Moreover, scenarios and predictions based on regression models usually bear an indicative character, and therefore actual developments may take a different or even a contradictory course. An incomplete or incorrect system representation may lead to unexpected and often unwanted outcomes of policy measures, fostering beliefs such as “nothing can be done to manage consumer behaviour” or “the price-mechanism is the only effective basis for changing consumer behaviour”. Effects like this have been found in experiments where decision-makers had to manage an artificial system, of which the underlying dynamics were only known to the researchers (e.g., Strohschneider, 1991, 1994a; 1994b; Brehmer and Dörner, 1993).

The consumat approach may be used as a tool to let policy makers experience plausible dynamics of consumer behaviour, and to help them in developing a more dynamical perspective on behavioural change. For this, it would be worthwhile to develop a relatively simple model that clearly demonstrates effects of habitual behaviour, the trickling down of new behaviour, and the occurrence of herd behaviour, and that allows for experimentation with various policy measures to study the effects on behavioural dynamics.
Directions for further research

As has been discussed in the sections above, the consumat approach provides tools that can be applied to various substantive issues. However, before starting to run, it is wise to learn to walk properly first, and therefore two important steps for a possible fruitful application of the consumat approach are suggested.

First, in order to increase our grip on the processes that evolve in non-deterministic simulations, it is necessary to develop procedures for statistical analysis of simulation runs. Referring to the non-deterministic resource experiments of Chapter 7, this implies the manipulation of large data sets. One simulation run yields data on several variables (e.g., resource size, behavioural process, levels of need satisfaction) for two or more agents for every time-step of the simulation. Using large numbers of experimental conditions in more complex simulation designs yields very large data sets (megabytes) that cannot be analysed in a straightforward manner by the current statistical software for personal computers. Especially when effects are being studied that require a large number of consumats, e.g., the effect of heterogeneity in consumat populations, the resulting data sets will be very large. To test certain hypotheses it would be possible to develop macro-level indicators, which in turn can be analysed using standard statistical software. For example, the Gini-index, which has been introduced in Chapter 9, provides a measure for the skewness of consumats' income distribution. On the basis of this Gini-index it should be possible to develop similar indicators for a distribution of the level of need satisfaction. Performing a relatively simple calculation on the original data set, it should be possible to derive a significantly smaller data set containing macro-level variables. Such a file would be more accessible for analysis using standard statistical software.

Second, an important step refers to the validation of the process-effects that have been identified in Chapter 7 on the management of a simple common resource. Recall that these effects are the imitation-effect, the optimism-effect and the adaptation-effect (see Chapter 7). It is proposed to test if these process-effects can be reproduced in laboratory experiments with human subjects. An essential requirement for such experiments is that valid data are obtained regarding the cognitive process the subjects actually engage in. One obvious method to obtain such data is to measure cognitive effort on a physiological level, e.g., using an E.E.C. Another possible method is to monitor how people retrieve relevant information by means of a computer display. By allowing subjects at each time-step to retrieve information on the state of the resource (environmental information) and on the past harvesting behaviour of other subjects (social information), the cognitive process could be monitored well. Such an experimental setting is suitable for testing which factors affect the quantity and type of information (environmental and/or social) the subjects retrieve. Several hypotheses can be tested, such as that when the subjects can monitor each other's behaviour (allowing the subjects to engage in social processing) and are quickly satisfied (allowing to engage in automated processing) an increase in the stochastic part (unpredictability) of a resource-growth function will elicit an imitation-effect. If these and other simulated effects are reproduced in representative experiments with real people, simulation research may gain a broader acceptance in mainstream social psychology too.