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Ethical issues in modeling: some reflections

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Jack P.C. Kleijnen

Abstract

Ethics are involved in a model's purposes (for example, the purpose might be to increase a heroin dealer's profits). These purposes imply consideration of the various stakeholders (modelers, users, public) and their values. Ethics also concern professional standards of conduct for the modelers. These standards require that the modelers validate the model assumptions. Hence, modelers should provide model documentation. Validation, however, is virtually impossible when the model represents unique events, such as nuclear accidents; credibility is then the maximum attainable. Anyhow, modelers should try to develop 'robust' models; that is, models that are not very sensitive to their assumptions. This article pays special attention to the use of models in crime, war, and nuclear applications, which might be controversial applications indeed. It also discusses freedom of science. Hopefully, this article will stimulate further discussion in the academic community!

Keywords: philosophy, education, modelling

1. Introduction

Should operations researchers worry about ethics? Let me give some preliminary answers:

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[1]The first version of this paper was prepared for the symposium titled *Ethical Issues in Modelling and Simulation,* organized at the occasion of the retirement of professor Maurice Elzas in Wageningen (the Netherlands) on 2 July 1999. I thank the participants of that symposium for their comments, and also Saul Gass (University of Maryland), Jon Helton (Sandia), Alan Pritsker (Symix Systems), Doug Samuelson (Infologix), Karel Soudijn (Tilburg University), Ann Taket (South Bank University), Eric Van Damme (Tilburg University), Warren Walker (RAND Corporation), and Jim Wilson (North Carolina State University) for their useful comments on various versions of this paper.

1. Operations Research (OR) societies have no formal codes of ethics, but other societies do have them!
2. Recently, some prominent OR academics have discussed ethics, at important fora.
3. Modelers are human beings, and all humans should face moral issues!

More precisely, neither the European OR societies nor the international Institute for Operations Research and the Management Sciences (INFORMS) have codes of ethics. There are only the old guidelines of the Operations Research Society of America (ORSA), drafted by Caywood et al. (1971) and recently criticized by Taket (1994).

However, in 1999 the American Statistical Association (ASA) published detailed ethical guidelines; see ASA (1999) and its web page (http://www.amstat.org/profession/ethicalstatistics.html). I find that these guidelines can be applied nearly ad verbatim to OR; after all, statistics is one of the OR techniques that is most often applied. Throughout its guidelines, ASA emphasizes validation. The guidelines also refer to international organizations (such as the United Nations) and other professional organizations (not further detailed).

There are more professional organizations that do have ethics codes. The American Psychological Association (APA) has such a code (and so does, for example, the Netherlands Institute of Psychologists). Indeed, psychologists are expected to adhere to a strict code of conduct (and so are medical doctors, lawyers, and journalists). Whereas classical OR only simulates human beings, social scientists work with real people; also see again ASA (1999). Some OR studies, however, use gaming so real people are involved (teaching business ethics with management and marketing games is described by Wolfe and Fritzsche (1998); Experimental Economics also uses simple games with real monetary payments to study egoistic versus altruistic behavior of people). The British school of ‘soft OR’ is another example of a type of OR that involves users - and modelers - more intensely; see Lane and Oiva (1998) and again Taket (1994).

Further, the Association for Computing Machinery (ACM) has a code of ethics; see Anderson (1992). A draft code for Software Engineering has been proposed by ACM and the Institute for Electrical and Electronic Engineering - Computer Society (IEEE-CS); see their web page (http://www.computer.org/tab/seprof/code.htm).

An example of a prominent OR academic discussing ethics, is professor Howard of

Stanford; he delivered the Distinguished Plenary Lecture on ‘The ethical OR/MS professional’ at the May 1999 INFORMS meeting in Cincinnati (see Howard 1999). Another OR example is the symposium on 'Ethics in modeling' reported by Wallace (1994). There was also a discussion on ethics in the British *Journal of the Operational Research Society*; see Taket (1994) once more. Gass (1994) discusses the code of ethics for the OR modeler as a member of the academic community: relationships as a professor with students, relationships as an author and referee, plagiarism, etc. (also see ASA 1999) Wilson (1997) elaborates principles of ethical conduct in science - especially in simulation; he emphasizes validation, and also reports on his experience as a departmental editor of *Management Science* (I add references to the websites of *MIS Quarterly* and Elsevier, which provide examples of editorial feedback: http://www.misq.org/archivist/editor.html and http://www.elsevier.nl/oasis/). Below I shall return to these publications.

In this article I discuss some ethical issues based on my personal experience as a modeler. But first: what is meant by the term *ethics*? *Webster’s New World Dictionary* (1984 edition) defines ‘ethical’ as ‘1. having to do with ethics; of or conforming to moral standards; 2. conforming to professional standards of conduct’. I claim that a mathematical model itself has no morals (neither does it have - say - color); a model is an abstract, mathematical entity that belongs to the immaterial world. The *purpose* of a model, however, does certainly have ethical implications; for example, a model meant to increase the profits of a heroin dealer has moral aspects. Note that I use the term ‘purpose’ to refer to the problem that the model is supposed to help solve.

I further claim that Webster’s second meaning (‘professional standards of conduct’) has to do with the *use* of a model by the modelers and their clients. More specifically, any model is based on particular *assumptions* (for example, it may assume linear equations or Poisson processes with specific parameter values). Hence, the model results apply if those assumptions hold. But, what happens when these assumptions do not hold? This is often not known - because the modelers did not investigate this issue - or is not emphasized enough - because the users did not want to be bothered by ‘all these technicalities’. Yet I think that this second meaning of ethical is of great practical importance!

My experience suggests that the interest in the validation of model assumptions is more articulated in the public domain, especially the military domain; in private business, proprietary aspects (confidentiality) dominate. Details on validation can be found in Kleijnen (1999, 1995b), including many more references. Below I shall also return to the validation issue.

The rest of this article is organized as follows. §2 discusses two earlier workshops on ethics in modeling, and also addresses the related issues of model validation and robustness. §3 examines ethical aspects of the purposes of models used in crime, war and peace. §4 studies ethical professional conduct, including threats to the freedom of scientists. §5 gives some conclusions. The articles finishes with thirty-five references for further study.

2. Literature on ethics, validation, and robustness

Most mathematical models are only subsystems of a decision support system (DSS). And like many other tools (hammers, knives, etc.), these DSSs can be used in good or in bad ways, by users or developers, consciously or not. And passers-by may be hit by the chips produced accidentally by those hammers, etc.

DSSs include models that might be used actively by clients themselves to answer ‘what if’ questions, whereas traditional OR models are run by modelers, not clients. Such model usage directly by the clients themselves may be dangerous, as we shall see below

Personally I got interested in the topic of ethics when I was invited to participate in an international videoconference on ‘Ethics in modeling’ on 28 October 1994. This conference connected four sites, which had the following discussion leaders: William Wallace at Rensselaer Polytechnic Institute, Warren Walker at Rand Europe, John Little at MIT, and Saul Gass at the University of Maryland. This conference emphasized that users may not understand the reasoning that is built into a particular model (I would say that it is like giving a bazooka to kids - or to adults, but without supplying them with an instruction manual). Therefore I wish to point out that the *documentation* of a model should explain the model’s underlying reasoning, especially its performance measures (responses, outputs) and its assumptions with their validation. For example, it makes a difference whether a model on drug usage is meant to maximize the dealer’s profits or to minimize the users’ consumption. Considering assumptions, I tried to explicitly state all assumptions in my critical analysis of IBM's inventory package “IMPACT" in Kleijnen and Rens (1978).

When testing the validity of a simulation model, ‘auxiliary assumptions’ are introduced; for example, normality of the simulation responses is often assumed (also see Wilson (1997)’s discussion of the so-called Duhem-Quine problem). Actually, OR modelers are brainwashed into assuming Gaussian distributions so they often forget distribution-free (non-parametric) tests and computer-driven statistical techniques such as jackknifing and bootstrapping. So the assumptions of any statistical techniques used for testing the validity of the simulation model, should also be documented. More details on model documentation can be found in Gass (1984) and ASA (1999) (e.g., multiple tests increase the probability of falsely rejecting a valid model: type I error or modeler’s risk).

Earlier - in 1989 - another workshop on the same issue was held at the Rensselaer Polytechnic Institute. That workshop is reported by Wallace (1994). He emphasizes that model documentation is necessary in order to enable other researchers to *replicate* the outcomes of the model; such replication is a basic principle of science (also see Wilson 1997)!

Further, Wallace (1994) emphasizes the role of *values*; that is, the values of clients, modelers, and other stake holders (for example, the public affected by the clients’ decisions). I think that a fascinating example is the simulation of liver transplants, especially the great many policies for the matching of donors and patients, as explained by Pritsker (1998) in an article titled ‘Life & death decisions’ in *OR/MS Today*. Another example of stakeholders (in which I was personally involved as chairman of a steering committee) is the simulation model that computes the financial consequences of changes in certain social security laws - for both the national government and the individual laborers in the Netherlands; see Bosch, Smit, Elsendoorn, and Verhees (1994). Note that values are related to the purposes of the model.

Next I consider various types of models. Unlike simulation models, *expert systems* try to explain their reasoning; that is, they perform not only what-if analysis, but also state the ‘why’ of their outcome (validation of the underlying expert rules is another issue). Both simulation and expert systems do not optimize, whereas mathematical programming models (e.g., linear programming) do provide the optimal solution - if the model’s assumptions hold and the correct response type is selected! My own experience in simulation is that instead of telling the users which decision to make, the simulationists should present the users with a set of non-dominated solutions. Depending on the users’ values, the users decide. In the private domain, managers are paid so well because they must make such decisions - and live with the consequences!

Spreadsheets can be a type of simulation. Many users, however, do not realize that a particular spreadsheet is indeed a simulation model! Consequently, these users may not be aware of the *garbage-in-garbage-out* (GIGO) characteristic of models (a dramatic example is the bombing of the Chinese embassy in Belgrade during the Kosovo war: wrong city map used!). Personally I remember that many years ago I was contacted by a mortgage broker who offered me a mortgage that was ‘ideal’ for me. When I voiced some doubts, he mentioned that his advice was based on a computerized spreadsheet - and the computer cannot be wrong! ASA (1999), however, says: ‘The fact that a procedure is automated does not ensure its correctness ...’ Note that most spreadsheet software complicates the validation of the underlying model, since that model is not explicitly formulated in terms of equations and inequalities. Also see Whittaker (1999).

I think that it is a challenge to develop *on-line documentation* on the model’s purposes and assumptions and their validation. This documentation should be accessible through a help button, as is now the case for modern software. Indeed, nowadays many discrete-event simulation models do provide part of their documentation through *animation*, which explains - in user terms - the system being simulated. (Animation, however, can be a misleading validation technique, since it uses very short simulation runs.)

Below I shall show that simulation models are often used in *uncertainty analysis* or *risk analysis*: they quantify the probability of a ‘disaster’, such as a nuclear accident, an ecological collapse, or a financial mis-investment. I emphasize that these disasters are unique events, whereas (say) a supermarket queueing model concerns repetitive events (e.g., customer waiting times). Consequently, validation in risk analysis is very difficult; see Jansen and De Vries (1998). A better term may then be *credibility*; see Fossett, Harrison, Weintrob, and Gass (1991), and Hodges (1991).

The dangers of wrong usage of a model become much smaller if that model is *robust*; that is, the model’s output is not very sensitive to the exact values of the model’s parameters and inputs. Taguchi has emphasized the importance of robustness, but he limited himself to physical products such as cars (not abstract products such as models). An example of the study on model robustness is the paper on pull production-planning systems - such as the Japanese Kanban systems - by Kleijnen and Gaury (1999). In that paper, various types of pull systems are first optimized assuming a specific, most likely scenario for the environment. Usually modelers then select the optimized system. In practice, however, the actual environment always differs from the assumed scenario. Even then, the system should not result in disastrous performance! Therefore Kleijnen and Gaury quantify this disaster probability, applying Monte Carlo sampling followed by bootstrapping (a statistical technique). So in general, we should consider a population of scenarios, which implies an average scenario and a worst-case scenario. Also see Rosenhead (1989).

These issues become even more important when the modelers do not know who the users will be! Let me compare a model with a *car*. A model without documentation is like a car without an instruction booklet! If the model is used respecting the documentation, then the users are entitled to a ‘warranty’: the modelers have to pay for wrong model conclusions. If, however, the clients are using the model outside its validity range, then these clients are to be blamed. While ’driving’ the model, red warning lights may switch on when inputs are entered into the model that violate its validity range (see Zeigler (1976)’s ‘experimental frame’). A car is periodically returned to the garage for maintenance; similarly a model may be returned to its builders, for updating. With other software it is well-known that maintenance is a crucial - and expensive - part of the life cycle! Note that illegal copies of software - including models - may be fought through hardware keys or by selling compiled versions only (instead of source code).

Another metaphor is the instructions that come with most medicines: these instructions warn against all kinds of undesirable side-effects. Likewise, the documentation of a model should warn against improper usage. And likewise, this documentation should be updated continually. Such updating is standard in software: new versions keep appearing, repairing ‘bugs’ discovered during usage.

3. Ethical model purposes?

The example of the heroin dealer given above, is an example that most modelers would find not conforming to their moral standards. How many models have been developed at the request of organizations that the government classifies as *criminal organizations*? I have no idea at all - but who has? These organizations themselves have no reason to publish such information; I do not know of any publications by the government on model usage by criminals. I do know of a few publications on the use of models by the authorities to fight crime. For example, Van Meel (1993) discusses two case studies within the Amsterdam municipal police force. The RAND Corporation developed a gaming model to study the USA's drug problem; see Caulkins (1995).

In practice, it is not always clear what constitutes a crime: is abortion a crime, even in case of rape (see again Howard, 1999)? In this context, I also mention my technical article on Gitlow's methodology for designing abortion clinics: Gitlow (1976), Kleijnen (1979).

Besides ‘law and order’ inside the nation, there are the essential and eternal problems of international *war and peace*. Not all scientists are prepared to work for the military establishment (yet, the origin of OR is the development of military models during World War II.) Personally I do not believe in the good nature of mankind, so I think that modeling for military defense is morally acceptable. But what is acceptable weaponry? Defensive weapons have been defined as those weapons that our country owns, whereas offensive weapons are by definition in the hands of our national enemies - whoever they are. One example of a military model that I was personally involved in and that has been published, is the use of sonar to search for mines on the sea bottom (my contribution was the use of statistical techniques for the validation of this simulation model; see Kleijnen 1995a).

Modern weaponry takes us inevitably to *nuclear* weapons; for many scientists a moral dilemma, for sure! (My own visit to the nuclear bomb museum in Albuquerque - New Mexico, USA - shed some new light on this issue, for myself.) But nuclear processes also play a role in modern medicine! And this takes me to another problem that I was involved in: the deposit of nuclear waste.

The USA must dispose of its radioactive waste (for example, contaminated garments). One practical solution to this problem is the disposal underground. For that purpose the *Waste Isolation Pilot Plant* (WIPP) has been built near Carlsbad, New Mexico, at 2,000 feet below the surface. Before this plant will start 'operation' (that is, storage of nuclear waste), it must obtain permission from the Environmental Protection Agency (EPA) of the Department of Energy (DOE). Since there is little practical experience with nuclear waste disposal, the EPA’s permission depends heavily on simulation of the WIPP. Part of this simulation consists of nonlinear partial differential equations with constraint equations, initial conditions, and boundary conditions. (One simulation run takes one to five hours of computer time on a VAX Alpha with VMS; 1,800 runs were executed and analyzed as part of the uncertainty analysis.) These equations form a deterministic simulation model (since the underlying physical and chemical processes are modeled deterministically; other simulation WIPP submodels, however, include random elements such as human activities that may lead to intrusions into the WIPP). Many parameters of this deterministic model, however, are unknown so they are sampled from statistical distribution functions - by means of Monte Carlo sampling (especially, a refined sampling technique called Latin Hypercube Sampling or LHS). This approach is known as *uncertainty analysis* or *risk analysis*. For details on WIPP and its uncertainty and sensitivity analyses I refer to Kleijnen and Helton (1999); also see Howard (1999)'s comments on nuclear waste disposal.

4. Ethical professional conduct?

Recently, Köbben and Tromp (1999) - two Dutch social scientists - wrote a book on the threats that scientists may have to face when they report results that their 'bosses' do not like. These authors present the case of a Dutch physicist (at KEMA; see http://www.kema.nl) who changed his position in the debate on nuclear energy from pro to contra; subsequently he had to change jobs! Another case is that of an expert at the National Institute for Fishery Research (Rijksinstituur voor Visserij-onderzoek, RIVO). This expert publicly criticized the reasoning behind the new fishing quota imposed by the Ministry. His management considered this public criticism to be 'disloyal', as the Ministry was the biggest customer of the Institute. (Also see Mentzel, Kohnstamm, and Becker 1995.)

Köbben also participated in the discussion on ethical questions in the social sciences that was organized by the Social Sciences Council (SWR in Dutch) of the Royal Netherlands Academy of Sciences (KNAW). This interesting discussion is reported - in Dutch - by Mentzel et al. (1995).

Last year (1999), Dutch parliament members raised questions about the permission to Amsterdam airport (Schiphol) for its expansion plans: one of the employees at the National Institute for Public Health and Environmental Protection (Rijksinstituur voor Volksgezondheid en Milieu, RIVM) claimed that this permission was based on a wrong model, not on real-world measurements of traffic noise and pollution. I do not wish to discuss here the advantages and disadvantages of modeling versus real-world measurements; instead I do wish to repeat the need for validation of models, and the related issues of sensitivity and uncertainty analyses (see the WIPP problem above).

A practical problem with both ethical and theoretical implications is: *who pays the bill?* ASA (1999) and Samuelson (1999) discuss this issue; I add that when more than a single party benefits, game theory may be applied to obtain an equitable answer.

An issue related to professional conduct is the protection of *whistle blowers* ('bell ringers'): employees who warn against fraud; see ASA (1999).

Finally, recent books on professional conduct are Kuçuradi (1999), Lawrence (1999), and MacLagan (1998).

5. Conclusion

Ethical issues in modeling are essential issues for all modelers, since there is life outside the office: all modelers are human beings, and humans are the only 'animals' facing moral problems!

Nevertheless - to the best of my knowledge - these issues are not part of the standard academic OR curriculum. Exceptions that I am familiar with, are the courses by Howard at Stanford University (see Howard 1999) and Walker at Delft University.

Occasionally these issues arise in the popular press (such as newspapers), but these issues are then not discussed in a scientific manner. I must admit that I myself have seldom stopped to think at much length about these problems. Therefore is has been a challenge to force myself to reflect some more on this problem when writing this article.

Since there seem to be so few specialists in this field, I hope that my article is a worthwhile contribution to the field, and that it will stimulate further discussion on the issues of ethics in OR modeling!

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