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Ethics in OR/MS: Past, Present and Future

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Abstract The pervasiveness and impact on society and on every day human life of technology has led to a growing awareness that science and technology cannot be considered above or beyond the realm of value judgements and hence of ethics. This is especially true for Operations Research / Management Science (OR/MS), that particular science which is concerned with methodologies for scientifically deciding how to design and operate man-machine systems in an optimal way, usually under conditions requiring the allocation of scarce resources. Here we try to give a historical account of the growing interest for ethics within the OR/MS community from its birth to present days. Starting from attempts to define models and codes of ethical behaviour in our profession, the OR/MS community has arrived at more fundamental questions about the ethical responsibility it faces in a world of growing inequalities and in which the ever greater stress that human activities impose on the environment puts at risk the very survival of human kind.

Keywords: Societal problem analysis, Ethics, Social implications of Operations Research practice

1 Introduction

The pervasiveness of technology and its ever stronger impact on society and on human life has led to a growing awareness that science, which is more and more intertwined with technology, cannot be considered above or beyond the realm of value judgements and hence of ethics. As Robert Oppenheimer put it after Hiroshima: "*scientists have now experienced sin*"(Jonas, 1985).

These considerations apply in a special way to Operations Research / Management Science (OR/MS) [1], which is a rather peculiar kind of science. Unlike natural sciences, OR/MS is a "science of the artificial" (Simon, 1969) in that it has as its object not natural reality but rather a man-made reality, the reality of man-machine complex systems. As an old ORSA definition (1977) states, "Operations Research is concerned with scientifically deciding how to best design and operate man-machine systems, usually under conditions requiring the allocation of scarce resources" (Müller-Merbach, 2002). Hardly any area in OR/MS can be considered far enough from the real world to escape from ethical considerations.[2]

The awareness of the relevance of ethics in Operations Research has been growing, especially in recent years. However, the interest in ethics dates back to the very beginning of OR/MS. Peter Horner in the volume of *OR/MS Today* which celebrates the 50 years of *INFORMS*, reports a discussion between G.B. Dantzig and C.W. Churchman during the meeting at which *TIMS* was founded, in New York, on Dec. 1, 1953 (*ORSA* had been founded the year before). The issue was ethics. "I am a philosopher. - so Churchman recalls the fact - When they said optimise, I thought they meant optimise in an ethical sense. You can optimise the decision-making function in linear programming and find out that it is only optimal in terms of what management perceives to be the monetary benefit minus cost. LP's only constraints are physical or purely financial, not ethical. [...] George was a mathematician, I was a philosopher. George was selling LP, and I was trying to sell ethics. Looking back, it's pretty obvious that George did a better job of selling than I did." (Horner, 2002).

From then on ethics, although not always under this name, has surfaced many times in the OR/MS literature. In 1971, the Operations Research Society of America (*ORSA*) published in its journal, *Operations Research*, a set of "Guidelines for the Practice of Operations Research". Later, in 1983, a "Code of Professional Standards" and "Guidelines for Professional Standards in Operations Research and Management Science" was proposed by the ORSA Ethics Committee (Cowton and Gass, 2003). In 1994 a book dedicated to Ethics in modelling was edited by Wallace (1994), the first

[1] As it is now becoming customary we will use OR/MS instead of simply OR: in fact in our opinion Management Science is a branch of Operations Research rather than an extension, but its use makes clearer the meaning of OR, which appears to be a rather obscure name to the profane.

[2] OR/MS has much in common with other sciences of the artificial, such as the engineering and the computer sciences. All these sciences are concerned with designing objects (artefacts) which in one way or the other have impact (sometimes a strong one) on human life, on society and on nature. What makes peculiar OR/MS is that it is concerned not only with designing objects (systems, organisations, ...), but also with the decision making process itself. Helping decision makers in their decisions and providing tools to make such decisions more effectively implementable puts in the hands of the OR/MS professional a large power, and makes his/her activity subject to ethical responsibility in a special way.

systematic attempt to analyse the ethical implications of the modelling activity. More recently a strong interest toward the relation between ethics and OR/MS has been growing in Europe. At the 2000 *EURO* conference in Budapest one of the plenary lectures had ethics as its subject (Brans, 2002a). In 2002, on the occasion of a European conference in Brussels, which had Ethics as one of its main topics, a working group on Ethics of *EURO*, the association of the European OR societies, was established, and its first workshop was held in April 2003 in Fontainebleau. The Brussels Conference was the occasion for the publication of new papers on the subject (Brans (2004), Clímaco (2004), Gallo (2004), Le Menestrel and Van Wassenhove (2004)).

There are probably two reasons why most of the papers on the subject of ethics have been published within the last ten years. The first is linked to a process which appears to be natural in all fields of applied science: when a discipline is young most of the attention of the researchers is dedicated to the exploration of new challenging application areas and to the development of the methodological tools and theories needed. Only a mature discipline starts reflecting about itself and questioning the sense of what is being done: ethics is a fundamental aspect of this self-reflection. The second reason appears to be completely different: some of the people who felt that ethics was fundamental, such as the already mentioned Churchman, became disappointed with a discipline which was becoming more and more mathematical [3]. It is not a mere coincidence that some of these people no longer call themselves operations researchers, although in what they do they use "a scientific approach to the solution of problems in the management of complex systems" (this is the definition of *OR/MS* provided by *IFORS*, the International Federations of Operations Research Societies), and hence what they do is in fact Operations Research.

In this paper we will try to give an account of how the discourse of Ethics has been developed in the OR/MS community. We will do it according to two different, although complementary, point of views.

On the one hand, we will make reference to the framework depicted in fig. 1, where the OR/MS researcher/professional is located at the centre of a triangle having three corners: *Models*, *Clients* and *Society*.

Everything that can be said about ethics has, in one way or another, to do with these three elements, Models, Clients and Society, and with the relations between them and the OR/MS researcher/professional.

[3] Talking of *TIMS* (now merged with *ORSA* into *INFORMS*) and its journal *Management Science*, Churchman says: "My notion was that a society and journal in the subject of a science of management would investigate how humans can manage their affairs well. For me "well" means "ethically", or in the best interest of humanity in a world of filthy oppression and murder [. . .] I find that 40 years later management scientists have been inventing all kinds of mathematical models and novelties (management by objectives, game theory, artificial intelligence, expert systems, TQM, chaos theory), and none of these has contributed much to the ethical benefit of human beings". (Churchman, 1994)

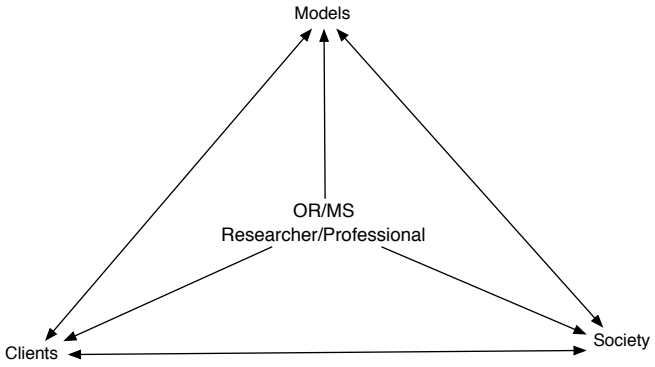

Fig. 1

On the other hand, we will make reference to a path running from an *internal* perspective of ethics to an *external* one. The first has to do with the behaviour of the researcher/professional within his/her activity: methodological rigour, objectivity, no advocacy, results emerging from analysis and not vice versa, correctness and honesty in relations with clients, ... The second has to do with the responsibility of the researcher/professional toward not only the clients but also toward all those people affected by the actions and decisions which are taken based on his/her models, and toward society and the external world at large: he/she cannot ignore the consequences of his/her action and will bear full ethical responsibility for them; he/she is not only a researcher/professional, but also a citizen, ...

The structure of the paper and the sequence of the sections will try to make clear the movement from an inner ethics to an external one, and at the same time will show the relative role of the three elements, models, client and society, in the development of an ethical discourse within the OR/MS community.

In sections 6 and 7 we go beyond the limits of a standard survey paper, focusing on the new challenges that the growing complexity of the problems which humanity is facing today pose to operations researchers. In one way or another all such problems can be encompassed under the general theme of *sustainability*. Can OR/MS help in managing the complexity of the World System and in defining a path of sustainable development? This is the fundamental question we have to pose ourselves today if we want our discourse on ethics to be really ethical.

2 Ethics, models and clients: objectivity and honesty

One of the first systematic attempts to analyse the relations between modelling and ethics was made at a workshop held in 1989 at the Rensselaer Polytechnic Institute, which brought together researcher and practitioners

from United States and Great Britain to share and discuss their views on the subject. The papers presented at the workshop, together with a few others, have been collected by William A. Wallace in the already cited book "Ethics in modeling" (Wallace, 1994). In Wallace's words there was at that workshop a general agreement "on some aspects of ethical conduct, such as the need for model builders to be honest, to represent reality as faithfully as possible in their models, to use accurate data, to represent the results of the models as clearly as possible, and to make clear to the model user what the model can do and what its limitations are".

The main idea that comes out from most of the contributions at that workshop is what Le Menestrel and Van Wassenhove define as *Ethics outside OR models*: models in OR/MS, no differently from models in natural science, are objective and do not (and do not have to) carry subjective values. They aim "at identifying an optimal solution independent of the perceptions, appreciation and feelings of the human beings. When this is the case, these models identify an 'objectively optimal' solution and any subjective value is abstracted. Objective models of Operational Research exclude ethical concerns in order to ensure the formal validity of their solution. [...] Not only are there no ethical concerns properly included within objective OR models, there *should be no ethical concern within them*" (Le Menestrel and Van Wassenhove, 2004). The only and fundamental ethical responsibility of the OR/MS researcher/professional is to guarantee "that the goal of any model building process is objectivity with clear assumptions, reproducible results, and no advocacy" (Wallace, 1994).

That also has implications on relations with clients. In one of the book's chapters, Mason (1994) describes the relationship between the model builder and the user as being based on *covenants*, three of which are: "(1) to represent reality to her clients adequately, (2) to understand and to incorporate the client's values into her model in an effective way, and (3) to insure that actions the client takes based on the model have the desired effect". These covenants in Mason's view can be resumed in the *covenant of reality*, one in which the model builder "is entrusted with understanding things as they actually exist in the problem area and representing their most salient features as accurately as possible", and the *covenant of values*, as one in which the model builder "is entrusted with the visions, goals, and objectives of her client and pledges to serve these values as loyally as possible". Mason acknowledges the possibility that the conscience of the management scientist might not abide the client's values, and, without taking side (at least explicitly), he recognises the existence of two alternative approaches: on the one side there are the management scientists who are *scientists first*, and on the other there are those who consider themselves *human beings first* and scientists second. For the former "the model builder's responsibility [...] is to insure that the model is built and executed with scientific precision using the best methods available. He or she is not responsible for what the client's values are or what client does with the model". For the latter, "the

model builder must look beyond the process of model building itself and take responsibility for the total impact on human kind".

The idea that models are objective and that no ethical value can be attached directly to them derives directly from the natural sciences, but encounters some difficulties in a science that has as its object not natural reality but rather a man-made reality, as in the case of OR/MS. It is often the case that more than one model can be used to answer the same questions, and that they may produce different, and sometimes contrasting, answers. Cases of this type have been described by Allison, Charnes, Cooper, and Sueyoshi (1994).

One possible solution to this difficulty is to make publicly available all the data used and to provide an exhaustive documentation of the work done in building the models, so to make the model and the results obtained open to public scrutiny. In Mulvey's words, models which are simple and which have been developed in an open fashion are ethically preferable to obscure and complex models. Closed and complex models are more prone to manipulation in order "to generate *the correct recommendation*" (Mulvey, 1994). Saul I. Gass, who, within the OR/MS community, has been one of the most active in the area of ethics (Gass, 1991b,a, 1994a,b,c), in his paper in Wallace's book states that the "most important ethical concern [OR analysts face] is the adhering to proper professional practices in the development and reporting of our work". He sees the problem mainly from the point of view of the replicability of the results: "data sources must be made available, methodological procedures must be reported in detail, and information must be provided so that external peer groups can replicate the results". He adds that the analyst "should retain the privilege of free and open publication whenever possible [and] should not work for a client who does not provide the necessary information and opportunities for presentation of the study and its finding". The need to make all the relevant information available also has another fundamental motivation which is formulated by Allison, Charnes, Cooper and Sueyoshi in the opening of their article: "The end of science is publicly available knowledge (i.e. knowledge that is available to all who seek it), and the ethic of science is truth (i.e. fully open honesty) in all parts of any representation intended as a contribution to science. Within science it is the *only* ethic"(Allison et al., 1994).

3 Codes of Ethics

One of the typical means of making ethical concern explicit in sectors which, like OR/MS, have at the same time the status of science and that of a profession, is the definition and adoption of *ethical guidelines* or of *ethical codes*. The codes of ethics of scientific/professional societies are, typically, sets of rules, sometimes well defined and sometimes rather generic. As an example the code of ethics[4] of *The Institute of Electrical and Electronics*

[4] www.ieee.org/about/whatis/code.html

Engineers (*IEEE*) consists of 10 points, some very precise, like the 3^{rd} (*to be honest and realistic in stating claims or estimates based on available data*) or the 4^{th} (*to reject bribery in all its forms*), while others are more general, like the 1^{st} (*to accept responsibility in making engineering decisions consistent with the safety, health and welfare of the public and to disclose promptly factors that might endanger the public or the environment*) or the 10^{th} (*to assist colleagues and co-workers in their professional development and to support them in following this code of ethics*).

Unfortunately, as pointed out by Cowton and Gass (2003) no OR/MS national society has adopted a code of ethics, with the very recent exception of the Japanese Society which has adopted a code of ethics in March 2003. Although the problem has been brought to the attention of *ORSA* in the early seventies (Caywood et al., 1971) and again in the eighties (Machol, 1982), no action has followed. Cowton and Gass conclude their research on the subject stating that "the history of ethical concern within the OR profession is rather weak". That is strange considering that many related organisations have long ago established their codes of ethics. We have already mentioned the code of ethics of *IEEE*. More interesting is the case of the Association of Computing Machinery (*ACM*), whose code of ethics[5] consists of 24 moral imperatives arranged in 4 sections; in Cowton and Gass' words this code "is a most inclusive one; it is rather complete in terms of the commitment a scientific and technical professional can make with respect to one's ethical professional conduct".

Another example of a code of ethics is the *Oath of Prometheus* which has been proposed by Brans (2002b) and out of which the EURO Working Group on Ethics has grown.

4 Ethics and models: subjectivity and values

As we have already seen the idea of objectivity and value neutrality of models is not completely satisfactory. The very fact that when we face a problem we have to choose among many approaches and models forces ethics to enter into the picture: whenever there is a choice there is some ethical responsibility. But there is something more fundamental: the very choice of a model reflects the modeller's values and vision of society. Take for instance *optimisation models*. As pointed out by Gallo (2004), "behind the development of *optimality* as a fundamental principle in the analysis of economic activities and in taking decisions related to such activities, there are two ideas which have relevant ethical implications: self-interest as the only motivation behind individuals' economic choices, and the utility function to be maximised as the formal way to model the individual's behaviour". A critical analysis of the contradiction between an ethical perspective and the utility maximising paradigm in economic analysis has been developed by Sen (1987). Sen

[5] www.acm.org/constitution/code.html

has pointed out that, remaining within the boundary of the utility maximising paradigm, there is no room for value judgements, nor are there ways to make interpersonal comparisons, which are needed if we want to go beyond Pareto optimality, to include equity as a measure of welfare. A further ethically relevant implication of the idea that a single utility function can be used to catch the complexities of human motivations is the too widely accepted assumption that everything can be measured in monetary terms. If we accept that, by applying the proper rate of substitution, everything can be traded for everything else, then the consequence is that everything can be assigned a monetary value. This is something which we would not accept in our private life, but which is rarely challenged outside the private sphere".

The dissatisfaction with "the utilitarian mono-rational ideology" (Clímaco, 2004) which is at the root of the 'optimisation paradigm' has lead some researchers to advocate the use of multicriteria approaches as a way to include subjectivity and hence ethical concerns within the models. This is what Le Menestrel and Van Wassenhove call *Ethics within OR models*. "In these models, there is no single objective function but several. How these functions combine their respective weights, depends on parameter values that are not determined by the objective functions themselves. In this sense, the solution depends on 'subjective' weights and is called 'reasonable', 'acceptable' or 'appropriate for the parties' rather than 'objectively optimal' " (Le Menestrel and Van Wassenhove, 2004). In these subjective models, due to the need to measure the weights and to the intrinsic subjectivity of these weights, an explicit role is given, within the model building process, to the users: "a relationship between the model builder and the model user is recognised and established". Different sets of weights might lead to different solutions, and, in practice, these models constitute an aid to decision-making rather than a tool providing the best, most rational, solution. A step further has been proposed by Brans (2002a). In his view ethics can be explicitly introduced in the models as specific sets of weights: while subjective weights reflect the subjective values of individuals, ethical weights should reflect relevant values at the level of society, humanity or environment. As an example, in the evaluation of the benefits of alternative projects a properly chosen discount rate may allow to take into account the need for intergenerational equity.

5 Ethics, clients and society: a wider perspective

In the preceding sections the focus was mainly on models, whether they should be strictly objective or should rather include some kind of subjectivity and embed ethical values. As for the clients, the main concern was the professional correctness in the relation between OR/MS professionals and their clients. The perspective might change substantially if we widen our view to include society at large.

This is the main thesis of Koch (2000): the OR/MS professional, when analysing a problem, cannot limit himself/herself to the specification of the problem provided by the customer; he/she must make an effort to analyse the context in which the problem is placed and to understand the consequences of its solution on the people affected and on the environment. The typical answer Koch says he has received, when asking the speakers in a session of an OR/MS Conference "what does this mean to you as a citizen?", was "it is not in the study's parameters".

Much more explicit and radical is the position of Rosenhead (1994). He starts from a simple question: who are our clients? For whom do we work? The answer is that the OR/MS people "have worked almost exclusively for one type of client: the management of large, hierarchically structured work organisations in which employees are constrained to pursue interests external to their own". Not that those are the only possible clients: other types of organisations exist, operating by consensus rather than chain-of-command, and representing various interests in a society (health, education, shelter, employment, environment). But such organisations usually have few resources at their disposal although the problems they face are no less challenging for the OR/MS profession.

This fact has a strong ethical relevance: "the use of models is source of power. The 'user', with an appropriate model, is able to scheme more effectively and to this extent is able to secure more favourable outcomes. (In a conflictual society, this in many cases means outcomes less desired by some others.)" The conclusion is that our profession is in danger of helping the powerful and neglecting the weak, thus contributing to the unbalance of power in the society.

A positive example cited by Rosenhead is the experience of *community operational research* in the United Kingdom. An initiative that has involved many OR/MS researcher in working with community groups such as associations, cooperatives and unions.

An interesting observation of Rosenhead is that working with such groups implies the development of new methods, methods "whose purpose is not the efficient solution of well-formulated problems but the provision of assistance in the process by which a number of stakeholders reach agreement on the nature of the problem that is of mutual concern. These "problem structuring methods" (Rosenhead, 1989) provide the type of participative and non-mystifying analysis that can in principle illuminate problem situations and facilitate consensus formation". That is a very important point which recalls some important considerations by one of the pioneers of decision sciences, Herbert A. Simon, who in 1969 wrote: "We have usually thought of city planning as a means whereby the planner's creative activity could build a system that would satisfy the needs of a populace. Perhaps we should think of city planning as a valuable creative activity in which many members of a community can have the opportunity of participating. [This change in perspective] permits us to attach value to the search as well as its outcome"(Simon, 1969).

In the same direction goes the proposal of Le Menestrel and Van Wassenhove for enlarging our consideration from the models to the whole modelling process. It is in the OR process which connects the real world and models that ethical concerns find their place. In this approach models keep their objectivity, while, at the same time, subjectivity and ethical values are taken into account in the problem formulation process, in the choice of the most appropriate model and in the use made of that model. This is what they call *Ethics beyond OR models*. The core of their idea is in the observation that "not only the result counts but also the way it has been obtained and will be applied in practice"(Le Menestrel and Van Wassenhove, 2004).

An enlarged perspective adds new and perhaps more compelling reasons to the plea to make scientific information and results (software among them) publicly available. A connected point concerns the inequalities at world level. In spite of all the hopes that technology, and especially the new information and communication technologies, would have opened a new era of wealth and development for third world countries, technologies have widened the divide between rich and poor countries. "A small part of the globe, accounting for some 15% of the earth's population, provides nearly all the world's technology innovations" (Sachs, 2000). The stronger and stronger assertion and enforcement of intellectual property rights has contributed to increasing global inequalities. The old aphorism which said: "*if someone is hungry, don't give him a fish; give him a fishing rod*" has been changed into "*if someone is hungry, don't give him a fish; give him your patented fishing rod and collect the royalties*". Using the words of Jeffrey Sachs, "rich countries should exercise restraint in the use of property rights. Rich countries are unilaterally asserting rights of private ownership over human and plant genetic sequences, or basic computer codes [...]. These approaches are of dubious legitimacy and will worsen global inequities." [6]

6 Ethics and OR/MS: the new challenges

Before the industrial revolution the natural world remained rather stable. The conditions for life on earth were favourable for billions of years. Human beings had no or little impact on the environment. During the 20th century

[6] Recently, on September 12th 2002, the Commission on Intellectual Property Rights, convened by Britain's Department for International Development, published a report whose central message is clear: "poor places should avoid committing themselves to rich-world systems of IPR (Intellectual Property Rights) protection unless such systems are beneficial to their needs. Nor should rich countries [...] push for anything stronger". It is also worth remembering that "[f]or most of the 19th century, America provided no copyright protection for foreign authors, arguing that it needed the freedom to copy in order to educate the new nation. Similarly, parts of Europe built their industrial bases by copying the inventions of others, a model which was also followed after the second world war by both South Corea and Taiwan. (Economist, 2002)

unbelievable progress was made in science and technology. It has been the most impressive century in the history of mankind.

On the one hand, countless fundamental discoveries have been made in science. In physics, thanks to the contributions of quantum mechanics and nuclear physics, it was possible, around 1920, to explain for the first time why the sun provides us with so much energy. Previously the huge quantity of energy emitted by the sun had remained one of the most inexplicable mysteries, and for that reason the sun was considered a God by several civilisations.

Thanks to the remarkable discoveries which took place in the field of chemistry it has been possible to develop artificial (man-made) products such as plastics, nylons, special fibres, new forms of ceramics, ... They are now part of our every day environment and it would be almost impossible to do without them in our daily lives.

In the field of biology and medicine living cells have been particularly investigated in recent years. The double helix structure was discovered in the 1960's. It is now clear how living cells reproduce, and how, thanks to appropriate bifurcations, they give rise to all kinds of animals and plants. It has, moreover, been shown that all living bodies, such as trees, ants or human beings have about 95% of their genetic patrimony in common. Again what a fascinating mystery explained!

Each time a scientific discovery is made, several additional unexplained phenomena arise. Fortunately research in science will never come to an end.

On the other hand the scientific discoveries also allowed unbelievable progress in technology. First of all, it was possible during the 20th century to provide mankind with an incredible amount of energy: electricity, coal, gas, oil, waterdams, ... Thanks to that energy fantastic supporting engines, such as skyscrapers, cranes, rolling bridges, ... were developed to facilitate our heaviest tasks. Marvellous equipment and solid buildings were created. In the field of agriculture a farmer can now run an area of several hectares alone, while in the past a huge number of workers were needed. Mobility is now made easier by motor cars, ships, trains, aeroplanes, ... In the field of communication, thanks to appropriate satellites we can get in touch instantly with anyone in the world by using mobile telephones or e-mail, while 100 years ago communication was only possible thanks to a postman. Radio and television now provide us with all kind of information. Our daily tasks are now simplified and the range of tasks possible enlarged with the support of impressive computers equipped with particularly efficient software. Thousands of effective organisations and socio-economic systems are now at our disposal to cover our needs, to enrich our life, to offer us attractive leisure time.

As science and technology continuously feed each other, progress occurs more and more rapidly. The present frame of human activity may look like a "wonderful paradise" landscape.

The end of the 20th and the beginning of 21st century is not only a turning point in time. Our natural world is becoming progressively more

and more unstable. Human beings now have a strong impact on their environment.

If we look to the future, we realise that the "wonderful paradise" is surrounded by an incredible number of major dangers. How are we going to produce clean energy, how are we going to overcome the exhausting of raw materials, the numerous forms of dangerous pollution, the lack of water, the erosion, the deforestation, the treatment of our seemingly limitless waste (each item produced always turns into waste, after a day, a week, a month, a year or after some centuries for some of them), the emissions of greenhouse gasses, the worrying increase of the temperature of the atmosphere, the propagation of terrible diseases, the problems related to biodiversity and genetic manipulation, ...

In addition to these worrying factors, human behaviour is also creating serious concerns such as intolerance, conflict, terrorism, corruption, lack of information, lack of education, poverty, unemployment, illiteracy, cultural confrontation, misuse of power, lack of freedom, ... The situation is often particularly critical in some developing areas.

All these physical and human components are not independent. Strong links often exist, such as conflicts over raw materials, the production of energy and the temperature of the atmosphere, the lack of education and soil erosion, terrorism and religious freedom, corruption and deforestation, ...

Some of these variables are now so worrying that human life on earth could be threatened in as little as fifty years from now.

Mankind is now facing serious problems. How to keep and to extend the wonderful paradise and at the same time how to guarantee sustainable development, how to keep and to offer future generations a decent, natural and friendly environment.

Of course science and technology could possibly provide us with major contributions. For instance if we were to succeed in producing unlimited amounts of electricity without pollution, and at a reasonable price, some major worrying problems could be solved.

However, in any case, in the next decades, an appropriate management of all physical and human variables involved will be compulsory. It is a problem for each individual, each community, each company, each factory, each government, ...

It is also an incredible challenge for OR/MS, the science of modelling human affairs, the science of decision aid for decision-makers, the science of management of human systems.

Of course the economic, technological, political and population communities share responsibility for the critical evolution of these variables. It is essential that the points of view of all these stakeholders be taken into account and respected. This respect is a question of ethics, and the need for the OR/MS community to take its share of responsibility in face of these new challenges, and to develop new techniques and approaches to modelling, is also a question of ethics.

7 Rethinking the OR/MS approach to modelling

In view of globalisation and the hyper complexity of human affairs all around the world, it seems to us urgent and necessary to rethink drastically the OR/MS modelling approach.

For any system facing the problems of mankind, the management landscape includes the past, the present, the short and long term future. Many interdependent variables are involved. At $t = 0$ the decision-makers usually have at their disposal an information system including historical data as well as information on the structure and the complexity of their systems.

The future is unpredictable. Evolution is chaotic and, in some cases even catastrophic with strong discontinuities. Structures change, unforeseen innovations are introduced, new factors can emerge at any time.

However, systems always include some degree of freedom (decision variables). These variables have to be fixed by the decision-makers. A management strategy is a positioning of all these variables. The most appropriate strategy should be selected each time. It is a problem that OR/MS should be able to deal with.

As we have seen before, the range of stakeholders always includes at least four communities: the economical, the technological, the political and the population communities, and together they have to behave ethically and respect each other.

The basic OR/MS models, and especially those belonging to the field of optimisation, are not appropriate to providing assistance for the management of such systems. New modelling schemes should be considered, and such new models should include among others:

- The possibility of considering a large number of interdependent variables.
- The possibility of approaching these variables in a "System thinking" way.
- The possibility of selecting at $t = 0$ an appropriate strategy (positioning of the decision variables) which respects the viewpoints of all the stakeholders.
- The possibility of considering, for each key variable, a trajectory starting at $t = 0$ and approaching a long-term objective recognised by the decision-makers as being achievable and desirable for the future. A dynamic management procedure then would consist in monitoring and controlling the system so that the observed evolution remains as close as possible to the trajectory adopted. As long as the observed deviations from the desired trend remain negligible, the selected strategy may be maintained, but as soon as they become critical the strategy has to be changed in order to keep the system moving in the desired direction.

The purpose of such models should then be to propose a dynamic management procedure. This means that the selected strategy as well as the pursued objectives can be changed at any time according to the emergence

of new factors. This is the only way to master the numerous uncertainties associated with the evolution of systems.

In the case of the emergence of new factors of influence, the dynamic management procedure should offer the possibility of modifying the modelling scheme of the involved variable by adding or cancelling some variables as well as the links between them. It should then also be possible to adopt other trajectories and long term objectives for the key variables according to the evolving circumstances.

Multicriteria decision aid procedures, as well as *multi-agent* ones, could possibly be considered at any time for the selection of the most appropriate strategies when the system is evolving. Ethical behaviour could then be obtained by including criteria representing the viewpoints of all the stakeholders as well as criteria in favour of the environment and the affected people.

Today quite a few models propose a dynamic management procedure to pilot systems over time (System Dynamics is not Dynamic Management). Such procedures would be particularly welcome. However some very interesting approaches have been proposed by the team of professor Rotmans (Rotmans and de Vries, 1997; Rotmans and van Asselt, 1999) and by the EURO working group on "World Societal Problems" (DeTombe, 2001, 2002). In addition to this a particular procedure, combining multicriteria decision aid and system dynamics to control the evolution of socio-economic processes in real-time has been proposed by Brans et al. (1998). Several applications using this procedure have been published and some extended research in the fields of energy, CO_2 emissions, transition processes, mobility, and housing is now under way (Kunsch et al., 2002, 2003, 2004; De Smet et al., 2002; Pruyt, 2003). It is a fascinating open field. It seems also to be a particularly promising way to master the critical problems generated by the various human activities which developed during the 20th century.

8 Conclusions

Our aim in this paper has been to provide an account of the reflections on ethics which have been developed in the OR/MS community in the last years. Is there such a thing as an ethical model? What type of methodological approach to modelling is better from an ethical point of view? What is the correct attitude of OR/MS professionals in the relation to their clients? Is the very choice of our clients subject to ethical scrutiny? Should the OR/MS societies have their own ethical codes? Does OR/MS have a special ethical responsibility toward society at large? These are the questions that are at the basis of the reflection on ethics in our scientific community, and it is in trying to answer these questions that ethical discourse has recently developed, progressively enlarging its scope. In the first 5 sections we have tried to give an objective account of this development and of the ideas of those who have contributed significantly to it. In particular we have tried to

outline the different types of answers that can be given to the above questions. On the one extreme there are those whose view on ethics is mainly internal, i.e. those who focus on the relation between OR/MS professionals and clients and on the way the modelling work is carried on. For them one behaves ethically when makes use of the best and more appropriate technical tools, when does not allow his/her values to interfere with the results of the analysis, when does not conceal the limits, the flaws and the weaknesses of the models he/she has built, when is honest and correct in the relations with the clients, ... On the other extreme there are those who believe that professionals, like everybody else, are part of the society in which they live, and bear a responsibility toward society at large (including nature) also as professionals. For them, an ethical professional behaviour means taking always into account the effects on society and nature of the decisions derived from their analyses and models, questioning not only the values and the objectives of the clients for whom they works, but also the same way they build their models and the tools they use, and also choosing the problems on which to work and the clients for whom to work.

At present the interest in ethics appears to be growing - a fact which is linked to the awareness that mankind is at a turning point: our natural world is becoming progressively more unstable, and the stress imposed by human activity on the environment is growing stronger and stronger to the point where our very future is at risk. This is the starting point of the last two sections in which we express our belief that in future, the role of OR/MS should be fundamentally rethought. The classical models, considering optimisation under constraints of objective functions representing profits, although quite interesting and elegant from a mathematical point of view, seem to be inappropriate for facing the future problems of mankind.

Human beings have several dimensions (not only one) such as technological, economic, social, ecological and cultural ones. The points of view not only of all the stakeholders but also of all the people affected should be taken into account. Decision aid procedures should now be developed to provide the most appropriate strategies to *pilot*, honestly, large systems including many interrelated variables, over time, and particularly when unforeseen influences suddenly take place. Mankind is now facing particularly worrying and critical problems. Technological progress will certainly help, but an appropriate management of the human affairs will definitely be necessary. The future of mankind now depends on ethically oriented technology and management. For OR/MS the field is open for imaginative and motivating new research.

It seems clear to us that in the future ethics should be considered as a major issue in OR/MS. Up to now it has not been the case. Most of the problems treated by OR/MS techniques and most of the papers published in the field did not consider ethics as such. New approaches should be considered to improve our decision processes. Among others:

- More attention should be paid to the involved stakeholders and to all the affected people.

- The consequences of the adopted decisions should be investigated not only from a short term financial point of view as often is the case, but also in the long term, especially in the social and the ecological fields.
- Cooperation and exchanges of knowledge with other scientists should be stimulated.
- A more appropriate modelling spirit should be developed, paying more attention to values such as respect, sustainability and progress for mankind, and to characteristics such as flexibility and reversibility which are crucial to the implementation of the precautionary principle.

An agenda of further actions in OR/MS should be set up, but this is not our purpose in this paper; it is rather the subject of further work the authors, together with other colleagues, intend to carry on within the EWG/ETHICS (European working group on Ethics), and, most important, it should be the task of all the OR/MS community.

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