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On Complaints About Applying Models Effectively

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ON COMPLAINTS ABOUT APPLYING MODELS EFFECTIVELY

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BACKGROUND AND MOTIVATION

There is a growing dissatisfaction in many quarters with the use of mathematical modelling, and skepticism about its effectiveness, particularly with large-scale models. In the past two to three months alone, this has been brought to my attention in at least six instances, some forcefully.

1. I was asked to participate in a select group contributing to a study for producing an issue paper on the subject. This study is sponsored by the U.S. National Bureau of Standards in response to Federal Government surveys indicating dissatisfaction by Government sponsors and users with their inability to utilize properly large-scale models as produced by contract and grant developer groups.

2. I was asked to sit in as an outside specialist (along with others) to observe and comment on a regular Review Panel's assessment of and suggestions to a project team's proposed course of action on an important modelling effort in the energy field. This amounted to a double-tiered review, obviously due to the sponsor's doubts and skepticism about the outcome of its project, almost before it began. This was in spite of the fact that the project team is from presti-gious academic institutions and the Review Panel includes highly competent professionals.

3. The Seminar chaired by Buz Holling on 16 June, with top-level support, about successes and failures at applied systems analysis, the latter far outnumbering the former.

4. Private discussions with IIASA staff members (in at least two areas) about inconsistencies which appear when two or more models are applied to the same situation, including strong professional misgivings about arbitrarily bounding one model to match another when both start from presumably consistent input, and should give consistent output.

5. During my recent visit to the USSR, misgivings were expressed about the methodology and mechanics of modelling, even though modelling is used very extensively there.

6. In one model here with which I am personally working, almost incred-ible computational difficulties have been encountered which my best efforts have failed to fully overcome, though some improvement has been made. This involves techniques and even computer routines

which have been used and accepted as sound for years.

I believe this is an extremely serious matter. Despite impressive pres-
tige and far-ranging efforts in an almost unbelievable number of places,
systems analysis is never its own sponsor. During the past quarter century,
an impressive array of theories, techniques, methods and know-how has been
created and effective use of this technology is now sorely needed in meeting
extremely serious problems. However, no funded activity can long survive and
prosper if it is not perceived as contributing something meaningful to society.
In short, our time has come but we had better be able to deliver because,
otherwise, we are merely an expensive frill.

Admittedly, the effectiveness of modelling is not entirely in the hands
of technical specialists — an issue to which IIASA is devoting much attention.
However, it is useful to be aware of how our efforts are viewed by others who
do sponsor projects in the field and some of the misgivings and complaints
which they express.

The study mentioned in 1. above was conducted by means of written reviewer
discussions of specific proposals for improving the use of models. This paper
will summarize the issues raised in that study, together with extracts from my
responses. The first should be taken seriously whether or not the reader agrees
with them. The second may be disagreed with completely, of course. That is
one main purpose of this paper — to stimulate thought and discussion, just as
the reviewer questionnaire stimulated them in me. In short, this is a kind of
issue paper in itself.

The other two purposes are as a corollary to Buz Holling's seminar, and
as background material for the efforts of the Computer Usage Planning Teams
recently established by the Director. I make no pretense of being comprehen-
sive on such a broad issue but at least there is written evidence that others
are concerned with the points raised.

SUMMARY OF THE SUGGESTIONS ADDRESSED

The study set forth 18 separate suggestions for improving the effective-
ness of (large-scale) models. It was not claimed that they were all mutually
exclusive or exhaustive. They can be grouped into seven or eight categories
withoug doing much violence. Each of the eighteen suggestions contained an
explanation for its proposal, a discussion of its nature, prior opinions both
pro and con, and a 5-point scale for voting on it plus space for reasons, etc.
They will be taken up under the following groupings:

A. The Data Problem.

B. Documentation and Training (in use).

C. Possibility of Classification of Models.

D. Administration and Management.

E. Project Direction.

F. Better Liaison (different levels and groupings).

G. Use of Review Panels.

H. Creation of Special Centers.

Some more general remarks will be made at the end. On reviewing the question-naire and my responses again after letting them get "cold", I found the whole approach somewhat disturbing, but this in itself may be important. Specifi-cally, there seemed to be a failure to get at the basic problems and a tendency to pass the buck for failure to administer and manage things in obvious ways. These will be pointed out in the sequel.

THE DATA PROBLEM

The first suggestion concerned data collection and availability for model development. The lack of data was noted as the most severe constraint on those modelling efforts surveyed by a National Science Foundation (NSF) study in 1971. The proposal consisted of three parts:

(1.1)   Prior to issuance of an RFP (Request For Proposal), most modelling projects should have a preliminary data availability and costing assessment, to be used by the sponsor to continue or stop the effort.

(1.2)   The RFP should require an explicit data collection effort, either by the model developer or another group.

(1.3)   The availability of suitable data at certain milestones should be a basis for determining whether project objectives can be attained.

These all seem like obviously sound policies when considered objectively. I supported the first and strongly supported the other two, a reservation on the first being that some way to ensure a competent initial assessment is needed.

However, the very fact that such a proposal appears necessary reveals that proper attention is not always paid to availability of meaningful data. Who of us, under oath, would not have to admit that this is so? The discus-sion of this proposal was either weak or banal, disclosing that others also recognize our failures here.

I added the comment that data availability is only part of the problem. Some models require such a wide spectrum of data that, even if nominally

available, it may be unmanageable. The cascading effect of combinatorial cases is also a severe problem.

DOCUMENTATION AND TRAINING

The next three proposals dealt with documentation, other standards, training in use of models, and plans and guidelines for providing these. They reflected the utter confusion and lack of sound management which prevails in this area. The first discussion began by noting that one survey concluded that about 75% of the models it examined had insufficient documentation to permit analysts to set up and make computer runs. However, it further noted that standards for other aspects of model development also appeared desirable. As a counter to the professional modeller who claims that standardization stifles creativity, etc., the usual examples of engineering and accounting were put forth. Generally, the discussion of the first of these proposals was weak and the statement was again in three parts, evidently designed to keep the reviewer alert. Abstracted, they were:

(2.1)   A joint Government/industry committee should be set up to investigate what can be standardized and to state their costs and benefits.

(2.2)   Any standards set forth by the Government should be voluntary.

(2.3)   Development of standards for computer routines, programming languages, data formats, etc. is <u>not</u> in the best interest of (Government) modelling activities.

I strongly opposed the first on the grounds that it is questionable that a viable committee to accomplish all this could be assembled or, if so, could produce worthwhile results in a reasonable time. Nevertheless, studies in this direction should be fruitful if well specified. (Some such efforts are, in fact, underway.) I weakly supported (2.2) mostly as a hedge but opposed (2.3) which is worded negatively. Certainly useful standards <u>would be</u> in the best interests of modelling activities. The rub lies in their nature. They must be <u>general</u>, not formulated narrowly by technicians looking at one problem.

The second of the three proposals in this group was one of the best ones which I strongly supported. The arguments for were also good and those against were weak. The proposal was in one part and is worth quoting verbatim:

(3)   All modelling projects should address the need to train others in the use and maintenance of a model, and where appropriate, a formal training activity should be made part of the developer's scope of work.

Nevertheless, I felt that a certain element of buck-passing was involved here and I will also quote my own comments:

(on 3)   One difficulty not considered above is the lack of interest by
           higher echelons of a sponsoring organization in actually understand-
           ing the nature and use of a model. It is not at all rare for the
           sponsor's responsible manager to lose interest in the substantive
           value of a project once the negotiations are complete and no serious
           default occurs. Delivery is often a kind of anti-climax. The sus-
           tained attention necessary for effective exercise of a model is often
           lacking in managers and even senior analysts, who have gone on to
           initiation of other tasks. Hence "training" may have to include
           "re-selling" and stimulation of renewed interest. But this is
           difficult to write into a contract, let alone accomplish. Lower
           echelons, of course, tend to reflect interest in the current "hot
           item" of their superiors.

     The third proposal in this set was in two parts, the first of which I
strongly supported and the second of which I opposed. The surprising thing
about the first part is that it should need proposing at all:

(4.1)   As part of their contract, computer model developers should specify
           a documentation plan at the beginning of the project that details
           the documents to be produced, the resources allocated and personnel
           responsibilities.

When I was taking commercial contracts, this was always a part of the statement
of work, with funding tied to completion. A partly new suggestion, however,
is that it should be closely tied to training.

     The second part has much the same problem as (2.1):

(4.2)   The Government should establish a flexible set of computer model
           documentation guidelines that can be used by the model developer
           and the model sponsor to establish a project's documentation plan.

The catch is in the words "Government" (or equally if "profession" were sub-
stituted) and "flexible". Models are diverse and "flexible" guidelines across
all is a contradiction in terms. This is not to say that guidelines and stand-
ards should not be imposed but judgment and good sense should be the basis, not
bureaucratic nonsense.

     At the detailed level of computer routines, it is my opinion that so-called
"system documentation" is almost never worth the cost, time and friction. Only
professional system programmers use it and, except for overall conventions and
a few detailed explanations of intricate arrangements, the computer program
is its own documentation. Standards with regard to comments are badly needed.
A comment which says what is immediately obvious from the code is worse than
useless.

POSSIBILITY OF CLASSIFICATION OF MODELS

The next suggestion was that of a bureaucrat with a smattering of cost/ benefit analysis. I do not regard it as worth considering except for the fact that some sponsoring agencies evidently do. The discussion was along the following lines. Based on three past surveys (which should be inflated), most models cost less than $250,000, the majority less than $50,000, with an average of $140,000. Should we worry about documentation for a $50,000 model to be used once? However, it might be improved later. Hence the proposal was to classify models, on some unstated basis but with suggestions such as cost, person-years, decision environment. The actual proposal was stated in two parts, the first being an exercise in futility:

(5.1)   If modelling standards or management procedures are developed by the Government, they should not be applied to all modeling projects. The basis for their application should be a function of the project's characteristics.

(5.2)   The Government should develop a scheme by which modelling projects can be classified. The classification of a model would then serve as a guide to the model sponsor and developer as to the level and depth of certain modelling activities such as documentation, verification, sensitivity analyses, etc.

I half-heartedly supported the second part but it is not clear who, within or outside the Government (or any large sponsoring group), has the breadth of experience to do it. Also, the suggested criteria do not seem appropriate. Attributes such as clear vs subtle, SOP* vs special studies, nature of data base, probability of continuing evolution, etc., seem better but are hard to specify precisely enough to be administered.

ADMINISTRATION AND MANAGEMENT

Four proposals dealt specifically with this area, although others had implications for it. (One with a related theme I have somewhat arbitrarily classified as project direction.) One of the four is, in my opinion, only the genesis of a bureaucratic boondoggle but the other three appear very sound. Again, however, it is surprising that they need to be proposed; they should be mostly SOP.

The discussion of the first of these four proposals is more revealing

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* For non-Americans, SOP means Standard Operating Procedure.

than the actual statement. One paragraph is worth quoting verbatim:

> Many statements of work are quite weak on specifics, thereby leaving
> the contractor with virtually a free hand to construct a model that
> may not necessarily meet the user's requirements. Admittedly, some
> new developmental models can and should not be constrained. If the
> contract is actually awarded to advance a research area, then it
> should be so stated in the contract in order to ensure that both
> the user and the developer understand that model specifications
> are not being set at the start. Objectives of the model and accep-
> tance criteria must be stated at contract negotiation time. If
> these are unclear at negotiation time, then they must be developed
> and agreed to during the developmental process.

The actual proposal was in three parts, all of which I supported, the second
one strongly, reflecting the above paragraph. However, reservations are also
in order. For example, the phrases "explicit statement of ... scope and
objectives" and "technical and management approaches" were used. This must
not be interpreted too narrowly. If the sponsor can specify everything in
detail at the outset, he might just as well go ahead and do the job. The
third part had to do with a review team to determine if the model would have
any value. It is hard to believe that this is not done now but evidently such
is the case.

The second proposal in this set dealt with a suggestion from a GAO report
for a five-phase approach to the management of a model development project,
with each phase having a stop-go checkpoint. Nearly five pages of discussion
were devoted to this, it clearly being controversial. It would be tedious to
review it here in detail. The most important conclusion I reached was that
modellers had better get their house in order before some agency like the GAO
begins dictating our daily activities. Projects certainly have phases but the
GAO's concepts do not reflect reality. The idea that the Government should
develop some model management guidelines (the second part of the proposal
statement) is probably good. The problem definition phase proposed by the GAO
also had some merit but thereafter they made the false assumption that indivi-
dual parts can be completed separately. This is not so. One must expect
problems in developing a model. Initial designs may have to be modified time
and again as interactions between the growing parts indicate. The development
manager may have to make quick judgments when new insights reveal original
misconceptions or mistakes, and action must be immediate. What is needed is
a mechanism for penalizing a developer who does not manage and monitor his

project properly. The difficulty is in deciding who makes this judgment. (These comments more properly belong to project direction.)

The third proposal in this set was to upgrade the Government Contract Officier's (i.e. the sponsor's) Technical Representative (COTR), specifically to invest funds in training and development of a professional cadre of such people. I strongly supported this idea with the following reservations:

> The COTR should not participate in the developer's work, but should be competent to support, evaluate and criticize it, including enough managerial ability to make his criticisms effective. However, without a strong COTR, a project is much more difficult and prone to eventual misunderstanding. The COTR must be able to stand up to his own superiors as well as to the developer. Managerial ability is more important than depth of technical competence.

> Appropriate personalities for COTRs may be a scarce resource. Cost of training should not be a restriction when the right people are found. It will be money well spent.

The last proposal of these four sounded like it should be SOP. The statement and my comments follow:

(14)   Modelling project contracts should require the model developer to submit periodic status reports that compare the project technical and financial plans to actual accomplishments. These reports would be used by the COTR to monitor better the progress of a project and to aid the developer in justifying any deviations.

(on 14)   In commercial contracts I have carried out, this was SOP. While it may sometimes seem a nuisance, it is actually good discipline. Although perhaps initially keyed to milestones, status reports should reflect what has really happened. They are both a protection and an important managerial tool for both the developer and the COTR. They also help maintain contact between the two and interest by the sponsor. Where there are multiple developers or technical consultants on a large project, coordination is difficult at best and regular status reports would appear indispensible.

PROJECT DIRECTION

I make some distinction between administration and management, and project direction, even though the latter has elements of the former. The two were not clearly distinguished in several proposals but one dealt specifically with an important element of project direction: verification and validation. The entire opening paragraph is worth quoting:

The basic requirements of all modelling efforts are that of verification, i.e., that the model does what the developer intended for it to do, and validation, i.e., results from the model conform in some acceptable degree to reality. Unfortunately, developers do not always carefully verify and validate their models. The suggestion here is for the contract statement-of-work to require that the model developer prepare a detailed verification and validation test plan, or provide reasons why this cannot be performed. It would also require that the developer's technical report include the description of and results from these tests. Depending upon what is appropriate for a particular case, these tests could include: internal functioning and interaction within a model; external consistency of generated output; comparison of generated output with empirical data; all reasonable combinations of computer program options; user interface with the computer program, etc.

The summary remarks following were essentially trivial and the actual proposal statement was weakened by the last sentence:

(7)   A detailed verification and validation test plan should be required of most modelling projects. The project reports should describe the results and their implications to the future use of the model. Exceptions to a detailed plan should be based on a model's complexity and proposed use.

Nevertheless, I strongly supported this proposal with the following comments:

(on 7)   Verification of a model is clearly part of the job; a delivery without verification is virtually fraudulent. However, there are limits to validation and hence verification cannot be 100%. (I have found and corrected bugs in software systems that have been in wide and satisfactory use for as long as 7 or 8 years.) The extent of validation and the criteria for acceptance should be spelled out either in the RFP or as part of an early stage of the project.

The most satisfactory validation is probably comparison between two approaches. This is not always possible and may be expensive. Judgment of results by knowledgable experts must nearly always be used, particularly for models with futuristic projections where rigorously defined ranges of variation and well-defined norms are lacking. Complexity is no excuse for excepting verification and some validation; on the contrary, they are then doubly important.

BETTER LIAISON

The idea of better liaison between various groups involved in modelling came up in different ways in three proposals. The first one, I believe, was very good and extremely important, possibly the crux of the whole area of difficulty: the relationship between the model user and developer. This proposal started out with an interesting observation:

> An NSF survey showed that models developed inside Federal agencies or by contract with for-profit orgainizations were much more often used for policy purposes than models developed for the Government by other groups, e.g., universities. This suggests, perhaps, that the usefulness of a model may be enhanced if the designated user agency were more involved in the model development. Thus, it may be possible to increase the usefulness of models developed externally by requiring the involvement of the ultimate user in the model development process.

The discussion continued as follows:

> The COTR should not be looked upon as a surrogate for the user (unless they are one and the same). The scope-of-work should stipulate who the ultimate user is to be, and require meetings and specification sign-offs by the user. Developers might argue that such a process would slow down the modelling effort. If this process results in a more useful model, however, the slower development might be worthwhile.

> When the idea for a model originates within a Federal agency and its source is at the policy level, the utilization rate is higher than for models that are originated externally.

The summary remarks were again trivial. The formal statement, which I strongly supported, was as follows:

(8)   Whenever possible, the ultimate user(s) of a model should be indicated in the RFP statement of work and the project plan require meetings between the model developer and user(s). The purpose of these meetings would be to aid the model developer in designing the model to meet user requirements.

The substance of my comments follow:

(on 8)   It is essential that the developer know the type of user and have direct contact with at least a sampling of such users. I have long and bitter experience in this regard. When computer manufacturers began to supply elaborate software and to contract out its development, they deliberately interposed an opaque wall between the outside

developer and the users (the manufacturer's customers). This hurt
everyone concerned and slowed progress in various application fields.
There is seldom a single "right" way to arrange operational, control
and reporting details. Indeed, there are classes of approaches and
the choice should be based on the expected style of usage. The
question of operational efficiency must also be decided in this context.

All the foregoing is in consonance with Buz Holling's reports and other similar
opinions expressed here. Note that the question of influencing decision-makers
is essentially involved.

The second proposal in this set was outside my competence to decide but
the discussion made the same observation as before and introduced useful
terminology:

> A NSF survey showed that models developed inside Federal agencies
> or by contract with for-profit organizations were much more often
> used for policy purposes than models developed by universities and
> not-for-profit institutions. This survey hypothesized that the
> "distance" between the developer and policy maker is one of the
> primary obstacles to use.

The summary remarks for this proposal were richer than in most cases but I
will omit them. The proposal proper was in two parts:

(10.1)   The Government should attempt to increase the model development
activities within Federal agencies, i.e., more models should be
designed and developed by Government analysts.

(10.2)   The current balance between internal and external model development
should be maintained.

I was undecided on both these but made the following comments:

(on 10)   I do not know the current balance or how realistic it would be to do
more development work in-house. My inclination -- based on varied
experience -- is to accept the conclusion of the NSF survey that
universities and not-for-profit organizations are less effective in
model development. I would be more brutal in explaining this,
however, particularly with respect to universities. R and D grants
to universities are viewed as a mechanism for subsidizing education
and educators, and not as a means for obtaining serious, practical
results. Whatever the merits of subsidies, the two purposes should
be clearly distinguished. Not-for-profit organizations are not so
easily categorized. Some are certainly first-rate and some are
essentially creations of the Government and should be close to their

sponsors. Perhaps not-for-profit organizations are able to maintain a higher level of independence and Government agencies do not like to listen to opinions which differ from their own. In any event, the problem of effectively assisting decision-makers — of actually influencing their decisions but for the better — is an extremely difficult and critical one for modellers and system analysts. In the long run, it may well be critical for the nation and the world.

After all, it doesn't seem to make too much difference who writes the salary checks for analysts, modellers and other researchers. The more important consideration is how well confidence between decision-makers and modellers can be built up and maintained. A study directed toward this question on a high plane without pre-judice should be very fruitful.

The third proposal in this set was for modelling forums of users and developers. It began with the following statement:

> Models in the areas of energy, economics, welfare, national and world resource allocation, etc. represent critical components of (...) decision-making processes. Researchers in these and other areas have recognized the need to strengthen the communication links between individuals, and for research centers to improve the validity (...) of their efforts.

This is more a horizontal liaison as opposed to the vertical liaisons of the preceding two proposals. Several supposedly successful conferences which led to establishment of permanent forums were cited. Some of the advantages and problems were discussed, particularly financing but with some suggestions for available help such as NSF and NBS. The actual proposal was in two parts:

(18.1) The Government should establish modelling forums that deal with specific application areas and/or methodologies that are of concern to (...) model sponsors and users.

(18.2) Whenever possible, a modelling forum should be organized with the support of the appropriate professional organizations and industrial groups.

I was undecided on both but made the following comments:

(on 18.1) I question the usefulness of these forums. Specific seminars, work-shops, summer schools (such as NATO sponsors) might be better. If a Modelling Research Center is established, it should take the lead in this area.

(on 18.2) Those who want to and can, will. What use is an opinion?

Others, no doubt, feel more strongly about the benefits of such forums.

USE OF REVIEW PANELS

There were two proposals in this group: one for a Model Post-Review Panel, one for a Model Ongoing Review Panel. Of the two, the second appears far superior although they do not serve the same purposes. It was not claimed that all models should have a post-review panel and one of the arguments against them generally was that the money would be better put in an ongoing panel. The chief advantages claimed for a post-review panel were:

(a) To protect potential users from misuse or use of a poor model.

(b) To provide incentive to the developer to do a good job, knowing he would be subject to a review.

(c) To give publicity to a worthwhile model.

There is some merit in the last two, particularly (c). The actual two-part statement of the proposal and my comments follow:

(11.1) Each model sponsor should determine if the proposed model will undergo a post-review by a panel. If yes, the model sponsor, independent of the developer, should establish the review panel and the ground rules under which they will perform the evaluation. If no, the reasons should be documented and become part of the project files.

(11.2) The decision whether a post-review panel will or will not be assigned to a model should be withheld from the model developer.

I opposed the first and strongly opposed the second:

(on 11.1) Although a post-review panel might serve a useful function in some cases, this would seem to have little to do with the project, per se. Post-mortems should be confined to a small, responsible group. Uninformed or unknowledgable publicity can do more harm than good.

(on 11.2) This would be sheer nonsense. A main value of a post-review panel would be to stimulate the developer to produce a better and more presentable product.

The discussion on ongoing review panels was about what one would expect. The summary remarks were essentially as follows:

(a) An ongoing review panel may be able to identify and correct poor modelling activities, thereby resulting in a more useful product.

(b) Having such a review panel would require the model developer to plan carefully and monitor the project.

(c) Having an ongoing review panel would increase the cost of the model-ling effort, as it would require project documentation and personnel

to support the panel's needs.

(d) Rather than supporting a committee of panelists, each of which might have only a casual part-time commitment to a particular model development project, it may be more effective to have a well trained and experienced COTR who spends a major portion of time monitoring a single project.

The actual proposal seemed strangely worded.   I was undecided but commented as shown below:

(12)   Each model sponsor should determine if the proposed modelling project should have an ongoing review panel. If yes, then contractual requirements for meetings should be made between the model developer and the panel.

(on 12)   First, the wording seems incorrect: the contract is not between the developer and the panel. Second, if the sponsor wants a review panel, he certainly can do so. I am opposed to them in most cases; they tend to make narrow judgments -- if they do anything at all. They work on incomplete information and can adversely affect a potentially excellent design by nit-picking before it is fully developed and presentable. In certain cases, however, a panel is useful. The sponsor must be competent to evaluate comments of panel members. Various management techniques may be required in sponsoring and monitoring any large project. A review panel is one possibility but singling it out as a preferred technique seems inappropriate.

In general, the proposals for review panels seemed to me to be further instances of passing the buck for failure to administer and manage projects properly.

CREATION OF SPECIAL CENTERS

There were three proposals in this group. The first two seem to me to be by far the worst of all and I vehemently opposed them. The third, on the other hand, was among the very best and I supported it equally strongly. I think these three proposals most clearly indicate the confusion existing in the whole subject. It appeared that the distinct differences in them had not been understood by prior study groups. I have also encountered this confusion in professional meetings, seminars and even here at IIASA. Indeed, it appeared already in project-initiation meetings here back in 1973 and 1974.

The three proposals were:

(15)   The Government should establish a central model clearinghouse that would be responsible for the collection and dissemination of model documentation and related materials.

(16)   The Government should establish a model testing center to which an agency may refer a model to undergo independent verification and validation.

(17.1)   The Government should investigate the need and value of a Government Modelling Research Center (GMRC).

(17.2)   The setting up of GMRCs is <u>not</u> in the best interests of the Government's modelling activities.

The summary remarks for (15) and my comments were as follows:

(a)   A clearinghouse would assist model developers, as it would reduce time and effort spent by researchers in attempting to identify related efforts and ideas.

(b)   A clearinghouse would assist model users in that they would be more aware of related models and comparable approaches, and would have a means of exchanging information between agencies.

(c)   The costs required for operating an additional bureaucratic operation such as a clearinghouse might well exceed whatever benefits that would be gained by users and model developers.

(d)   A clearinghouse may facilitate the dissemination of models of poor or unproven quality to users incapable of identifying flaws.

(on 15) One could write a long essay on what is wrong with this idea. It is difficult to state oppositions succinctly. The two advantages stated are deceptions; the two disadvantages are not the most important ones. Among the disadvantages are:

(i)   Such a collection would be a meaningless pot-pourri; a worst case of mixing apples and oranges.

(ii)   Such a clearinghouse would soon demand standardization of the worst sort: stereotyped forms which would not apply to any situation and would create endless confusion.

(iii) Requests for everything would be made by innumerable researchers. Reproduction and mailing costs would be enormous, the flood of paper outrageous.

(iv) No reasonable group could even classify all models, let alone be of any help to a legitimate requestor.

(v)   Ignorant perusal of lists would be used to prevent needed effort on the basis of "duplication of effort".

The discussion and summary remarks for (16) were mostly a re-hash of those from other proposals, the only fairly new one being:

> Operating a model verification and validation center may be costly. It may be difficult to find a staff with an appropriately wide range of skills, although a basic cadre could be supplemented by external experts.

My comments were as follows:

(on 16)   This is even worse than the clearing-house. To begin with, it is impossible of accomplishment. Secondly, assuming it could in some sense be done, how long would it take to get a model tested? Would it be withheld from use until tested? Would a "satisfactory" test constitute Government endorsement? It certainly will not be done by a group outside the Government unless they are well paid for it. One could keep a battery of large computers running; are such costs reasonable and, if so, would they in fact be authorized? Or would the testing agency be expected to get along with "access" to some Government installation? Who will give competent opinions on results; where will test data come from? Even though the idea may may sound great at first blush, it is really utter nonsense.

One of the arguments against (17) I found surprising:

> The bureaucratic aspects of a GMRC are overwhelming. The Government would be better off encouraging each agency to increase and improve its modelling research activities.

This reveals either a complete misunderstanding or an attempt to divert attention by someone with vested interests. My comments were lengthy but I will include them here anyway:

(on 17)   The bureaucratic aspects are no worse than for, say, NBS, certainly less than for GAO's phased approach. The idea of a GMRC is entirely different from a clearing-house or a testing center. Of course, a GMRC could become a big boondoggle but hopefully not. The first and most important prerequisite is that it NOT be run by a university or in academic tradition. It would have need of the services of theoreticians and possibly studies by outstanding teams at universities but only for specific purposes and goals under very explicit contracts. Those who would wish to head developmental efforts in the GMRC must be part of its staff with administrative as well as technical responsibility. The goal must be to develop practical, workable modelling techniques, meaning computerization in a professional sense. There

should be an advisory board to help determine the most critical
needs and promising directions but also allowance for extensive
experimentation in an operational sense. The GMRC should develop
its own elaborate software systems, not for distribution, but to
facilitate R and D. It might offer computational services but this
would not be a primary goal.

The GMRC should become a leader and pathfinder, hold advisory seminars
on its findings, respond to requests for opinions, guidance and,
subject to its own approval, specific developmental tasks. This is
entirely different from monitoring, appraising, testing and distribu-
ting the work of others.

The management of the GMRC must be highly motivated, dedicated and
tough-minded. Projects must be directed toward specific goals and
realistically controlled while allowing fairly free rein to its own
staff to achieve these goals. It must have a business-like profession-
alism, and yet not be picayune in details.

The Government must do this if significant progress is to be made.
There is no real money to be made from developing models or modelling
techniques. It is expensive and no secure market exists. In the
long run, the GMRC would save the Government money and be valuable
to the private sector as well, but saving money is not the purpose.
The purpose is to advance the state of an art that is badly needed
in innumerable critical problem areas. By and large, the use of
mathematical models in the public sector is not now effective. It
must become so if we are to effectively grapple with the complexity
of today's problems. We may not like to admit it, but this is an
area in which free enterprise is simply inadequate.

Indeed, a first major task would be to simply collect, refine, coor-
dinate and integrate existing techniques which have great potential
but are inexpertly used. Even such a basic and old-hat technique as
linear programming is not expertly used in many places, and available
tools are not consistently taken advantage of. There also remain
many needed developments (even in this area) which can not be effect-
ively realized until a new plateau of system professionalism is attained.

(My remarks on location and reporting chain are not pertinent here.)

GENERAL OBSERVATIONS

There is an implication that either some set of improved management techniques must be devised to patch up unsatisfactory relationships and output, or else the Government must crack down on abuses. There may be some truth to this but many of the better suggestions seem like obvious things which ought to be in effect now — it is even hard to believe they are not.

Many of the discussions and proposals seem to overlook basic problems. For example:

1. Creation of an elaborate modelling capability is a very difficult and exacting task, requiring clear concepts about the nature and pitfalls of such an effort, together with tough-minded management. Why give contracts to groups who do not appear to have this experience and know-how?

2. Many theoretical concepts — though perhaps mathematically provable or even rather elementary — are not necessarily practical to implement. Even supposedly proven algorithms applied to purportedly reliable data may show instabilities or other unexpected difficulties. Such troubles must be expected and, if the effort is to result in something useful, corrections must be made regardless of original plans and specifications. (Apparently the GAO can't conceive of this.)

3. We are concerned with computerized models. This means some sort of application software. Such software, if it is to really do the job, must constitute a system and is, in effect, a complicated machine which will require man-machine interplay for its effective employment. In other words, a computerized model is a working model. Most analysts do not seem to understand this; they never experience interaction with the working model.

There is a fourth difficulty which was touched on in the discussions, namely, how to gain the confidence of decision-makers so that they really use models. But many analysts and model builders don't believe in their own models themselves, that is, as practical, usable mechanisms. They always treat them as a kind of patch-board prototype. Obviously the decision-makers want a more finished product. Working models require construction and operation. These are engineering and management jobs, not subjects for PhD dissertations.

This is not to deny that concepts, theories and erudite insights are the foundation of modelling — of course they are. There is a lot of physics behind

building a bridge but who would drive over a bridge built by a physicist. One wants a good bridge engineer and an experienced construction contractor. Unfortunately the computer has been made to look like something almost anybody can use but few use it well. Mathematicians bandy about algorithms and "new approaches" but most of them don't understand arithmetic, much less symbology and control logic, or the unending attention to detail that goes into a reliable software system. People who do understand these things must manage model development. Theoreticians should be consultants, not project directors.

Fundamentally, modelling and related activities are suffering from lack of a professional and well-organized technology, the kind that made the U.S. the leader in such things as commercial aircraft, computers, telephone systems and other high-technology items. Computerized, mathematical models are high-technology items and must be handled as such. Unfortunately, their intangible nature does not attract investment in the ordinary sense although some leading industrial corporations understand this and invest internally for their own use.

This is why I am so keen on a GMRC (or an international version). Only a government-funded agency of some kind can do the job that needs to be done. Otherwise there will never be a standardized and reliable technology. It may be an open question as to whether a government or supra-government agency is capable of initiating and operating the right type of organization. But it would be a "not-for-profit" par excellance and who else will do it?

I think the alternative is an increasing disenchantment with mathematical models and the analytical use of computers. If so, this would be to cast aside one of the greatest developments of all time, or more likely, to relegate it to a kind of irrelevant side activity, too fascinating to drop but too impractical to believe. We are almost at the point of being able to contribute significantly to critical national and global problems but some additional discipline must be imposed.

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