International Institute for
Applied Systems Analysis
www.iiasa.ac.at

Where Does the Tisza Go From Here?

Fiering, M.B.

IIASA Working Paper

1974

WHERE DOES THE TISZA GO FROM HERE?

M. Fiering

June 1974   WP-74-18

MEMORANDUM

To: Professors Letov, Dantzig, Raiffa   **Date:** 14, March 1974

From: M. Fiering

Subject: Where Does the Tisza Go From Here?

1) Before we deal with this question in a systematic way, we must specify the client for our work. There is, first of all, IIASA and its associated members. As the Tisza model is currently structured, or even if it is substantially elaborated, it would offer little benefit to water resource specialists from the United States, Canada, Poland, Hungary, the U.K., and both German Republics. I attach a document written nearly thirteen years ago by one colleague and one of my students; its publication is only slightly more recent. The techniques proposed at that time are similar to those in the current network model of the Tisza, and in some respects the earlier work contains hydrologic and engineering richness which our current model does not. Therefore the benefits of working with our model would accrue mainly to those among us who put it together and experiment with it. These benefits are not inconsequential, but there are probably easier ways to achieve the same results. In any case, the results of our elementary model study should not be published; if important advances are incorporated so that the model offers some new methodological insights, this position can always be reversed.

Another client for our work is that set of Hungarian agencies and experts who deal with the Tisza. It is hard to argue that a model of the Tisza, however realistic and complicated, could benefit these experts if such a model deals only with those reaches of the river which lie in Hungary. The consequences of other riparian users, must be taken into account if a model limited to the Hungarian portion of the system is to represent the prototype sufficiently well. Unless the system can be cleanly excised at its boundaries with the other riparian nations, it is hard to see how Hungary could benefit. I discuss this possibility below.

The third and last client is the collection of governments which comprise the Tisza region. A major study, which would encompass the entire basin, could presumably be undertaken by the next wave of water-resources staff. Spofford and Kindler are very experienced in this area, particularly with regard to non-linear models and large-scale simulations, but they will probably not remain with IIASA long enough to complete this work. Part of the difficulty is that water quality management is a major issue in such a large study; my experience suggests that such a topic requires a long warm-up time with respect to data collection and model evaluation, so that our best intentions might go astray.

The next sections deal with strategies which might be undertaken to serve alternate clients. The last section contains several recommendations with respect to these options.

2) Assume that IIASA is the client and that we wish to enrich the model from the point of view of its decision-making formalisms. I can identify 6 classes of complication which might be tried.

   a) Uncertainty could be explicitly included by following, or perhaps enlarging upon, the technique introduced by Harold Thomas and Peter Watermeyer, as explained in the attached paper. I strongly urge that all participants in the Tisza study should read the paper, after which I would be happy to participate with David Bell in organizing a session devoted to explaining any unresolved intricacies. It would be necessary to move from a network formalism to a general linear programming code. However, this should pose no hardship because I understand it is our intent to use a linear programming code in any case.

   b) Navigation and recreation benefits could be added to the model, as suggested in our meeting in Hungary. It is probably not wise to include any power benefits because variable head introduces non-linearities which unduly complicate the mathematics at this point. It is not only the fact that energy bears a non-linear relationship to discharge but also the notion that over a two-month time interval the head is likely to change over a range sufficiently great to invalidate the use of the initial head (prior to adjustment for withdrawals during the two-month interval) as a suitable

estimate of the head throughout the entire
interval. An iterative procedure is required
to converge to an intermediate head from
which the average energy can be deduced; this
will generally differ from the mean head.

Navigation and recreation uses can readily
be introduced by manipulation of flow con-
straints downstream of, and within, reservoir
nodes.

c) Constraints which reflect the various flow
and withdrawal requirements can be subject
to uncertainty by the introduction of chance
constrained programming. This is particularly
important with respect to consumptive with-
drawals and maintenance of low flows in the
channels. By systematically varying the target
levels of demands, we can show how different
operating rules are generated by various
security levels. Moreover, it might be possible
to identify abrupt changes in system response
at particular levels of reliability, thereby
justifying the establishment of one or another
level of security.

d) It would be useful to begin systematically to
identify water quality parameters for water
quality standards because it is clear that in
all but the most primitive resource systems
the mere maintenance of flow (adequate for
dilution) does not constitute pollution abat-
ment or management. It therefore becomes
necessary to formulate indices of water quality,
to route the various physical pollutants through
the system, and to impose standards within the
basin.

e) Finally, with an eye to actually implementing
the "enriched" model, it would be useful to
begin to identify potential sources of conflict
among the several users of the basin's water
resource. This includes not only the obvious
conflicts among the several nations, but also
potential conflicts between the various vested
interests within one region or country. It
would also be useful to begin systematically
to examine non-traditional alternatives for
quality and for flood control. These include
advanced treatment methods, bypass of treat-
ment facilities, in-stream treatment, and major
storage facilities on the Danube (upstream of

the confluence with the Tisza) to provide
flood storage while augmenting irrigation,
I lay special stress on this exercise
because it is through systematic examination
of such sources of conflict that we begin
to identify alternative objective functions
for system design.

The reason this is important is that we
might wish to utilize this Tisza model and
any subsequent simulation studies in a con-
junctive mode, which has been widely used
in water-resource engineering. For example,
major regional studies of the Tiber River
basin and of the Vega de Granada have
utilized linear programming models to define
optimal operation of existing or otherwise
predetermined systems and have selected from
these alternatives a small number of promising
designs for major simulation analysis. In the
Tiber study, important conflicts between water
qualitiy management and power generation were
identified by those interests who were charged
with the responsibility of constructing system
benefit functions. In some cases it is clear
that these issues can be resolved by legislation,
authoritarian dictate, or even compromise.
But in some the issues which separate the
parties are not based on perceptions of eco-
nomic gain but rather on system stability,
resilience and susceptibility to disastrous
outcomes. For these, a new calculus is re-
quired.

In the language of game theory, the criterion
function for identifying the optimal strategy
can be optimistic or pessimistic; one can chose
a strategy other than the classical equilibrium
strategy if it were desired to minimize the
probability of a poor outcome, to minimize the
extent of the worst possible outcome,etc.
These would lead to different mixes than those
ordinarily derived from the Minimax result.
It would be a useful exercise to vary the ob-
jective function not merely by assigning
different weights to the outcomes but rather
by prescribing the objective in quite different
terms; this would have the obvious advantage
of introducing into the Water Resources Project
some of the ideas which Holling and the Ecology
Group have developed.

f) Formulation of the problem in terms of conflicting
objectives enables us to give explicit consideration

to matters of quality and environmental
standards. Again the Tiber River study
provides a good example. In this work a
set of transfer coefficients was developed
for several reaches (or, in our language,
arcs) of the river along which water quality
was a consideration. For a given pattern
of waste inflow, the transfer coefficients
enable us to calculate the waste output at
critical locations or nodes, where quality
standards can be imposed. The calculation
is linear even though the biological decay
process are not. The development of this
coefficient matrix is described in the Tiber
River report which I have provided to
members of the Water Resources Project.
Professor Joseph Harrington, Harvard Uni-
versity, has written a computer program for
providing the coefficients from sparse data
on quality,and I am certain that this program
could be made available or, more effectively,
be run in the United States with data pro-
vided for the Tisza river system. In the
Tiber study this matrix approach to water
quality estimation was generalized for
inclusion in the simulation of the entire
basin, leading to important conclusions
concerning the quality of the estuary; I
could visualize that subsequent detailed
models of the Tisza would require major
hydraulic and sanitary calculations con-
cerning the possibility of back-water effects
and oscillatory surges at the confluence of
the Tisza and the Danube. The hydraulic
details of such a model might proved a useful
focus for the highly specialized expertise
of the member nations, while we provide the
over-all supervision and administrative
structure for utilizing the outputs. We are
not now, no can we be reasonably be expected
to be, staffed adequately to undertake this
form of computation.

3) Still considering that IIASA is the client, the model
can be enriched from a physical point of view.

a) We should undertake a more detailed study of
the extrema, floods and droughts, whose absence
was the basis of most of the objections raised
by our Hungarian colleagues. This will involve
two potential avenues: (i) a study of hydrograph
shapes to identify peaks and troughs in the flow
pattern, from which economic consequences can
be deduced, or (ii) direct regression (or other

functional) relationships between the mag-
nitude and extent of the extrema and their
economic consequences. We have alrealy
discussed these.

b) It is essential that we undertake a major
study of flood damages due to back-water
flooding in the lower reaches of the Tisza.
This flooding is not so much a function of
excess flow in the Tisza as of oscillatory
features relating to the confluence of the
Tisza and Danube. The use of dummy arcs to
represent conduits for excess flow during
flood season, with associated economic con-
sequences, is inadequate for this type of
flooding. We should devote considerable
effort to an appropriate physical mechanism
for incorporating this phenomenon in the model.

c) The Hungarian experts insisted that the major
physical and economic issues for day-to-day
water management in the lower reaches of the
Tisza turn on the relationships between
topography, drainage and runoff. We should
seek ways to incorporate these phenomena, if
possible, in our early models because their
exclusion would seriously compromise the
validity of the models and the ease with which
they might be implemented (even as screening
exercises). The major difficulty with direct
inclusion of such hydrologic and hydrodynamic
issues is that they occur very slowly, over
periods of months or even years, as compared
to the rate of flow in a channel. That is,
the time interval characteristic of the net-
work or linear programming solutions may be
incompatible with that for analyzing surface
drainage; this important issue has not
received adequate attention in the water re-
sources literature, and we might be able to
make a contribution here.

d) I think it unlikely that we will be able
further to complicate the model without
making it so cumbersome that it would no
longer serve as a screening technique. If
we choose to simulate the entire system, or
employ some more sophisticated methodological
procedure, it would be appropriate to intro-
duce realistic economic considerations, flood
routing procedures, reservoir operating
policies for flood management, and other
formalisms which have, to my knowledge, never
adequately been squeezed into a programming
formulation. This does not mean that we should
no try to do so, but rather that we recognize

it might be more fruitful, from the point of
view of water-resource experience, to move
along more certain lines. However, if the
Methodology Group perceives that there is
some prospect of finding more general or
powerful algorithms to embrace further compli-
cation, it might be a.useful parallel exercise
It should be emphasized that such a decision
must be taken outside the Water Resources
Group because, under any circumstances, there
would be little input that that group could
provide to face the methodological questions.

4) If the client is limited to our Hungarian colleagues, our
role would be to help abstract and represent, in convenient
form, the hydrologic and hydraulic issues which intersect
the Tisza system at its various national borders. That
is, if a regional study is not undertaken, we would have
to help develop the statistical analysis of <u>modified</u> flows
because we cannot obtain the virgin flows in the system.
The upstream storage and regulation units, operated by
riparian users, would distort the virgin flows so that the
system's hydrological inputs would be drawn from truncated,
strongly skewed, distributions. In consultation with our
colleagues, we would have to initiate a major data col-
lection program, and presumably would have to travel
widely throughout Hungary to consult with groundwater and
drainage experts in order to assess the data. The result-
ing model, probably a simple simulation study, would be a
hybrid or compromise between a mathematical programming
regime and a more sophisticated simulation of the entire
basin. Given the strenuous objections raised by the
Hungarians to the use of a gross model for determination
of daily operating procedures, we would surely have to
augment any programming or network analysis by a modest
simulation effort.

5) If the client is in fact the entire Tisza region, we would
have to undertake everything on a different scale. For
example, because the first Water Resources Research Con-
ference recommended against an international study, we
would have to present to the next Conference some
evidence that we are willing and able satisfactorily to
perform such a study. This would mean that it would be
necessary soon to begin laying the lines for successful
collaboration amongst the five countries involved.
Professor Raiffa has suggested that Dr. Tokhadze should
very soon undertake to contact the relevant agencies in the
several countries in order to determine what forms of co-
operation can be initiated. Assuming that everything goes
well, it would be necessary immediately thereafter for one
of us, presumably me, to travel with Tokhadze to the
several agencies in order physically to examine the data

which might have been promised. Experience shows that
agencies and bureaucrats are often willing to cooperate,
but that when it comes to producing actual records or
economic parameters, the system falls apart. All of this
would have been done very quickly to be sure that I
could complete it before my departure on July 1, and in
time to put it on the agenda of our conferences. It
should be recalled that Professor Kaczmarak told us the
other day that data collection and tabulation for the
Vistuala system in Poland required three years! There
was no institutional opposition, there was no language
problem, there was no difference in units of measure-
ment, and there was general agreement that this was a
useful study. And the data were primarily for use in
a simple programming model, not the sort of detailed
simulation at issue here. Nonetheless, three years
were required. It is my judgement that data collection
for such a Tisza study would require even more time,
which may suggest that we should undertake parallel
efforts: one devoted to furthering the analytical or
programming models, replacing "artificial" data with
real values as they become available, while at the same
time launching a major data collection enterprise and
formulating some of the conceptual properties of what-
ever (simulation) effort is to follow. Should the
simulation effort ultimately fail, we will have very
little to offer in terms of publication or dissemination
of the analytical model; on the other hand, we will
have something important to say about the feasibility,
even under optimal circumstances, of constructing a
model for studying a major international river basin.

6) I therefore recommend that we adopt a strategy for which
the analytical models currently under construction serve
a preliminary or screening function, that these models
be organized so as not to generate design alternatives but
rather to operate a manageably small set of pre-determined
alternatives, that we consult widely with our Hungarian
colleagues as to how a reasonable set should be
structured, and that we think about the long-range
planning process in a holistic way by encouraging Dr.
Tokhadze to advise us on the institutional feasibility
of such collaboration.