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CONSULTING REPORT

on

Grain Management Model and Systems Science Training

Based on a Field Trip to Seoul, Korea
June 16-29, 1974

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USAID Contract No. AID/csd-2975

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June 29, 1974

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PART I. GRAIN MANAGEMENT MODEL

Some Conclusiosn on GMP Activities Over the Next Several Months

In our conversations here it has become clear that getting the GMP together and to the point where even limited practical applications can be derived from it is a very large undertaking. The following steps and thrusts appear necessary to expedite this work:

i) In the next couple of months efforts should concentrate on getting existing components integrated, debugged, working together, and tested against real world data. New model development should include only changes and improvements which can be easily incorporated (See the statement "Grain Management Model - Some Areas for Further Model Development and Suggested Priorities" for a list of improvements it appears feasible to introduce now).

ii) Accomplishing this will require substantial time and effort. To keep the work moving it is important that Forrest Gibson be relieved of as much non-GMP work as possible. It is also important that he have substantial help. Claudia Winer is a very good person for this because of her background in systems as well as computer programming. Much of this work with Claudia can start when Forrest is in the U.S.

iii) Once the model has been assembled, tested and verified to some extent, some limited applications to policy questions should be possible. It will also be the time to get heavily involved in developing control mechanisms for the system. Some has decisions will have to be made about priorities at this point and these will affect the timing of the completion of the doctoral program.

Grain Management Model: Some Areas for Further Model Development and Suggested Priorities

Area	Comment
1) Lags in generation of aggregate prices.	Easy - should be included in 1st model version.
2) Lags in observation of market prices and price derivatives. (For feedback mechanisms).	Easy - should be included in 1st model version.
3) Inclusion of urban consumer stocks, etc., malnutrition.	Developed in rough form - should be included in 1st version.
4) Inclusion of producer area and yield responses.	Should be included in rudimentary form in 1st version. (Perhaps in response to net margin/ha).
5) Inclusion of rice/barley/IR 667 mix.	Desirable to handle in rudimentary form in 1st version. Handle more realistically later.
6) Accounting to get key performance variables.	High priority for 1st version.
7) Regionalization of production component.	Important but not for 1st version.
8) Response of private storage capacity to economic variables.	Important but not for 1st version.
9) Random disturbances in production; consumption.	Include in later model version.
10) Conversion to <u>real prices</u> in the model with base in an appropriate recent year.	Important and not too difficult - include in 1st version.
11) Incorporation of targets on rates of change of desired prices (and perhaps of desired stock lebels). This is in conjunction with feedback of $\frac{1}{p}$ etc.	Worth doing in 1st model version.
12) Model should be able to respond to various government policies on wheat-- Quantity of releases and government prices.	In 1st version.

Grain Management Model:

Equations for an Urban Consumption Component with Consumer Storage

Assume a Cobb-Douglas type demand function for improved realism over linear equations

$$1)\quad Q_i(t) = AO_i\ P_1^{\,t_{i1}}\ P_2^{\,t_{i2}}\ P_3^{\,t_{i3}} \left[\frac{CONSU(t)}{POP_u(t)}\right]^{\epsilon_{Ii}} * POP_u(t)$$

Q_i = demands for rice, barley, wheat

$CONSU$ = total urban consumption (from KASS model)

POP_u = urban population (from KASS model)

t_{i1}, t_{i2}, t_{i3} = price elasticities

ϵ_{Ii} = income elasticities

$$2)\quad AO_i = Q_i(0)/(P_{10}^{\,t_{i1}}\ P_{20}^{\,t_{i2}}\ P_{30}^{\,t_{i3}} \left[\frac{CONSU(0)}{POP_u(0)}\right]^{\epsilon_{Ii}} * POP_u(t)$$

$Q_i(0)$ = base consumption

P_{i0} = base prices

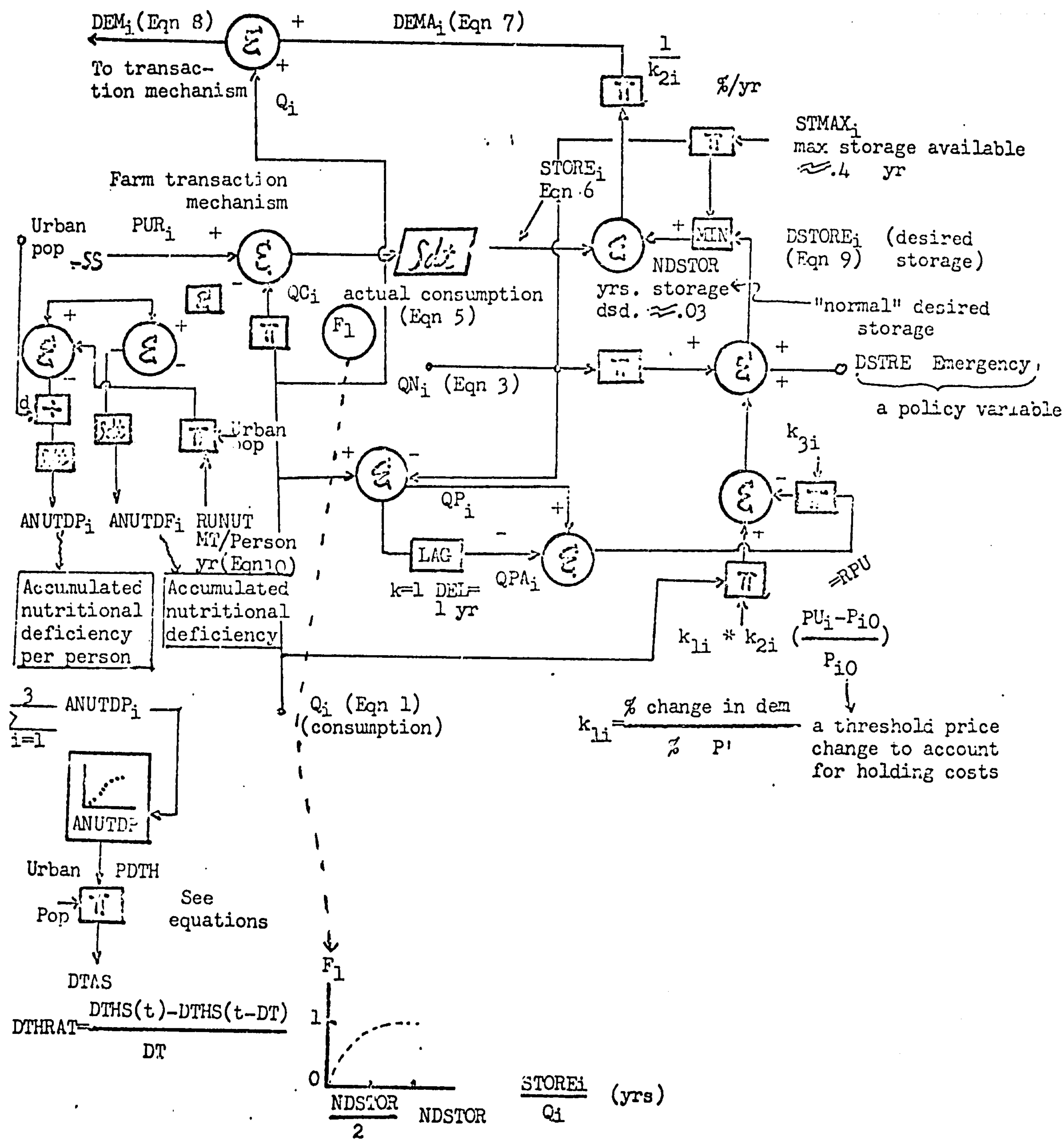
$CONSU(0)$ = base urban consumption

$POP_u(0)$ = base population

(This equation forces the demand curves through the base period consumption and price values).

$$3)\quad QN_i(t) = AO_i\ P_{10}^{\,t_{i1}}\ P_{20}^{\,t_{i2}}\ P_{30}^{\,t_{i3}} \left[\frac{CONSU(t)}{POP_u(t)}\right]^{\epsilon_{Ii}} * POP_u(t)$$

QN_i = "normal" consumption at fixed prices equal to base prices


DEMi (Eqn 8)
To transaction mechanism
DEMAi (Eqn 7)
1/k2i
%/yr
Qi
STMAXi
max storage available ≈.4 yr
STOREi Eqn 6
Farm transaction mechanism
Urban pop -SS
PURi
DSTOREi (Eqn 9)
(desired storage)
NDSTOR
yrs. storage dsd. ≈.03
QCi
actual consumption (Eqn 5)
F1
"normal" desired storage
QNi (Eqn 3)
DSTRE Emergency
a policy variable
Urban pop
k3i
QPi
ANUTDPi
ANUTDFi
RUNUT MT/Person yr (Eqn 10)
LAG
k=1 DEL= 1 yr
QPAi
≈RPU
Accumulated nutritional deficiency per person
Accumulated nutritional deficiency
k1i * k2i ((PUi-Pi0)/Pi0)
Qi (Eqn 1) (consumption)
k1i = % change in dem / % P'
a threshold price change to account for holding costs
ANUTDPi
ANUTDP
Urban Pop
PDTH
See equations
DTHS
DTHRAT= (DTHS(t)-DTHS(t-DT))/DT
F1
1
0
NDSTOR/2
NDSTOR
STOREi/Qi (yrs)

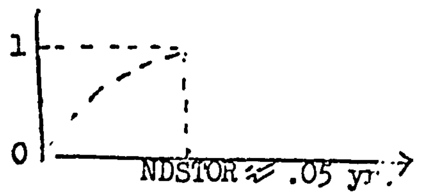
4) $QP_i(t) = Q_i(t) - QN_i(t)$

QP_i = change in demand due to price effects

5) $QC_i(t) = F_1 * Q_i(t)$

QC = actual consumption (constrained by the availability of stocks)

F_1 = a function defined below:



$$\frac{STORE_i}{Q_i} = \frac{\text{Consumer inventory (MT)}}{\text{Desired consumption (MT/yr)}}$$

NDSTOR = normal desired storage (years of consumption)

Some "ballpark" estimates of data for F_1:

F_1	$\frac{STORE_i}{Q_i}$
1	NDSTOR
1	.8 NDSTOR
.98	.6 NDSTOR
.9	.4 NDSTOR
.4	.2 NDSTOR
0	0

Equation (5) reduces consumption when consumer stocks are significantly below normal. This reflects consumer behavior in the event food becomes short in supply. It also precludes negative consumer stocks (STORE).

6) $STORE_i(t + DT) = STORE_i(t) + DT * (PUR_i(t) - QC_i(t))$

PUR_i = consumer purchases (from the transaction mechanism) — MT/yr

QC_i = actual consumption — MT/yr

$STORE_i$ = consumer stock — MT

Storage is managed by consumer ordering in proportion to the difference between desired and actual stocks:

7) $DEMA_i(t) = \frac{1}{k_{2i}} (MIN(DSTORE_i(t), STMAX_i * QN_i) - STORE_i(t))$

DEMA = demand to adjust inventory -- MT/yr

DSTORE = desired storage (See.Equation) -- MT

$STMAS_i$ = maximum storage capacity available (yrs of storage ≈ .4 yr)

k_{2i} = a parameter that determines the rate of inventory adjustment (k_{2i} ≈ .1 years)

Total demand is DEMA, the inventory adjustment, plus demand to satisfy normal consumption requirements

8) $DEM_i(t) = DEMA_i(t) + Q_i(t)$

Q_i = desired consumption (Eqn. 1) — MT/yr

Will now define desired storage (DSTORE used in Eqn. 7 in terms of its components)

9) $$DSTORE_i(t) = NDSTOR * QN_i(t) + DSTRE + k_{3i}*(QP_i(t) - QPA_i(t)) + k_{1i} * k_{2i} * \left(\frac{RPU_i - RPU_O}{RPU_O}\right) * QN_i(t)$$

where:

NDSTOR = normal desired storage (years of consumption)

QN = normal consumption defined by Eqn. 3

DSOTRE = Emergency storage desired in the event of pending food shortage

QP_i = change in demand due to price changes

$QPA_i(t+DT) = QPA_i(t) + (DT/DELPA) * (QP_i(t) - QPA_i(t))$

RPU_i = consumers estimate of rate of change of price -- \$/MT-yr

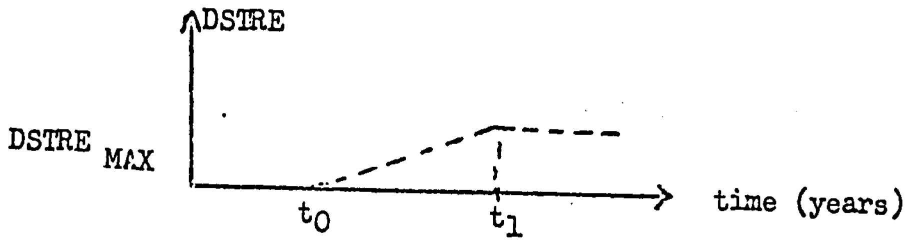
RPU_O = consumers cost of holding additional storage -- \$/MT-yr

$RPU_O \approx PU_i(t) * RI$ (RPU_O is approximately the commodity price times the real interest rate, RI).

The first term on the right of Eqn (9) is the normal storage (years of consumption) that consumers wish to have on hand (perhaps .03 yr). The third term augments desired storage by an additional amount which is based upon price changes and demand elasticities. This term introduces a decrease in desired storage if prices are higher than average and an increase in desired storage if prices are lower than normal. (Price changes have their effect upon the terms QP and QPA which enter Eqn (9). The value of k_{3i} in this term must be determined experimentally, however, a value of .1 might be a reasonable starting point). The fourth term in Eqn 9 introduces adjustments to desired storage when prices are rising on falling. The parameter k_{1i} corresponds to the % change in demand per percent rate of price change. Its value is on the order of one or less though it also will require experimental tuning when the model is run against historical time series.

Returning to the second term in Eqn 9 -- DSTRE. This term introduces an increase in storage as an emergency measure in the event of a pending food shortage. It can be used as a policy variable to determine the market and other consequences of increasing consumer reserves. A variety of time profites on DSTRE might be of interest.

One such appears below:



The model calculates urban nutrition and nutrition deficits as follows. Required grain intake is computed as

10) $RUNUT(t) = POPU(t) * GRPP$

RUNUT = required urban grain consumption -- MT/yr

POPU = urban population

GRPP = total grain required per person (rice, barley, wheat) -- MT/person-yr (≈.2)

Total grain consumption, TGC, is

11) $TGC(t) = QC_1(t) + .9 * QC_2(t) + QC_3(t)$

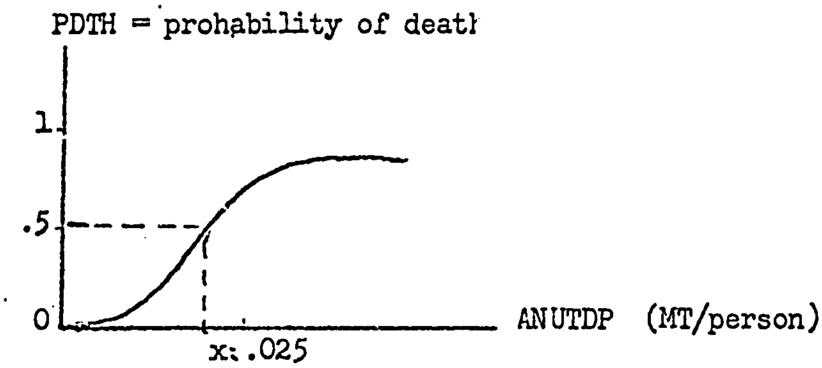
where QC_i is actual consumption calculated in Eqn 5 and the factor (.9) discounts barley consumption because of the lower nutritional value of barley. Accumulated urban nutritional deficit, ANUTDF computed as

12) $ANUTDF(t+DT) = ANUTDF(t) + DT * (RUNUT(t) - TGC(t))$ (MT)

Accumulated nutritional deficit per person, ANUTDP, is

13) $ANUTDP(t+DT) = ANUTDP(t) + DT * \left(\frac{RUNUT(t) - TGC(t)}{POPU(t)}\right)$ (MT/person)

Deaths due to malnutrition in the event of acute food shortage can be related to the accumulated food deficit per capita. One formulation that makes sense from a physiological point of view is to relate the probability of death by malnutrition to the variable ANUTDP. A typical function representing these variables appears below:



14) PDTH = TABLIE (VALPD, ... , ANUTDP)

A normal curve would be expected to represent differences in the physiology of individuals. However, since the curve applies to the entire urban population it would perhaps be warped to reflect a non-normal distribution of income (and ability to buy food). Clearly more work is needed here. The coordinats (.5, .025) on the above curve are roughly estimated from the knowledge that the average person can survive 1-2 months without food (a nutritional debt of about .017 to .034 MT of grain equivalent).

Since this curve is a probability density function it is clear that

15) $P_\lambda \left\{ \text{Death} \;\middle|\; A < \text{ANUTDP} < A+a \right\} = \text{PDTH}(A+a) - \text{PDTH}(A)$

and that hence

16) $P_\lambda \left\{ \text{Death} \;\middle|\; t_0 < t < t_0 + DT \right\} = \text{PDTH}(\text{ANUTDP}(t_0+DT)) - \text{PDTH}(\text{ANUTDP}(t_0))$

assuming that ANUTDP is monotonically increasing or constant.

We can therefore write·

17) $\text{DTHS}(t) = [\text{PDTH}(\text{ANUTDP}(t)) - \text{PDTH}(\text{ANUTDP}(t-DT))]\,\text{POPU}(t-DT)$

where DTHS(t) = the number of deaths that occur in the interval (t-DT,t)
We can therefore write for the urban population

18) POPU(t) = POPU(t) - DTHS(t) - DT * MIGO(t)

where:

POPU(t) = adjusted urban population to account for deaths and outmigration due to malnutrition

POPU(t) = unadjusted urban population (from KASS projections)

DTHS(t) = deaths in (t-DT,t) due to malnutrition

MIGO = out migration rate due to malnutrition (people seeking food in rural areas etc.) -- Person/yr

Total deaths due to malnutrition are simply

19) TDTHS(t) = TDTHS(t - DT) + DTHS(t)

It should be re-emphasized that this model of malnutrition and resultant deaths is based upon the assumption of an increasing food shortage (ANUTDP increasing). It therefore it simulates a once-only food crisis. The model is no longer valid if food supplies become more abundent and ANUTDP starts to decrease.

A Note on the Potential Use
of the KASS GMP Model in On-line Control

The following ideas are adapted from a paper by Michell Athous[1].
The scheme assumes a model that approximates the real world system to be controlled as shown in the figure below:

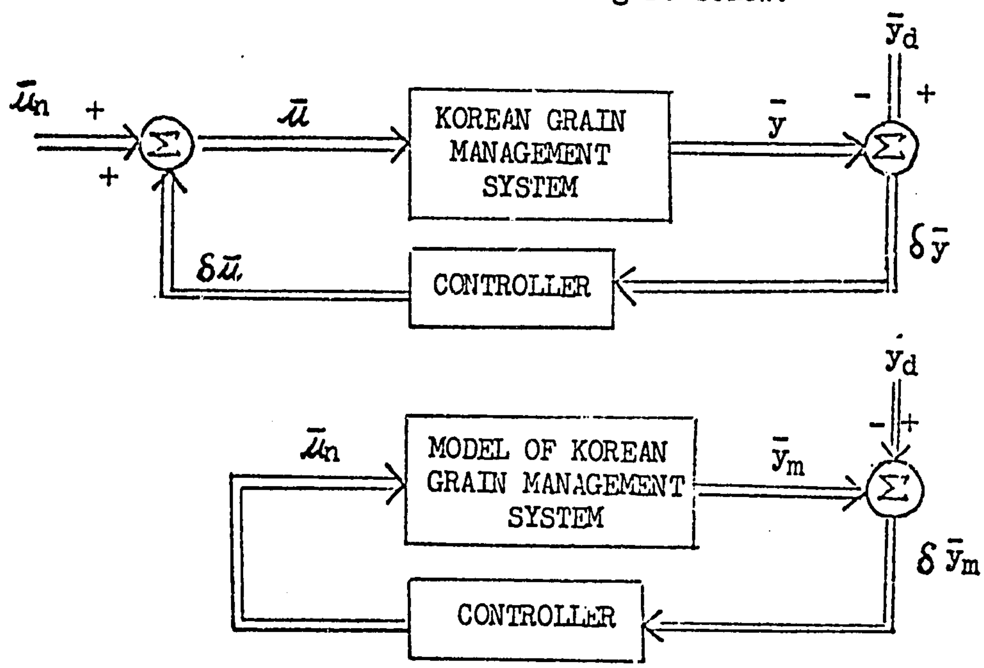


Figure (1)

On-line Control of Korean Grain Management System

1/ Auhous M., "The Role and Use of the Stochastic Linear-Quadraic-Gaussion Problem in Control System Design," IEEE Transactions on Automatic Control Vol. AC-16, NBR 6 Dec. 1971, pp. 529-552.

The variables in the figure are defined as follows:

$\bar{y}_d$ = desired values over time of the variables to be controlled — prices, stock levels and their rates of change, etc.

$\bar{y}$ = actual (real world) values over time of the variables in the y_d vector (usually distorted by observation errors).

$\bar{u}$ = the vector of real world control variables (government grain purchases and sales, imports, etc.).

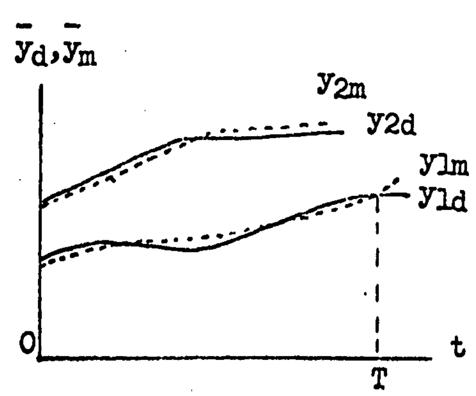
$\bar{y}_m$ = the vector of model outputs (there is a one-to-one correspondence between the elements of $\bar{y}$ and the elements of $\bar{y}_m$).

$\bar{u}_n$ = a vector of model control functions over time that will produce model outputs $\bar{y}_m$ over time that are "close to" the desired real world outputs $\bar{y}_d$.

The approach here consists of the following steps:

1) Initialize the model so that its state variables at t = 0 are nearly equal to the values of the corresponding real world states.

2) Operate the model over the desired time horizon (0,T) and find the set of control functions $\bar{u}_n$ that produce model outputs $\bar{y}_m$ that are "close to" the desired values $\bar{y}_d$. The figure below illustrates:



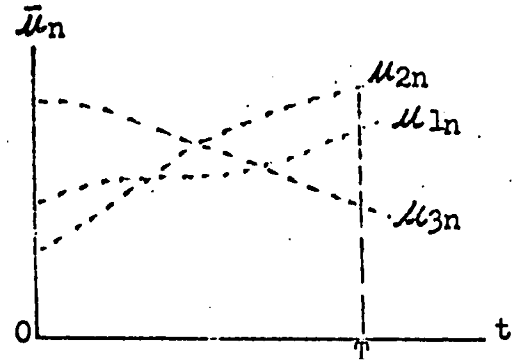


Figure (2)

This control vector $\bar{u}_n$ may be determined by trial and error, or better, by means of a (perhaps feedback) controller.

3) Steps 1 & 2 are performed on-line, however, and now use the control vector $\bar{u}_n$ on line as a set of prescriptions over time for the grain management system. As time evalues the real system output $\bar{y}$ will almost certainly not be equal to the set of desired values $\bar{y}_d$ giving rise to the error $\delta\bar{y}$ in Figure (1). This error is due to model error, measurement error in real world variables and other random disturbances which affect the real world system.

4) Step 4 involves computing a correction vector $\delta\bar{u}$ to apply to the real world system. This is done given δy and a controller designed using the system model.

In continuous on-line control the above steps are repeated as frequently as necessary to keep the system model "honest."

While conceptually straight-forward this approach will undoubtedly require considerable data and work to implement in the Korean grain management system. Athous (1) has much more to say about this and his article is well worth spending some time with.* The main advantage of the method as I see it is that it realistically deals with the fact that the system model is imperfect. The on-line feedback control is a practical may of dealing with this deficiency. I don't know of a better way to deal with this complex control problem.

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* Athous discusses application of optimal control theory and use of Kalman filtering to minimize observation errors in output variable measurements. Much of this may not be applicable in this complex system.

PART II. SYSTEMS SCIENCE TRAINING

Some Notes on Meetings to Discuss Availability of Korean System Science Personnel for KASS Work in Korea

Several promising sources of people trained in system science emerged. The more promising appeared to be the programming staff at KIST and the Korean Advanced Institute of Science. TWC has reported on two meetings I attended with Dr. Kim Dong Hi and others and I won't comment further on those. I will comment on a meeting I attended with Kim, Dong Hi and a Dr. Lee of the Industrial Engineering Department at KAIS.

Dr. Lee (the only Korean on the KAIS Industrial Engineering staff as the other three are now from Standford and U.C. Berkeley) reported that his department was very interested in expanding the scope of their applications to large socio-economic systems. Further, he reported that they would be interested in collaboration with NAERI to develop more experience and useful applications in the area of rural development.

In the ensuing discussion two possible means of collaboration between KAIS and NAERI emerged. One would be to set up an arrangement whereby one or more KAIS students, highly qualified in technical areas, could work with KASS personnel on a practical problem application. Ideally this arrangement could lead to a master's thesis for the KAIS student, further experience for KAIS in an important socio-economic area, progress on KASS work and persons with systems expertise who might be able to contribute to further NAERI work in the systems-simulation area. On the negative side it is my view that such an arrangement could only succeed if:

a) All persons engaged in the interdisciplinary project work were sufficiently broad to be able to communicate and interact effectively (many of these kinds of efforts have failed in the past because disciplinary specialists were thrown into a complex multi-disciplinary problem area before they were ready for it).

b) Experienced KASS systems people invest an appreciable amount of time to provide guidance and direction.

If these conditions can be met,this sounds like a great idea. A second proposed arrangement would be to send one or more KAIS Industrial Engineering students to MSU to participate in the 1 year Development Analysis Study Program. The students would take appropriate course work and write a master's thesis as part of the program. In one respect this approach would be more likely to succeed than the first, KAIS students would be "broadened" considerably by participation in the activities and selected courses of the D.A.S.P. On the negative side the student(s) would have restricted access to data and other information relating to the Korean problem they were addressing. This aspect could be minimized by close coordination with KASS before the student departs for the U.S.

In summary some form of interaction with the KAIS Industrial Engineering Department is well worth pursuing further.

A final comment. I was very pleased to hear that Mr. Lee Mu Shin is interested in KASS work and that Dr. Sung at KIST is amenable to some kind of a joint appointment arrangement with NAERI. Mr. Lee is the kind of person who would be a major asset to NAERI in my view. I'll take the responsibility of communicating with Mr. Lee when I get back to the U.S. and will keep KASS informed.

Attachment #1

MEMORANDUM

June 24, 1974

To: Training

From: Tom W. Carroll

Subject: Meeting on System Science Training

Present: Kim DH, Jones, Rossmiller, Manetsch, Carroll

1. Need for Ph.D. in System Science. Long lead time to start training from Bachelor's degree. Try to find candidate who has a good math background and has completed several years of graduate training. Possible sources: SNU/COA, KAIS, KIST.

2. Administrative arrangements need to be worked out to program candidate directly into NAERI or into consulting arrangement with NAERI.

3. Also try to find someone from SNU/COA faculty for one-year training program beginning in September.

4. Kim Sang Gee and Lee Sang Won will go into Development Analysis Study Program (DASP) at MSU on non-degree basis with conversion to M.S. program in systems science if they perform well. An Chang Bok will go for one year in the DASP and then return.

5. Kim Dong Hi will set up meeting with Park Chan Mo of KAIS and Sung Ki Soo of KIST to discuss possible candidates.