RESEARCH OF DECISION AND PLANNING ON THE DEVELOPMENT OF TIANJIN CAN INDUSTRY

——Application of System Dynamics

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ABSTRACT:

The paper analyses the system of Tianjin Can Industry using System Dynamics method. It puts foward suggestions to the development decision and planning of the seventh five year and the year 2000 of the Can Industry. The model simulutes and analyses emphatically the returns on various investment and the efficiency of various developing products, which should be a reference for the decision-maker.

A new idea of using Optimal Technology to optimize the System when the model simulation is carrying on is brought forth in the paper, and good results are obtained.

1. S.D. MODEL OF TIANJIN CAN INDUSTRY

Tianjin Can Industry lags behind other areas in China. That's quite improper according to the condition that Tianjin is in. So it's imperative to develop Tianjin Can Industry.

1.1 The Mechanism and Inner Structure of the Development of Tianjin Can Industry

Raising the economic efficiency is the guiding ideology of Tainjin Can Industry. More output, more taxes and profits for the state, more foreign incomes along with the demand of domestic market are the main goals of the development.

Investment is the main factor affecting the development.

Fig.1 shows the basic causal structure of the system.

1.2 S.D. Model of Tianjin Can Industry

The flow diagram of the system is estabished according to the causal relations. And, main equations between the factors are established from the statistical data and the experts' suggestions. Therefore, S.D. Model of Tianjin Can Industry is established. There are more than 300 factors in the model, in which, 20 level variables, 21 rate variables, others are auxiliary variables.

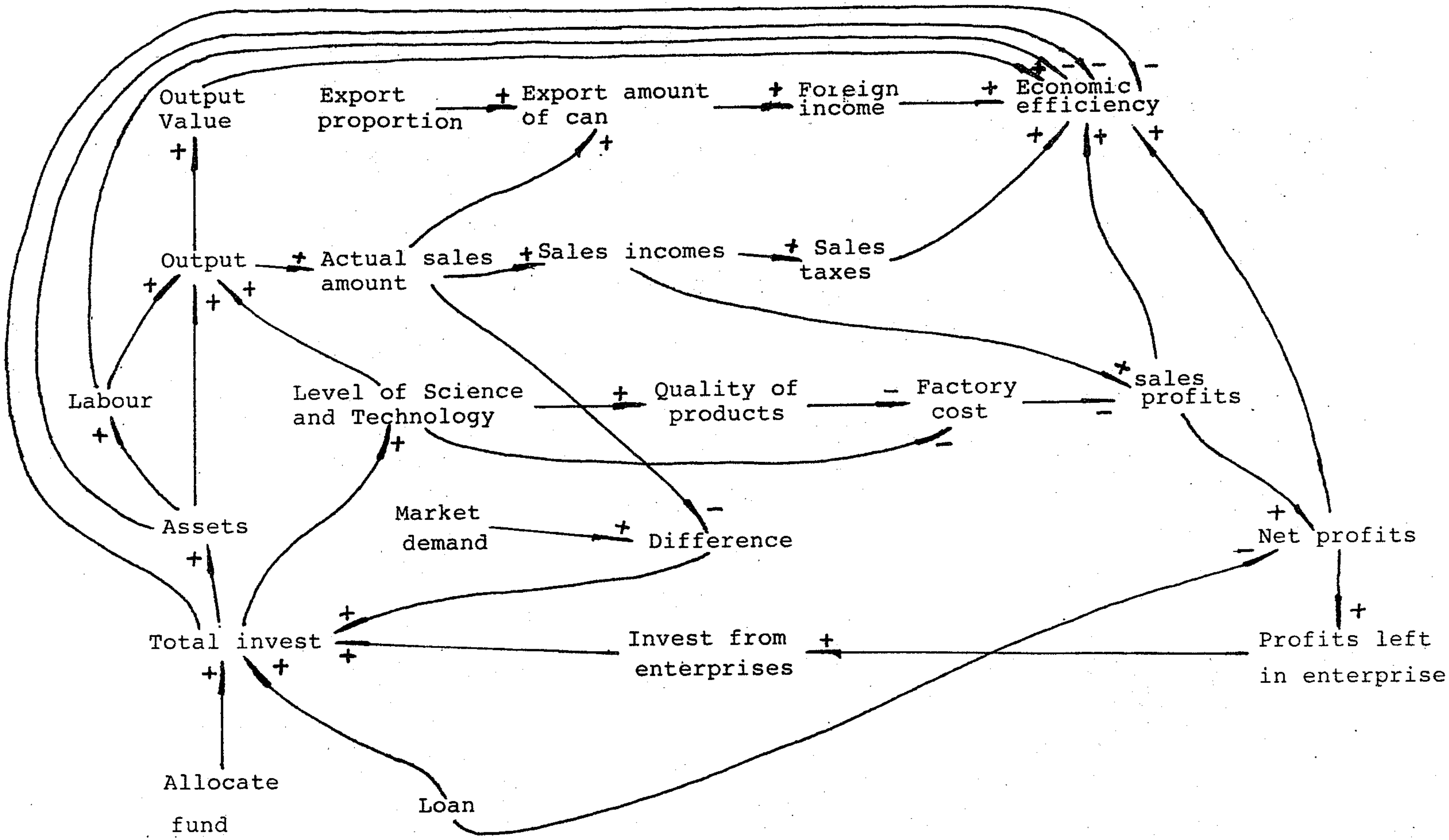


Fig.1 Basic Causal Structure of TIanjin Can Industry

1.3 Validity Verification of the S.D. Model

TABLE.1 gives relative error of some main factors, so as to verify the validity of S.D. Model.

Whether the set of the variables, causal relations and the equations between the variables are correct or not should mainly depend on whether the simulation results are proper and near to the real system or not. From TABLE 1, the relative error of every main variables is small, so the S.D. Model basicly describes the structure and function of the actual system. It lays a good foundation for the decision and planning of the seventh five year and till the year 2000 of Tianjin Can Industry below using the main structure of the S.D. Model.

2. COMBINING OF OPTIMAL TECHNOLOGY WITH S.D. SIMULATION METHOD

2.1 Combining of Optimal Technology with S.D. Simulation Method (first aspect)

S.D. Model is an approximate description of actual system. So, the S.D. Model itself can be considered to be the constraint condition. Combined with a specific optimal goal, the optimization is able to carry on.

From mathematical point of view, a S.D. Model is described as:

$$\begin{cases} \dot{q}_i=f_i(q_1,q_2,\cdots,q_n) \\ q_i=g_i(q_1,q_2,\cdots,q_n) \\ Q=[q_1,q_2,\cdots,q_n] \\ q_i(t_0)=q_{i0} \qquad i=1,2,\cdots,n \end{cases} \qquad \text{-------------(1)}$$

where: Q— the whole set of variables;
f_i— the contraint relation of i-th level variable ;
g_i— the contraint relation of i-th other variable ;
q_{i0}— initial value of q_i;
n— the number of all variables.

Assuming the objective function as follows:

$$\max J(Q) \qquad \text{-------------(2)}$$

So, the optimal model of optimal technology combining with S.D. simulation method is obtained:

$$\max J(Q)$$
$$\text{s.t.} \begin{cases} \dot{q}_i=f_i(q_1,q_2,\cdots,q_n) \\ q_i=g_i(q_1,q_2,\cdots,q_n) \\ Q=[q_1,q_2,\cdots,q_n] \\ q_i(t_0)=q_{i0}, \qquad i=1,2,\cdots,n \end{cases} \qquad \text{-------------(3)}$$

The way to optimize (3) is: a) take the S.D. model established to be the constraint condition—(1); b) Change certain changeable variables (i.e. decision variables) forming multi-plan decision-making; c) run the simulation model; d) obtain enough different variable sets of [Q]; e) at the same time, the objective variable set is assumed as Q_M, i.e. $\max J(Q)=J(Q_M)$,

TABLE1.1. Relative error of certain factors

F / E / YEAR	FAOV	TSW	ATSW	AFAOV	TAOC	FADA	FANV	AFANV	ACF	ACFP	AACFP	TAOMC	MCE	MCD	OCD
1976	0	0	3.612	0.008	1.126	8.500	4.778	5.658	0.118	0.200	0.350	1.133	1.142	1.126	1.123
1977	1.35	7.093	11.089	1.386	0.141	1.762	1.091	1.300	4.894	11.336	0.444	0.144	0.145	0.146	0.155
1978	0.858	31.980	25.757	0.8851	9.405	5.499	2.176	2.574	13.675	19.272	8.600	9.434	9.431	9.488	9.352
1979	5.508	7.103	6.940	3.288	12.146	2.035	10.352	12.232	7.130	4.777	10.816	12.422	12.419	12.412	12.431
1980	13.965	8.878	9.861	6.277	23.621	1.294	6.970	5.397	4.275	5.983	9.833	23.617	23.613	26.549	23.821
1981	13.200	1.468	6.760	4.869	11.146	0.876	20.289	4.647	3.609	4.095	22.004	11.149	11.145	11.205	11.185
1982	5.018	5.248	3.823	17.284	2.059	6.852	9.466	19.288	0.760	7.987	10.776	2.062	2.060	2.086	2.082
1983	9.365	7.614	6.299	4.545	6.960	3.114	13.631	8.281	6.789	13.051	3.395	6.963	6.958	6.983	6.774
1984	1.713	4.267	1.882	9.852	3.841	1.808	1.677	12.809	17.885	11.527	11.607	3.840	3.835	3.843	3.865
1985	1.680	2.060	4.400	0.5561	3.986	6.158	4.794	1.427	4.320	0.025	14.520	3.981	3.977	3.985	4.017
AVERAGE	4.266	7.51	8.032	4.895	7.47	3.79	5.522	7.367	6.346	7.825	9.236	7.475	7.473	7.782	7.481

f) Compute J(Q); g) if a certain set $Q_S \to Q_M$, then, the satisfactory variable set is Q_S. So, the satisfactory decision is to choose the plan corresponding to Q_S.

Because of the continuity of the actual system, and the finiteness of the actual changeable set Q, the satisfactory solution which is quite near to the optimal solution of (3) can be obtained after enough times of simulation tests.

It shows apparent advantages using model (3) established by combining Optimal Technology with S.D. simulation method. The satisfactory solution Q_S may be much more optimal than the pure optimal solution that gives by a optimal model (O.M.) that can be expressed in an explicit mathematical function and be able to obtain a pure optimal solution within the limit of the present mathematical optimization method. Because in the process of establishing O.M., it is probable that the abstract model itself has not been the actual system that to be optimized, the "optimal solution" is not the optimal solution of the actual system, thus " optimal" is in no position. Therefore, the above method of finding a satisfactory solution according to (3) is more valid in actual use for a complex actual system.

Applying the above method to the investment decision-making of the seventh five year and till the year 2000 of Tianjin Can Industry.

The objective function that judges between good or bad the investment decision should be is:

$$J=C_1*(\text{the rate of payment for investment}) +C_2*(\text{payment for investment}) -C_3*\text{ investment} \qquad (4)$$

where:

C_1, C_2, C_3 are weighting variables.

i.e.

$$J=C_1*\frac{\Delta ATOV}{AIFA} + C_2*ATOV - C_3*AIFA \qquad (5)$$

where:

ΔATOV— increase of output value of can products during the investment period

ATOV— output value of can products that has reached

AIFA— total invest during the period

Thus, the optimal model of the investment decision-making of Tianjin Can Industry is established as follows:

$$J=\max[C_1*\Delta ATOV/AIFA + C_2*ATOV - C_3*AIFA]$$

$$\text{s.t.} \begin{cases} q_i=f_i(q_1,q_2,\dots q_n) \\ q_i=g_i(q_1,q_2,\dots q_n) \\ Q=[q_1,q_2,\dots,q_n] \\ q_{i0}=q_i(t_0) \qquad i=1,2,\dots,n \end{cases} \qquad (6)$$

The constraint condition in model (6) is the S.D. model of Tianjin Can Industry already established. AIFA is considered as decision variable.

It is known by many times of simulation tests with various values of AIFA that with the increase of AIFA, the objective value J in model (6) appears peaks as shown in Fig.2. The task of the simulation tests is to try enough times of experiments within the feasible boundaries ($AIFA_1$, $AIFA_2$), so that the investment decision variable AIFA approaches the optimal investment decision variable $AIFA_m$, then the satisfactory solution——$AIFA_s$ is obtained, i.e. $AIFA_s \rightarrow AIFA_m$.

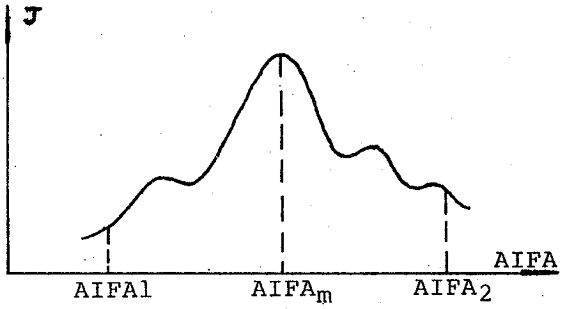


Fig.2. J—AIFA relation

The results of the optimal computation of 16 investment decision plans during the seventh five year and 19 investment decision plans till the year 2000 are shown in TABLE2, Fig.3 and TABLE 3, Fig.4.

TABLE2. 16 investment decision plans (seventh five year)

AIFA J	1.25 1715.9	5.00 1590.1	11.82 1857.8	10.00 1624.0	20.00 1726.1	30.00 1828.6	42.69 1953.7	42.89 1953.[illegible]
AIFA J	45.89 1954.5	48.88 1955.1	51.88 1955.5	54.88 1955.6	66.89 1954.4	90.89 1943.7	117.68 1921.0	138.8[illegible] 1716.[illegible]

TABLE3. 19 investment decision plans (till the year 2000)

AIFA J	148.14 3415.0	154.14 3397.9	161.64 3297.5	172.14 3315.4	175.14 3437.4	193.14 3344.2	196.14 3332.8	202.14 3309.7	202.14 3444.8	215.64 3443.9
AIFA J	226.14 3452.8	229.15 3440.1	238.15 3366.2	244.10 3340.1	256.14 3426.0	298.14 3435.1	310.15 3375.2	394.14 3349.3	418.15 3414.0	

From above TABLE 2 and TABLE 3, the satisfactory investment decisions are $AIFA_s$=54.88 (the seventh five year) and $AIFA_s$=226.14 (till the year 2000).

2.2 Conbining of Optimal Technology with S.D. Simulation Method (second aspect)

After the optimal simulation in 2.1, the satisfactory investment decision $AIFA_s$ is obtained. Then, further step is to plan the optimal proportional of the various products.

Suppose there are N various products, their quantity is $x_1, x_2, \cdots, x_N$, the optimal model is:

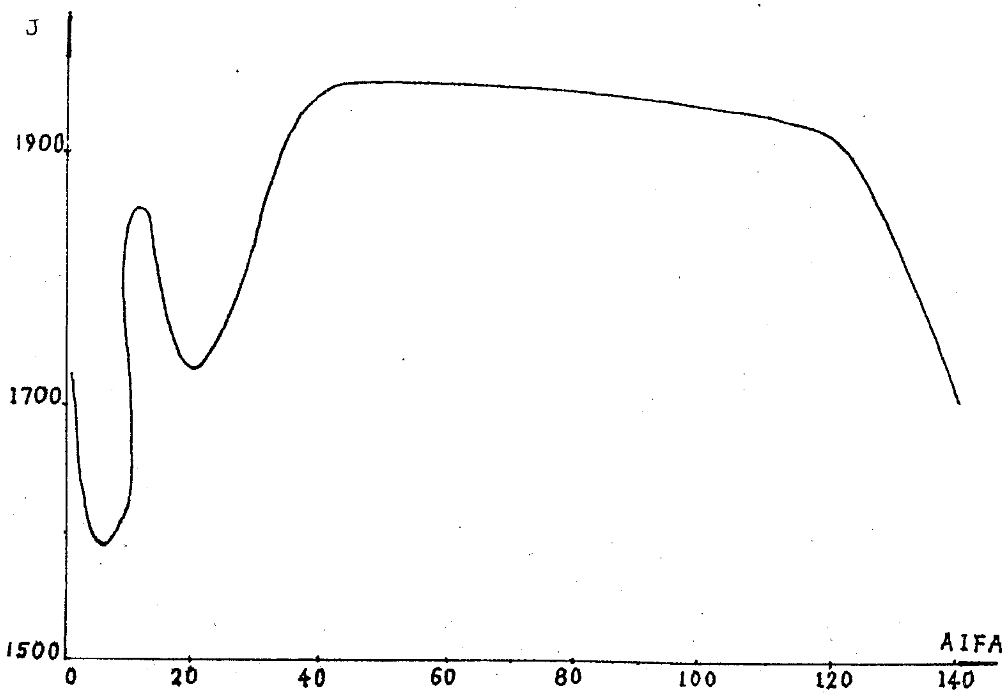
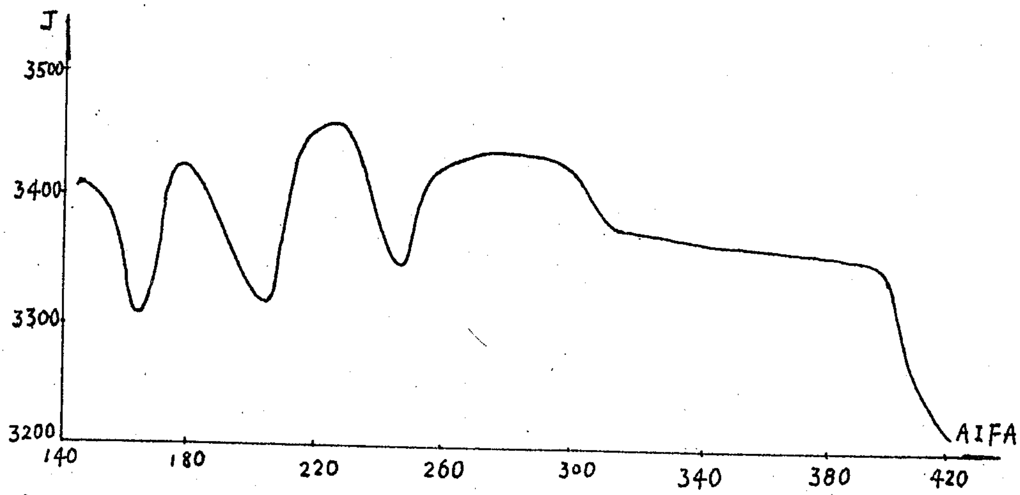


Fig.3 J—AIFA(the seventh five year)



$$\max J(x_1,x_2,\cdots,x_N)$$
$$\text{s.t.}\begin{cases} f(x_1,x_2,\cdots,x_N)\leqslant 0 \\ g(x_1,x_2,\cdots,x_N)\geqslant 0 \end{cases} \qquad \cdots\cdots\cdots\cdots(7)$$

Comparatively to the development plan of various products of Tianjin Can Industry, the following Linear Programming model is established.

J=max [D_1*(taxes and profits)+D_2*(foreign incomes)]
 =max [$C_Ax_1+C_Bx_2+C_Cx_3+C_Dx_4$]

$$\text{s.t.}\begin{cases} x_1+x_2+x_3+x_4 \leqslant b_1 \\ x_1+x_3 \geqslant b_2 \\ x_2+x_4 \geqslant b_3 \\ x_1+x_2 \geqslant b_4 \\ x_3+x_4 \geqslant b_5 \\ x_1 \geqslant b_6 \\ x_2 \geqslant b_7 \\ x_3 \geqslant b_8 \\ x_4 \geqslant b_9 \end{cases} \qquad \cdots\cdots\cdots\cdots(8)$$

where:

D_1,D_2 are weighting variables;
x_1 is quantity of meat can for export;
x_2 is quantity of meat can for domestic market;
x_3 is quantity of other can for export;
x_4 is quantity of other can for domestic market;
$C_A=D_1$*(profits and taxes per unit meat can for export)
  +D_2*(solds incomes per unit meat can for export);
$C_B=D_1$*(profits and taxes per unit meat can for domestic market
$C_C=D_1$*(profits and taxes per unit other can for export)
  +D_2*(sales incomes per unit other can for export);
$C_D=D_1$*(profits and taxes per unit other can for domestic marke

By anual optimal computation and S.D. simulation, the optimal development plan of various products can be obtained.

3. RESULT ANALYSIS AND COMBINED ASSESSMENT OF THE INVESTMENT DECISION AND THE PRODUCTS DEVELOPMENT PLAN OF TIANJIN CAN INDUSTRY

3.1 Result Analysis and Assessment of the Investment Decision

In order for the decision-maker to analize and compare the various investment plans and results of six various feasible investment plans (till the year 2000) that either reaches certain goals or invests complying with certain forms of investment are given by using the S.D. Model.

TABLE 4 shows the value of J in model (6) of the six plans, in which AIFA=226.14 is still corresponding to the maximumvalue of J. This further verifies the validity of the combining of the Optimal Technology with the S.D. simulation method (first aspect)

TABLE 4.Six feasible investment plans

AIFA	21.85	130.14	193.14	226.14	229.15	256.14
J	2152.7	3023.0	3239.2	3452.8	3440.1	3426.0

3.2 Result Analysis and Assessment of the Products Development Plan

TABLE 5 shows the gains of two development plans under the same investment. Proportional of various produts of one plan (A) is decided by experience, the other (B) is decided by optimization procedure using model (8).

TABLE 5.two various development plan of various products

YEAR	1986	1987	1988	1989	1990	1991	1992	1993
Taxes & Profits (Plan(B)-plan(A))	0.345	0.817	1.421	1.522	2.06	4.046	3.68	4.45
Foreign Incomes (Plan(B)-Plan(A))	1.92	4.33	10.04	8.01	10.69	27.41	19.57	28.31
YEAR	1994	1995	1996	1997	1998	1999	2000	TOTAL
Taxes & Profits (Plan(B)-Plan(A))	5.207	5.608	5.588	6.146	7.143	9.218	10.78	68.22
Foreign Incomes (Plan(B)-Plan(A))	33.55	33.21	36.40	44.01	56.26	62.26	69.44	445.7

It is known from TABLE 5 that the economic benifits of plan (B) is much higher than that of plan (A). Thus, it verifies that the Combining of Optimal Technology with S.D. simultion method (second aspect) is extremely valid.

4. CONCLUSIONS

4.1 The S.D. Model of TIanjin Can Industry provides the decision maker a decision-making laboratory that near to the actual system. And it can give tendency and forcasting results of many main variables under various different investment decisions.

4.2 The combining of Optimal Technology with the S.D. simulation method scientifically provides the decision maker a valid method to reach a certain system goal.

4.3 The connecting of DYNAMO with other computer language will be the further research.

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