h. IFI model.

The last example provided is not from the ICS. It represents a situation in a university department, IFI, teaching information sciences. The department offers exams after the first, second, third, fourth and advanced terms. From experience a certain fraction of students transfer from one term to the next while another fraction end their study of the subject. A third group remains because of inability to make their exams or wanting to improve their results. The problem is how to dimension the intake of new students without overloading the capacity. This problem can be conveniently studied by a simulation model.

Our model has 25 equations. The first ten equations represent constants defining the assumptions about transition and output fractions from the different levels. Also the number of total students which the teaching and working capacity permits (in our example 160 students) is one constant equation. There are 15 variable equations of which 5 is level equations (one for each term) and 10 rate equations for input and output to and from each level. The time unit, DT is one term=1/2 year and the simulation period runs from 1 to 20. The only equation which need some comments is the equation X 6 which explains the input to the first term. It is represented by a PULSE function which indicate that the first input is at the second time unit and that the repeating inputs are every second time unit and that the number of students accepted should be whatever is the positive difference between 160 and the number of students already accepted and not having left the department.

The simulation run tables indicate in the tables that the number of new students at the first level should be about 75 while the number of students from the advanced levels would be about 10 annually.
(*IFI MODEL*)

PROCEDURE MODEL;
BEGIN
C(1,1)=0.8; (*TRANSITION FRACTION TO SECOND TERM*)
C(2,1)=0.1; (*OUTPUT FRACTION FROM FIRST TERM*)
C(3,1)=0.7; (*TRANSITION FRACTION TO THIRD TERM*)
C(4,1)=0.2; (*OUTPUT FRACTION FROM SECOND TERM*)
C(5,1)=0.5; (*TRANSITION FRACTION TO FOURTH TERM*)
C(6,1)=0.4; (*OUTPUT FRACTION FROM THIRD TERM*)
C(7,1)=0.3; (*TRANSITION FRACTION TO ADVANCED TERMS*)
C(8,1)=0.6; (*OUTPUT FRACTION FROM FOURTH TERM*)
C(9,1)=0.3; (*OUTPUT FRACTION FROM ADVANCED TERMS*)
C(10,1)=160; (*INITIAL NUMBER OF STUDENTS*)

X(1,0,1)=86; (*INITIAL NO OF FIRST TERM STUDENTS*)
X(2,0,1)=10; (*INITIAL NO OF SECOND TERM STUDENTS*)
X(3,0,1)=60; (*INITIAL NO OF THIRD TERM STUDENTS*)
X(4,0,1)=4; (*INITIAL NO OF FOURTH TERM STUDENTS*)
X(5,0,1)=25; (*INITIAL NO OF ADVANCED TERMS STUDENTS*)

X(7,JK,1)=C(1,1)*X(1,1,JK,1); (*STUDENT INPUT TO 2ND TERM*)
X(8,JK,1)=C(3,1)*X(2,2,JK,1); (*STUDENT INPUT TO 3RD TERM*)
X(9,JK,1)=C(5,1)*X(3,3,JK,1); (*STUDENT INPUT TO 4TH TERM*)
X(10,JK,1)=C(7,1)*X(4,4,JK,1); (*STUDENT INPUT TO ADVANCED TERMS*)

X(11,JK,1)=C(2,1)*X(1,1,JK,1); (*OUTPUT FROM 1ST TERM*)
X(12,JK,1)=C(4,1)*X(2,2,JK,1); (*OUTPUT FROM 2ND TERM*)
X(13,JK,1)=C(6,1)*X(3,3,JK,1); (*OUTPUT FROM 3RD TERM*)
X(14,JK,1)=C(8,1)*X(4,4,JK,1); (*OUTPUT FROM 4TH TERM*)
X(15,JK,1)=C(9,1)*X(5,5,JK,1); (*OUTPUT FROM ADVANCED TERMS*)

X(2,K,1)=X(2,2,JK,1)+DT*X(7,JK,1)-X(12,JK,1)-X(8,JK,1); (*2ND TERM STUDENTS*)
X(3,K,1)=X(3,3,JK,1)+DT*X(8,JK,1)-X(13,JK,1)-X(9,JK,1); (*3RD TERM STUDENTS*)
X(4,K,1)=X(4,4,JK,1)+DT*X(9,JK,1)-X(14,JK,1)-X(10,JK,1); (*4TH TERM STUDENTS*)
X(5,K,1)=X(5,5,JK,1)+DT*X(10,JK,1)-X(15,JK,1); (*ADVANCED TERMS STUDENTS*)
X(6,K,1)=PULSE(1,2,2)*C(10,1)*X(2,2,JK,1)-X(3,3,JK,1)-X(4,4,JK,1)-X(5,5,JK,1)-X(11,JK,1)-X(7,7,JK,1); (*INPUT TO 1ST TERM*)
X(1,1,JK,1)=X(1,1,JK,1)+DT*X(6,JK,1)-X(11,JK,1)-X(7,7,JK,1); (*1TERM STUDENTS*)

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VI. Model size restrictions

The size of the model which can be run with SYSPAS depends on the computer capacity. The SYSPAS program can easily be adjusted to the computer environment by changing the following constants in the program:

- MAXVAR: maximum of variables
- MAXPAR: maximum of constants
- MAXTIME: maximum of time intervals
- MAXCHAR: maximum of characters per line
- MAXTAB: maximum number of TABLE functions
- WIDTH: width of each table column
- FRAC: decimals in each column
- MAXDEL1: maximum number of DELAY1 functions
- MAXDEL3: maximum number of DELAY3 functions
- TABCOL: maximum number of columns per table
- LINEWITH: number of y-values in plots
- MAXPLOT: maximum number of variables in each plot

The values used in the source listing in the next section are those used for producing the examples in the previous section.
VII. SYSPAS II source listing

PROGRAM SYSPAS2(INPUT,OUTPUT);
(*COPYRIGHT SVEIN NORDBOTTEN,1984*)

CONST MAXVAR=20;
   MAXPAR=20;
   MAXTIME=50;
   MAXCHAR=30;
   MAXTAB=5;
   MAXCOL=12;
   WIDTH=10;
   FRAC=2;
   MAXDEL1=3;
   MAXDEL3=3;

TYPE TIME=0..MAXTIME;
   XVAR=1..MAXVAR;
   MATRIX=ARRAY(XVAR,TIME) OF REAL;
   VECTOR=ARRAY(1..MAXPAR) OF REAL;
   STRING=ARRAY(1..MAXCHAR) OF CHAR;
   LIST=ARRAY(1..MAXVAR,1..MAXCHAR) OF CHAR;
   PLIST=ARRAY(1..MAXPAR,1..MAXCHAR) OF CHAR;
   TAB=ARRAY(1..MAXTAB,1..MAXCOL) OF REAL;
   DEL1=ARRAY(1..MAXDEL1) OF REAL;
   DEL3=ARRAY(1..MAXDEL3,1..3) OF REAL;

VAR TI,DT,TT,T,NVAR,NPAR,V,NTAB,NVAL,NS,I,II : INTEGER;
   SEED : REAL;
   J,K,L,JK,KL : TIME;
   A,CH : CHAR;
   NL : LIST;
   NP : PLIST;
   X : MATRIX;
   C : VECTOR;
   TABMAT : TAB;
   L1 : DEL1;
   L3 : DEL3;

PROCEDURE SPECIFICATIONS;
LABEL 31,32,33,34,35;
VAR MN :STRING;
BEGIN
   WRITELN('TYPE NAME OF MODEL(TERMINATE BY ","): ');
   I:=1;
   REPEAT
      READ(CH);
      MN(I):=CH;
      I:=I+1;
UNTIL (CH='.',') OR (I>MAXCHAR); READLN; WRITE(LP,'MODEL: '); I:=1; REPEAT WRITE(LP, MN(.I,.),','); I:=I+1 UNTIL I>MAXCHAR; WRITELN(LP); WRITELN(LP); 31:WRITELN( 'TYPE INITIAL, DELTA AND TERMINATION TIME:' ); READLN(TI,DT,TT); IF ((TT-TI)/DT>MAXTIME+1) THEN BEGIN WRITELN( 'TIME SPECIFICATIONS OUT OF RANGE' ); GOTO 31; END; WRITELN(LP, 'INITIAL TIME : ',TI); WRITELN(LP, 'DELTA TIME : ',DT); WRITELN(LP, 'TERMINATION TIME : ',TT); WRITELN(LP); WRITELN(LP); 32:WRITELN('TYPE NO VARIABLES:'); READLN(NVAR); IF (NVAR>MAXVAR) THEN BEGIN WRITELN( 'NUMBER OF VARIABLES TOO LARGE' ); GOTO 32; END; FOR V:=1 TO NVAR DO BEGIN WRITELN('TYPE NAME OF VAR NO *',V,'(TERMINATE BY ",")'); FOR I:=1 TO MAXCHAR DO NL(. V, I) = ' '; I:=1; REPEAT READ(CH); NL(. V, I,:) = CH; I:=I+1; UNTIL (CH='.',') OR (I>MAXCHAR); READLN; END; WRITELN(LP, ' LIST OF VARIABLES'); WRITELN(LP, '-----------------------'); WRITELN(LP); WRITELN(LP, 'ID: ',10,'NAME: ',12); WRITELN(LP); FOR V:=1 TO NVAR DO BEGIN WRITE(LP, V:10,' '); FOR I:=1 TO MAXCHAR DO BEGIN WRITE(LP, NL(. V, I,));
END;
WRITELN(LP)
END;
WRITELN(LP);
33:WRITELN('TYPE NO OF CONSTANTS:');
READLN(NPAR);
IF (NPAR>MAXPAR) THEN
BEGIN
WRITELN('NUMBER OF CONSTANTS TOO LARGE');
GOTO 33;
END;
FOR V:=1 TO NPAR DO
BEGIN
WRITELN('TYPE NAME OF CONST NO. ',V, '(TERMINATE BY ",",/')
FOR I:=1 TO MAXCHAR DO NP(*V,I)>:=CH
REPEAT
READ(CH);
NP(*V,I)>:=CH;
I:=I+1;
UNTIL (CH=',' ) OR (I>MAXCHAR);
READLN;
END;
IF (NPAR>0) THEN
BEGIN
WRITELN(LP,' LIST OF CONSTANTS');
WRITELN(LP, '---------------------');
WRITELN(LP);
WRITELN(LP,' ID: ',10,' NAME: ',12);
WRITELN(LP);
FOR V:=1 TO NPAR DO
BEGIN
WRITE(LP,V:10,' ');
FOR I:=1 TO MAXCHAR DO
BEGIN
WRITE(LP, NP(*V,I));
END;
WRITELN(LP)
END;
END;
SEED:=TT;
END;

PROCEDURE TABULATION;
LABEL 10,11,12;
CONST TABCOL=5;
TYPE COL=ARRAY(.1..TABCOL,) OF INTEGER;
VAR TV :INTEGER;
TC : COL;
TNAME : STRING;

BEGIN
11: WRITELN('DO YOU WANT RESULTS TABULATED (Y/N)?');
READLN(A);
IF A='N' THEN GOTO 10;
WRITELN('YOU CAN GET MAXIMUM ',MAXTAB,' VARIABLES IN '); 
WRITELN('EACH TABLE.');
WRITELN('TYPE NAME OF TABLE (TERMINATE BY ",",)',TC); 
FOR I:=1 TO MAXCHAR DO TNAME(I):=' ';
I:=1;
REPEAT 
READLN(A);
TNAME(I):='CH'; 
I:=I+1;
UNTIL (CH='.' OR (I>MAXCHAR));
READLN;
12:WRITELN('TYPE NUMBER OF VARIABLES IN THE TABLE?');
READLN(TV);
IF (TV>TABCOL) THEN
BEGIN 
WRITELN('NUMBER OF VARIABLES IN TABLE TOO LARGE');
GOTO 12;
END;
END;
FOR V:=1 TO TV DO 
BEGIN 
WRITELN('TYPE VARIABLE ID OF TABLE VARIABLE NO. ',V,'?'); 
READLN(TC(V));
END;
WRITELN(LP);
WRITELN(LP);
WRITELN(LP,' TABLE',TNAME);
WRITELN(LP,' ');;
WRITELN(LP);
FOR V:=1 TO TV DO 
BEGIN 
WRITE(LP,' VARIABLE ',V,'?'); 
FOR I:=1 TO MAXCHAR DO WRITE(LP,NL(TC(V,I),I));
WRITELN(LP);
END;
WRITELN(LP);
WRITELN(LP);
WRITE(LP,' TIME '); 
FOR V:=1 TO TV DO WRITE(LP,V:WIDTH); 
WRITELN(LP);
WRITELN(LP);
T:=0;
REPEAT 
WRITE(LP,TI+D*T;5); 
FOR V:=1 TO TV DO WRITE(LP,X(TC(V,T),WIDTH:FRAC));
WRITELN(LP);
PROCEDURE PLOTTING;

LABEL 20,21,22,23;

CONST LINEWIDTH=50;
MAXPLOT=5;

TYPE RANGE=ARRAY(1..LINEWIDTH) OF CHAR;

SYMBOL=ARRAY(1..MAXPLOT) OF CHAR;

PVAR=ARRAY(1..MAXPLOT,1..2) OF INTEGER;

BOUND=ARRAY(1..MAXPLOT,1,1) OF REAL;

VAR LC,CV :INTEGER;

B :BOUND;

AL :RANGE;

CNAME :STRING;

S :SYMBOL;

PV :PVAR;

BEGIN
21: WRITELN('DO YOU WANT PLOTTED RESULTS (Y/N):');

READLN(A);

IF A='N' THEN GOTO 20;

WRITELN('MAX.',MAXPLOT,' VARIABLES IN EACH CHART:');

WRITELN(LP);

WRITELN('TYPE NAME OF CHART (TERMINATE BY "","):');

FOR I:=1 TO MAXCHAR DO CNAME(I):=' '; 

I:=1;

REPEAT

READ(CH);

CNAME(I):=CH;

I:=I+1;

UNTIL (CH='.') OR (I>MAXCHAR);

READLN;

22:WRITELN('TYPE NO. OF VARIABLES IN CHART:');

READLN(CV);

IF (CV>MAXPLOT) THEN
BEGIN

WRITELN('NUMBER OF VARIABLES IN CHART TOO LARGE');

GOTO 22;

END;

FOR V:=1 TO CV DO
BEGIN

WRITELN('TYPE ID. OF PLOT VARIABLE NO. ',V,':');

READLN(PV(V));

END;

END;
23: WRITELN('TYPE SYMBOL TO REPRESENT THE VARIABLE:');
READLN(S(.V,));
IF (S(V,)="L") OR (S(.V,)="H") THEN
BEGIN
WRITELN("L" AND "H" UNACCEPTABLE SYMBOLS);
GOTO 23;
END;
WRITELN('TYPE LOWER AND UPPER BOUNDARIES:');
READLN(B(.V,1.),B(.V,2.));
END;
WRITELN(LP);
WRITELN(LP,'CHART: ',CNAME);
WRITELN(LP,'--------');
WRITELN(LP);
FOR V:=1 TO CV DO
BEGIN
WRITE(LP,'VARIABLE ',V,' : '); FOR I:=1 TO MAXCHAR DO WRITE(LP,NL*,PV*,I.),
WRITELN(LP,' SYMBOL: ',S(.V,));
END;
WRITELN(LP);
FOR V:=1 TO CV DO
BEGIN
WRITELN(LP,'VAR ',V,' LOW BOUND: ',B(MV,1.):WIDTH:FRAC,
HIGH BOUND: ',B(V,2.):WIDTH:FRAC);
END;
WRITELN(LP);
T:=0;
REPEAT
WRITE(LP,TI+DTX4,');
FOR LC:=1 TO LINEWIDTH DO AL( LC, ) := ' ';
FOR V:=1 TO CV DO
BEGIN
IF (X(PV(.V,),T,) >= B(V,1.)) AND (X(PV(.V,),T,) < B(V,2.)) THEN
BEGIN
LC:=1+TRUNC((LINEWIDTH-2)x(X(PV(.V,),T,) - B(V,1.))/(B(V,2.)-B(V,1.)));
AL(LC,):=S(.V,)
END ELSE
IF X(PV(.V,),T,) < B(V,1.)) THEN AL(V,1,) := 'L' ELSE
AL(.,LINEWIDTH,):="H"
END;
FOR LC:=1 TO LINEWIDTH DO WRITE(LP,AL(LC,));
WRITELN(LP);
TI:=TI+1;
UNTIL TI+DTX4>TT;
GOTO 21;
20: WRITELN;
END;

PROCEDURE TB(TBLN:INTEGER;X1,X2,X3,X4,X5,X6,X7,X8,X9,
BEGIN
IF (TABMAT(.TBLN,1.)=0) THEN
BEGIN
  TABMAT(.TBLN,1.):=X1;
  TABMAT(.TBLN,2.):=X2;
  TABMAT(.TBLN,3.):=X3;
  TABMAT(.TBLN,4.):=X4;
  TABMAT(.TBLN,5.):=X5;
  TABMAT(.TBLN,6.):=X6;
  TABMAT(.TBLN,7.):=X7;
  TABMAT(.TBLN,8.):=X8;
  TABMAT(.TBLN,9.):=X9;
  TABMAT(.TBLN,10.):=X10;
  TABMAT(.TBLN,11.):=X11;
END;
END;

FUNCTION STEP(HEIGHT:REAL;STTIME:INTEGER):REAL;
BEGIN
  IF (T>=STTIME) THEN STEP:=HEIGHT ELSE STEP:=0.0
END;

FUNCTION TABLE(TBLNO:INTEGER;X,MINV,MAXV,INT:REAL):REAL;
VAR CLN :INTEGER;
BEGIN
  IF (X<MINV) THEN XI=MINV;
  IF (X>MAXV) THEN XI=MAXV-0.00001;
  CLN:=TRUNC((X-MINV)/INT)+1;
  TABLE:=TABMAT(.TBLNO,CLN.)+(TABMAT(.TBLNO,CLN+1.)-
    TABMAT(.TBLNO,CLN.))*((X-MINV)-(CLN-1)*INT)/INT;
END;

FUNCTION DELAY1(D1NO:INTEGER;RO,D:REAL):REAL;
VAR R1:REAL;
BEGIN
  R1:=L1(.D1NO,.)/D;
  L1(.D1NO,.):=L1(.D1NO,.)+DT*(RO-R1);
  DELAY1:=R1;
END;

FUNCTION DELAY3(D3NO:INTEGER;RO,D:REAL):REAL;
VAR R1,R2,R3 :REAL;
BEGIN
  R1:=3*L3(.D3NO,1.)/D;
  R2:=3*L3(.D3NO,2.)/D;
  R3:=3*L3(.D3NO,3.)/D;
  L3(.D3NO,1.):=L3(.D3NO,1.)+DT*(RO-R1);
  L3(.D3NO,2.):=L3(.D3NO,2.)+DT*(R1-R2);
  L3(.D3NO,3.):=L3(.D3NO,3.)+DT*(R2-R3);
  DELAY3:=R3;

FUNCTION SMOOTH(SNO:INTEGER;R0,D:REAL):REAL;
BEGIN
  SMOOTH:=X(.SNO,T-1,)*(D-DT)/D+(R0*D/D);
END;

FUNCTION PULSE(X:REAL;ST,INT:INTEGER):REAL;
BEGIN
  IF (T-ST) OR ((T-ST)/INT=TRUNC((T-ST)/INT)) THEN
    PULSE:=X ELSE
    PULSE:=0
  END;

FUNCTION NOISE :REAL;
BEGIN
  SEED:=SQR(SEED+3,1415927);
  SEED:=SEED-TRUNC(SEED);
  NOISE:=SEED-1/2;
END;

FUNCTION NORMRN(E,S:REAL):REAL;
VAR SUM:REAL;I:INTEGER;
BEGIN
  SUM:=0;
  FOR I:=1 TO 12 DO SUM:=SUM+(NOISE+1/2);
  NORMRN:=S*(SUM-6)+E;
END;

FUNCTION XLAG(VN,LAG:INTEGER):REAL;
BEGIN
  IF (T- Lag<0) THEN XLAG:=0 ELSE XLAG:=X(.VN,T-LAG,)
END;

(*INCLUDE statement or MODEL procedure*)

(*MAIN PROGRAM*)
BEGIN
  SPECIFICATIONS;
  PAGE;
  I:=1;
  T:=TI+DT;
  REPEAT
    J:=I-1;
    K:=I;
    L:=I+1;
    JK:=I;
    KL:=I+1;
    MODEL;
    I:=I+1;
    T:=T+DT;
  UNTIL (I MAXTIME) OR (T>TT);
VIII. References

