General Algebraic Modeling System

GAMS

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GAMS Development Corporation

GOR Workshop "Modeling Languages"

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Change in Focus

Computation
Past

- **Algorithm limits** applications
- Problem representation is low priority
- Large costly projects
- Long development times
- Centralized expert groups
- High computational cost, mainframes
- **Users left out**

Model
Present

- **Modeling skill limits** applications
- Algebraic model representation
- Smaller projects
- Rapid development
- Decentralized modeling teams
- Low computational cost, workstations
- Machine independence
- **Users involved**

Application
Future

- **Domain expertise limits** application
- Off-the-shelf graphical user interfaces
- Links to other types of models
- Models embedded in business applications
- New computing environments
- Internet/web
- **Users hardly aware of model**

GAMS

Some Lessons From History

4 (c) Regional farmer employment accounting rows:

$$-RESr + 3 \sum_{d \in r} \sum_{q} dFLq + \sum_{d \in r} \sum_{t} dFLt = 0, \quad \text{each } r$$

$$-\left[\begin{array}{c}\text{Regional farmer}\\ \text{employment}\\ \text{activity}\end{array}\right] + 3\left[\begin{array}{c}\text{Sum over districts}\\ \text{and quarters of}\\ \text{quarterly farmer}\\ \text{employment}\end{array}\right]^{37}$$

$$+\left[\begin{array}{c}\text{Sum over districts}\\ \text{and months of}\\ \text{monthly farmer employment}\end{array}\right]^{37} = 0$$

1 (d) Total employment accounting row in man-years:

$$-12\,LMAN + \sum_{t} LMANt = 0$$

$$-12\left[\begin{array}{c}\text{Total employment}\\ \text{in man-years}\end{array}\right] + \left[\begin{array}{c}\text{Sum over months of}\\ \text{total employment}\\ \text{in man-months}\end{array}\right] = 0$$

12 (e) Total monthly employment accounting rows in man-months:

$$-2.2\,LMANt + \sum_{d} dDLt + \sum_{d} dFLq + \sum_{d} dFLt = 0,$$

each t and q such that $t \in q$

$$-2.2\left[\begin{array}{c}\text{Total}\\ \text{employment}\\ \text{in month } t\end{array}\right]^{38} + \left[\begin{array}{c}\text{Sum over districts of}\\ \text{day labor employment}\\ \text{in month } t\end{array}\right]$$

$$+\left[\begin{array}{c}\text{Sum over districts of}\\ \text{quarterly farmer}\\ \text{employment in the}\\ \text{quarter containing}\\ \text{month } t\end{array}\right] + \left[\begin{array}{c}\text{Sum over districts}\\ \text{of monthly farmer}\\ \text{employment}\end{array}\right] = 0$$

[37] In irrigation districts the quarterly contract device is used for farmers, but in non-irrigated districts farmers are assumed to be available on a monthly basis, so that seasonal migration to irrigated areas may occur.

[38] The activities for hiring farmers and day laborers are stated in units of tens of man-days per month (or quarter), and there are 22 working days per month; hence the conversion factor of 2.2 is required in the first term of this equation.

Table 3
Sequence of standard operations for cotton cultivation (days of unskilled labor, machinery services, and draft animal services required per hectare by month)

Cultivation month and operation	Mechanized		Partially mechanized			Non-mechanized	
	Unskilled labor	Machinery	Unskilled labor	Machinery	Animals	Unskilled labor	Animals
1st Preparatory tasks		0.12		0.12		1.0	2.0
Fallow		0.5		0.5		3.0	6.0
Cross-plowing						2.5	5.0
Harrowing		0.2		0.2		0.5	1.0
Land levelling		0.25		0.25		1.0	2.0
Canal cleaning	1.0		1.0			1.0	
2nd Irrigation ditches	1.0	0.2	1.0	0.2		2.0	2.0
Forming borders [a]		0.2		0.2		2.0	
Linking borders [b]	1.0		1.0				
Water application	2.0		2.0			2.0	
Harrowing		0.2		0.2		2.0	4.0
Seeding and fertilization	0.2	0.2	0.2	0.2		4.0	
Maintenance of field works		0.2	0.2			2.0	
3rd Thinning plants	4.0		4.0			4.0	
Cultivation		0.2	2.0		4.0	2.0	4.0
Weeding	6.0		6.0			6.0	
Applications of insecticides (2) [c]							

```
Y(248)'X(248)                                                                    COMPPB
  IF (X(248),LT,0,5,AND,X(248),GT,,00) Y(248)'Z(248,1)*(1+X(248))
Y(249)'X(249)                                                                    COMPIB
  IF (X(249),LT,0,5,AND,X(249),GT,,00) Y(249)'Z(249,1)*(1+X(249))
Y(250)'X(250)                                                                    COMNEI
  IF (X(250),LT,0,5,AND,X(250),GT,,00) Y(250)'Z(250,1)*(1+X(250))
Y(251)'X(251)                                                                    COMONE
  IF (X(251),LT,0,5,AND,X(251),GT,,00) Y(251)'Z(251,1)*(1+X(251))
Y(252)'X(252)                                                                    COMTWO
  IF (X(252),LT,0,5,AND,X(252),GT,,00) Y(252)'Z(252,1)*(1+X(252))
Y(253)'X(253)                                                                    COMTHR
  IF (X(253),LT,0,5,AND,X(253),GT,,00) Y(253)'Z(253,1)*(1+X(253))
Y(254)'X(254)                                                                    COMFOU
  IF (X(254),LT,0,5,AND,X(254),GT,,00) Y(254)'Z(254,1)*(1+X(254))
Y(255)'Y(266)+Y(267)                                                             COMFIV
Y(256)'X(256)                                                                    COMLCT
  IF (X(256),LT,0,5,AND,X(256),GT,,00) Y(256)'Z(256,1)*(1+X(256))
Y(257)'X(257)                                                                    COMLCG
  IF (X(257),LT,0,5,AND,X(257),GT,,00) Y(257)'Z(257,1)*(1+X(257))
Y(258)'X(258)                                                                    COMOLS
  IF (X(258),LT,0,5,AND,X(258),GT,,00) Y(258)'Z(258,1)*(1+X(258))
Y(259)'X(259)                                                                    CO 6-
  IF (X(259),LT,0,5,AND,X(259),GT,,00) Y(259)'Z(259,1)*(1+X(259))
Y(260)'X(260)                                                                    C-  -
  IF (X(260),LT,0,5,AND,X(260),GT,,00) Y(260)'Z(260,1)*(1+X(260))
Y(261)'Y(63)                                                                     EXPORT
Y(262)'X(262)                                                                    NETDII
  IF (X(262),LT,0,5,AND,X(262),GT,,00) Y(262)'Z(262,1)*(1+X(262))
Y(263)'X(263)                                                                    NETDFI
  IF (X(263),LT,0,5,AND,X(263),GT,,00) Y(263)'Z(263,1)*(1+X(263))
Y(264)'X(264)                                                                    WRKRMT
  IF (X(264),LT,0,5,AND,X(264),GT,,00) Y(264)'Z(264,1)*(1+X(264))
Y(265)'X(265)                                                                    NETTRN
  IF (X(265),LT,0,5,AND,X(265),GT,,00) Y(265)'Z(265,1)*(1+X(265))
Y(266)'X(266)                                                                    DFFCUR
  IF (X(266),LT,0,5,AND,X(266),GT,,00) Y(266)'Z(266,1)*(1+X(266))
Y(267)'X(267)                                                                    DFFCAP
```

```
   25     1     8     0     0     0     1      AGGREGAT
        0.12                    0.0165
ALA ALG ALV ARO AZU CAR CEG CHV FRI GAR JIT JON MAI MAT MEL P
PLU SAL SAN SOR SOT SOY TRI
     0.0286
      99999
AZU AZU    -0.25       1.0          0.0070     2627020.
JIT JIT    -0.4        1.0          0.1150     174752.
PEP PEP    -0.6        1.0          0.0590     19.
PLU PLU    -1800.      1.0          0.5770     85209.
CCC
CHI        1    -0.2
CHV         0.1500     14.459       1.0
FOR        6    -0.3
SOR         0.0630     285.818      1.0
CEG         0.0930     0.665        1.0
ALV         0.0100     226.109      1.0
ALA         0.0400     179.019      1.0
GAR         0.0990     1.427        1.0
MAI         0.0860     77.997       1.0
FEC        4    -0.3
FRI         0.1830     33.001       1.0
ARO         0.1220     126.197      1.0
PAP         0.0930     27.138       1.0
GAR         0.0990     0.158        1.0
GRA        2    -0.1
MAI         0.0860     132.804      1.0
TRI         0.0800     343.979      1.0
FRU        2    -2.0
SAN         0.0780     10.850       1.0
MEL         0.0680     6.9350        1.0
OLE        4    -1.2
SAL         0.0830     193.910      1.0
JON         0.2410     9.224        1.0
CAR         0.1550     72.490       1.0
SOY         0.1600     57.220       1.0
END
ALA         .02        0.0
ALV         .005       .006
ARO         .061       3.825
AZU         .0068      925.359
CAR         .155       2.126
CEG         .0463      .002
CHV         .0748      1.66
FRI         .1846      2.118
GAR         .1832      .019
JIT         .12        96.287
JON         .3981      .369
```

```
X,ASGHC1   R,,,GHC1          1,00000
X,ASGHC1   B,AS,,C1         -1,00000
X,ASGHC1   A,TRA             6,98400
X,ASGHC2   D,,,GH,N          0,31000
X,ASGHC2   R,,,GHC2          1,00000
X,ASGHC2   B,AS,,C2         -1,00000
X,ASGHC2   A,TRA             6,98400
X,ASGHC3   D,,,GH,N          0,33500
X,ASGHC3   R,,,GHC3          1,00000
X,ASGHC3   B,AS,,C3         -1,00000
X,ASGHC3   A,TRA             6,98400
X,ASGHAS   D,,,GH,N          0,20600
X,ASGHAS   R,,,GHAS          1,00000
X,ASGHAS   B,AS,,AS         -1,00000
X,ASGHAS   A,TRA             6,98400
X,ASGHS1   D,,,GH,P          0,15000
X,ASGHS1   R,,,GHS1          1,00000
X,ASGHS1   B,AS,,S1         -1,00000
X,ASGHS1   A,TRA             6,98400
X,ASGHCN   R,,,GHCN          1,00000
X,ASGHCN   B,AS,,CN         -1,00000
X,ASGHCN   A,TRA             6,98400
X,ASKSC1   D,,,KS,N          0,26000
X,ASKSC1   R,,,KSC1          1,00000
X,ASKSC1   B,AS,,C1         -1,00000
X,ASKSC1   A,TRA             7,56000
X,ASKSC2   D,,,KS,N          0,31000
X,ASKSC2   R,,,KSC2          1,00000
X,ASKSC2   B,AS,,C2         -1,00000
X,ASKSC2   A,TRA             7,56000
X,ASKSC3   D,,,KS,N          0,33500
X,ASKSC3   R,,,KSC3          1,00000
X,ASKSC3   B,AS,,C3         -1,00000
X,ASKSC3   A,TRA             7,56000
X,ASKSAS   D,,,KS,N          0,20600
X,ASKSAS   R,,,KSAS          1,00000
X,ASKSAS   B,AS,,AS         -1,00000
X,ASKSAS   A,TRA             7,56000
X,ASKSS1   D,,,KS,P          0,15000
X,ASKSS1   R,,,KSS1          1,00000
X,ASKSS1   B,AS,,S1         -1,00000
X,ASKSS1   A,TRA             7,56000
X,ASKSCN   R,,,KSCN          1,00000
X,ASKSCN   B,AS,,CN         -1,00000
X,ASKSCN   A,TRA             7,56000
X,ASDAC1   D,,,DA,N          0,26000
X,ASDAC1   R,,,DAC1          1,00000
X,ASDAC1   B,AS,,C1         -1,00000
X,ASDAC1   A,TRA             7,41600
```

```
      BRANCH      *           MAJERR

      NEXT

      REVISE      REV5        TAPE14
```

***** CARD READ SUMMARY ****

```
HEADER, CARD NO.      1    @NAME          REVA
HEADER, CARD NO.      2    @COLUMNS
HEADER, CARD NO.      3    @  MODIFY
HEADER, CARD NO.      6    @RHS
HEADER, CARD NO.      7    @  MODIFY
HEADER, CARD NO.     18    @ENDATA
HEADER, CARD NO.     19    @NAME          REV1
HEADER, CARD NO.     20    @COLUMNS
HEADER, CARD NO.     21    @  MODIFY
HEADER, CARD NO.     42    @ENDATA
HEADER, CARD NO.     43    @NAME          REV2
HEADER, CARD NO.     44    @COLUMNS
HEADER, CARD NO.     45    @  MODIFY
HEADER, CARD NO.     51    @ENDATA
HEADER, CARD NO.     52    @NAME          REV4
HEADER, CARD NO.     53    @RHS
HEADER, CARD NO.     54    @  MODIFY
HEADER, CARD NO.     68    @ENDATA
HEADER, CARD NO.     69    @NAME          REV5
HEADER, CARD NO.     70    @RHS
HEADER, CARD NO.     71    @  MODIFY
        CARD NO.     72    @    RHS1      CLA,V,01     5,03328
        CARD NO.     73    @    RHS1      CLA,V,02     5,03328
        CARD NO.     74    @    RHS1      CLA,V,03     5,03328
        CARD NO.     75    @    RHS1      CLA,V,04     5,03328
        CARD NO.     76    @    RHS1      CLA,V,05     5,03328
        CARD NO.     77    @    RHS1      CLA,V,06     5,03328
        CARD NO.     78    @    RHS1      CLA,V,07     5,03328
        CARD NO.     79    @    RHS1      CLA,V,08     5,03328
        CARD NO.     80    @    RHS1      CLA,V,09     5,03328
        CARD NO.     81    @    RHS1      CLA,V,10     5,03328
        CARD NO.     82    @    RHS1      CLA,V,11     5,03328
        CARD NO.     83    @    RHS1      CLA,V,12     5,03328
        CARD NO.     84    @    RHS1      CLA,V,TO    60,39936
HEADER, CARD NO.     85    @ENDATA
```

PRINT OPTION = COMPLETE OUTPUT W/SPECIAL TIVE = 28.18489
NAME = CENTRAL OBJ = OBJ RHS = RHS1 BND = LIMITS 1.0000 RPSRHS = 1.0000
DIR = MAXIMIZE COBJ = CRHS = RNG = 0.0000 RPCHRHS = 0.0000

NUMBER	NAME	TYPE	STATUS	COL ACTIVITY	OBJ COEF	D UPPER	MARGINAL
101	CBE1V..	PL	LOWER	.	-47.80000	+INF	-6.46851
102	CBE2F..	PL	ACTIVE	.00087	-701.00000	+INF	.
103	CBE3C..	PL	ACTIVE	.	-10330.60000	+INF	.
104	CBE4F..	PL	LOWER	.	-2429.70000	+INF	-912.25118
105	CBE5C..	PL	LOWER	.	-9418.00000	+INF	-2342.38642
106	CBE6C..	PL	ACTIVE	.	-5118.00000	+INF	.
107	CBE7C..	PL	ACTIVE	.06067	-13.20000	+INF	.
108	CSG.V..	PL	ACTIVE	.	-231.57000	+INF	.
109	CSG.F..	PL	ACTIVE	.00226	-231.57000	+INF	.
110	CPD.V..	PL	ACTIVE	.	-139.67000	+INF	.
111	CPD.F..	PL	ACTIVE	.00002	-139.67000	+INF	.
112	CPD.C..	PL	ACTIVE	.00045	-139.67000	+INF	.
113	CEG.V..	PL	ACTIVE	.	-76.71000	+INF	.
114	CEG.F..	PL	ACTIVE	.00025	-76.71000	+INF	.
115	CEG.C..	PL	ACTIVE	.00128	-76.71000	+INF	.
116	CDA.CX.	PL	ACTIVE	.07685	12.91000	+INF	.
117	CDF.CX.	PL	LOWER	.	180.74000	+INF	-87.19134
118	CDC.CX.	PL	LOWER	.	167.83000	+INF	-256.39963
119	CDS.CX.	PL	ACTIVE	.06968	121.35000	+INF	.
120	CDL.CX.	PL	ACTIVE	.00225	91.66000	+INF	.
121	CWS.CX.	PL	ACTIVE	.00606	109.74000	+INF	.
122	CWL.CX.	PL	ACTIVE	.00748	77.46000	+INF	.

PLANNING PROBLEM AND OBJECTIVES INITIALLY OFTEN

UNSTRUCTURED

ILL-DEFINED

CONFLICTING

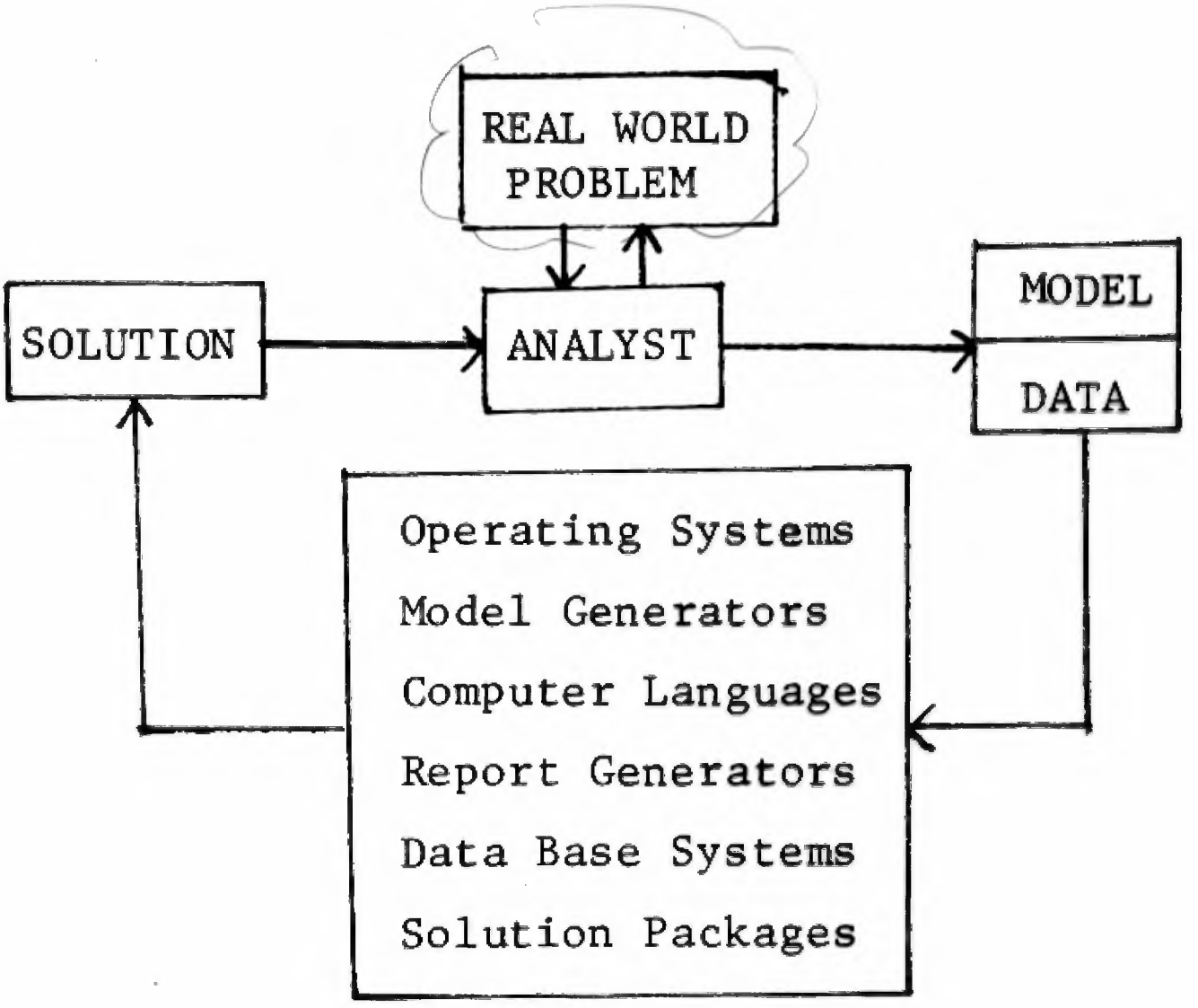
UNCERTAIN

CHANGING

EMOTIONAL

MATHEMATICAL MODEL USED TO RECOGNIZE AND FORMULATE PROBLEMS, DEFINE ISSUES AND EXPLORE SOLUTION SPACE

PRESENT TECHNOLOGY



RESULT: - Drain of resources (technical, time, money)

- Essentially no documentation

MAJOR CONSTRAINTS : COST

SKILLS

TIME

TOOLS

DOCUMENTATION

TRUST

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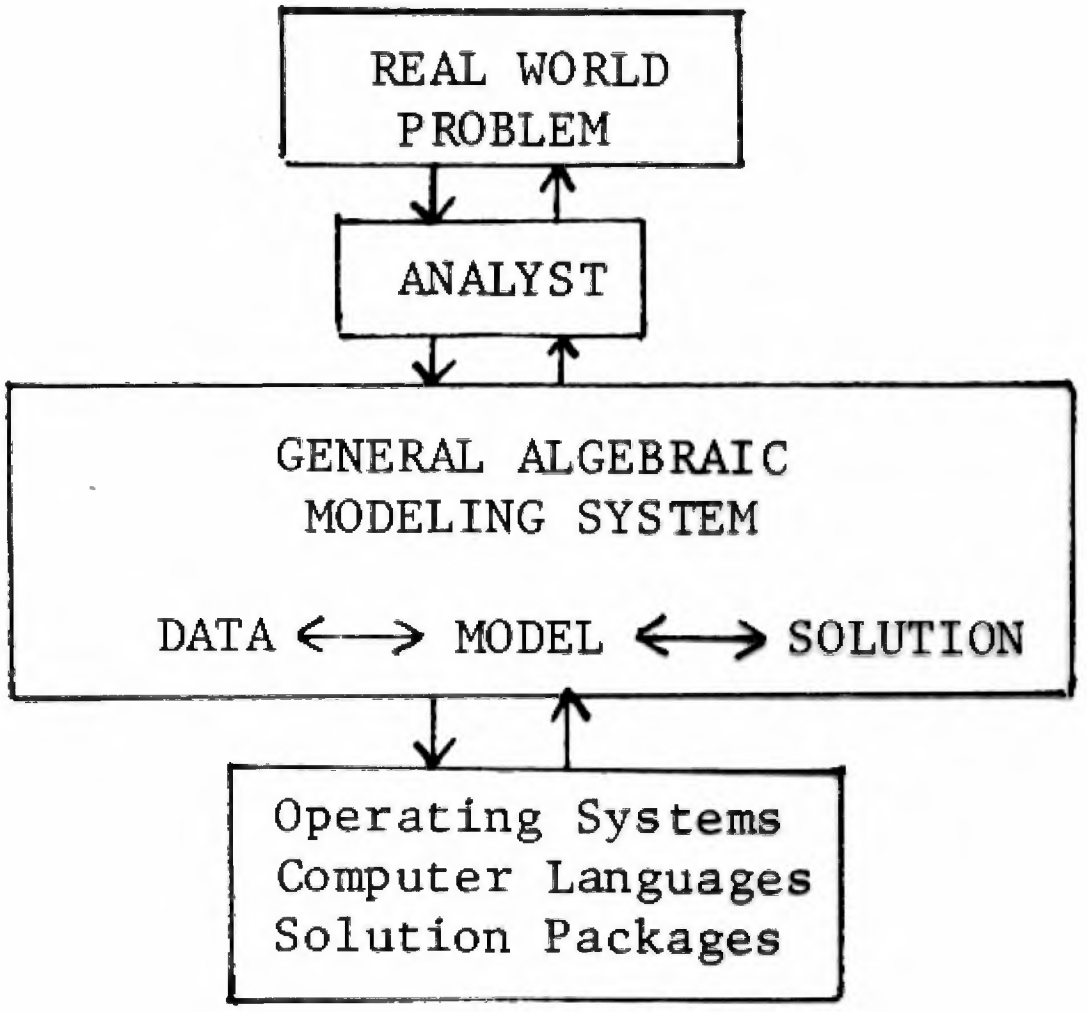
IDEAL TECHNOLOGY



RESULT:
- Limited drain of resources
- Same representation of models for humans and machines
- Model representation is also model documentation

DEVELOPMENT OF GAMS

Phase 1 (1978)

- The system can be used to represent and analyze any algebraic model (be it linear or nonlinear)

- The system can perform algebraic manipulations on all data

- The system can generate and solve linear programs automatically

- The system can generate reports on data and solutions via simple 'display' statements

DEVELOPMENT OF GAMS

Phase 2 (1979)

- The system can generate and solve nonlinear programs

- The system will provide links to special-purpose algorithms for econometric problems, network problems, etc.

- Appropriate extensions to the language will be made as the need arises

DEVELOPMENT OF GAMS

Phase 3 (?)

- Automatic structure recognition
- Internal generation of *exact* point-derivatives
- Improved data-base design with e.g. unit analysis, and links to existing data bases
- Availability of GAMS on different machines
- World-wide availability of the system so that it can be used as a market for testing models and algorithms

GAMS Overview

- Started as a Research Project at the World Bank 1976
- GAMS went commercial in 1987
- Opened European Office in Cologne, Germany 1996
- 10,000s of customers in over 100 countries

GAMS

Basic Principles

- Separation of model and solution methods
- Models is a data base operator and/or object
- Balanced mix of declarative and procedural approaches
- Computing platform independence
- Multiple model types, solvers and platforms

GAMS

Multiple model types

- LP Linear Programming
- MIP Mixed Integer Programming
- NLP Nonlinear Programming
- MCP Mixed Complementarity Programming
- MINLP Mixed Integer Nonlinear Programming
- MPEC NLP with Complementarity Constraints
- MPSGE General Equilibrium Models
- Stochastic Optimization

Supported Solvers

BDMLP	LP solver that comes with any GAMS system
CONOPT	Large scale NLP solver from ARKI Consulting and Development
CPLEX	High-performance LP/MIP solver from Ilog
DECIS	Large scale stochastic programming solver from Stanford University
DICOPT	Framework for solving MINLP models. Needs both an NLP solver and a MIP solver. From Carnegie M
MILES	MCP solver from University of Colorado at Boulder that comes with any GAMS system
MINOS	NLP solver from Stanford University
MPSGE	Modeling Environment for CGE models from University of Colorado at Boulder
OSL	High performance LP/MIP solver from IBM
OSLSE	OSL Stochastic Extension for solving stochastic models
PATH	Large scale MCP solver from University of Wisconsin at Madison
SBB	Branch-and-Bound algorithm from ARKI Consulting and Development for solving MINLP models, requi
SNOPT	Large scale SQP based NLP solver from Stanford University
XA	Large scale LP/MIP system from Sunset Software
XPRESS	High performance LP/MIP solver from Dash

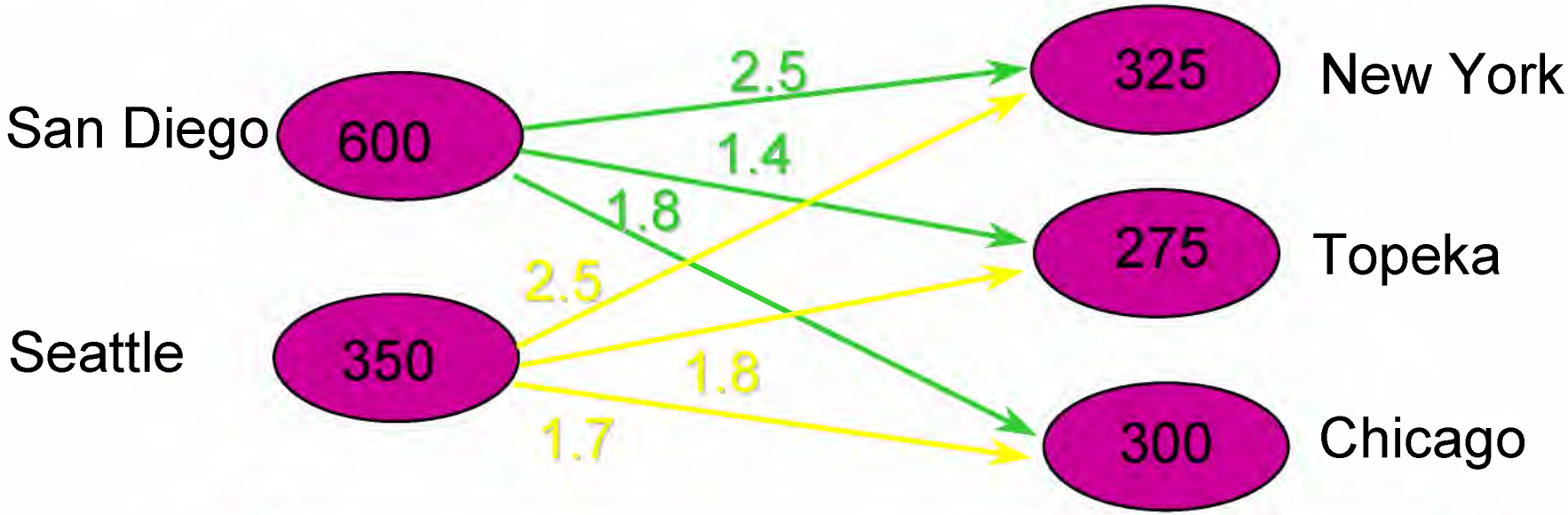
Beta Solvers

BARON	Branch-And-Reduce Optimization Navigator for proven global solutions from The Optimization Firm
CONVERT	Frame work for translating models into scalar models of other languages
LGO	Lipschitz global optimizer from Pinter Consulting Services
MOSEK	Large scale LP/MIP plus conic and convex non-linear programming system from EKA Consulting
NLPEC	MPEC to NLP translator that uses other GAMS NLP solvers
OQMS	Multi-start method for global optimization from Optimal Methods Inc.
PATHNLP	Large scale NLP solver for convex problems from University of Wisconsin at Madison

Contributed Plug&Play Solvers

AMPLwrap	Framework for using AMPL solver for GAMS models
DEA	Large scale Data Envelop Analysis Solver from University of Wisconsin at Madison
Kestrel	Framework for using remote NEOS solvers with a local GAMS system
QPwrap	Quadratic programming in GAMS

Transport Example

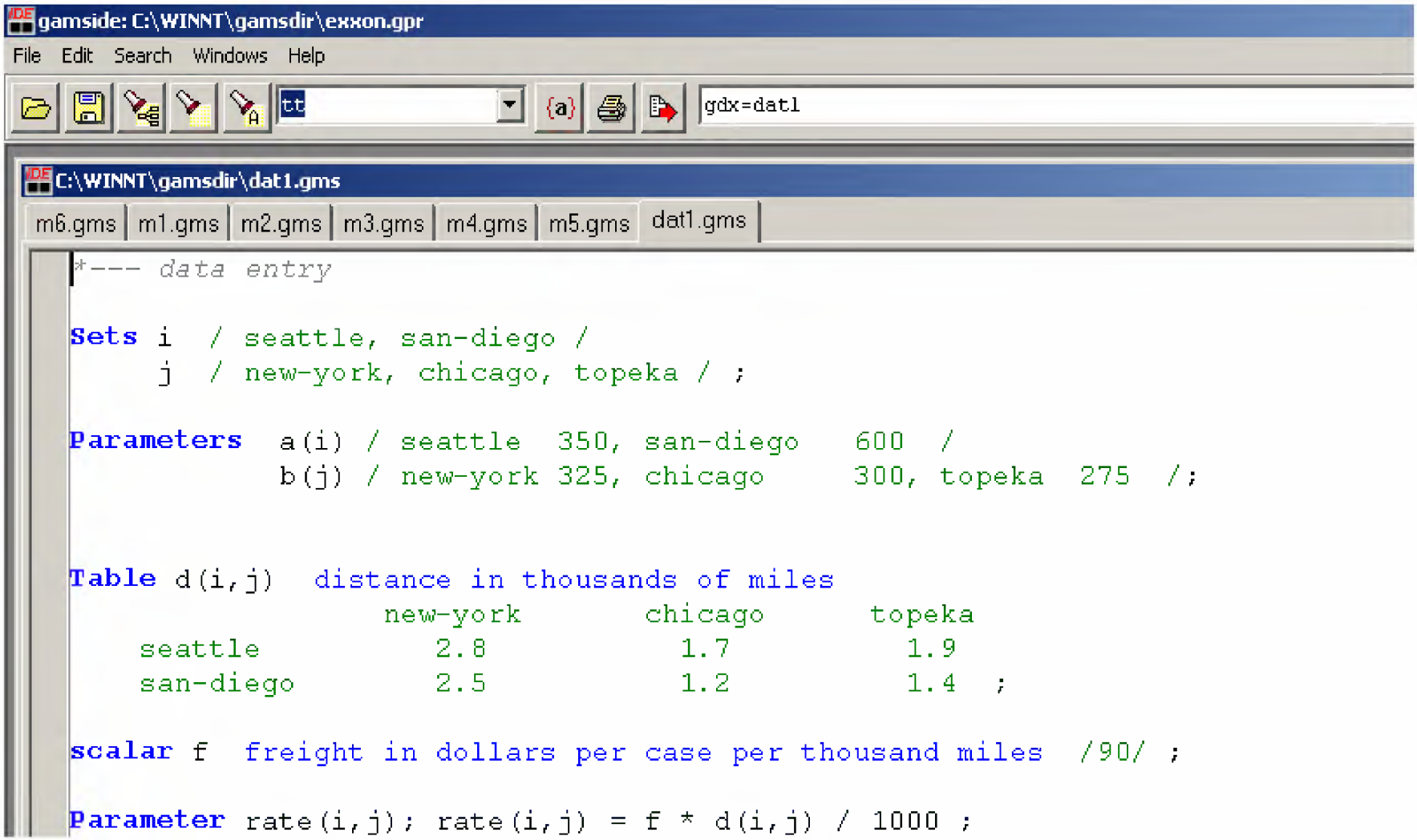


Minimize	Transportation cost
subject to	Demand satisfaction at markets
	Supply constraints

GAMS Implementation

- Using the GAMS IDE to build a model
- Data Entry
- Max/Min Shipments
- Nonlinear Cost
- MCP Formulation
- Flexible Demand
- call GAMS IDE

GAMS IDE


gamside: C:\WINNT\gamsdir\exxon.gpr
File Edit Search Windows Help
gdx=dat1
C:\WINNT\gamsdir\dat1.gms
m6.gms m1.gms m2.gms m3.gms m4.gms m5.gms dat1.gms
*--- data entry
Sets i / seattle, san-diego /
j / new-york, chicago, topeka / ;
Parameters a(i) / seattle 350, san-diego 600 /
b(j) / new-york 325, chicago 300, topeka 275 /;
Table d(i,j) distance in thousands of miles
new-york chicago topeka
seattle 2.8 1.7 1.9
san-diego 2.5 1.2 1.4 ;
scalar f freight in dollars per case per thousand miles /90/ ;
Parameter rate(i,j); rate(i,j) = f * d(i,j) / 1000 ;

Model m1.gms

C:\WINNT\gamsdir\m1.gms

m6.gms | m1.gms | m2.gms | m3.gms | m4.gms | m5.gms | dat1.gms

```
sets i   canning plants
     j   markets

parameters a(i)    capacity of plant i in cases
           c(i,j)  transport cost in thousands of dollars per case
           b(j)    demand at market j in cases

Variables  x(i,j)  shipment quantities in cases
           z       total transportation costs in thousands of dollars
Positive Variable x ;

Equations cost        define objective function
          supply(i)   observe supply limit at plant i
          demand(j)   satisfy demand at market j ;

cost ..        z  =e=  sum((i,j), c(i,j)*x(i,j)) ;

supply(i) ..   a(i) =g= sum(j, x(i,j)) ;

demand(j) ..   sum(i, x(i,j))  =g=  b(j);

Model m1 /all/ ;
```

Model m1.gms (cont.)

```
Model m1 /all/ ;

$call gams dat1 gdx=dat1
$gdxin dat1
$load i j a b c=rate

*--- solve LP and store results

Solve m1 us lp min z ;

parameter rep(i,j,*) Summary Report;

rep(i,j,'lp') = x.l(i,j);
```

Min/Max Shipments

```
*  min and max shipmenst
option limcol=0,limrow=0;
scalars xmin / 100 /
        xmax / 275 /;
binary variables ship(i,j)    decision variable to ship
equations        minship(i,j) minimum shipments
                 maxship(i,j) maximum shipments ;

minship(i,j).. x(i,j) =g=   xmin*ship(i,j);
maxship(i,j).. x(i,j) =l=   xmax*ship(i,j);

model m2 min shipmenst / cost,supply,demand,minship,maxship /;
solve m2 using mip minimizing z;

rep(i,j,'mip') = x.l(i,j); display rep;
```

Nonlinear Cost

```
* nonlinear cost
equation nlcost nonlinear cost function; scalar beta;

nlcost.. z =e= sum((i,j), c(i,j)*x(i,j)**beta);
model m3 / nlcost,supply,demand /;

beta = 1.5; solve m3 using nlp minimizing z;
rep(i,j,'nlp-convex') = x.l(i,j);

beta = 0.6; solve m3 using nlp minimizing z;
rep(i,j,'nlp-non') = x.l(i,j);

option nlp=baron; solve m3 using nlp minimizing z;
rep(i,j,'nlp-baron') = x.l(i,j); display rep;
```

Min/Max and NL objective

```
* min/max and nl obj

model m4 / nlcost,supply,demand, minship,maxship /;

option minlp=baron; solve m4 using minlp minimizing z;
option nlp  =snopt;          option optcr=0;
option minlp=sbb; solve m4 using minlp minimizing z;

rep(i,j,'minlp') = x.l(i,j); display rep;
```

MCP Formulation

```
* lp as mcp
positive variables w(i) shadow price at supply node
                   p(j) shadow price at demand node;

equations profit(i,j) zero profit condition;

profit(i,j).. w(i) + c(i,j) =g= p(j);

model m5 / profit.x, supply.w, demand.p /;

solve m5 using mcp;

rep(i,j,'mcp') = x.l(i,j); display rep;
```

Flexible Demand

```
* flexible demand
parameter pbar(j) reference price
                  esub(j) price elasticity
                / new-york 1.5, chicago 1.2, topeka 2.0 /;
equation flexdemand(j) price responsive demand;
flexdemand(j).. sum(i, x(i,j)) =g= b(j)*(pbar(j)/p(j))**esub(j);
model m6 / profit.x, supply.w, flexdemand.p /;

pbar(j) = p.l(j); solve m6 using mcp; rep(i,j,'mcp-flex') = x.l(i,j);
```

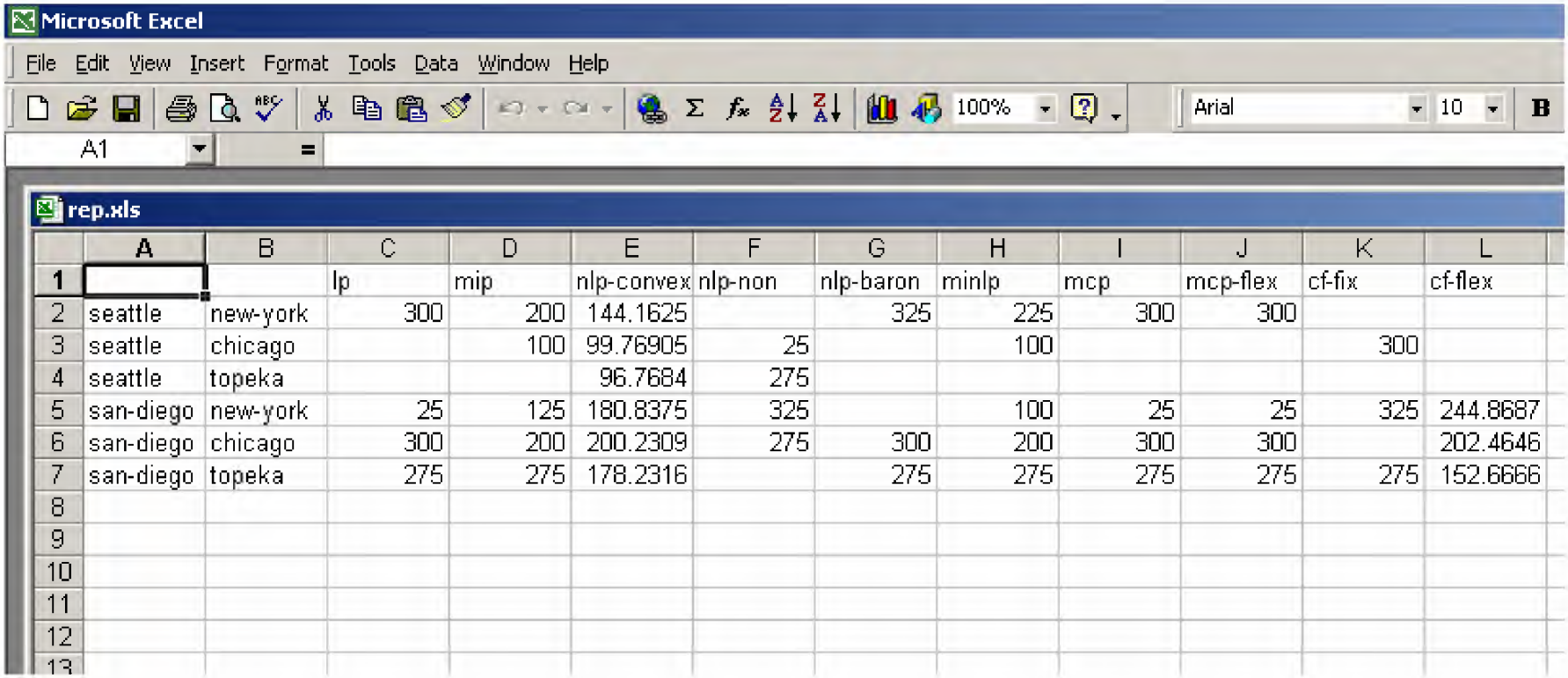
Counter Factual

```
* counter factual
c('seattle',j) = 2.0*c('seattle',j);

solve m5 using mcp; rep(i,j,'cf-fix' ) = x.l(i,j);
solve m6 using mcp; rep(i,j,'cf-flex') = x.l(i,j);
display rep;

$libinclude xldump rep rep
```

Summary Result



	A	B	C	D	E	F	G	H	I	J	K	L
1			lp	mip	nlp-convex	nlp-non	nlp-baron	minlp	mcp	mcp-flex	cf-fix	cf-flex
2	seattle	new-york	300	200	144.1625		325	225	300	300		
3	seattle	chicago		100	99.76905	25		100			300	
4	seattle	topeka			96.7684	275						
5	san-diego	new-york	25	125	180.8375	325		100	25	25	325	244.8687
6	san-diego	chicago	300	200	200.2309	275	300	200	300	300		202.4646
7	san-diego	topeka	275	275	178.2316		275	275	275	275	275	152.6666
8												
9												
10												
11												
12												
13												

Definition of MCP

$$\text{Find } y \text{ such that}$$

$$h(y) \perp y \in \boldsymbol{B} = \{y \mid a \leq y \leq b\}$$

The variable y "complements" the function h

$$\text{Exactly one of}$$

$$(a)\ a_i < y_i < b_i \text{ and } h_i(y) = 0$$
$$(b)\ y_i = a_i \text{ and } h_i(y) \geq 0$$
$$(c)\ y_i = b_i \text{ and } h_i(y) \leq 0$$

Special Cases

Nonlinear equations:

$$a_i = -\infty, b_i = +\infty \;\Rightarrow\; h_i(y) = 0$$

Nonlinear complementarity:

$$a_i = 0, b_i = +\infty \;\Rightarrow\; 0 \le y_i,\; h_i(y) \ge 0$$
$$y_i h_i(y) = 0$$

Key: either $y_i = 0$ or $h_i(y) = 0$

GAMS Model

```
* data specified i,j,A,b,c,g
positive variables p(i), z(j);
equations S(i), L(j);
S(i).. b(i) + sum(j, A(i,j)*z(j))
          - c(i)*sum(k, g(k)*p(k)) / p(i) =g= 0;
L(j).. - sum(i, p(i)*A(i,j)) =g= 0;
model walras /S.p, L.z/;
solve walras using mcp;
```

Definition of MPEC

$$\begin{aligned} &\text{minimize } f(x,y) \\ &\text{such that } g(x,y) \leq 0 \end{aligned}$$

Add complementarity to definition of h; parameter x

$$h(x,y) \perp y \in \boldsymbol{B}$$

Theory hard; no constraint qualification

NCP Functions

Definition : $\phi(r,t) = 0 \Leftrightarrow 0 \leq r \perp t \geq 0$

Example : $\phi_{min}(r,t) = \min\{r,t\}$

Example : $\phi_F(r,t) = \sqrt{r^2+t^2} - r - t$

Componentwise definition : $\Phi_i(x,y) = \phi(h_i(x,y), y_i) = 0$

$\Phi(x,y) = 0 \Leftrightarrow 0 \leq h(x,y) \perp y \geq 0$

MPEC Approaches

- Implicit: $\min f(x,y(x))$
- Auxiliary variables: $s = h(x,y)$
- NCP functions: $\Phi(s,y) = 0$
- Smoothing: $\Phi_\mu(s,y) = 0$
- Penalization: $\min f(x,y) + \mu \{s'y\}$
- Relaxation: $s'y <= \mu$
- Different problem classes require different solution techniques

Parametric algorithm NLPEC

- `Equreform = 1`
- `Initmu = 0.01`
- `Numsolves = 5`
- `Updatefac = 0.1`
- `Finalmu = 0`
- `Initslo = 0`

$$\text{NLP}(\mu): \min f(x,y)$$
$$g(x,y) \leq 0$$
$$s = h(x,y)$$
$$0 \leq s,\ y \geq 0$$
$$s_i y_i = \mu$$

Reformulate problem and set up sequence of solves

Running NLPEC

- Create the GAMS model as an MPEC
- Setup nlpec.opt
- `Gams modelfile mpec=nlpec optfile=1`
- Reformulated automatically
- Results returned directly to GAMS

Benefits/Drawbacks

- Easy to adapt existing models
- Large-scale potential
- Customizable solution to problem
- Available within GAMS right now
- Models hard to solve
- Local solutions found
- Scarcity of MPEC models

GAMS

Frontiers

- Find all or multiple equilibria
  - Use nlp=baron parametrically
- Structural identification
  - Inverse problems
- Optimal tariff calculations
  - Large-scale datasets
- Stackelberg (leader/follower) games

GAMS

What is a Model?

- List of Equations
  - *Mathematical Programming (MP) Model*
- Collection of several intertwined (MP) Models
  - Data Preparation and Calibration
  - "*Solution*" Module
  - Reporting Module
- Categorization of Models by answering:
  - Who is the *User* of a Model?

Who is the *User* of a Model?

- (Academic) Researcher
  - One time use (Research Paper)
- Domain&Model Expert
  - Model Results used for Consulting
- Black Box User
  - Model integrated in (Optimization) Application
- Each Category has its own needs
  - Development & Deployment

GAMS

Research Models

- 95% of Model Source is (Equation) Algebra
- Declarative Modeling
- Set of (Benchmark) Problem Instances
- Modeling Language Differences: Few
- *Taste* (Syntax, Development Environment,…)
- Platform, Model Type, *Solver*

Supported Platforms

Solver/Platform availability - 20.7 June 14, 2002							
	Intel		Sun Sparc	HP 9000	DEC Alpha	IBM RS-6000	SGI
	Windows 95/98/Me/NT/2000/XP	Linux	Solaris	HP-UX 10	Digital Unix 4.0	AIX 4.3	IRIX
BDMLP	✔	✔	✔	✔	✔	✔	✔
CONOPT	✔	✔	✔	✔	✔	✔	✔
CPLEX 7.5	✔	✔	✔	✔	✔	✔	✔
DECIS	✔	✔	✔		✔		✔
DICOPT	✔	✔	✔	✔	✔	✔	✔
MILES	✔	✔	✔	✔	✔	✔	✔
MINOS	✔	✔	✔	✔	✔	✔	✔
MPSGE	✔	✔	✔	✔	✔	✔	✔
OSL V3	✔	✔	✔	✔		✔	✔
PATH	✔	✔	✔	✔	✔	✔	✔
SBB	✔	✔	✔	✔	✔	✔	✔
SNOPT	✔	✔	✔	✔	✔	✔	✔
XA	✔	✔	✔	✔	✔	✔	
XPRESS 13.02	✔	✔	✔	13.01			

Model Types

GAMS is able to formulate models in many different types of problem classes. That means switching from one model type to another can be done with a minimum of effort. You can even use the same data, variables, and equations in different types of models at the same time.

GAMS supports the following basic model types:

LP	Linear Programming
NLP	Non-Linear Programming
DNLP	Non-Linear Programming with Discontinuous Derivatives
MIP	Mixed-Integer Programming
MINLP	Mixed-Integer Non-Linear Programming
MCP	Mixed Complementarity Problems
CNS	Constrained Nonlinear Systems
MPEC	Mathematical Programs with Equilibrium Constraints

GAMS

Supported Solvers

BARON	Branch-And-Reduce Optimization Navigator for proven global solutions from The Optimization Firm
BDMLP	LP solver that comes with any GAMS system
CONOPT	Large scale NLP solver from ARKI Consulting and Development
CPLEX	High-performance LP/MIP solver from Ilog
DECIS	Large scale stochastic programming solver from Stanford University
DICOPT	Framework for solving MINLP models. Needs both an NLP solver and a MIP solver. From Carnegie Mellon University
LGO	Lipschitz global optimizer from Pinter Consulting Services
MILES	MCP solver from University of Colorado at Boulder that comes with any GAMS system
MINOS	NLP solver from Stanford University
MOSEK	Large scale LP/MIP plus conic and convex non-linear programming system from EKA Consulting
MPSGE	Modeling Environment for CGE models from University of Colorado at Boulder
OQNLP	Multi-start method for global optimization from Optimal Methods Inc.
NLPEC	MPEC to NLP translator that uses other GAMS NLP solvers
OSL	High performance LP/MIP solver from IBM
OSLSE	OSL Stochastic Extension for solving stochastic models
PATH	Large scale MCP solver from University of Wisconsin at Madison
PATHNLP	Large scale NLP solver for convex problems from University of Wisconsin at Madison
SBB	Branch-and-Bound algorithm from ARKI Consulting and Development for solving MINLP models, requires an NLP solver
SNOPT	Large scale SQP based NLP solver from Stanford University
XA	Large scale LP/MIP system from Sunset Software
XPRESS	High performance LP/MIP solver from Dash

Solver Links

- *Supported Solvers*:
  - GAMS Support includes Solver Support
  - Standardized Solver Interface
    - Return Codes, Limits, Interrupts, …
  - Common Solver Attributes (e.g. time) through GAMS options
  - Specific Solver Options through Option"file"
- Standardized Solver Interface allows "hassle free" replacement of solvers:

```
option nlp=conopt;
```

- IO Library (C, Fortran, Delphi) provides access to
  - Matrix, Function/Derivative Evaluator, …

Solver Links – Cont.

Linking your Solver to GAMS
THE COMPLETE NOTES

Don't Panic !!

Available Solvers

- Growing number of MP Solvers (often out of Academic Labs)
- NEOS: >40 Solvers
- Impractical to have Interface to *all* Modeling Languages
- "Solution": Model Translation

- Multi-solvers
- Semi-infinite Optimization
- Mixed Integer Nonlinearly Constrained Optimization
- Mixed Integer Linear Programming
- Nonlinearly Constrained Optimization
- Semidefinite & Second Order Cone Programming
- Linear Programming
- Bound Constrained Optimization
- Unconstrained Optimization
- Linear Network Optimization
- Complementarity Problems
- Nondifferentiable Optimization
- Stochastic Linear Programming
- Global Optimization
- Application-specific Optimization
- Miscellaneous
- Administration

Model Translation

Instructions

In order to use the GMS2XX translation service which is based on the "solver" GAMS/CONVERT you have to attach your model to an email and send it to our translation server at gms2xx@gamsworld.org. You specify the language in the subject line, for example

```
Subject: GAMS
```

At the moment we support the following *languages*:

- AMPL
- BARON
- CplexLP
- CplexMPS
- GAMS
- LGO
- LINGO
- MINOPT
- ALL (this creates scalar versions of all supported languages, listed above)

Model Translation – Cont.

- Translation of MP Model into *Scalar Model*
  - List of Variables/Equations
- Advantages:
  - Syntax for Scalar Models almost identical for different Modeling Languages (easy Translation)
  - Hides proprietary Information
- Seamless Modeling System Connection
  - For example: GAMS/AMPL with Kestrel (NEOS)

```
Set I Products         /P1*P2/
    J Cutting Patterns /C1*C2/;

Parameter c(J)    cost of raw material                  /C1 1, C2 1/
          cc(J)   cost of change-over of knives         /C1 0.1, C2 0.2/
          b(I)    width of product roll-type I          /P1 460, P2 570/
          nord(I) number of orders of product type I    /P1 8, P2 7/
          Bmax    width of raw paper roll               /1900/
          Delta   tolerance for width                   / 200/
          Nmax    max number of products in cut         /   5/
          bigM    max number of repeats of any pattern  /  15/;

Variable  y(J)    cutting pattern
          m(J)    number of repeats of pattern j
          n(I,J)  number of products I produced in cut J
          obj     objective variable;

Binary Variable y; Integer Variable m, n;

Equation defobj, max_width(J), min_width(J), max_n_sum(J),
                 min_order(I), cut_exist(J), no_cut(J);

defobj..          sum(j, c[j]*m[j] + cc[j]*y[j]) =e= obj;
max_width(j)..    sum(i, b[i]*n[i,j])            =l= Bmax;
min_width(j)..    sum(i, b[i]*n[i,j]) + Delta    =g= Bmax;
max_n_sum(j)..    sum(i, n[i,j])                 =l= Nmax;
min_order(i)..    sum(j, m[j]*n[i,j])            =g= nord[i];
cut_exist(j)..    y[j]                           =l= m[j];
no_cut(j)..       m[j]                           =l= bigM*y[j];

m.up[j] =  bigM; n.up[i,j] = nmax;

model trimloss /all/;
solve trimloss minimize obj using minlp;
```

```
*  MINLP written by GAMS Convert
Variables
b1,b2,i3,i4,i5,i6,i7,i8,x9;
Binary Variables b1,b2;
Integer Variables i3,i4,i5,i6,i7,i8;
Equations
e1,e2,e3,e4,e5,e6,e7,e8,e9,e10,
           e11,e12,e13;

e1..  0.1*b1 + 0.2*b2 + i3 + i4 - x9
=E= 0;
e2..  460*i5 + 570*i7 =L= 1900;
e3..  460*i6 + 570*i8 =L= 1900;
e4..  460*i5 + 570*i7 =G= 1700;
e5..  460*i6 + 570*i8 =G= 1700;
e6..  i5 + i7 =L= 5;
e7..  i6 + i8 =L= 5;
e8..  i3*i5 + i4*i6 =G= 8;
e9..  i3*i7 + i4*i8 =G= 7;
e10.. b1 - i3 =L= 0;
e11.. b2 - i4 =L= 0;
e12.. - 15*b1 + i3 =L= 0;
e13.. - 15*b2 + i4 =L= 0;

* set non default bounds
i3.up = 15; i4.up = 15; i5.up = 5;
i6.up = 5;  i7.up = 5;  i8.up = 5;

Model m / all /;
Solve m using MINLP minimizing x9;
```

```
#  MINLP written by GAMS Convert
var b1 binary;
var b2 binary;
var i3 integer >= 0, <= 15;
var i4 integer >= 0, <= 15;
var i5 integer >= 0, <= 5;
var i6 integer >= 0, <= 5;
var i7 integer >= 0, <= 5;
var i8 integer >= 0, <= 5;

minimize obj:
     0.1*b1 + 0.2*b2 + i3 + i4;

subject to

e2:  460*i5 + 570*i7 <= 1900;
e3:  460*i6 + 570*i8 <= 1900;
e4:  460*i5 + 570*i7 >= 1700;
e5:  460*i6 + 570*i8 >= 1700;
e6:  i5 + i7 <= 5;
e7:  i6 + i8 <= 5;
e8:  i3*i5 + i4*i6 >= 8;
e9:  i3*i7 + i4*i8 >= 7;
e10: b1 - i3 <= 0;
e11: b2 - i4 <= 0;
e12: - 15*b1 + i3 <= 0;
e13: - 15*b2 + i4 <= 0;
```

GAMS

Consulting Models

- *Model* is Tool for Problem Analysis
- 10% of Model Source is (Equation) Algebra
- User: Domain & Modeling Expert (not necessary the same person)
- *Living* Model (changes with the problem)
  - Lifecycle: At least 10 years
  - Technology Change (Platform, Solver, …)

GAMS

Example: Hill & Associates

-  HILL & ASSOCIATES INC. Annapolis MD, USA
- Consulting Company: Coal/Electricity
- Products:
  - Electric Generation, Coal and Emissions Forecasting System (Annual, Multi-Client)
  - International Coal Trade Study (Annual, MC)
  - Individual Coal/Electricity related Studies
- Staff: Economists & Engineers

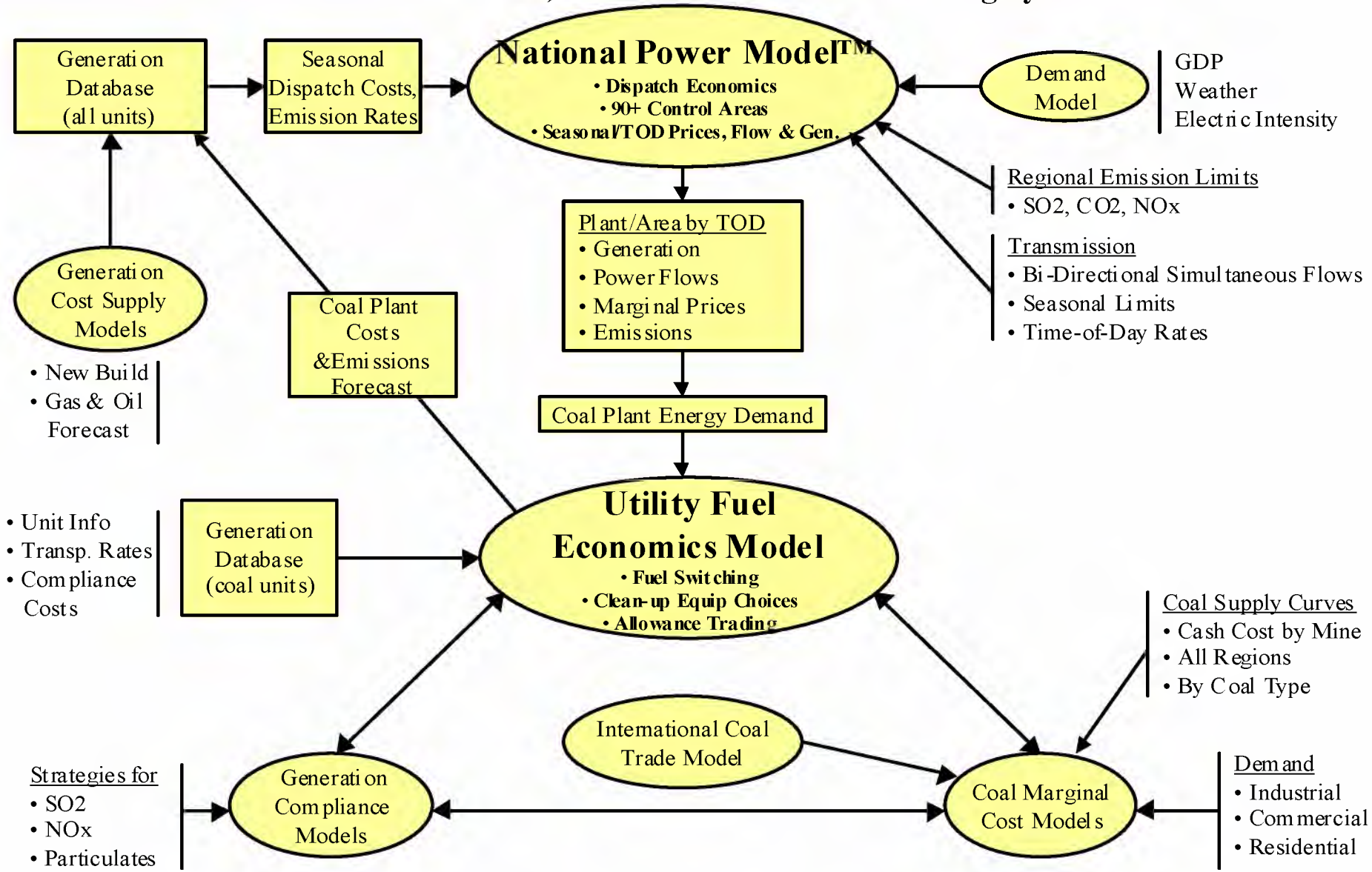
Hill Models

- UFEM – Utility Fuel Economics Model
  - Coal Supply/Choice, Clean-up Investment
  - 3000 lines of GAMS code
- NPM – National Power Model
  - Dispatch of Power Plants, Wheeling of Power
  - 2200 lines of GAMS code
- ICT – International Coal Trade
  - Demand/Supply/Transport of Coal worldwide
  - 1000 lines of GAMS code
- Challenging LP/MIP Models (several million NZ)

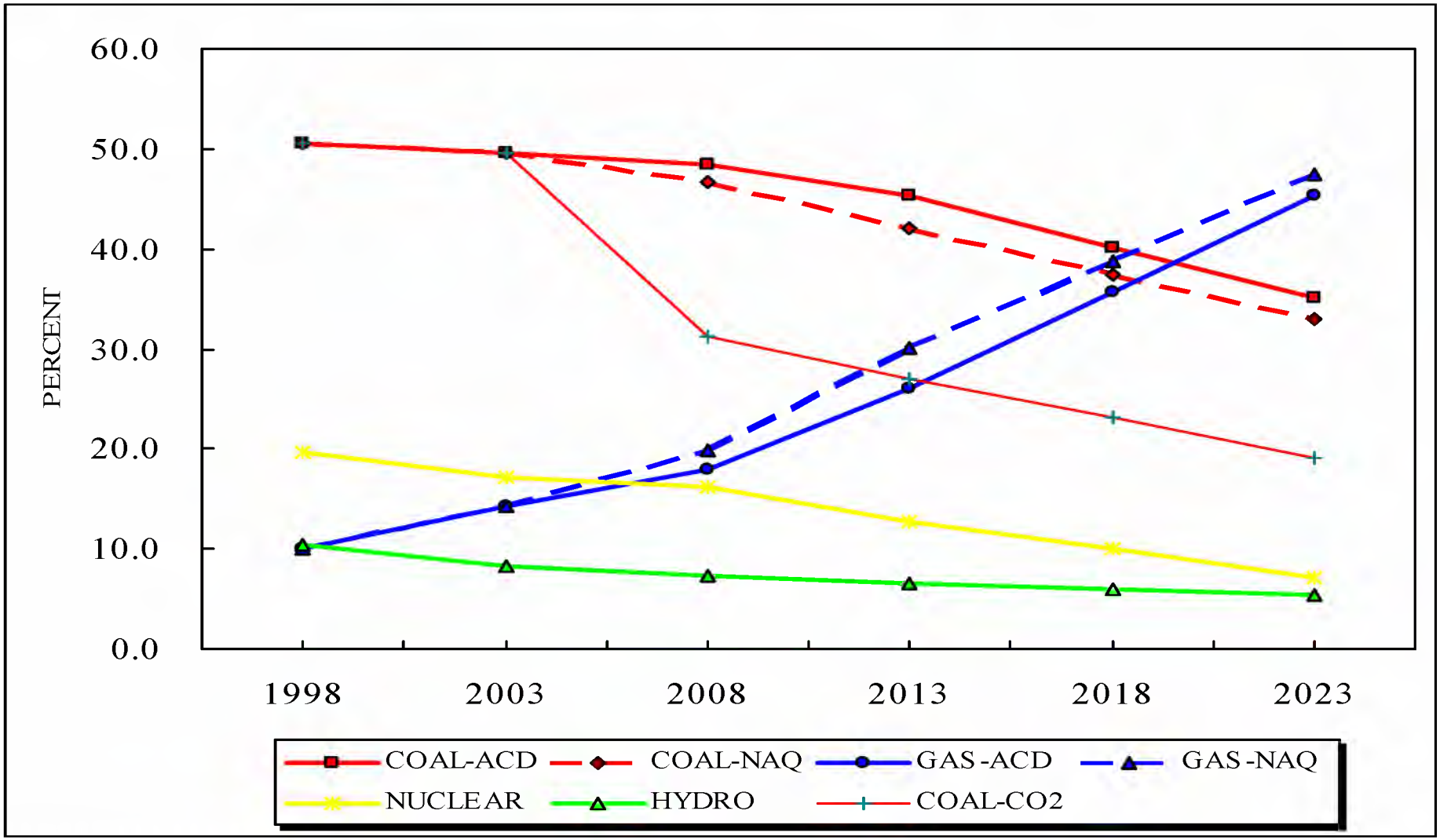
Figure I-1

Hill and Associates, Inc.

Electric Generation, Coal and Emissions Forecasting System



Fuel Shares


60.0
50.0
40.0
30.0
20.0
10.0
0.0
PERCENT
1998
2003
2008
2013
2018
2023
COAL-ACD
COAL-NAQ
GAS-ACD
GAS-NAQ
NUCLEAR
HYDRO
COAL-CO2

GAMS

Hill Computing Environment

- Diversity!!!
- Development
  - Linux&Emacs, DOS&kedit, Windows&IDE
- Deployment
  - Process driven by Technology&Experience
  - 5 years ago: Receipe/Walk-through (Human Intervention after each Step)
  - Today: Semi-automated Scripts
  - PC: DBase, MS Office, MapInfo (Model&Presentation)

Modeling System Requirements

- *Survive* in such a diverse Environment
- Compatibility
  - 10 year lifecycle
- Data Connectivity/Exchange
  - Programs **and** People
- Support for Analysis/Reporting
  - Modeling System Tools and external Program

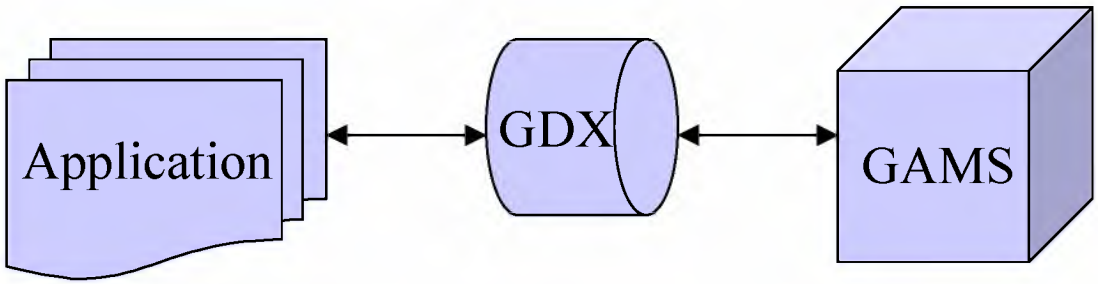
GAMS

Data Connectivity

- Data Import/Export from *Standard Applications*
  - MS Office, Database, Text files, …
- Capture an *Instance* of a Model Failure
  - Reproducibility of Model/System Bugs
  - Problems: Life Database/different Platforms
- Definition of Data Interface
  - Gams Data eXchange (GDX)
  - Separation of Responsibility for Data and Model

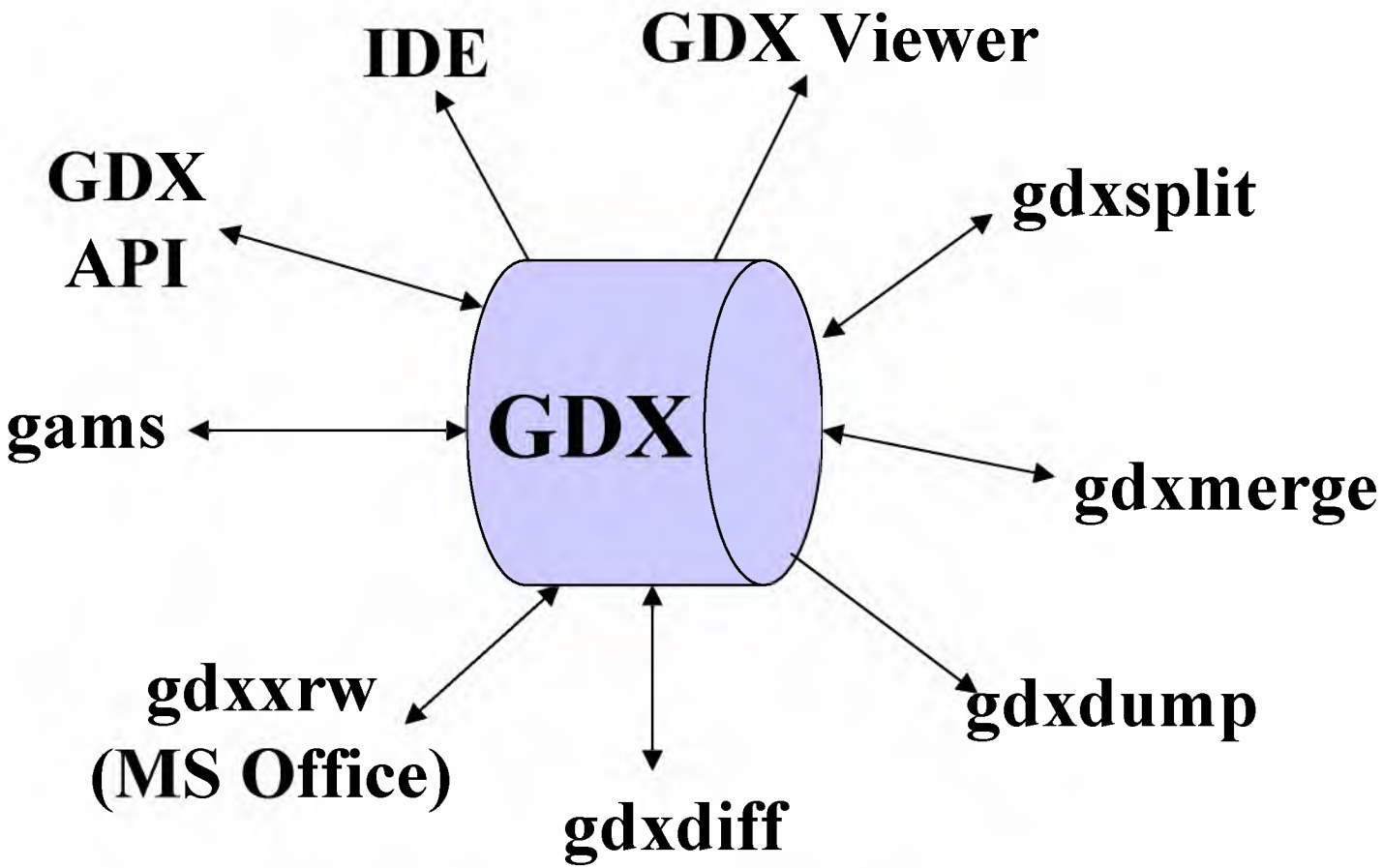
Gams Data eXchange

- Gams Data eXchange (GDX):



- Complements the ASCII text data input
- Advantages:
  - Fast exchange of data
  - Syntactical check on data before model starts
  - Compile-time and Run-time Data Exchange

GDX Tools


IDE
GDX Viewer
GDX
API
gdxsplit
gams
GDX
gdxmerge
gdxxrw
(MS Office)
gdxdiff
gdxdump

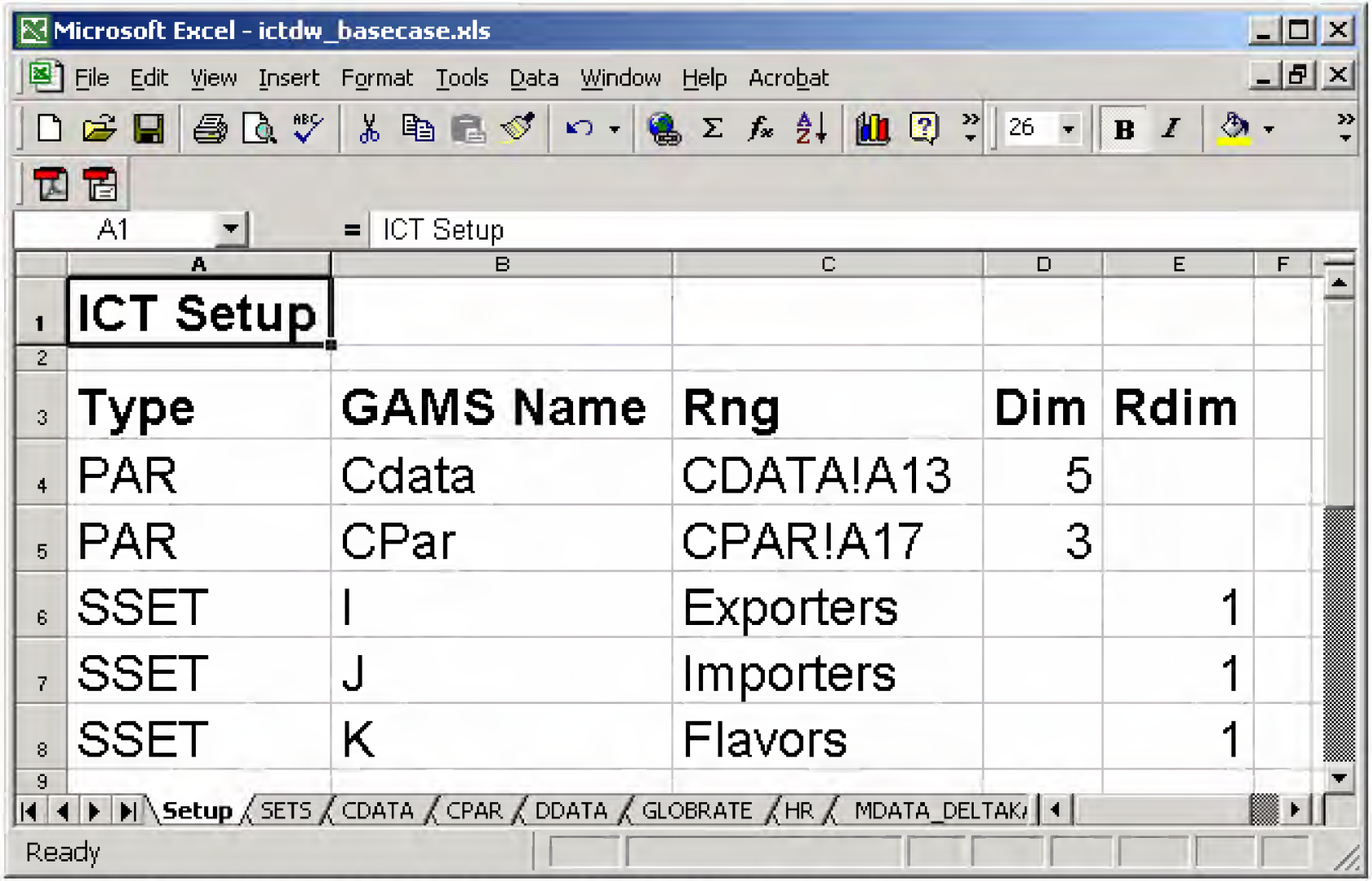
Data Contract in GAMS

```
$onecho > dbf2txt.prg
use plt_data
copy to plt_data.txt type delimited fields PLT_CODE3,UTILABBR,;
  MWPLANT,GASMILES,CONGEST,LOCALE,SLUDGEMIL,MINGRIND,MINSULF,;
  HEATRATE,EPALAW_ON,EPA_SIPS02,TONS_HG for MWPLANT>1000
$offecho
$call =dbase dbf2txt.prg
$if errorlevel 1 $abort 'Problems with DBASE'


* Process the delimited files from DBASE
$call cat plt_data.txt | cut -d, -f1,3- | sort | uniq > pdata.txt
$call cat plt_data.txt | cut -d, -f1    | sort | uniq > plant.txt

set p Plant Code /
$include plant.txt
                 /
table pdata(p,*)
$ondelim
$include pdata.txt
$offdelim
;
```

Data Contract in Excel



	A	B	C	D	E	F
1	**ICT Setup**					
2						
3	**Type**	**GAMS Name**	**Rng**	**Dim**	**Rdim**	
4	PAR	Cdata	CDATA!A13	5		
5	PAR	CPar	CPAR!A17	3		
6	SSET	I	Exporters		1	
7	SSET	J	Importers		1	
8	SSET	K	Flavors		1	
9						

Data Contract in Excel – cont.

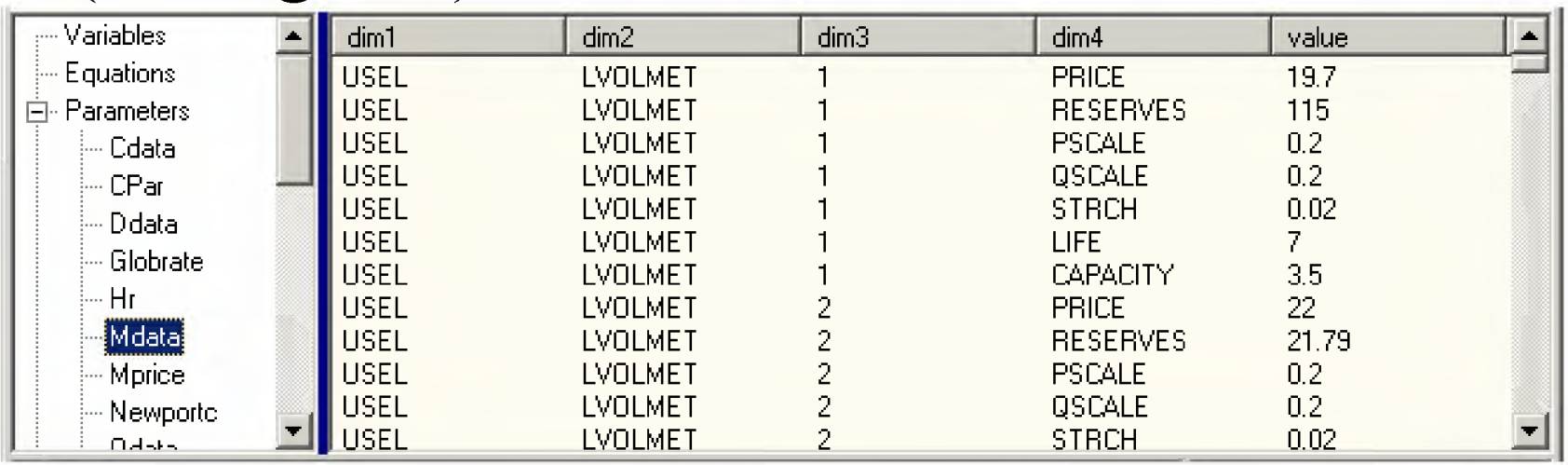
```
SETS   I   Exporters
       J   Importers
       K   Flavors
       L   Sectors of demand
         / Met          Metallurgical
           Thr          Thermal    /
       R   Contract type   / 1*6 /
Parameter
       Cdata (i,k,l,j,r) Contract data for first year
       CPar (i,l,r)      Contract distribution (fractions)

* Get data from the Excel file
$call gdxxrw ict.xls o=ictin.gdx index=ictparms

* Data include from GDX
$gdxin ictin.gdx
$load  I J K Cdata CPar
```

GDX used as a Database

- Data passed through GDX Interface is also captured in a GDX file (extention .gdx)
- Contains Structured GAMS Data: Sets, Parameters, Variable- and Equation values (not algebra)



dim1	dim2	dim3	dim4	value
USEL	LVOLMET	1	PRICE	19.7
USEL	LVOLMET	1	RESERVES	115
USEL	LVOLMET	1	PSCALE	0.2
USEL	LVOLMET	1	QSCALE	0.2
USEL	LVOLMET	1	STRCH	0.02
USEL	LVOLMET	1	LIFE	7
USEL	LVOLMET	1	CAPACITY	3.5
USEL	LVOLMET	2	PRICE	22
USEL	LVOLMET	2	RESERVES	21.79
USEL	LVOLMET	2	PSCALE	0.2
USEL	LVOLMET	2	QSCALE	0.2
USEL	LVOLMET	2	STRCH	0.02

Capture Failure Instance

- Capture Input Files
  - Multiple Files in different directories
  - Requires similar Computing Environment
  - Life Database
- GAMS option: **`dumpopt`**
  - **`gams mymodel dumpopt=11`**
  - **`mymodel.dmp`** with all source and data

Capture Failure Instance – cont.

```
* This file was written with DUMPOPT=11 at 04/23/03 05:31:18
*
*    INPUT = C:\HILLGDX\ICT\ICT_011.GMS
*     DUMP = C:\HILLGDX\ICT\ICT_011.DMP
*
*** CALL        gdxxrw ict.xls o=ictin.gdx index=ictparms
*** GDXIN       C:\HILLGDX\ICT\ICTIN.GDX

Set I(I) Exporters /
   USEL,USEB,USEN,USGM,USGO,USNB,USSB,USWE,ALAS,CANW,
   CANP,QABB,QGLA,QHAY,NKEM,NWTH,COLB,COLO,COLM,VENZ,
   RSAF,INDO,GERM,UNIK,POLA,RUSS,RUSE,OEUP,PRCH,OTHR,COLD /;

Set J(J) Importers /
   BEL,BRA,CAN,DEN,FRA,GER,HON,IBE,IND,IRL,ISR,ITA,JAP,
   KOR,MAL,MED,MEX,NET,OAS,OEE,OLA,OTH,OWE,PHI,SCA,TAI,
   TUR,UKI,USA,PAC /;

Set K(K) Flavors /
   LVOLMET,MVOLMET,HVOLMET,SEMISCC,LS-LBTU,LS-HBTU,MS-LBTU,
   MS-HBTU,HSSTEAM,VLOWBTU /;
```

Model Support/Analysis

- "Although I didn't change the data I get different answers"
- "Why is this run so different from the one I did last week"
- "My 'back on the envelope calculation' says this number should be close to x. Why is it y?"

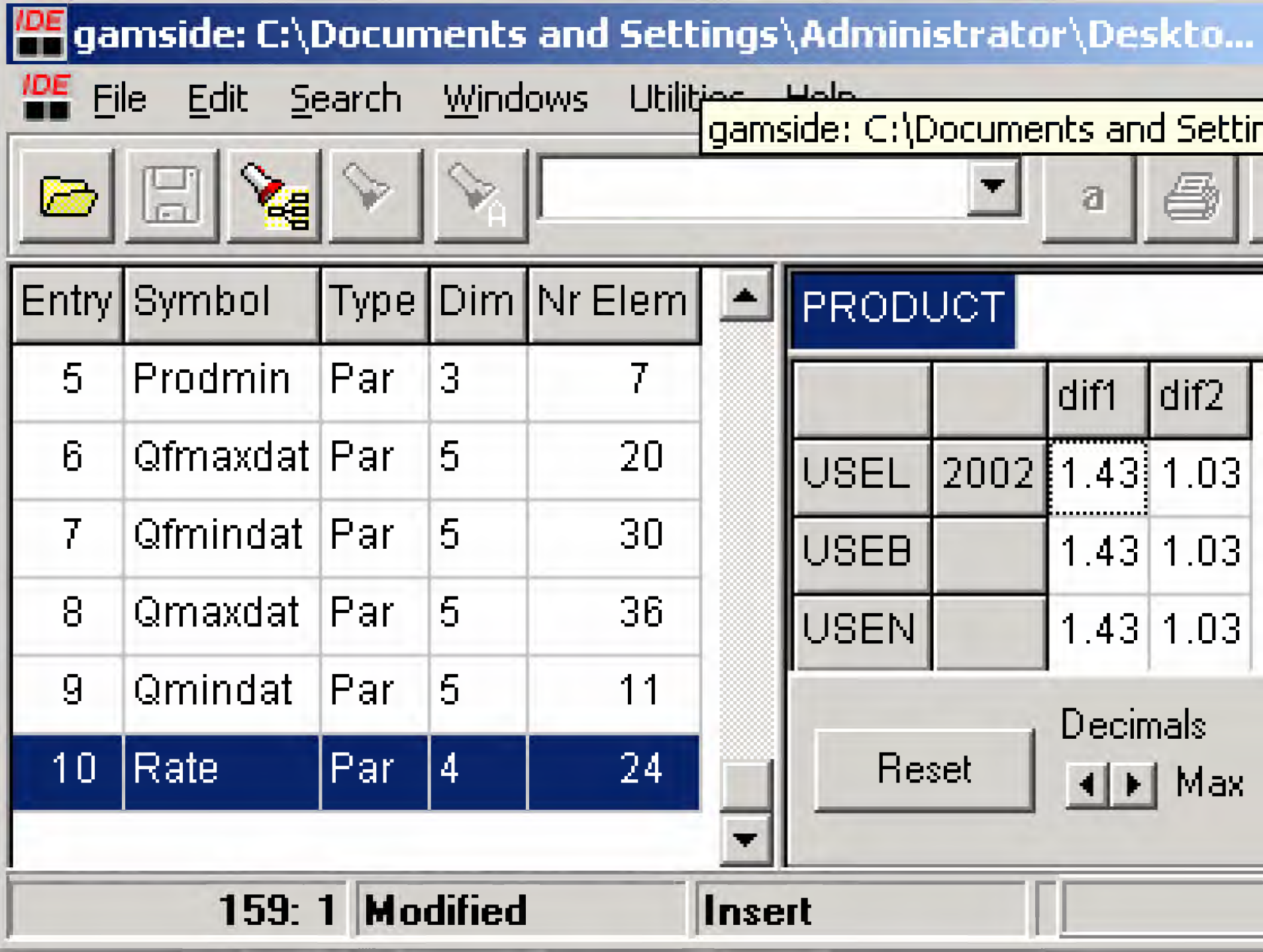
Analysis with GDX Tools

- Visual Inspection
  - GAMS IDE (Integrated Developers Environment)
  - gdxdump (Simple ASCII dump)
  - GDX Viewer
- Scenario Management Support
  - gdxmerge, gdxsplit combine and separate GDX files resulting from different scenarios of the same model
  - gdxdiff compares two GDX files

Example: Compare Inputs

- ICT Model reads data from Excel spreadsheet and creates a GDX file called **`ictin.gdx`** that captures all inputs to the model.
- Compare **`ictdw_basecase`** and **`ictdw1230c:`**

```
gams ict_011 --xlsfile ictdw_basecase.xls
copy ictin.gdx basecase.gdx
gams ict_011 --xlsfile ictdw1230c.xls
copy ictin.gdx 1230c.gdx
gdxdiff basecase.gdx 1230c.gdx
gamside diffile.gdx
```


gamside: C:\Documents and Settings\Administrator\Deskto...
File Edit Search Windows Utilities Help
gamside: C:\Documents and Settin
Entry Symbol Type Dim Nr Elem
5 Prodmin Par 3 7
6 Qfmaxdat Par 5 20
7 Qfmindat Par 5 30
8 Qmaxdat Par 5 36
9 Qmindat Par 5 11
10 Rate Par 4 24
PRODUCT
dif1 dif2
USEL 2002 1.43 1.03
USEB 1.43 1.03
USEN 1.43 1.03
Reset
Decimals
Max
159: 1 Modified Insert

GDXDIFF Results

- gdxdiff creates a summary of differences:

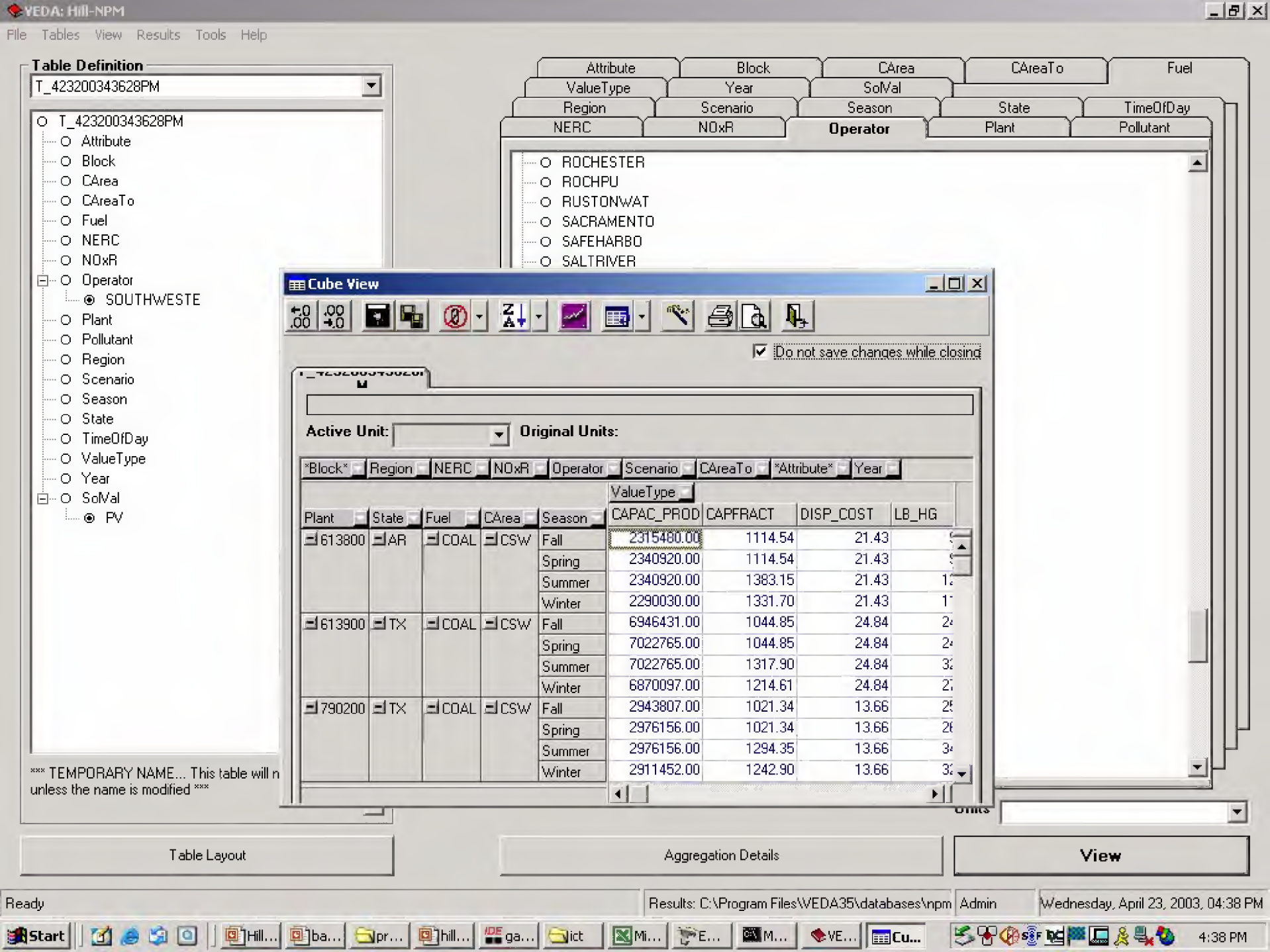
```
Summary of differences:
   Ddata   Data is different
       I   Data is different
   Mdata   Keys are different
       …
```

- gdxdiff creates a GDX file diffile.gdx with details
  - ins1 refers to a record in file1 which is not in file2
  - dif1/dif2 refer to different values for a record

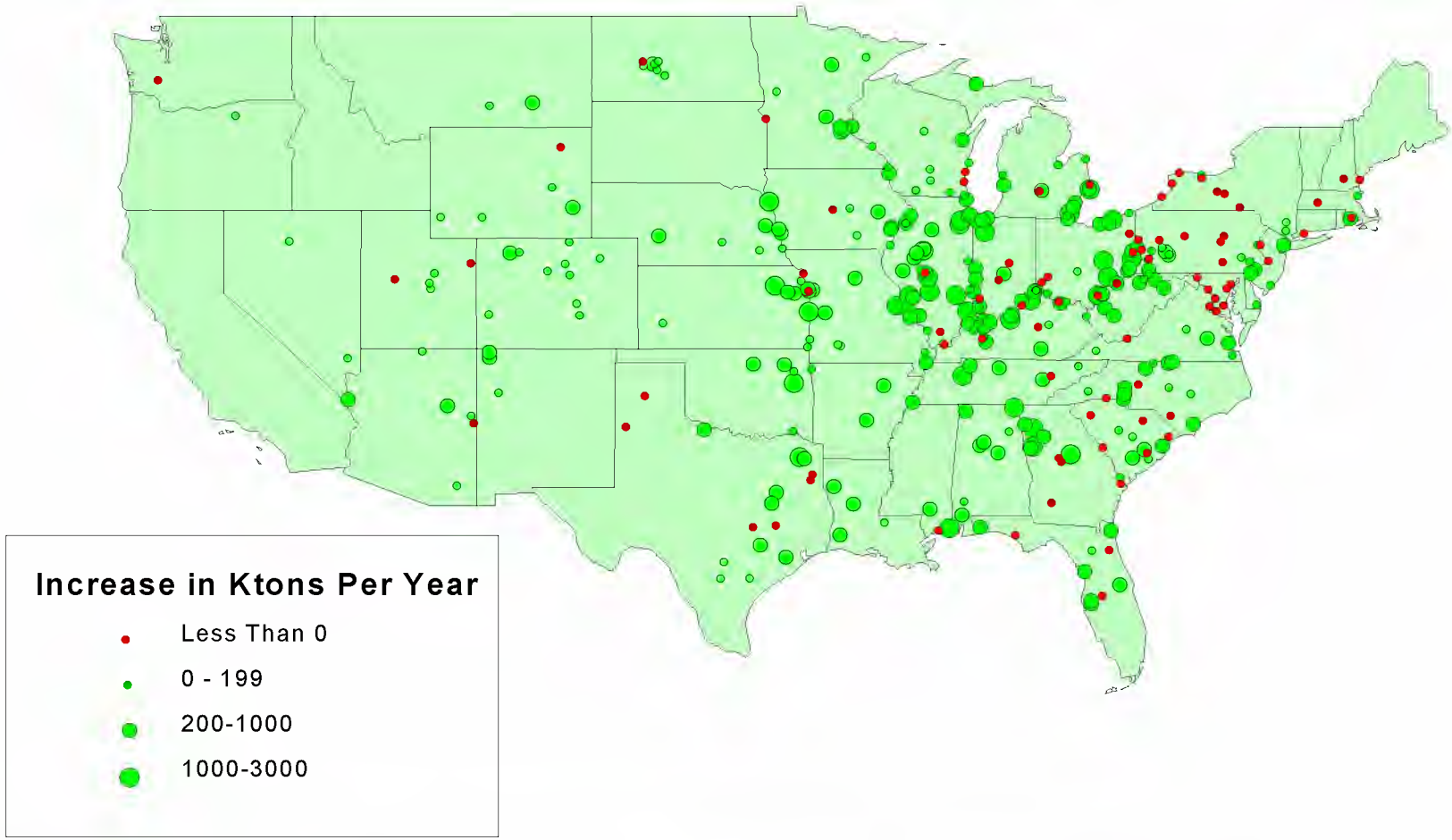
GAMS

Reporting

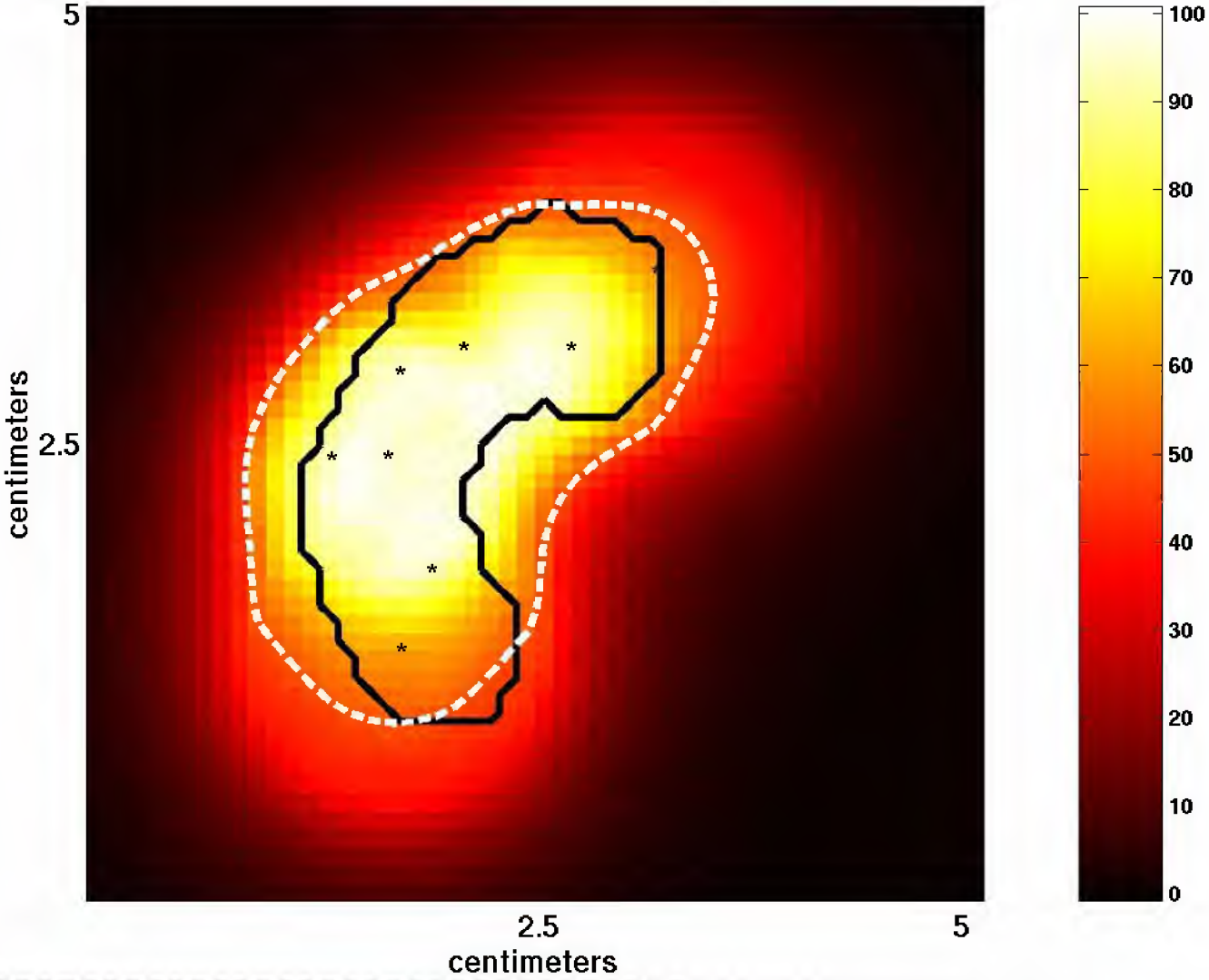
- Integrated Standard Reporting Facilities
  - MS Office, text files, …
- Specialized Reporting
  - Scenario Management/Data Cube: VEDA
  - Geographical Information System: MapInfo
  - Visualization with MATLAB
- Provide Help Interfacing with GAMS


VEDA: Hill-NPM
File Tables View Results Tools Help
Table Definition
T_423200343628PM
T_423200343628PM
Attribute
Block
CArea
CAreaTo
Fuel
NERC
NOxR
Operator
SOUTHWESTE
Plant
Pollutant
Region
Scenario
Season
State
TimeOfDay
ValueType
Year
SolVal
PV
*** TEMPORARY NAME... This table will n
unless the name is modified ***
Attribute
Block
CArea
CAreaTo
Fuel
ValueType
Year
SolVal
Region
Scenario
Season
State
TimeOfDay
NERC
NOxR
Operator
Plant
Pollutant
ROCHESTER
ROCHPU
RUSTONWAT
SACRAMENTO
SAFEHARBO
SALTRIVER
Cube View
Do not save changes while closing
Active Unit:
Original Units:
Block
Region
NERC
NOxR
Operator
Scenario
CAreaTo
Attribute
Year
ValueType
Plant
State
Fuel
CArea
Season
CAPAC_PROD
CAPFRACT
DISP_COST
LB_HG
613800 AR COAL CSW Fall 2315480.00 1114.54 21.43
Spring 2340920.00 1114.54 21.43
Summer 2340920.00 1383.15 21.43
Winter 2290030.00 1331.70 21.43
613900 TX COAL CSW Fall 6946431.00 1044.85 24.84
Spring 7022765.00 1044.85 24.84
Summer 7022765.00 1317.90 24.84
Winter 6870097.00 1214.61 24.84
790200 TX COAL CSW Fall 2943807.00 1021.34 13.66
Spring 2976156.00 1021.34 13.66
Summer 2976156.00 1294.35 13.66
Winter 2911452.00 1242.90 13.66
Table Layout
Aggregation Details
View
Ready
Results: C:\Program Files\VEDA35\databases\npm
Admin
Wednesday, April 23, 2003, 04:38 PM
Start
4:38 PM

GAMS/MapInfo



GAMS/MATLAB


5
2.5
centimeters
2.5
5
centimeters
100
90
80
70
60
50
40
30
20
10
0

Black Box Model

- *Innocent* User
- Bulletproof Optimization Application
  - No *failures*: e.g. No Infeasible Models
- Model embedded in larger System:

- Optimization
- Takes Longer than one is willing to wait
- It will eventually fail

- Application
- Real Time
- Always need a *Solution* to Problem

Scheduling US Military Academy West Point

" … each student's daily activities are a carefully regimented balance of academic, military, and physical requirements."

An Optimization Model

$$\min \sum_{ro}(p1_{ro} * \pi 1_{ro} + p2_{ro} * \pi 2_{ro}) + \sum_{c}(p3_c * \pi 3_c + p4_c * \pi 4_c)$$

$$\sum_{o} x_{c,ro} = 1 \quad \text{(for all 8TAP entries)}$$

$$\sum_{r} x_{c,ro} \leq 1 + \pi 3_c \quad \text{(for all cadets } c \text{ for all time slots } o\text{)}$$

$$-\sigma - \pi 4_c \leq \sum_{ro \text{ on day-1}} x_{c,ro} - \sum_{ro \text{ on day-2}} x_{c,ro} \leq \sigma + \pi 4_c \quad \text{(for all cadets } c\text{)}$$

$$x_{c,ro} = 0 \quad \text{(for all } c, ro \text{ where } c \text{ has activity at } o\text{)}$$

$$\sum_{c} x_{c,ro} \leq cap_{ro} + \pi 1_{ro} \quad \text{(for all course hours } ro\text{)}$$

$$\sum_{c \text{ freshman\&athlete}} x_{c,ro} - 0.6 \sum_{c} x_{c,ro} \leq \pi 2_{ro} \quad \text{(for all course hours } ro\text{)}$$

Problems MP Model

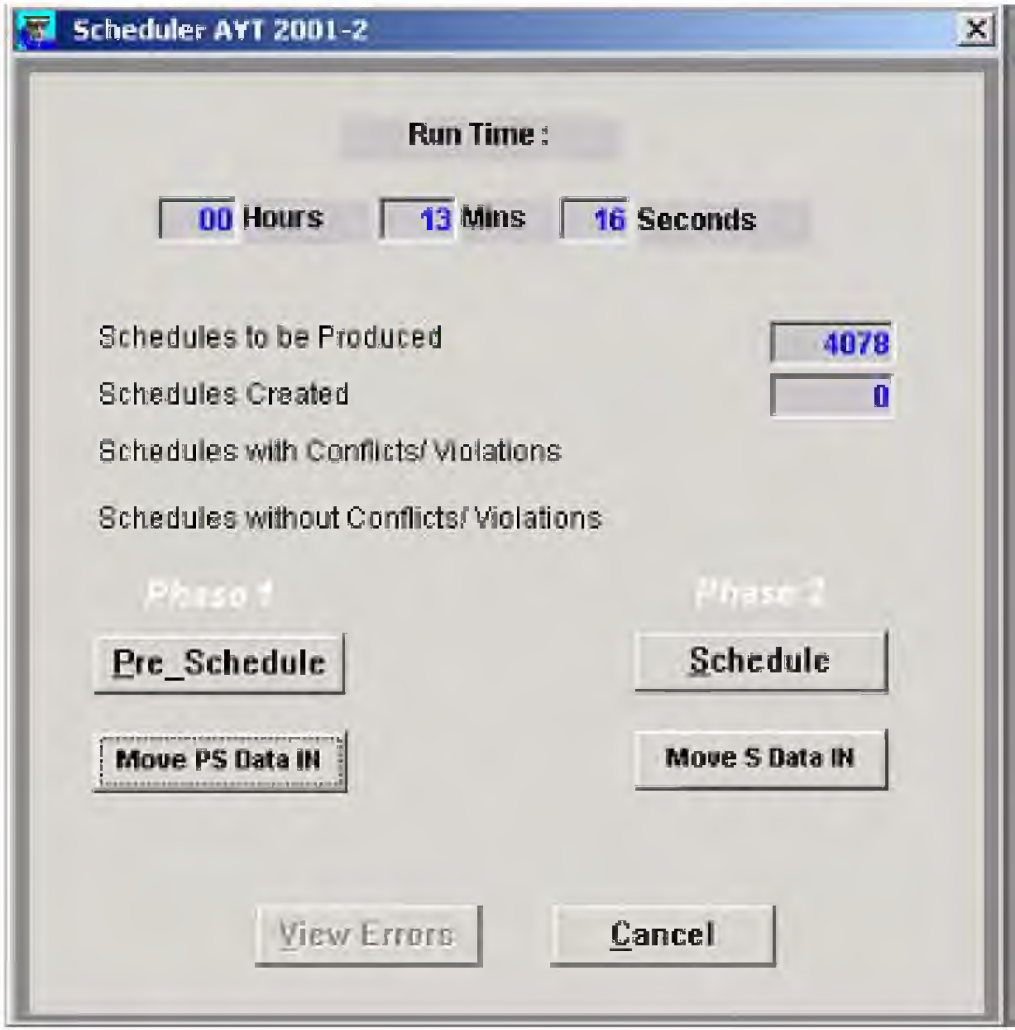
- There is no solution subject to *all* constraints/rules for real data
- Infeasibilties
  - Individual Cadet Infeasibilities
  - System Infeasibility (e.g. Capacity)
- *Goal Programming:*
  - Relax constraints/rules by penalizing violations
  - How to Select penalties for constraint violations
  - Penalty depend on individual Cadet

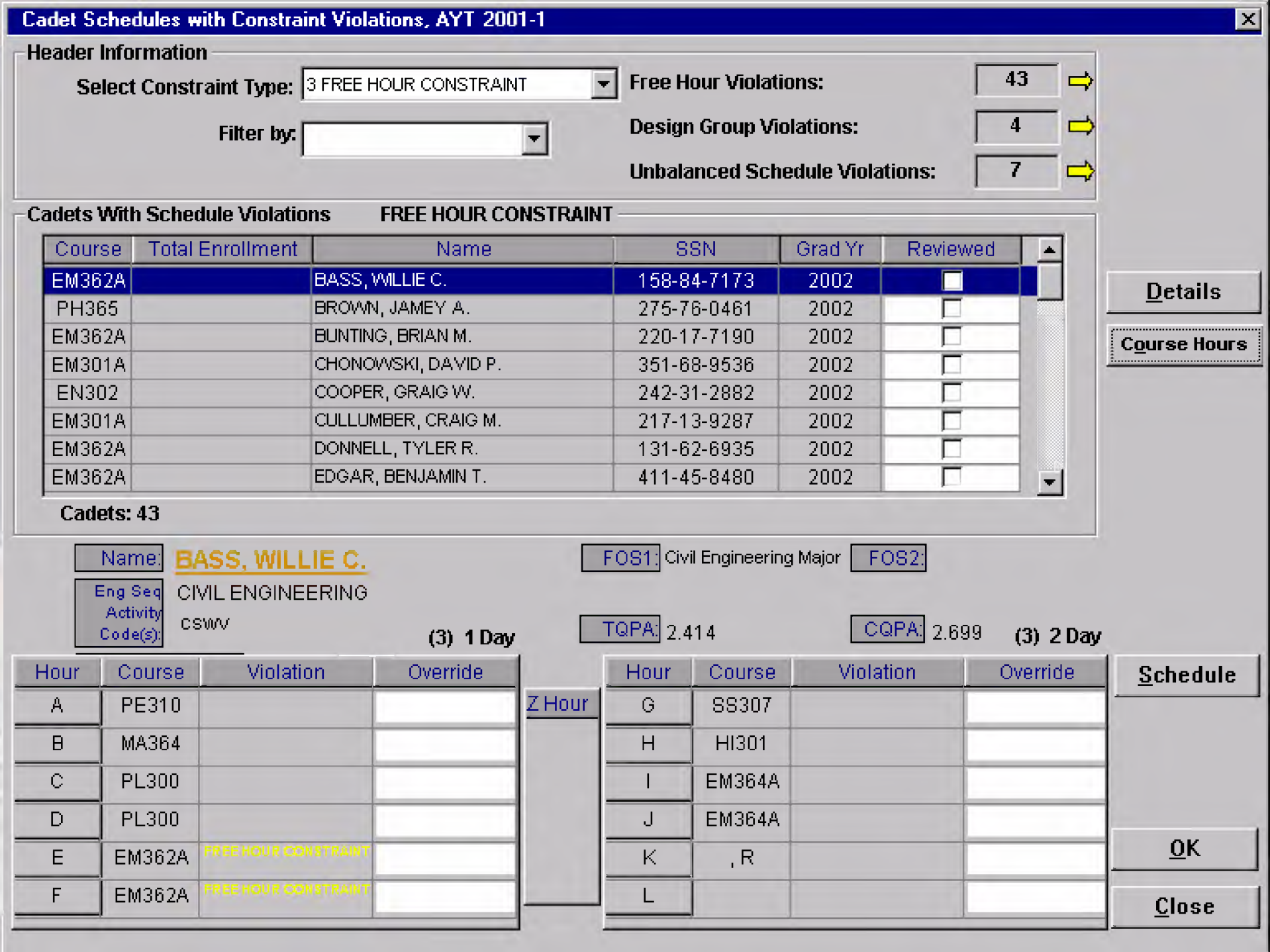
Two-Stage Approach

- Pre-Scheduling
  - Filter cadets with no feasible schedule
  - Overcome infeasibility by waiving constraint or data changes
- Scheduling
  - All individual constraints/rules are hard constraints
  - Find assignment that does not exceed capacity (or penalize overloads)

Pre-Scheduling

- One cadet at a time
- Thousands of small MIPs
- If infeasible produce several infeasible schedules
- Human accepts infeasible schedule or modifies data




Cadet Schedules with Constraint Violations, AYT 2001-1
Header Information
Select Constraint Type: 3 FREE HOUR CONSTRAINT
Filter by:
Free Hour Violations: 43
Design Group Violations: 4
Unbalanced Schedule Violations: 7
Cadets With Schedule Violations
FREE HOUR CONSTRAINT
Course | Total Enrollment | Name | SSN | Grad Yr | Reviewed
EM362A | BASS, WILLIE C. | 158-84-7173 | 2002
PH365 | BROWN, JAMEY A. | 275-76-0461 | 2002
EM362A | BUNTING, BRIAN M. | 220-17-7190 | 2002
EM301A | CHONOWSKI, DAVID P. | 351-68-9536 | 2002
EN302 | COOPER, CRAIG W. | 242-31-2882 | 2002
EM301A | CULLUMBER, CRAIG M. | 217-13-9287 | 2002
EM362A | DONNELL, TYLER R. | 131-62-6935 | 2002
EM362A | EDGAR, BENJAMIN T. | 411-45-8480 | 2002
Cadets: 43
Details
Course Hours
Name: BASS, WILLIE C.
FOS1: Civil Engineering Major
FOS2:
Eng Seq Activity Code(s): CIVIL ENGINEERING CSWV
TQPA: 2.414
CQPA: 2.699
(3) 1 Day
(3) 2 Day
Hour | Course | Violation | Override
A | PE310
B | MA364
C | PL300
D | PL300
E | EM362A | FREE HOUR CONSTRAINT
F | EM362A | FREE HOUR CONSTRAINT
Z Hour
Hour | Course | Violation | Override
G | SS307
H | HI301
I | EM364A
J | EM364A
K | , R
L
Schedule
OK
Close

GAMS

Modeling System Requirements

- Reliable System
- Using Third Party Software (Solver)
  - Keep Resource Usage of Solver in check
  - Solver will eventually crash
- Possibility to Implement Simple Heuristics
- Platform Choice
- Less important: Data Import/Export
  - IT does not want Modeling System to *mess* with DB
  - Simple/Thin Interfaces (text files, XML)

GAMS

Future Directions

- Value Added Applications
- Solution Service Providers
- Distributed System Architectures
- New Solution Approaches
- Continued Changes in the Modeling 'Industry'

Contacting GAMS Development

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