GAMS

Past, Present, and Future

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Workshop on Optimization/Modeling/Applications

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Model Structure

4 (c) Regional farmer employment accounting rows:

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

$$- \begin{bmatrix} \text{Regional farmer} \\ \text{employment} \\ \text{activity} \end{bmatrix} + 3 \begin{bmatrix} \text{Sum over districts} \\ \text{and quarters of} \\ \text{quarterly farmer} \\ \text{employment} \end{bmatrix}^{37} + \begin{bmatrix} \text{Sum over districts} \\ \text{and months of} \\ \text{monthly farmer employment} \end{bmatrix}^{37} = 0$$

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

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

$$-12 \begin{bmatrix} \text{Total employment} \\ \text{in man-years} \end{bmatrix} + \begin{bmatrix} \text{Sum over months of} \\ \text{total employment} \\ \text{in man-months} \end{bmatrix} = 0$$

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

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

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

$$-2.2 \begin{bmatrix} \text{Total} \\ \text{employment} \\ \text{in month } t \end{bmatrix}^{38} + \begin{bmatrix} \text{Sum over districts of} \\ \text{day labor employment} \\ \text{in month } t \end{bmatrix} + \begin{bmatrix} \text{Sum over districts of} \\ \text{quarterly farmer} \\ \text{employment in the} \\ \text{quarter containing} \\ \text{month } t \end{bmatrix} + \begin{bmatrix} \text{Sum over districts} \\ \text{of monthly farmer} \\ \text{employment} \end{bmatrix} = 0$$

[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.

Model Data

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]							

Matrix Generator

```
Y(248)'X(248)                                                            CUMPPB
  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)                                                            CUMNEI
  IF (X(250),LT.0.5,AND,X(250),GT.,00) Y(250)'Z(250,1)*(1+X(250))
Y(251)'X(251)                                                            CUMONE
  IF (X(251),LT.0.5,AND,X(251),GT.,00) Y(251)'Z(251,1)*(1+X(251))
Y(252)'X(252)                                                            CUMTWO
  IF (X(252),LT.0.5,AND,X(252),GT.,00) Y(252)'Z(252,1)*(1+X(252))
Y(253)'X(253)                                                            CUMTHR
  IF (X(253),LT.0.5,AND,X(253),GT.,00) Y(253)'Z(253,1)*(1+X(253))
Y(254)'X(254)                                                            CUMFOU
  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)                                                     CUMFIV
Y(256)'X(256)                                                            CUMLCT
  IF (X(256),LT.0.5,AND,X(256),GT.,00) Y(256)'Z(256,1)*(1+X(256))
Y(257)'X(257)                                                            CUMLCG
  IF (X(257),LT.0.5,AND,X(257),GT.,00) Y(257)'Z(257,1)*(1+X(257))
Y(258)'X(258)                                                            CUMDLS
  IF (X(258),LT.0.5,AND,X(258),GT.,00) Y(258)'Z(258,1)*(1+X(258))
Y(259)'X(259)                                                            CU 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)                                                            MKKRMT
  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)                                                            OFFCUR
  IF (X(266),LT.0.5,AND,X(266),GT.,00) Y(266)'Z(266,1)*(1-X(266))
Y(267)'X(267)                                                            OFFCAP
```

Matrix Generator Input

```
    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    73.490    1.0
SOY         0.1600    57.220    1.0
END
ALA         .02       0.0
```

MPS File – Column Section

```
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
```

MPS Revision File

```
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
```

MPS Output

```
DATE 07/30/76  TIME 22.12.21                                  C O L U M N S        APEX-III  1.000  PAGE

   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  RPCHRMS =       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	CPO.V...	PL	ACTIVE	.	-139.67000	+INF	.
111	CPO.F...	PL	ACTIVE	.00002	-139.67000	+INF	.
112	CPO.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	COF.CX..	PL	LOWER	.	180.74000	+INF	-87.19134
118	CDC.CX..	PL	LOWER	.	167.83000	+INF	-256.39963
119	COS.CX..	PL	ACTIVE	.06968	121.35000	+INF	.
120	COL.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	.

WB Old Slide 1

PLANNING PROBLEM AND OBJECTIVES INITIALLY OFTEN

UNSTRUCTURED

ILL-DEFINED

CONFLICTING

UNCERTAIN

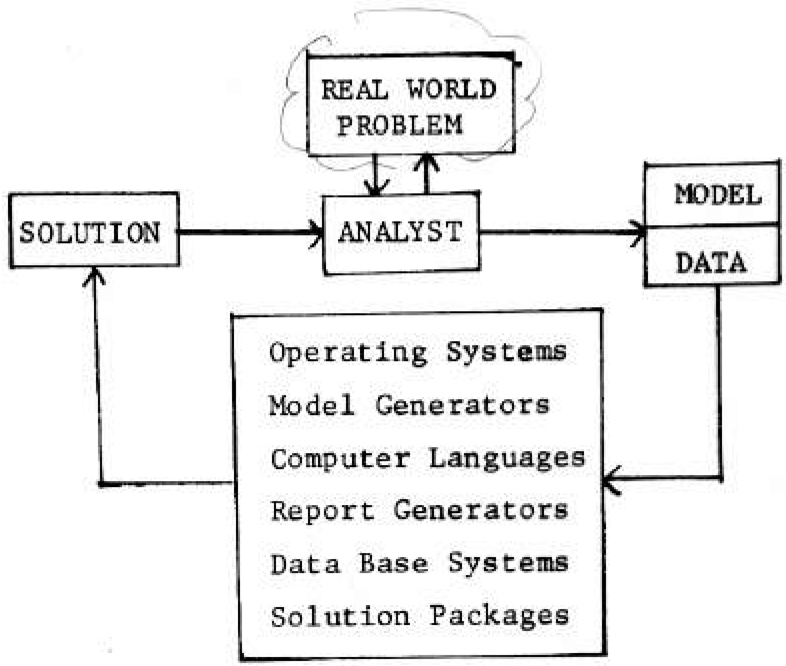
CHANGING

EMOTIONAL

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

WB Old Slide 2

PRESENT TECHNOLOGY



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

- Essentially no documentation

WB Old Slide 3

MAJOR CONSTRAINTS : COST

SKILLS

TIME

TOOLS

DOCUMENTATION

TRUST

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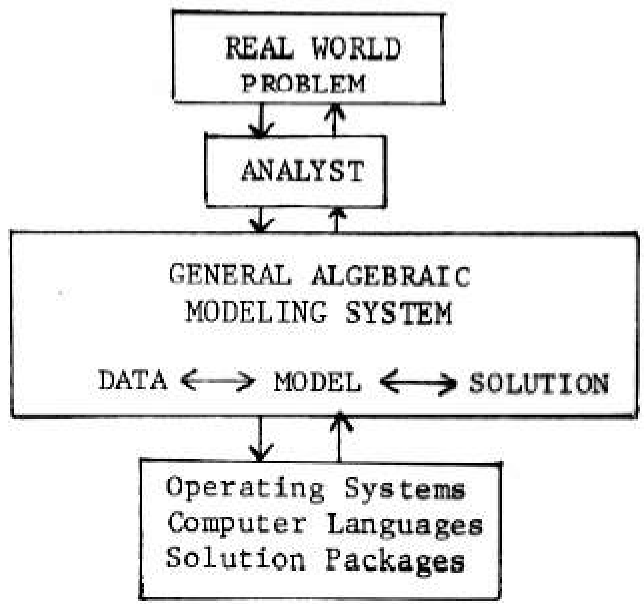
WB Old Slide 4

IDEAL TECHNOLOGY



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

WB Old Slide 5

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

WB Old Slide 6

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

WB Old Slide 7

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

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

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**

Dinner Table Assignment

- ‘Couples” on the same table
- Mix backgrounds and interest (algorithms,applications,World Bank, GAMS staff and family)
- Allow for last minute changes
- Use a model to shed responsibility for ‘poor’ assignments

List of Participants

show.xls [Shared]

	A	B	C	D
1	Firstname	Lastname	Email	Organization
2				
7	Michael	Ferris		UW Madison
8		Jane		
9	Nelissen	Franz		GAMS Software
10	Gary	Goldstein		IRG
11		Cheryl		
12	Forest	Hill		Hill and Associates
13	Bob	House		USDA
14	Gerd	Infanger		Stanford
15	Lloyd	Kelly		Hill and Associates
16	David	Kendrick		UT Austin
17	Bjarni	Kristjanssen		MAXIMAL Software
18	Sven	Leyffer		Argonne National Labora
19		Fr. Leyffer		
20	Alan	Manne		Stanford
21	Bruce	McCarl		TAMU
22	Todd	Munson		Argonne National Labora
23	Fred	O'Brien		USMA West Point

Problem Domains

Edit Search Windows Utilities Help

symblookupx

C:\test\super\seating.gms

seating.gms | seating.lst

```
$Title Seating Model for GAMS Birthday Party
$eolcom //
Set pp All guests
    g  Groups / S  'Solver/Modeling Providers'
                A  'Application Specialists'
                W  'World Bank'
                G  'GAMS'
                F  'Family'
               /
    cc Couples  / c1*c20, none/
    tt tables   / t1*t10 /
    h  headings / Show, Conference, Dinner, GO, BBQ, TableNo /

Parameter bd(pp,g,cc,h) Birthday Data;

$call gdxxrw show.xls set=pp rdim=1 rng=e4:e82 par=bd dim=4 rng=e3:m82
```

New Excel Input

Microsoft Excel

File Edit View Insert Format Tools Data Window Help

K38 =

show.xls [Shared]

	A	B	C	D	F	G	H	I	J
1	Firstname	Lastname	Email	Organization	Group	Couples	Show	Conference	Dinner
2								55	76
7	Michael	Ferris		UW Madison	S	c1	1	1	1
8		Jane			F	c1	1	0	1
9	Nelissen	Franz		GAMS Software	G		1	1	1
10	Gary	Goldstein		IRG	A	c2	1	1	1
11		Cheryl			F	c2	1	0	1
12	Forest	Hill		Hill and Associates	A		1	0	1
13	Bob	House		USDA	A		1	1	1
14	Gerd	Infanger		Stanford	S		1	1	1
15	Lloyd	Kelly		Hill and Associates	A		1	1	1
16	David	Kendrick		UT Austin	A		1	1	1
17	Bjarni	Kristjanssen		MAXIMAL Software	S		1	1	1
18	Sven	Leyffer		Argonne National Labora	S	c3	1	1	1
19		Fr. Leyffer			F	c3	1	0	1
20	Alan	Manne		Stanford	A		1	1	1
21	Bruce	McCarl		TAMU	S		1	1	0
22	Todd	Munson		Argonne National Labora	S		1	1	1

Model Definition

C:\test\super\seating.gms

seating.gms | seating.lst

```
Binary variables x(pp,tt)     assignment guest to table
                 cx(cc,tt)    couple assignment
Variable gcnt(g)              maximum number of guest of a group at each table
         z                    objective variable
Equation  onep(pp)            one table per guest
          onec(cc)            one table per couple
          defcouple(cc,pp,tt) couple mapping
          defmaxg(g,tt)       maximum number of guest of a group at each table
          defz                balance all groups
          deftsize(tt)        table size
;

onep(p)..    sum(t, x(p,t)) =e= 1;

onec(c)..    sum(t, cx(c,t)) =e= 1;

defcouple(cp(c,p),t)..   x(p,t) =e= cx(c,t);

deftsize(t)..   sum(p,x(p,t)) =l= 8 + over(t);

defmaxg(g,t)..  sum(gp(g,p), x(p,t)) =l= gcnt(g);

defz.. sum(g$(not xg(g)),card(p)/sum(p,gp(g,p))*gcnt(g)) =e= z;

model seat /all/;
```

Solve Summary

C:\test\super\seating.lst

seating.gms | seating.lst

```
MODEL STATISTICS

BLOCKS OF EQUATIONS         6     SINGLE EQUATIONS      425
BLOCKS OF VARIABLES         4     SINGLE VARIABLES      825
NON ZERO ELEMENTS        2795     DISCRETE VARIABLES    819


GENERATION TIME      =        0.030 SECONDS    1.6 Mb      WIN212-136


EXECUTION TIME       =        0.040 SECONDS    1.6 Mb      WIN212-136
□GAMS Rev 136  MS Windows
Seating Model for GAMS Birthday Party
Solution Report     SOLVE seat Using MIP From line 70


               S O L V E      S U M M A R Y

     MODEL   seat                OBJECTIVE  z
     TYPE    MIP                 DIRECTION  MINIMIZE
     SOLVER  CPLEX               FROM LINE  70

**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      1 OPTIMAL
**** OBJECTIVE VALUE              684.0000

 RESOURCE USAGE, LIMIT          0.220      1000.000
 ITERATION COUNT, LIMIT       237         10000
```

Output Report

```
solve seat min z using mip;

Set        rep(tt,pp,g)
Parameter rept;

rep(t,p,g)$gp(g,p)  = round(x.l(p,t));
rept(t,g)           = sum(gp(g,p)$rep(t,p,g),1);
rept('total',g)     = sum(t, rept(t,g));
rept(t,'total')     = sum(g, rept(t,g));
rept('total','total')     = sum((t,g), rept(t,g));

option rep:0:0:1, rept:0:1:1; display rep, rept;

Parameter toxls(pp,g,cc,h);
toxls(p,g,c,h)          = bd(p,g,c,h);
toxls(p,g,c,'TableNo') = sum(rep(tt,p,g),ord(tt));

execute_unload 'toxls', toxls;
execute 'gdxxrw toxls.gdx o=show.xls par=toxls dim=4 rng=e3:m83 merge';
```

MIP emphasis: balance opt

Group Balance

C:\test\super\seating.lst

seating.gms | seating.lst

---- 81 PARAMETER rept

	S	A	W	G	F	total
t1	3	2	1	1	2	9
t2	3	2	1	1	2	9
t3	1	1	1	1	5	9
t4	2	3		1	3	9
t5	3	2	1		2	8
t6	2	3		2	1	8
t7	2	3	1	1	1	8
t8	1	3	1	1	2	8
t9	3	3		2		8
total	20	22	6	10	18	76

EXECUTION TIME = 2.694 SECONDS 1.5 Mb WIN212-136

Excel Report

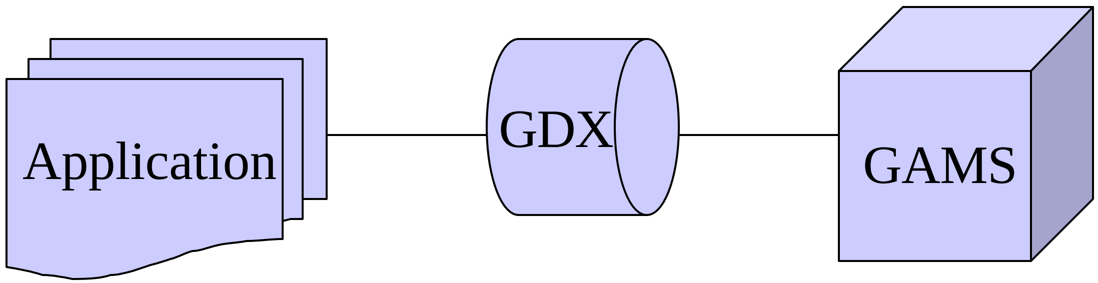
C	D	F	G	H	I	J	K	L	M	
Email	Organization	Group	Couples	Show	Conference	Dinner	GO	BBQ	TableNo	Con
					55	76	18			
	Paragon	S		1	1	1	1		5	
	Carleton Univeristy	S		1	1	1	1		3	
	ARKI	S		1	1	1	1	1	4	
	UW Madison	S	c1	1	1	1			5	
		F	c1	1	0	1			5	
	GAMS Software	G		1	1	1	1		9	
	IRG	A	c2	1	1	1			8	
		F	c2	1	0	1			8	
	Hill and Associates	A		1	0	1			6	
	USDA	A		1	1	1			6	
	Stanford	S		1	1	1			4	
	Hill and Associates	A		1	1	1			9	

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

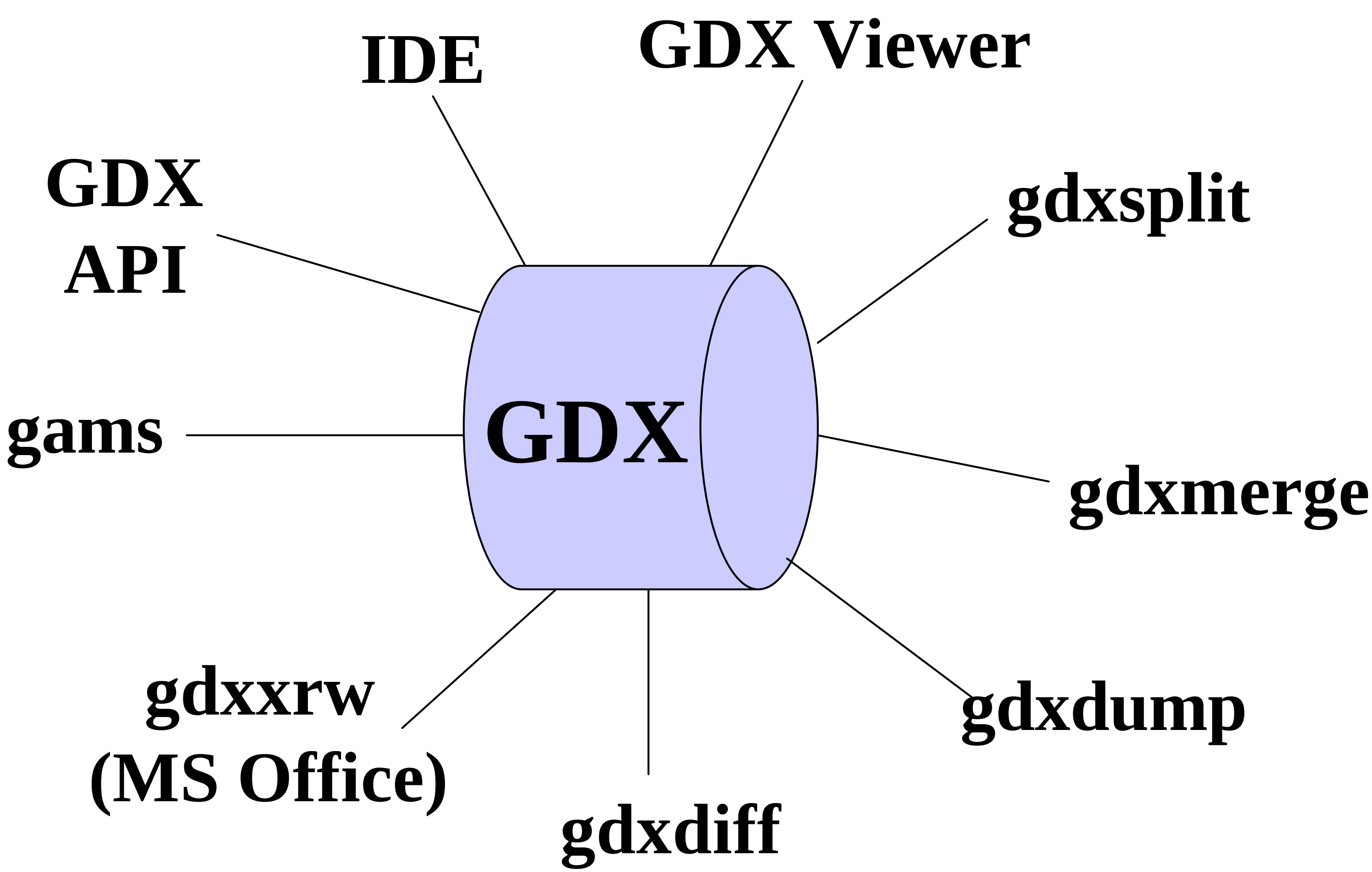
Gams Data eXchange

- 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

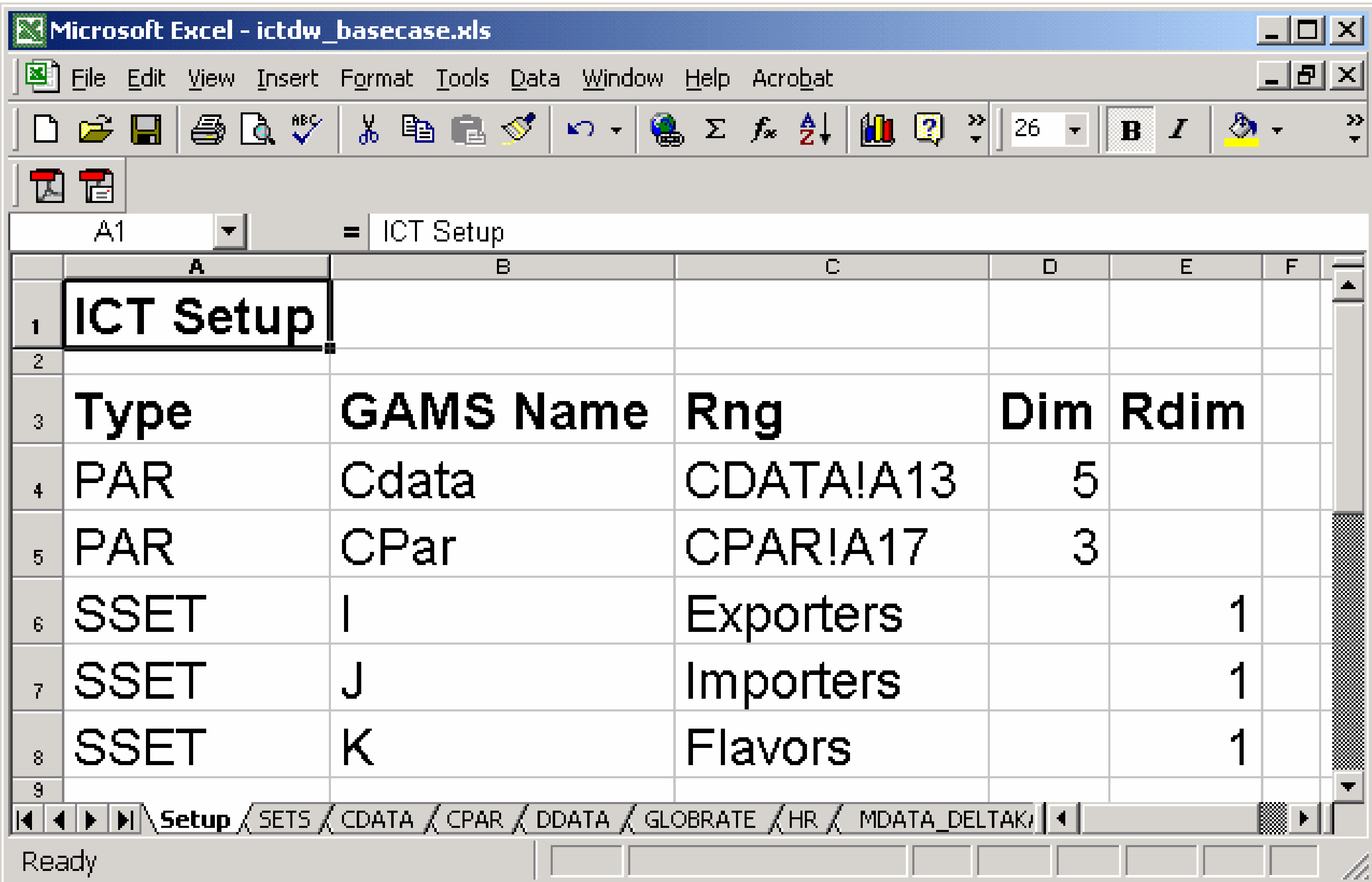
GDX Tools


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

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

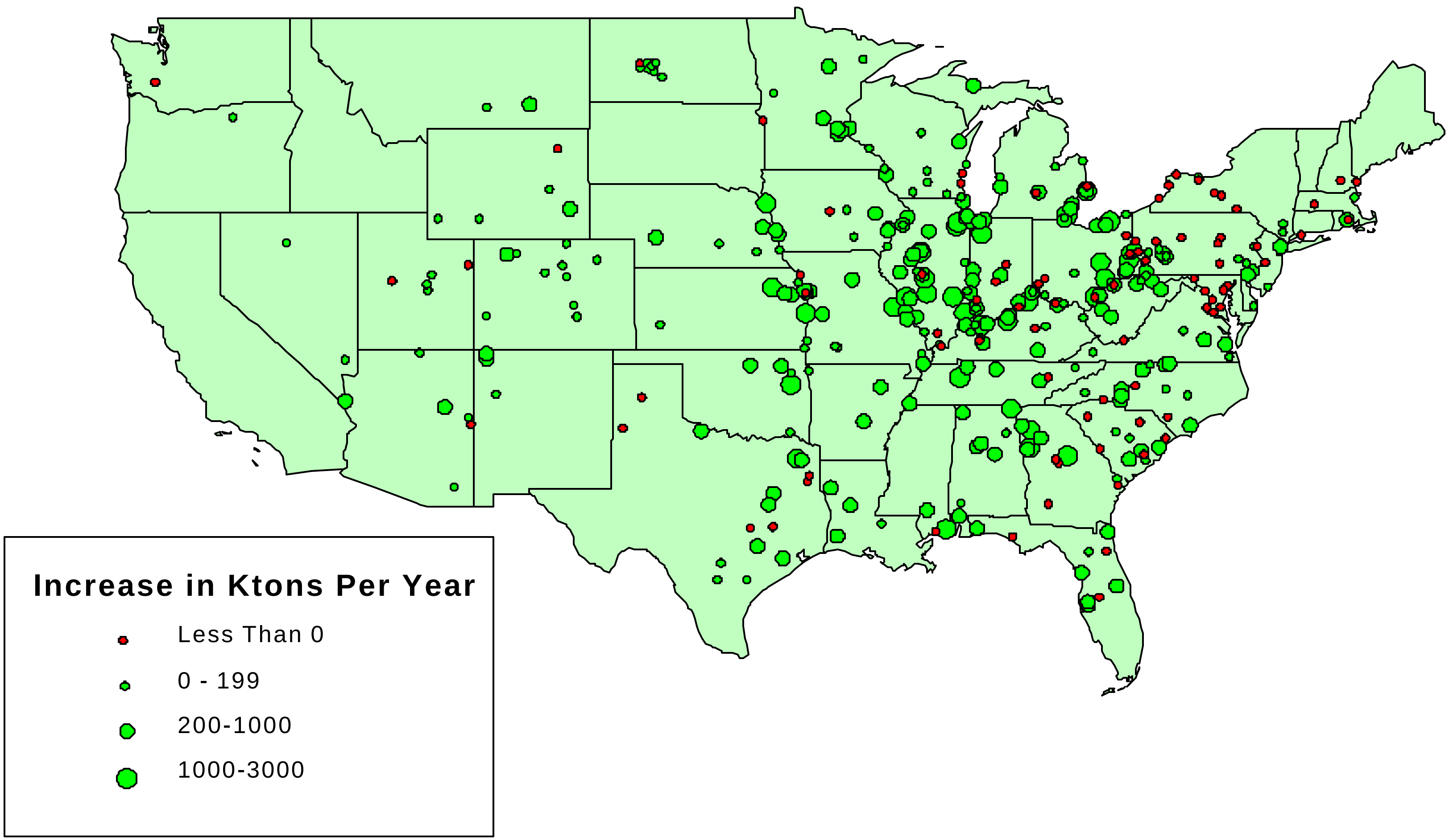


ICT Setup				
Type	GAMS Name	Rng	Dim	Rdim
PAR	Cdata	CDATA!A13	5	
PAR	CPar	CPAR!A17	3	
SSET	I	Exporters		1
SSET	J	Importers		1
SSET	K	Flavors		1

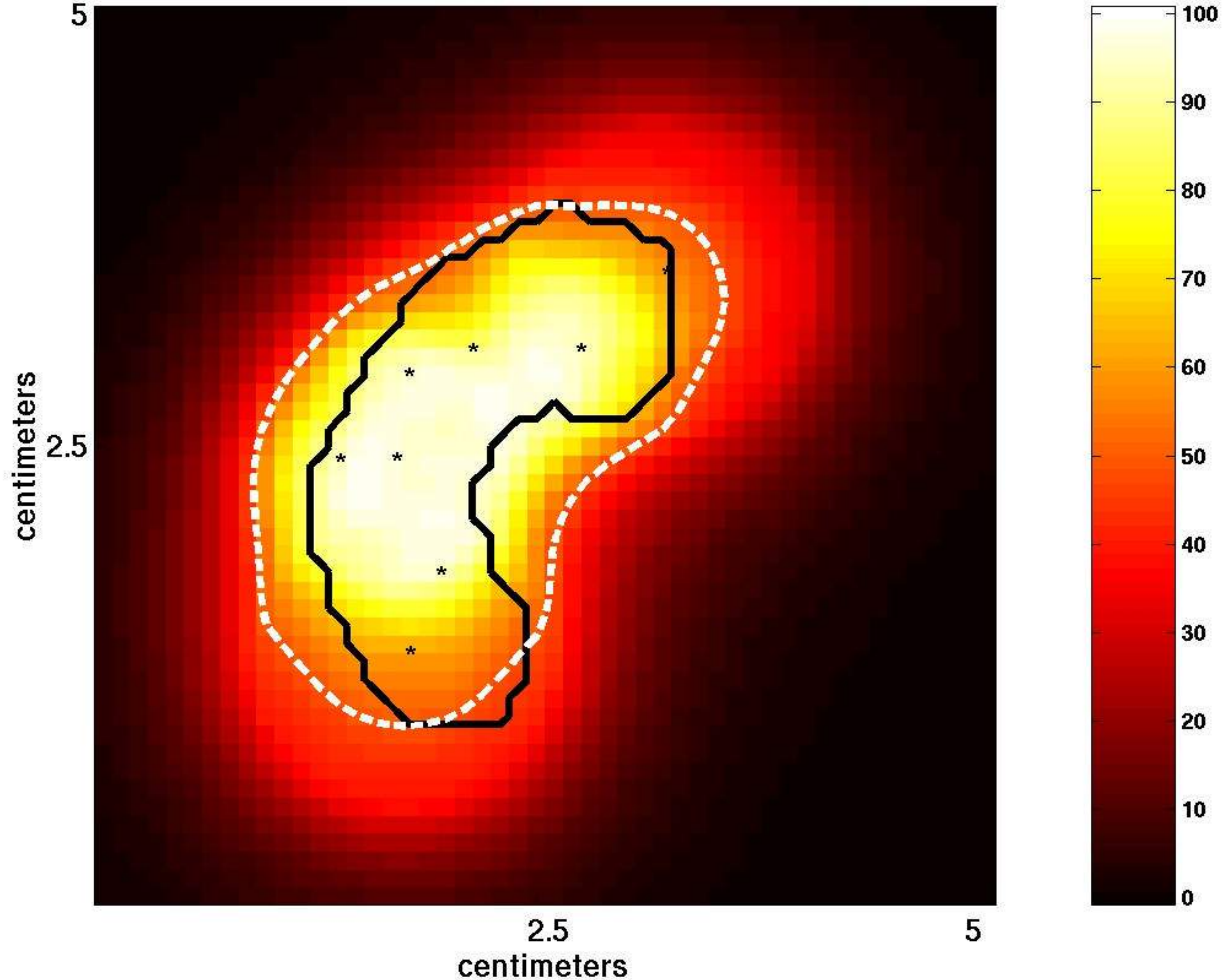
Data Contract in Excel – cont.

```
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
```

GAMS/MapInfo



GAMS/MATLAB



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

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				2002	☐
PH365				2002	☐
EM362A				2002	☐
EM301A				2002	☐
EN302				2002	☐
EM301A				2002	☐
EM362A				2002	☐
EM362A				2002	☐

Cadets: 43

Details | Course Hours

Name:

FOS1: Civil Engineering Major　FOS2:

Eng Seq Activity Code(s): CIVIL ENGINEERING　CSWV

TQPA: 2.414　CQPA: 2.699

(3) 1 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

(3) 2 Day

Hour	Course	Violation	Override
G	SS307		
H	HI301		
I	EM364A		
J	EM364A		
K	, R		
L			

Schedule | OK | Close

Three Examples of GDX

- VEDA : post processing and ad-hoc information restructuring
- LOGMIP: experimental language extensions, algorithmic design studies
- Branch & Cut & Heuristic: automation of complex solver enhancements

The VErsatile Data Analyst (VEDA)

Amit Kanudia, KanORS Consulting Inc.

Gary A. Goldstein, IRG

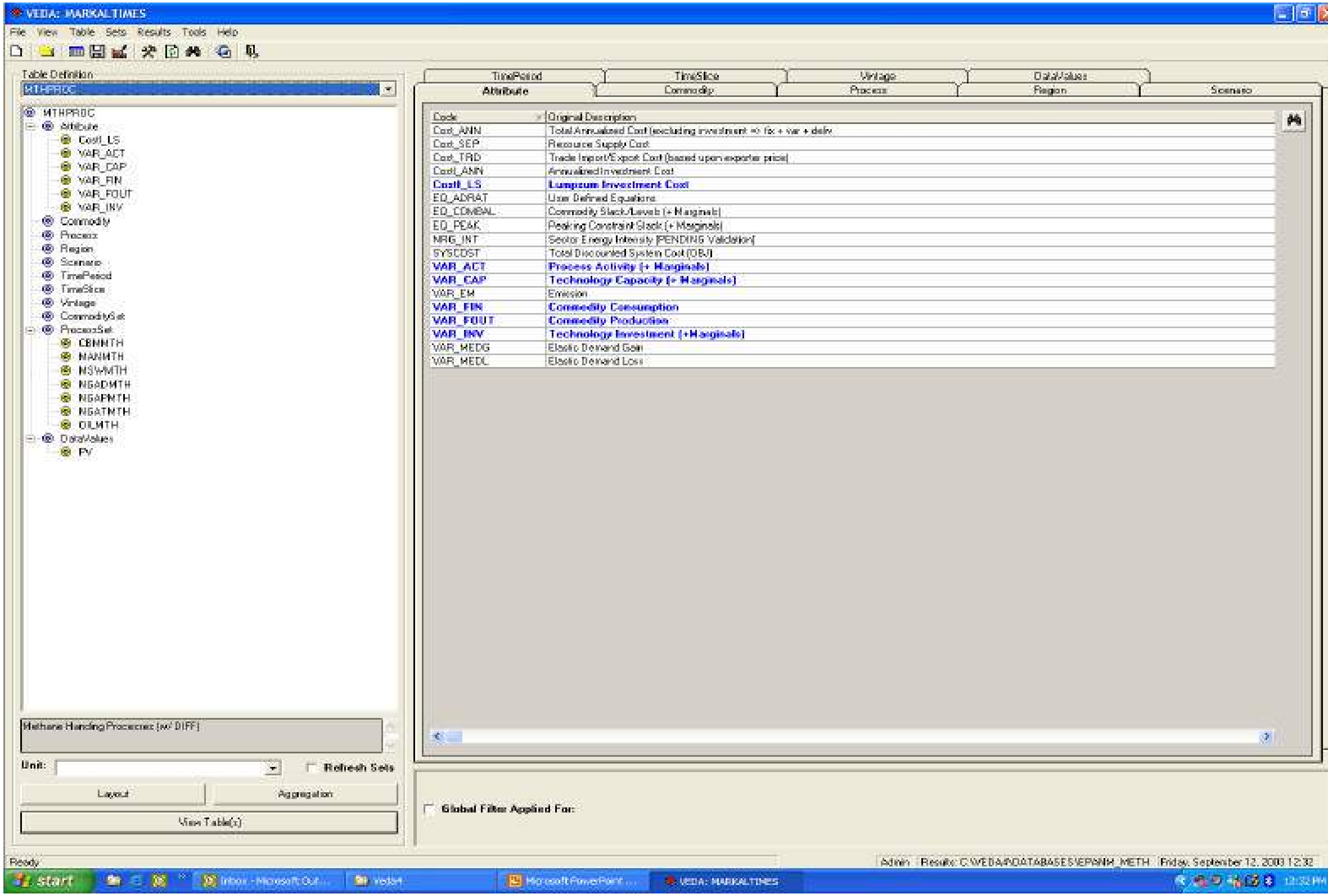
VEDA Description

- Manages GAMS Sets, Parameters and Model Results for the purpose of dynamic viewing and re-organizing, and presentation to others.
- Allows for cross-cutting access to parameters and results according to index structure and element values.
- Supports construction of user-defined sets, definition of new tables, and manipulation of tables.
- Provides powerful filtering capabilities on both elements names and descriptions.

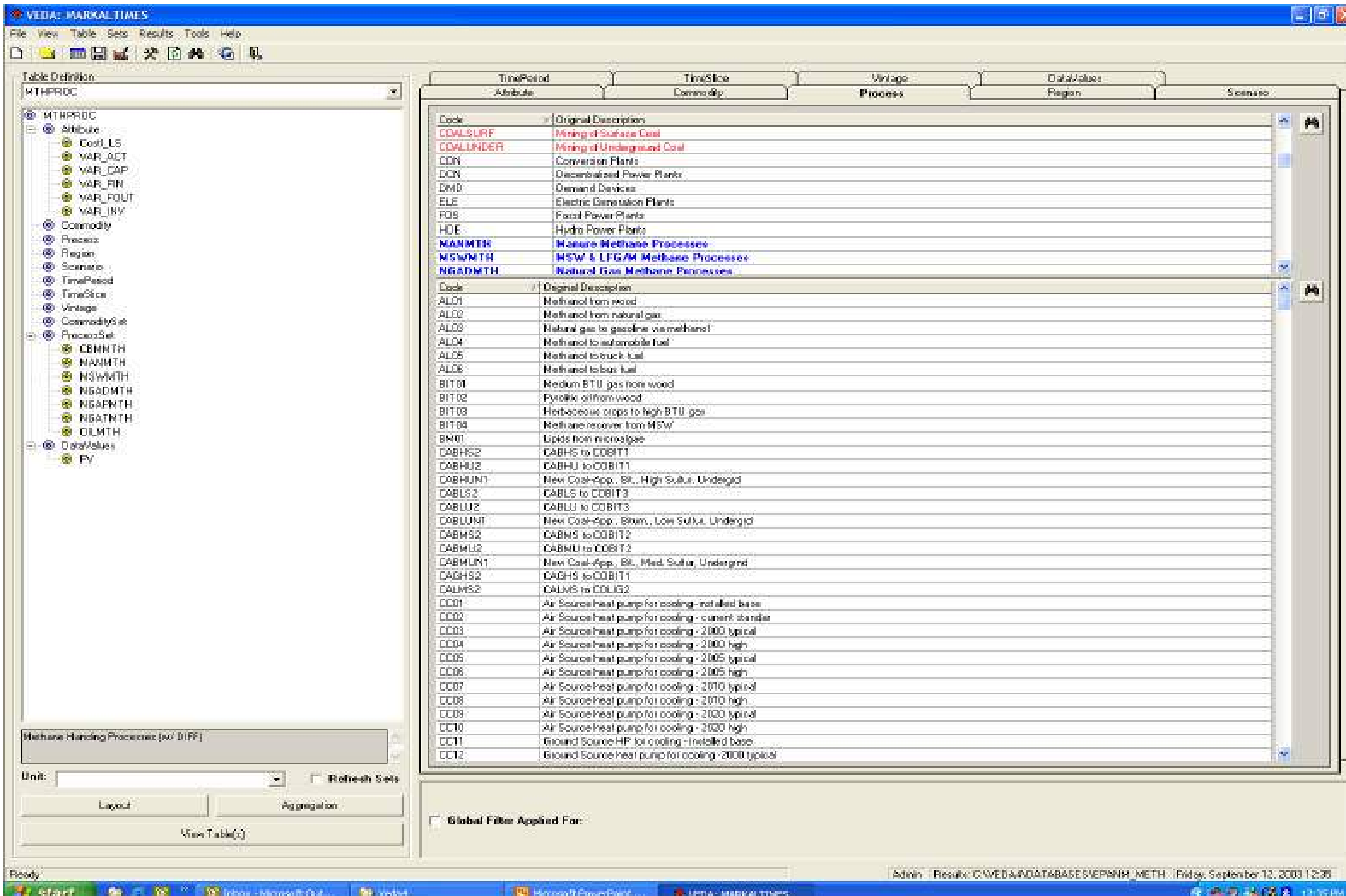
VEDA Description

- Employs customizable n-dimensional Data Cube component for displaying tables.
- Full-blown graphing facilities, as well as exporting to Excel, Word, PPT, HTML.
- Web-enabled, allowing model results to be made available over the web in user-friendly, reconfigurable tables.
- Convenient GDX2VEDA data definition file for identification of information to be ported from GAMS to VEDA.

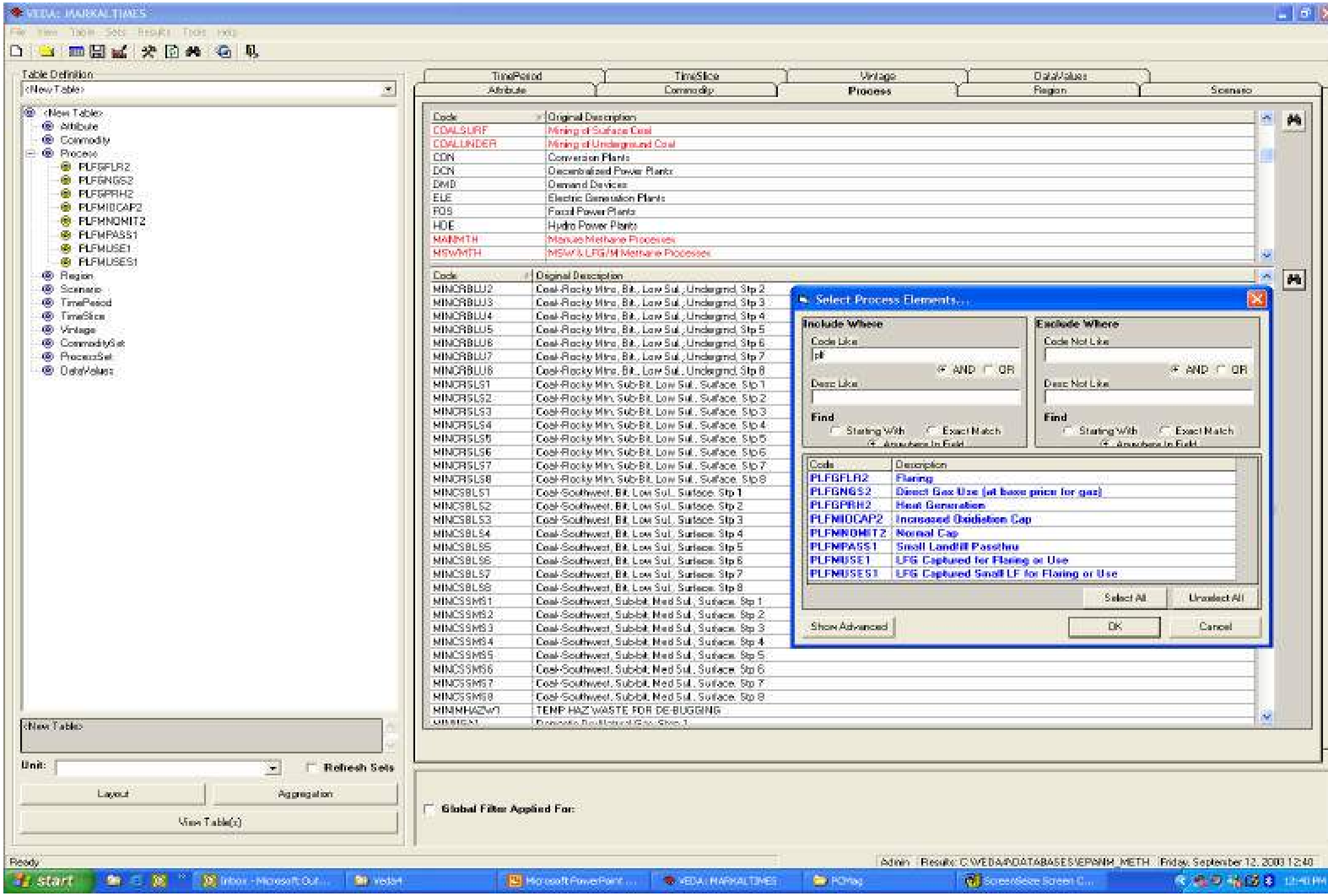
VEDA Table Form – Attribute List



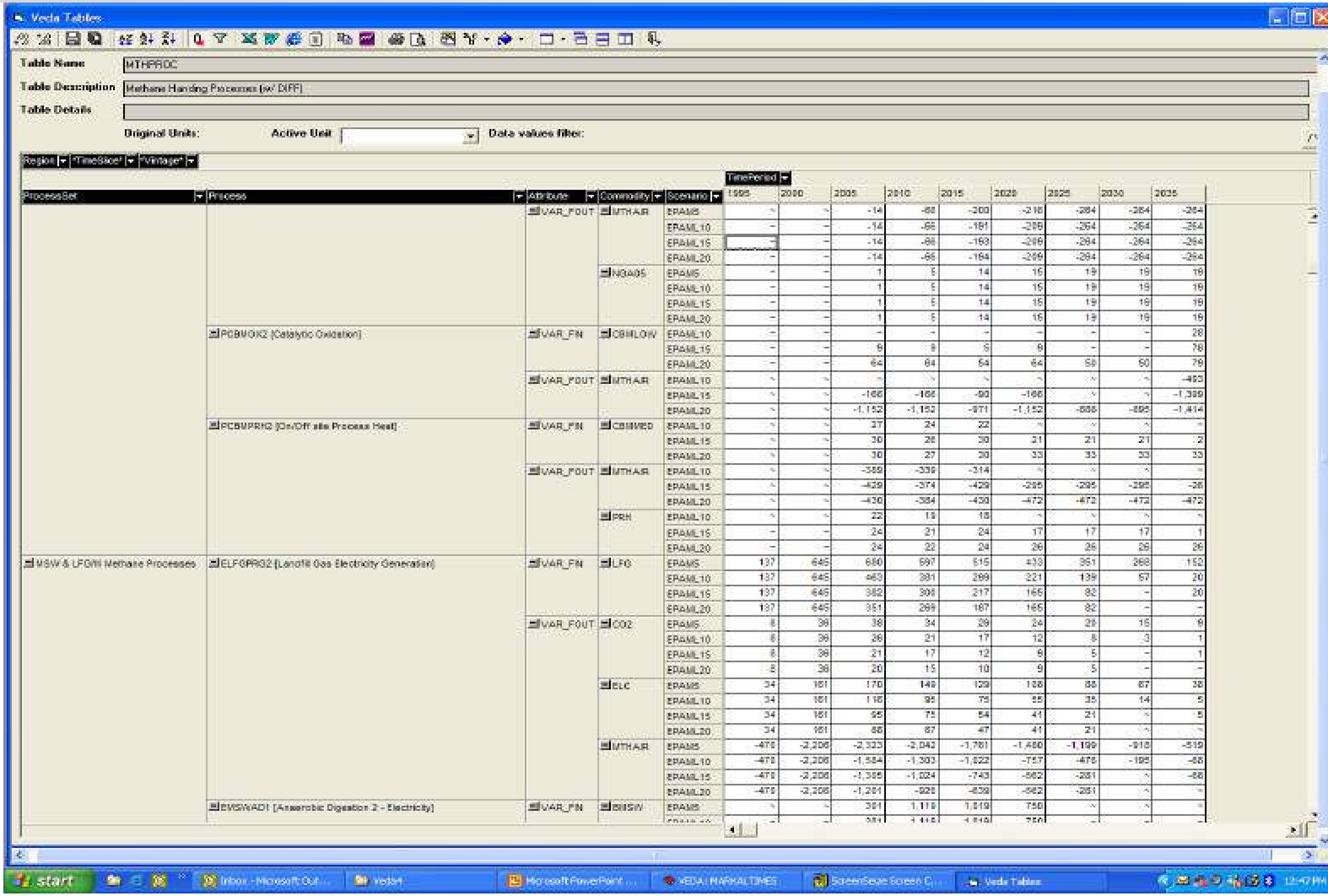
VEDA Table Form – Sets (Model&User)/Elements



VEDA Table Form – Search & Select Engine

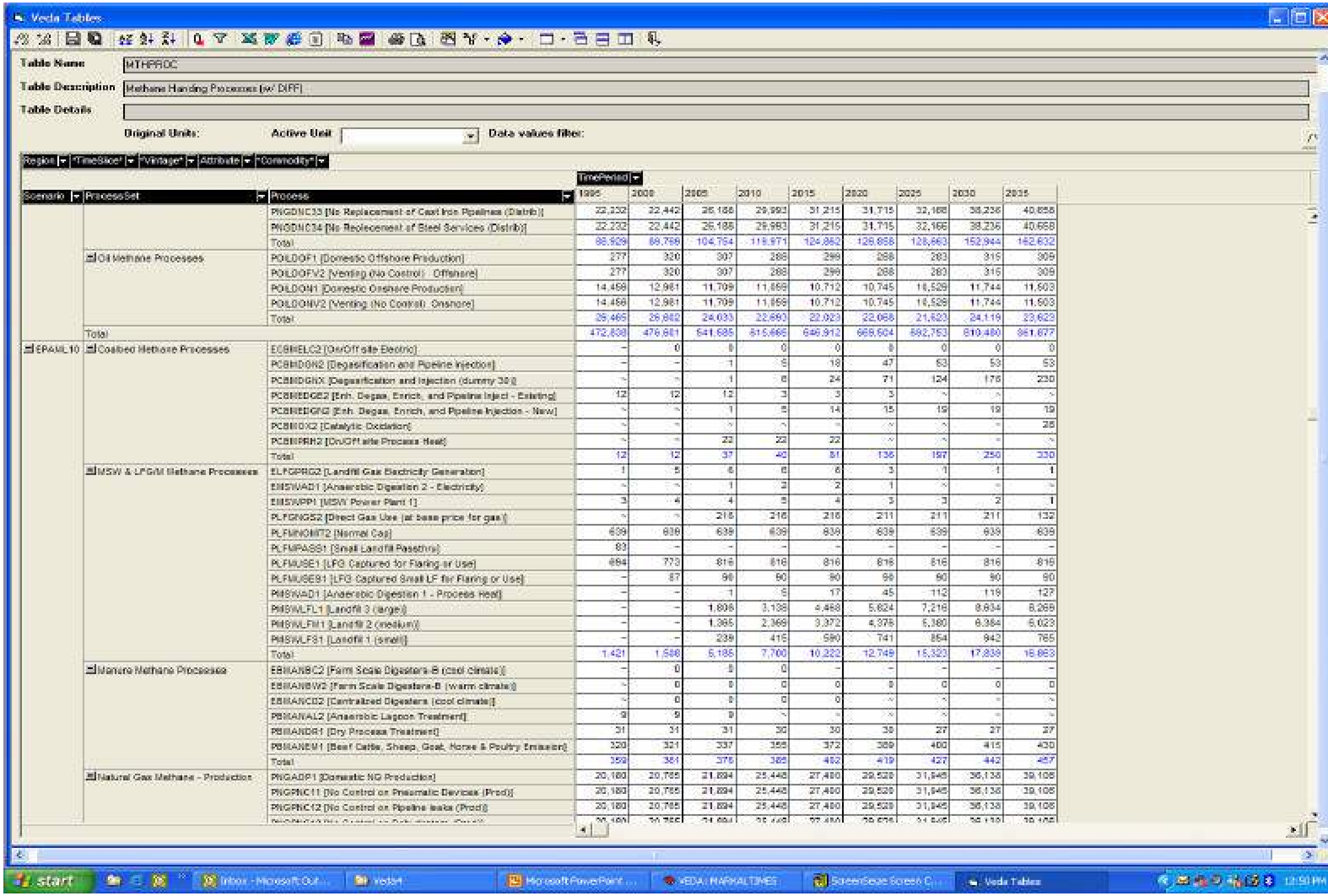


ProcessSet/Process/Commodity/ Scenario



ProcessSet	Process	Attribute	Commodity	Scenario	1995	2000	2005	2010	2015	2020	2025	2030	2035
		VAR_FOUT	MTHAIR	EPAMS	-	-	-14	-66	-200	-216	-264	-264	-264
				EPAML10	-	-	-14	-66	-181	-209	-264	-264	-264
				EPAML15	-	-	-14	-66	-163	-209	-264	-264	-264
				EPAML20	-	-	-14	-66	-184	-209	-264	-264	-264
			NGA05	EPAMS	-	-	1	5	14	16	19	19	19
				EPAML10	-	-	1	5	14	16	19	19	19
				EPAML15	-	-	1	5	14	16	19	19	19
				EPAML20	-	-	1	5	14	16	19	19	19
	PCBMOX2 [Catalytic Oxidation]	VAR_FIN	CBMLOW	EPAML10	-	-	-	-	-	-	-	-	28
				EPAML15	-	-	9	9	5	9	-	-	78
				EPAML20	-	-	64	64	54	64	50	50	78
		VAR_FOUT	MTHAIR	EPAML10	-	-	-	-	-	-	-	-	-493
				EPAML15	-	-	-166	-166	-90	-166	-	-	-1,399
				EPAML20	-	-	-1,152	-1,152	-971	-1,152	-898	-898	-1,414
	PCBMPRH2 [On/Off site Process Heat]	VAR_FIN	CBMMED	EPAML10	-	-	27	24	22	-	-	-	-
				EPAML15	-	-	30	26	30	21	21	21	2
				EPAML20	-	-	30	27	30	33	33	33	33
		VAR_FOUT	MTHAIR	EPAML10	-	-	-389	-339	-314	-	-	-	-
				EPAML15	-	-	-429	-374	-429	-295	-295	-295	-36
				EPAML20	-	-	-430	-384	-430	-472	-472	-472	-472
			PRH	EPAML10	-	-	22	19	18	-	-	-	-
				EPAML15	-	-	24	21	24	17	17	17	1
				EPAML20	-	-	24	22	24	26	26	26	26
MSW & LFG/W Methane Processes	ELFGPRG2 [Landfill Gas Electricity Generation]	VAR_FIN	LFG	EPAMS	137	645	680	597	515	433	351	268	152
				EPAML10	137	645	463	381	299	221	139	57	20
				EPAML15	137	645	382	300	217	165	82	-	20
				EPAML20	137	645	351	269	187	165	82	-	-
		VAR_FOUT	CO2	EPAMS	8	38	38	34	29	24	29	16	9
				EPAML10	8	38	26	21	17	12	8	3	1
				EPAML15	8	38	21	17	12	9	5	-	1
				EPAML20	8	38	20	15	10	9	5	-	-
			ELC	EPAMS	34	161	170	149	129	108	88	67	38
				EPAML10	34	161	116	95	75	55	35	14	5
				EPAML15	34	161	95	75	54	41	21	-	5
				EPAML20	34	161	88	67	47	41	21	-	-
			MTHAIR	EPAMS	-476	-2,206	-2,323	-2,042	-1,761	-1,480	-1,199	-918	-519
				EPAML10	-476	-2,206	-1,584	-1,303	-1,022	-757	-476	-195	-68
				EPAML15	-476	-2,206	-1,305	-1,024	-743	-562	-281	-	-68
				EPAML20	-476	-2,206	-1,201	-920	-639	-562	-281	-	-
	EMSWAD1 [Anaerobic Digestion 2 - Electricity]	VAR_FIN	BMSW	EPAMS	-	-	381	1,119	1,019	750	-	-	-

VEDA Cube – Scenario/ProcessSet Totals



Veda Tables

Table Name: MTHPROC

Table Description: Methane Handing Processes (w/ DIFF)

Table Details:

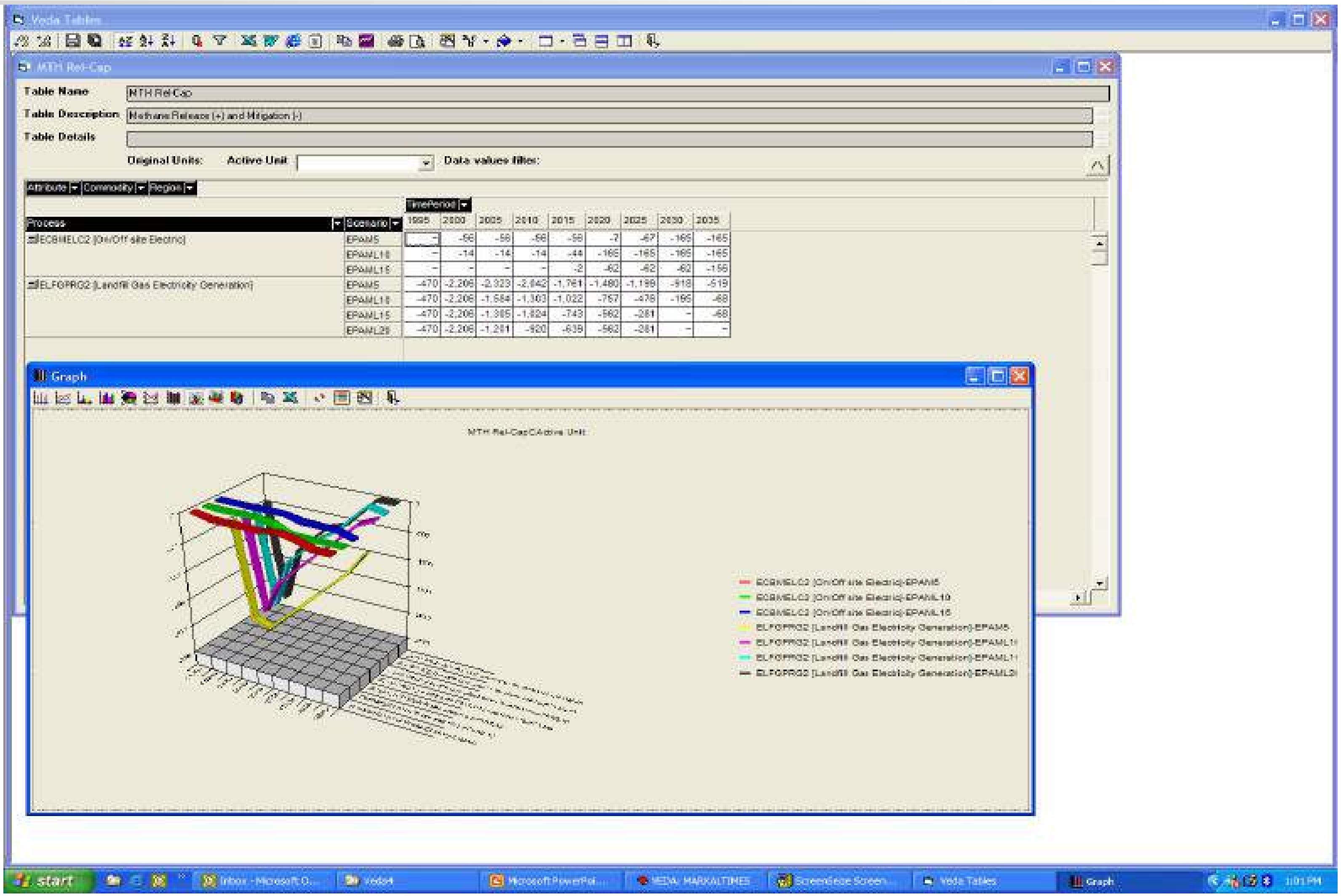
Original Units: Active Unit Data values filter:

Region | *TimeSlice* | *Vintage* | Attribute | *Commodity*

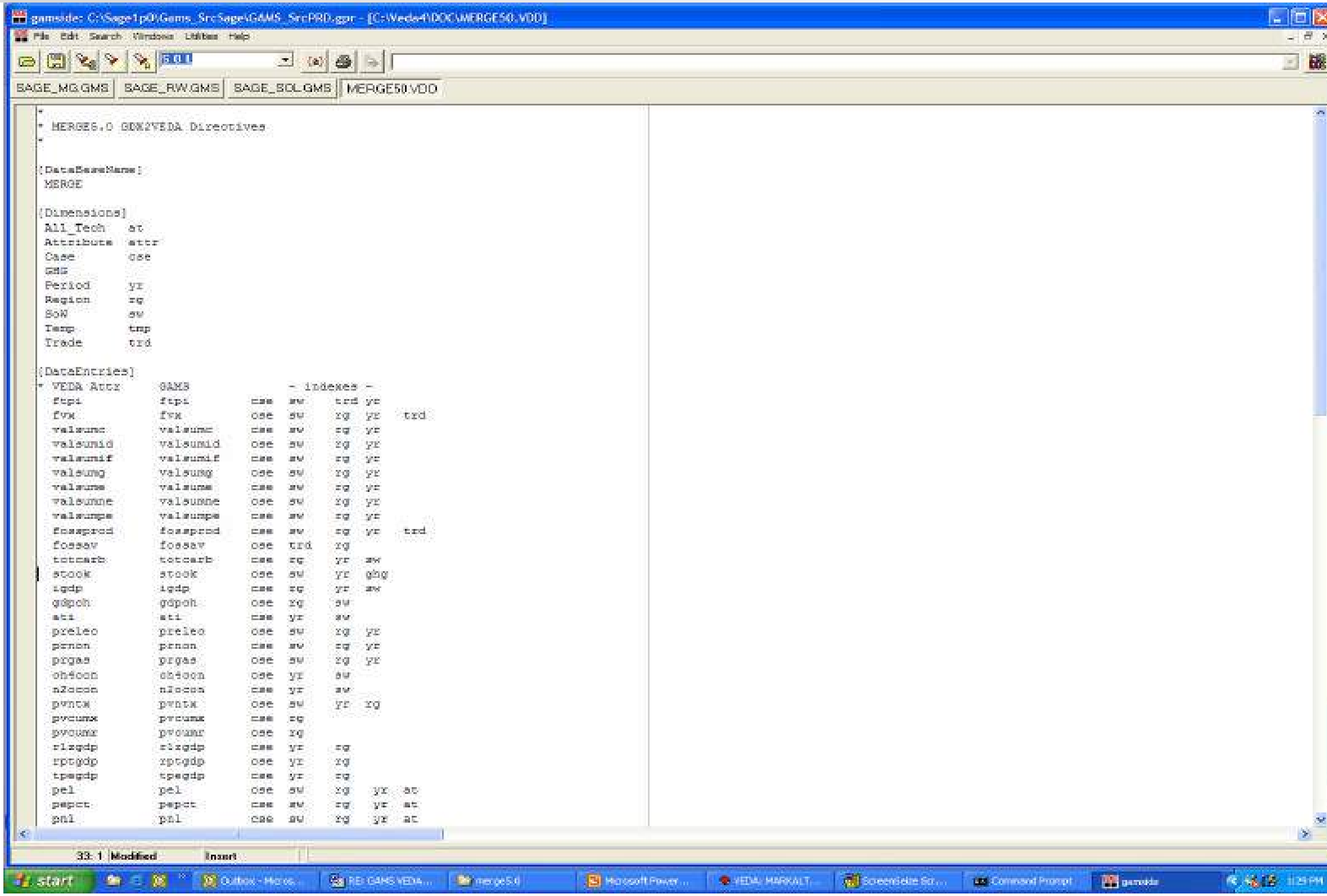
TimePeriod

Scenario	ProcessSet	Process	1995	2000	2005	2010	2015	2020	2025	2030	2035
		PNGDNC33 [No Replacement of Cast Iron Pipelines (Distrib)]	22,232	22,442	26,188	29,993	31,215	31,715	32,166	38,236	40,658
		PNGDNC34 [No Replacement of Steel Services (Distrib)]	22,232	22,442	26,188	29,993	31,215	31,715	32,166	38,236	40,658
		Total	88,929	89,766	104,754	119,971	124,862	126,858	128,663	152,944	162,632
	Oil Methane Processes	POILDOF1 [Domestic Offshore Production]	277	320	307	288	299	268	283	315	309
		POILDOFV2 [Venting (No Control) Offshore]	277	320	307	288	299	268	283	315	309
		POILDON1 [Domestic Onshore Production]	14,458	12,981	11,709	11,859	10,712	10,745	16,529	11,744	11,603
		POILDONV2 [Venting (No Control) Onshore]	14,458	12,981	11,709	11,859	10,712	10,745	16,529	11,744	11,603
		Total	29,465	26,802	24,033	22,693	22,023	22,068	21,623	24,119	23,623
	Total		472,838	476,881	541,685	615,665	646,912	668,504	692,753	810,480	861,677
EPAML10	Coalbed Methane Processes	ECBMELC2 [On/Off site Electric]	-	0	0	0	0	0	0	0	0
		PCBMDGN2 [Degasification and Pipeline Injection]	-	-	1	5	18	47	53	53	53
		PCBMDGNX [Degasification and Injection (dummy 30)]	-	-	1	6	24	71	124	176	230
		PCBMEDGE2 [Enh. Degas, Enrich, and Pipeline Inject - Existing]	12	12	12	3	3	3	-	-	-
		PCBMEDGN2 [Enh. Degas, Enrich, and Pipeline Injection - New]	-	-	1	5	14	15	19	19	19
		PCBMOX2 [Catalytic Oxidation]	-	-	-	-	-	-	-	-	28
		PCBMPRH2 [On/Off site Process Heat]	-	-	22	22	22	-	-	-	-
		Total	12	12	37	40	81	136	197	250	330
	MSW & LFG/M Methane Processes	ELFGPRG2 [Landfill Gas Electricity Generation]	1	5	6	6	6	3	1	1	1
		EMSWAD1 [Anaerobic Digestion 2 - Electricity]	-	-	1	2	2	1	-	-	-
		EMSWPP1 [MSW Power Plant 1]	3	4	4	5	4	3	3	2	1
		PLFGNGS2 [Direct Gas Use (at base price for gas)]	-	-	216	216	216	211	211	211	132
		PLFMNOMT2 [Normal Cap]	639	639	639	639	639	639	639	639	639
		PLFMPASS1 [Small Landfill Passthru]	83	-	-	-	-	-	-	-	-
		PLFMUSE1 [LFG Captured for Flaring or Use]	694	773	816	816	816	816	816	816	816
		PLFMUSES1 [LFG Captured Small LF for Flaring or Use]	-	87	90	90	90	90	90	90	90
		PMSWAD1 [Anaerobic Digestion 1 - Process Heat]	-	-	1	5	17	45	112	119	127
		PMSWLFL1 [Landfill 3 (large)]	-	-	1,808	3,138	4,468	5,624	7,216	8,834	8,269
		PMSWLFM1 [Landfill 2 (medium)]	-	-	1,365	2,369	3,372	4,376	5,380	6,384	6,023
		PMSWLFS1 [Landfill 1 (small)]	-	-	239	415	590	741	854	942	765
		Total	1,421	1,598	5,185	7,700	10,222	12,749	15,323	17,838	16,863
	Manure Methane Processes	EBMANBC2 [Farm Scale Digesters-B (cool climate)]	-	0	0	0	-	-	-	-	-
		EBMANBW2 [Farm Scale Digesters-B (warm climate)]	-	0	0	0	0	0	0	0	0
		EBMANCD2 [Centralized Digesters (cool climate)]	-	0	0	0	0	-	-	-	-
		PBMANAL2 [Anaerobic Lagoon Treatment]	9	9	9	-	-	-	-	-	-
		PBMANDR1 [Dry Process Treatment]	31	31	31	30	30	30	27	27	27
		PBMANEM1 [Beef Cattle, Sheep, Goat, Horse & Poultry Emission]	320	321	337	355	372	389	400	415	430
		Total	359	361	376	385	402	419	427	442	457
	Natural Gas Methane - Production	PNGADP1 [Domestic NG Production]	20,180	20,765	21,894	25,448	27,480	29,520	31,945	36,138	39,106
		PNGPNC11 [No Control on Pneumatic Devices (Prod)]	20,180	20,765	21,894	25,448	27,480	29,520	31,945	36,138	39,106
		PNGPNC12 [No Control on Pipeline leaks (Prod)]	20,180	20,765	21,894	25,448	27,480	29,520	31,945	36,138	39,106

VEDA Cube – Analysis Graph



GDX2VEDA Specification



GAMS

LOGMIP

Characterization and Formulation of Disjunctions and their Relaxations

Aldo Vecchietti [(*)], Sangbum Lee[(+)] and Ignacio Grossmann[(+)]

[(+)] Chemical Engineering Department - Carnegie Mellon University
[(*)] INGAR - Instituto de Desarrollo y Diseño
UTN - Facultad Regional Santa Fe

Problem Formulations

Accepted Formulations

MILP and MINLP formulations are the most accepted by academia and the industry for problems involving discrete decisions

Recent formulations

Constrained Logic Programming (CLP):

general logic constraints, applied mainly for highly combinatoric problems

Generalized Disjunctive Programming (GDP) :

disjunctions and logic propositions for discrete choices

Disjunctions

$$\min \quad Z = \Sigma_k c_k + f(x) + d^T y$$

sujeto a:

$$g(x) \leq 0$$

$$r(x) + Dy \leq 0$$

$$Ay \geq a$$

$$\bigvee_{i \in D_k} \begin{bmatrix} Y_{ik} \\ h_{ik}(x) \leq 0 \\ c_k = \gamma_{ik} \end{bmatrix} \quad k \in SD$$

$$\Omega(Y) = True$$

$$x \in R^n, \; y \in \{0,1\}^q$$

$$Y \in \{True, False\}^m, \; c_k \geq 0$$

- y binary variables (0-1)
- x y c_k continuous variables
- Y_{ik} Boolean variables to establish if a disjunction term is true or false
- $f(x)$ objective function (linear or not linear)
- $d^T y$ Linear cost term
- $g(x)$ constraint (linear or not linear) independent of discrete choices
- $r(x)+Dy \leq 0$ mixed integer constraint (linear or not linear)
- $Ay \geq a$ integer constraint
- $\Omega(Y)$ propositional logic relating Boolean variables (disjunction terms)

Big-M Relaxation

Big-M

Linear

$$F = \bigvee_{i \in D} \left[a_i^T x \le b_i \right] \quad x \in R^n$$

$$a_i^T x \le b_i + M_i (1 - y_i)$$

$$\sum_i y_i = 1$$

$$M_i = \max\{ a_i^T x - b_i \mid x^{lo} \le x \le x^{up} \}$$

Non Linear

$$F = \bigvee_{i \in D} \left[h_i(x) \le 0 \right] \quad x \in R^n$$

$$h_i(x) \le M_i(1-y_i)$$

$$\sum_i y_i = 1$$

$$M_i = \max\{ h_i(x) \mid x^{lo} \le x \le x^{up} \}$$

Beaumont Surrogate

$$\sum_i \frac{a_i^T x}{M_i} \le \sum_i \frac{b_i}{M_i} + N - 1$$

$$\sum_i \frac{h_i(x)}{M_i} \le N - 1$$

Convex Hull Relaxation

Linear

$$F = \bigvee_{i \in D} \left[a_i^T x \le b_i \right] \quad x \in R^n$$

$$x - \sum_{i \in D} v_i = 0 \qquad x, v_i \in R^n$$

$$a_i^T v_i - b_i y_i \le 0$$

$$\sum_{i \in D} y_i = 1 \quad , 0 \le y_i \le 1, \; i \in D$$

$$0 \le v_i \le v_i^{up} y_i$$

Non linear

$$F = \bigvee_{i \in D} \left[h_i(x) \le 0 \right] \quad x \in R^n$$

$$x - \sum_{i \in D} v_i = 0 \qquad x, v_i \in R^n$$

$$y_i h_i(v_i / y_i) \le 0$$

$$\sum_{i \in D} y_i = 1 \quad , 0 \le y_i \le 1, \; i \in D$$

$$0 \le v^i \le v_i^{up} y_i$$

Relaxation Comparison

Improper disjunction of special interest in Process Engineering

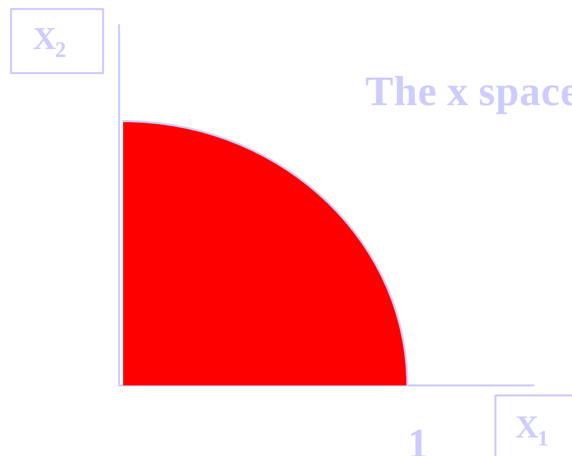
$$\min Z = (x_1 - 1.1)^2 + (x_2 - 1.1)^2 + c_1$$

$$s.t.$$

$$\begin{bmatrix} Y_1 \\ x_1^2 + x_2^2 \le 1 \\ c_1 = 1 \end{bmatrix} \vee \begin{bmatrix} \neg Y_1 \\ x_1 = x_2 = 0 \\ c_1 = 0 \end{bmatrix}$$

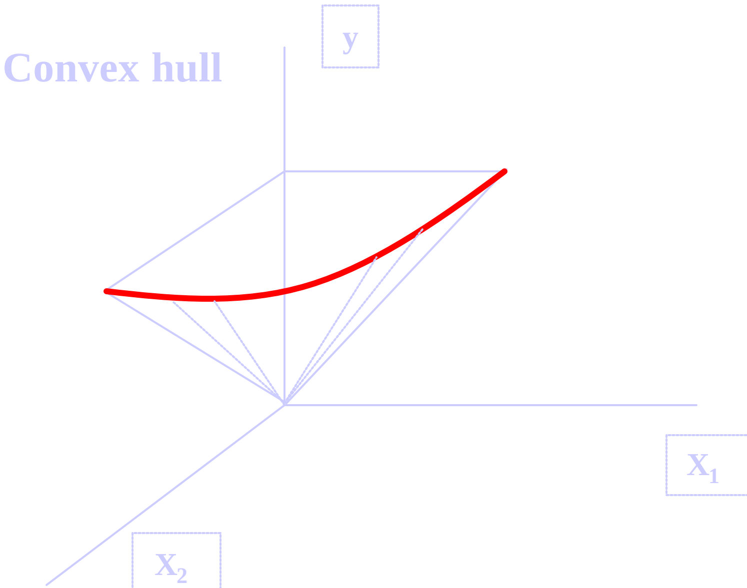
$$0 \le x_1, x_2 \le 1;\ 0 \le c_1$$

$$Y_1 \in \{ true, false \}$$



Both relaxations have the same feasible region

X – Y Space



$$\min Z = (x_1 - 1.1)^2 + (x_2 - 1.1)^2 + y_1$$

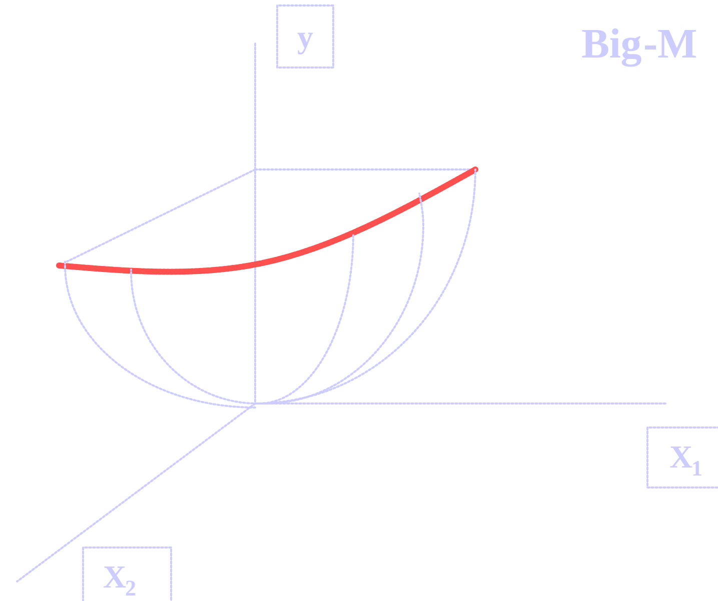
$$s.t.$$

$$x_1^2 + x_2^2 \le y_1^2$$

$$0 \le x_1 \le y_1$$

$$0 \le x_2 \le y_1$$

$$0 \le y_1 \le 1$$



$$\min Z = (x_1 - 1.1)^2 + (x_2 - 1.1)^2 + y_1$$

$$s.t.$$

$$x_1^2 + x_2^2 \le y_1$$

$$0 \le x_1, x_2 \le 1; 0 \le y_1 \le 1$$

Two Term Disjunction

$$\begin{bmatrix} \textit{True} \\ \textit{Constraint 1} \end{bmatrix} \vee \begin{bmatrix} \textit{False} \\ \textit{Constraint 2} \end{bmatrix}$$

Modeling two terms disjunction

IF (condition$_1$) THEN
Constraints to be considered when condition$_1$ is True
ELSE
Constraints to be considered when condition$_1$ is False
END IF

N Term Disjunction

$$\begin{bmatrix} \mathit{1} \\ \mathit{Constraints\ 1} \end{bmatrix} \vee \begin{bmatrix} \mathit{2} \\ \mathit{Constraints\ 2} \end{bmatrix} \vee .. \vee \begin{bmatrix} \mathit{N} \\ \mathit{Constraints\ N} \end{bmatrix}$$

IF (condition$_1$) THEN

Constraints to be considered when condition$_1$ is True

ELSIF (condition2) THEN

Constraints to be considered when condition$_1$ is True

ELSIF (condition3) THEN

...

ELSIF (conditionN) THEN

Constraints to be considered when condition$_1$ is True

END IF

Example

$$\min \; c + 2x_1 + x_2$$

$$\begin{bmatrix} Y_1 \\ -x_1 + x_2 + 2 \le 0 \\ c = 5 \end{bmatrix} \vee \begin{bmatrix} Y_2 \\ 2 - x_2 \le 0 \\ c = 7 \end{bmatrix}$$

$$\begin{bmatrix} Y_3 \\ x_1 - x_2 \le 1 \end{bmatrix} \vee \begin{bmatrix} \neg Y_3 \\ x_1 = 0 \end{bmatrix}$$

$$Y_1 \wedge \neg Y_2 \Rightarrow \neg Y_3$$

$$\neg (Y_2 \wedge Y_3)$$

$$0 \le x_1 \le 5, \; 0 \le x_2 \le 5, \; c \ge 0$$

$$Y_j \in \{true, \; false\}, \; j = 1,2,3.$$

GAMS Implementation

```
EQUAT1.. X('2')- X('1') + 2 =L= 0;
EQUAT2.. C =E= 5;
EQUAT3.. 2 - X('2') =L= 0;
EQUAT4.. C =E= 7;
EQUAT5.. X('1')-X('2') =L= 1;
EQUAT6.. X('1') =E= 0;
INT1..  Y('1')+ Y('3') =L= 1;
INT2..  Y('2')+ (1-Y('3')) =G= 1;
INT3..  Y('2')+ Y('3') =L= 1;
FICT.. SUM(I, Y(I)) =G= 0;
OBJECTIVE.. Z =E= C + 2*X('1') +
X('2');
X.UP(J)=20;
C.UP=7;
```

```
$ONTEXT BEGIN LOGMIP
IF Y('1') THEN
        EQUAT1;
        EQUAT2;
ELSIF Y('2') THEN
        EQUAT3;
        EQUAT4;
ENDIF;
IF Y('3') THEN
        EQUAT5;
ELSE
        EQUAT6;
ENDIF;
$OFFTEXT END LOGMIP
OPTION MIP=LOGMIPC;
MODEL PEQUE2 /ALL/;
SOLVE PEQUE2 USING MIP MINIMIZING Z;
```

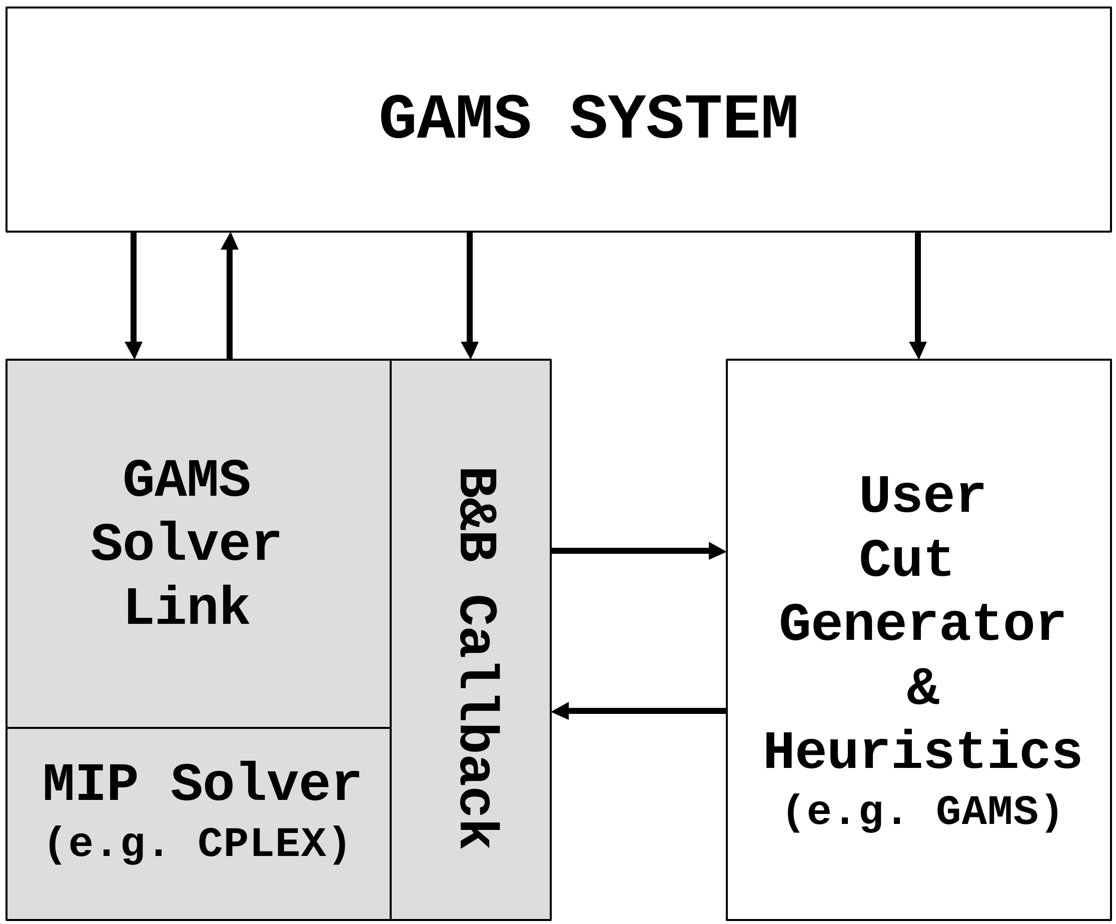
Branch-and-Cut & Heuristics in GAMS for MIP Problems

Hua (Edward) Ni
George Washington University

Branch-and-Cut (B&C)

- B&C is an established algorithm to improve the B&B search.
- Implementation facilities:
  - MIP solver callback functions (CPLEX, XPRESS, …)
  - B&C framework (ABACUS, COIN BCP, …)
- Required Knowledge for B&C
  - IT knowledge (C/C++/JAVA, Solver APIs)
  - Mathematical programming knowledge
  - Application specific knowledge
- Supply GAMS users with an easy access to B&C

Design Principle



A Steiner Tree Problem

- Berlin52 – from SteinLib
  - 52 nodes (1 source, n'=15 sinks), 1326 edges
- Flow formulation:

$$\min \sum_{(i,j)\in A} f_{ij} y_{ij}, s.t. \sum_{(j,i)\in d^-(i)} x_{ji} - \sum_{(i,j)\in d^+(i)} x_{ij} = b_i, 0 \le x_{ij} \le n' y_{ij}, y \in \{0,1\}$$

- Dicut: $\sum_{(i,j)\in\delta^-(S)} y_{ij} \geq 1$ if S⊂V and b(S)>0.
- Separation:

$$\xi = \min\left\{ \sum_{(i,j)\in A} \bar{y}_{ij} z_j (1 - z_i) \ : \ \sum_{i\in V} b_i z_i > 0,\ z_i \in \{0,1\}\ \forall\ i \in V \right\}$$

Cut Generator in GAMS I

C:\Documents and Settings\Administrator\Desktop\Dicuts.gms

Dicuts.gms

```
Set nn          nodes
    arc(nn,nn) arcs; alias(nn,n,m);
Parameter demand(nn)      node demand
          fcost(nn,nn)    fixed cost
$gdxin NetInfo.gdx
$load nn demand fcost

Variables ybar(nn,nn)    the fractional y solution
          cost
binary variables z(nn);
Equations Obj      objective
          SC       positive demand over the node block;
Obj..    sum(arc(m,n), ybar.l(m,n)*z(n)*(1-z(m))) =e= cost;
SC..     sum(n, demand(n)*z(n)) =g= 1;

Model Dicut /Obj, SC/;
execute_load 'CutCBSol.gdx' ybar=y;
arc(m,n)$fcost(m,n) = yes;
Solve Dicut mini cost using MINLP;
```

Cut Generator in GAMS II

C:\Documents and Settings\Administrator\Desktop\Dicuts.gms

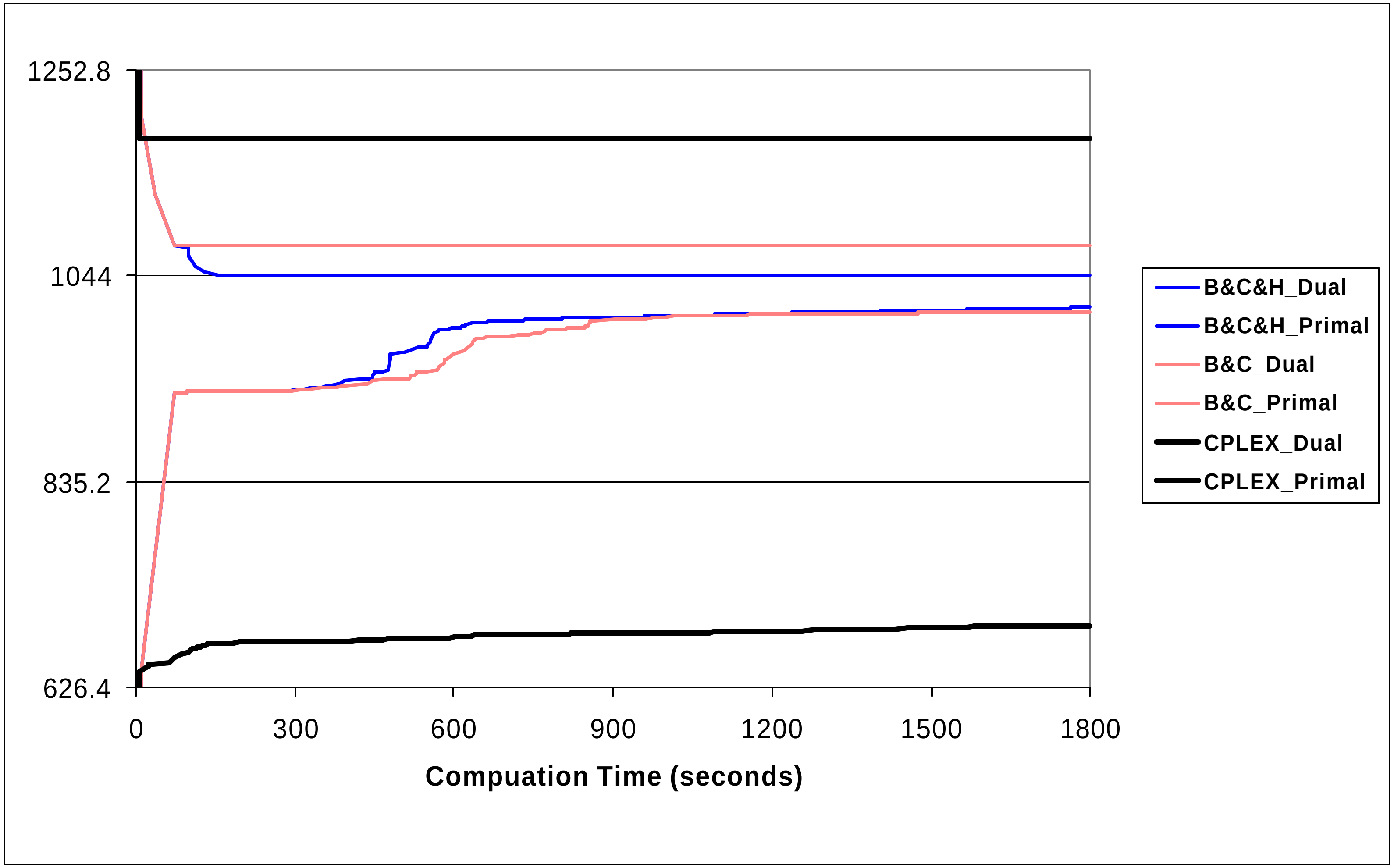
Dicuts.gms

```
arc(m,n)$fcost(m,n) = yes;
Solve Dicut mini cost using MINLP;

Set S(nn) Nodes in the node block; S(n) = round(z.l(n));
Set cc number of cuts generated / 1 /;

Parameter CC_y(cc,nn,nn)          coefficient of the y variables in the cut
          CRHS(cc)                cut rhs
          CSENSE(cc)              the sense of the cuts
          NUMCUTS /1/;

if(cost.l>=1, NUMCUTS = 0;
else CSENSE(cc) = 3;
     CRHS(cc)   = 1;
     CC_y(cc,arc(m,n)) = not S(m) and S(n);
);

execute_unload 'CutCBCuts.gdx' NUMCUTS, CRHS, CSENSE, CC_y ;
```

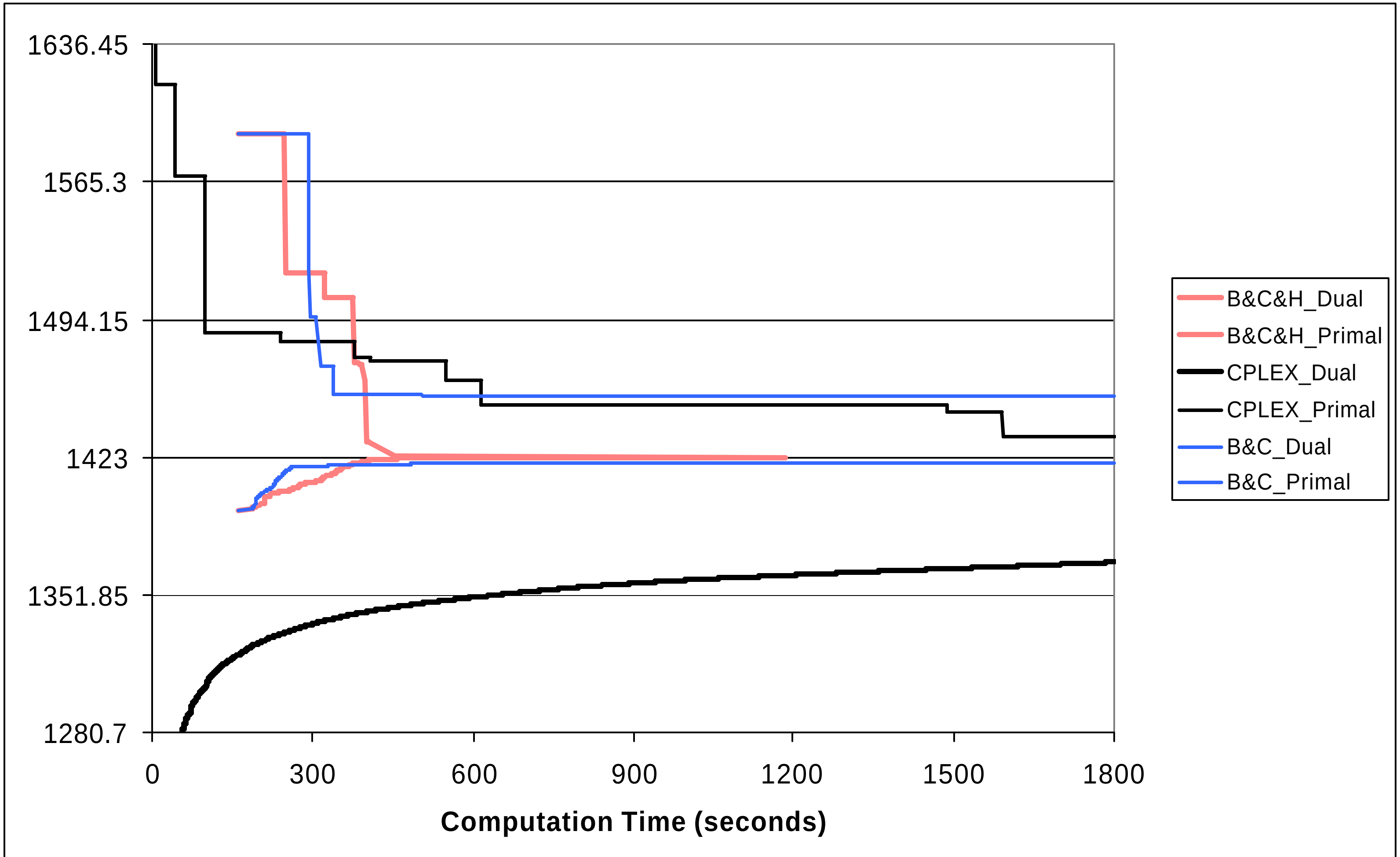
Computational Results

- Overhead
  - Time spent within the callback functions minus MIP computation on cuts and heuristics.
  - 20% ~ 25%
- Performance Improvements (B&C vs. regular GAMS/CPLEX)
  - Steiner: 6 hours vs. 2+ days (unsolvable)
  - Pipeline Design: 20 minutes vs. 450 minutes

Convergence – Steiner Tree



Convergence – Pipeline Design



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

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 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

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

NEOS Solvers

- 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)

GAMS

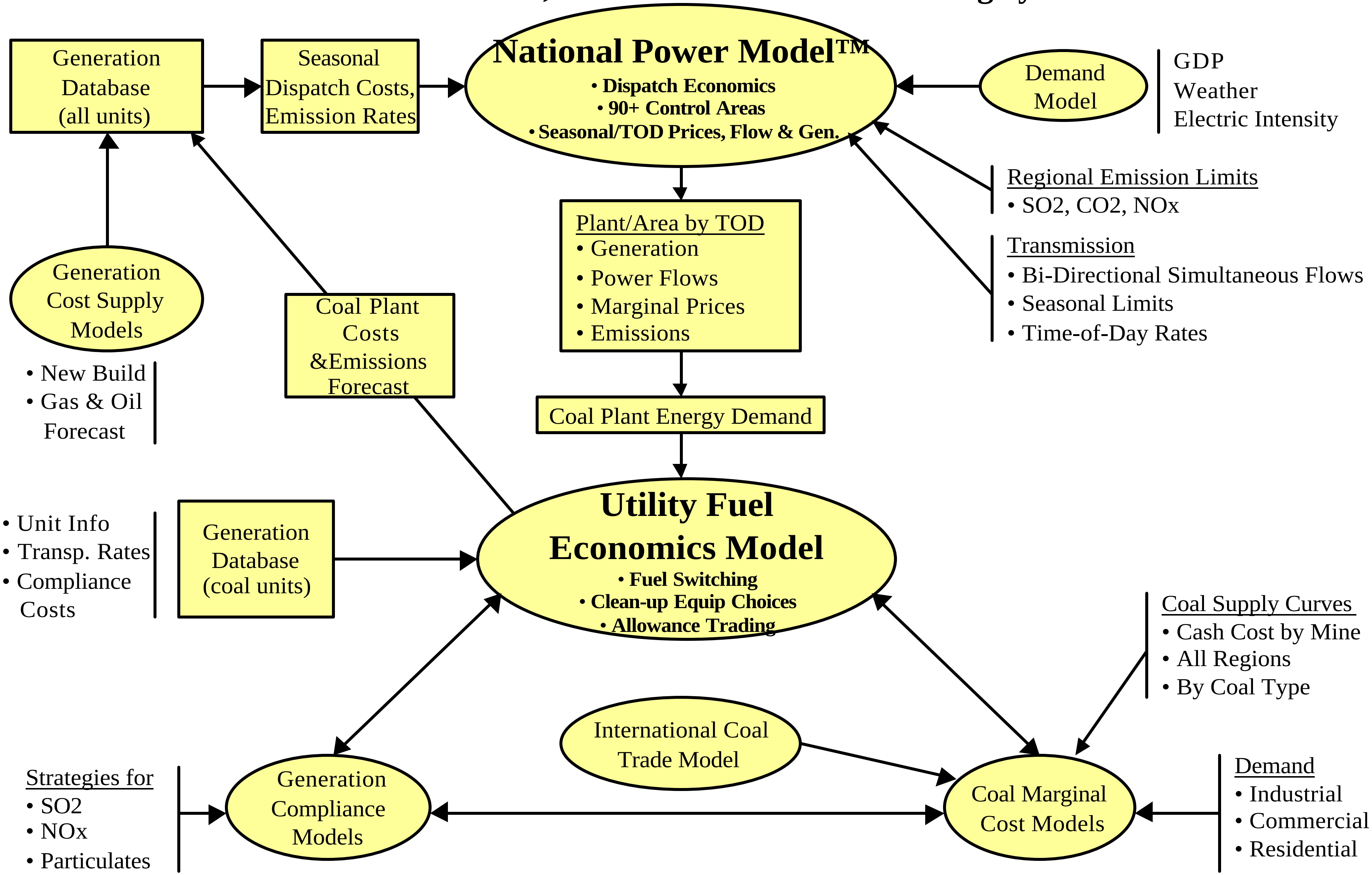
Consulting Models

- *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, …)

Figure I-1

Hill and Associates, Inc.

Electric Generation, Coal and Emissions Forecasting System



Modeling System Requirements

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

Black Box Model

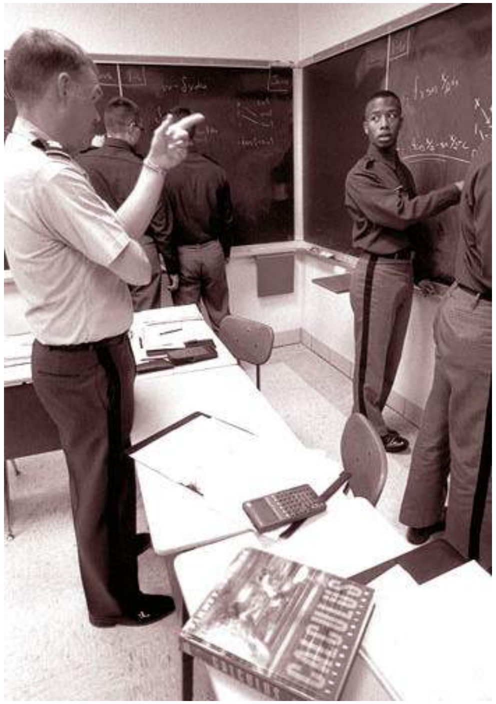
- *Innocent* User
- Bulletproof Optimization Application
  - – No *failures*: e.g. No Infeasible Models
- Model embedded in larger System:

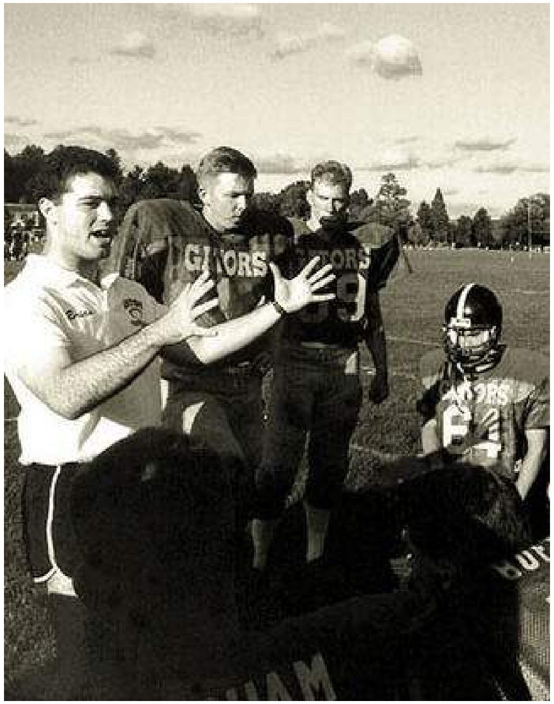
- Optimization
- Takes Longer than one is willing to wait
- It will eventually fail

- 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.”





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)

Future Directions

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