Models and Their Roles

Or

"A Model is a Model is a Model*

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Aachen, July 2012

*** Freely adapted from the poetry of Gertrude Stein, 1874-1946, American writer**

Agenda

- What is GAMS
- What is a GAMS model
- Roles of a Model
- Market Demands and Challenges

Agenda

- What is GAMS
- What is a GAMS model
- Roles of a Model
- Market Demands and Challenges

Matrix Generator

```
Y(248)'X(248)                                                          CUMPPB
  IF (X(248).LT.0.5.AND.X(243).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)                                                          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)                                                          CUMFCU
  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)                                                          CUMOLS
  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)                                                          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)                                                          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
```

MPS Output

DATE 07/30/76 TIME 22.12.21 COLUMNS APEX-III 1.000 PAGE

PRINT OPTION = COMPLETE OUTPUT W/SPECIAL
NAME = CENTRAL OBJ = OBJ RHS = RHS1 BND = LIMITS ...TIVE = 28.18489
DIR = MAXIMIZE COBJ = CRHS = RNG = ...1.0000 RPSRHS = 1.0000
...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	.
118	CDC.CX..	PL	LOWER	.	167.83000	+INF	-87.19134
119	COS.CX..	PL	ACTIVE	.06968	121.35000	+INF	-256.39963
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	.

Algebraic Modeling Languages

What's that?
http://en.wikipedia.org/wiki/Algebraic_modeling_language

- High-level **computer programming languages** for the formulation of **complex mathematical optimization problems**

- **Notation similar to algebraic notation**: Concise and readable definition of problems in the domain of optimization

- **Do not solve problems directly**, but ready-for-use links to state-of-the-art algorithms

➔Simplified model building
➔Efficient solution process
➔Increased productivity

Firefox | W General Algebraic Modeling Sys... | +

en.wikipedia.org/wiki/General_Algebraic_Modeling_System

Google

Log in / create account

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The Free Encyclopedia

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General Algebraic Modeling System

From Wikipedia, the free encyclopedia

The **General Algebraic Modeling System (GAMS)** is a high-level modeling system for mathematical optimization. GAMS is designed for modeling and solving linear, nonlinear, and mixed-integer optimization problems. The system is tailored for complex, large-scale modeling applications and allows the user to build large maintainable models that can be adapted to new situations. The system is available for use on various computer platforms. Models are portable from one platform to another.

GAMS

Developer(s)	GAMS Development Corporation
Stable release	23.7.3 / August 23, 2011
Development status	Active
Platform	Cross-platform
Type	Algebraic Modeling Language (AML)
License	Proprietary
Website	GAMS USA GAMS Germany

GAMS was the first algebraic modeling language (AML) and is formally similar to commonly used fourth-generation programming languages.[citation needed] GAMS contains an integrated development environment (IDE) and is connected to a group of third-party optimization solvers. Among these solvers are BARON, COIN solvers, CONOPT, CPLEX, DICOPT, GUROBI, MOSEK, SNOPT, and XPRESS.

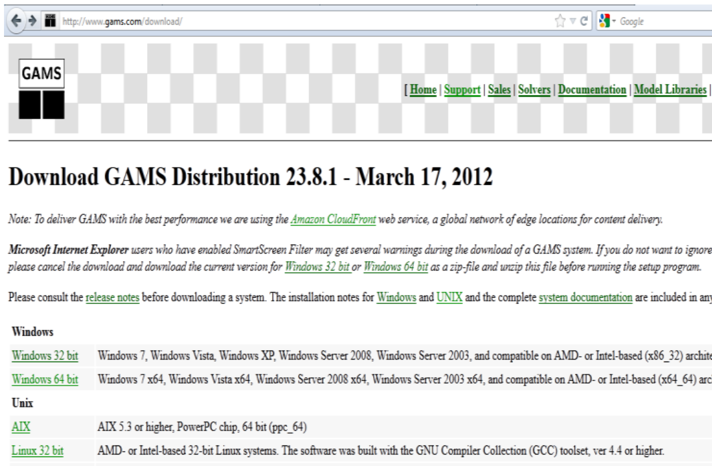
GAMS facilitates the users to implement a sort of hybrid algorithms combining different solvers in a seamless way. Models are described in concise algebraic statements which are easy to read, both for humans and machines. GAMS is among the most popular input formats for the NEOS Server for Optimization. Although initially designed for applications related to economics and management science, it has a large community of users from various backgrounds of engineering and science.

Contents [hide]

General Algebraic Modeling System

- Roots: World Bank, 1976
- Went commercial in 1987
- GAMS Development Corporation (Washington, Houston)
- GAMS Software GmbH (Cologne, Braunschweig)
- Broad academic & commercial user community and network

Monthly System Downloads



http://www.gams.com/download/

GAMS

[Home | Support | Sales | Solvers | Documentation | Model Libraries |

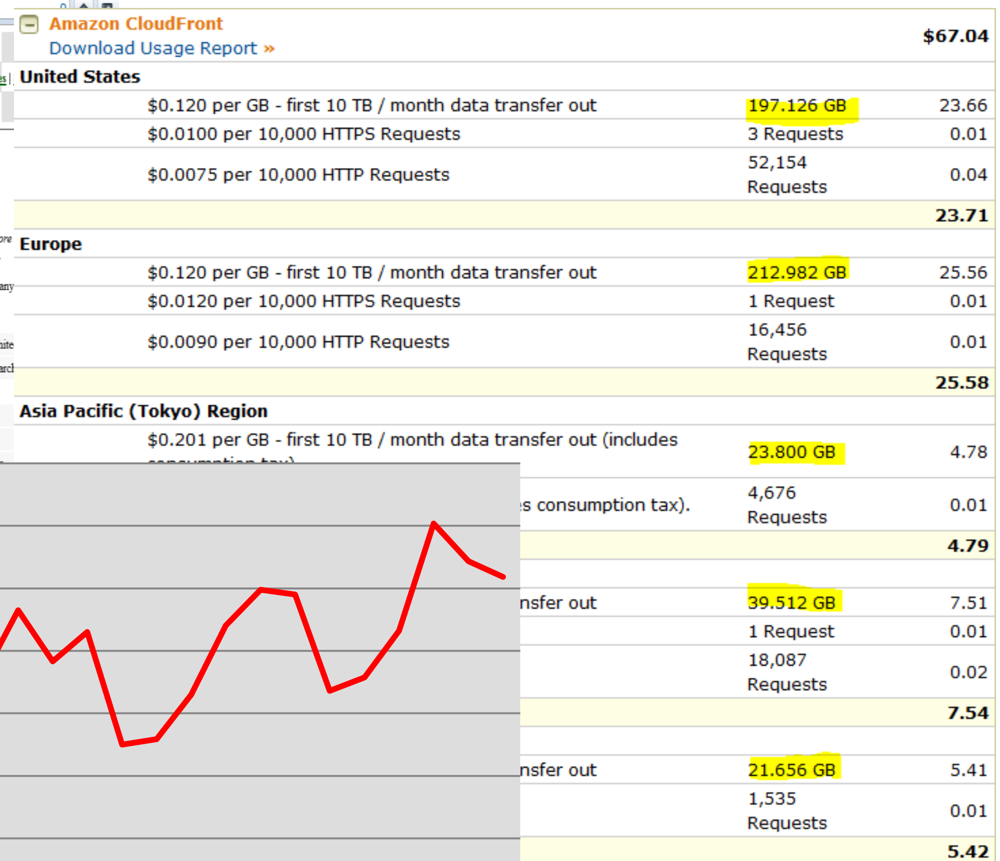
Download GAMS Distribution 23.8.1 - March 17, 2012

Note: To deliver GAMS with the best performance we are using the Amazon CloudFront web service, a global network of edge locations for content delivery.

***Microsoft Internet Explorer** users who have enabled SmartScreen Filter may get several warnings during the download of a GAMS system. If you do not want to ignore please cancel the download and download the current version for Windows 32 bit or Windows 64 bit as a zip-file and unzip this file before running the setup program.*

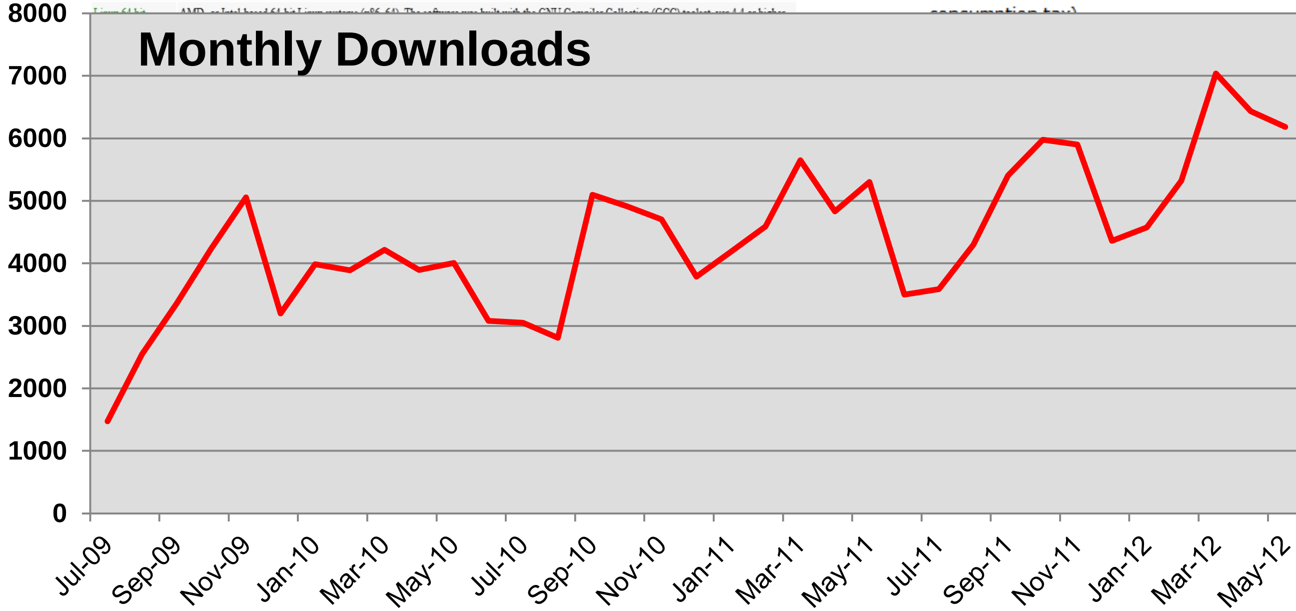
Please consult the release notes before downloading a system. The installation notes for Windows and UNIX and the complete system documentation are included in any

Windows	
Windows 32 bit	Windows 7, Windows Vista, Windows XP, Windows Server 2008, Windows Server 2003, and compatible on AMD- or Intel-based (x86_32) archite
Windows 64 bit	Windows 7 x64, Windows Vista x64, Windows Server 2008 x64, Windows Server 2003 x64, and compatible on AMD- or Intel-based (x64_64) arch
Unix	
AIX	AIX 5.3 or higher, PowerPC chip, 64 bit (ppc_64)
Linux 32 bit	AMD- or Intel-based 32-bit Linux systems. The software was built with the GNU Compiler Collection (GCC) toolset, ver 4.4 or higher.



Amazon CloudFront — Download Usage Report » — **$67.04**

United States		
$0.120 per GB - first 10 TB / month data transfer out	197.126 GB	23.66
$0.0100 per 10,000 HTTPS Requests	3 Requests	0.01
$0.0075 per 10,000 HTTP Requests	52,154 Requests	0.04
		23.71
Europe		
$0.120 per GB - first 10 TB / month data transfer out	212.982 GB	25.56
$0.0120 per 10,000 HTTPS Requests	1 Request	0.01
$0.0090 per 10,000 HTTP Requests	16,456 Requests	0.01
		25.58
Asia Pacific (Tokyo) Region		
$0.201 per GB - first 10 TB / month data transfer out (includes	23.800 GB	4.78
s consumption tax).	4,676 Requests	0.01
		4.79
nsfer out	39.512 GB	7.51
	1 Request	0.01
	18,087 Requests	0.02
		7.54
nsfer out	21.656 GB	5.41
	1,535 Requests	0.01
		5.42



GAMS

GAMS at a Glance

- **Balanced mix of declarative and procedural elements**
- **Platform independence**
- **Hassle-free switch of solution methods**
- **Open architecture and interfaces to other systems**
- **Independent Layers**

- **Declarative:** Model Algebra
- **Procedural:** Programming Flow Control Features
  - Loop, For, While, Repeat
  - If, else, else…
  - Macros
  - Access to external programs/libraries
  - …

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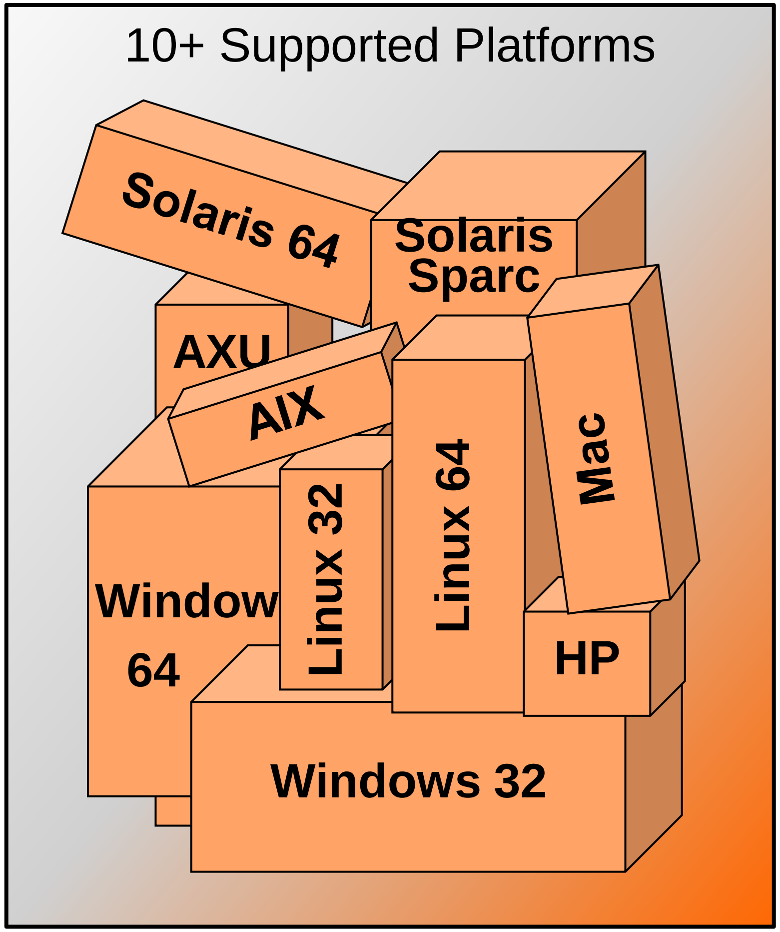

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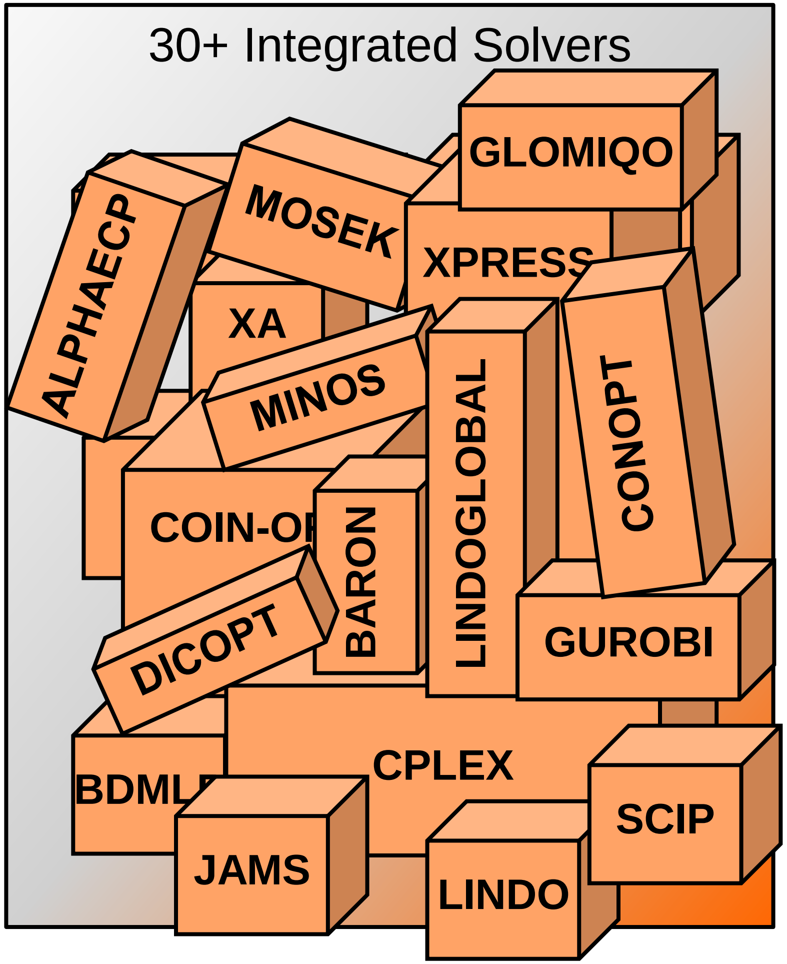

GAMS at a Glance

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- ASCII
- **G**ams **D**ata e**X**change (Binary)
  - MS Excel, MS Access
  - Databases
  - Matlab, R, ….
- API's
- Component Libraries
- .NET Integration (Alpha)

GAMS at a Glance

Independence of

- Model and data
- Model and solution methods (solver)
- Model and operating system
- Model and user interface

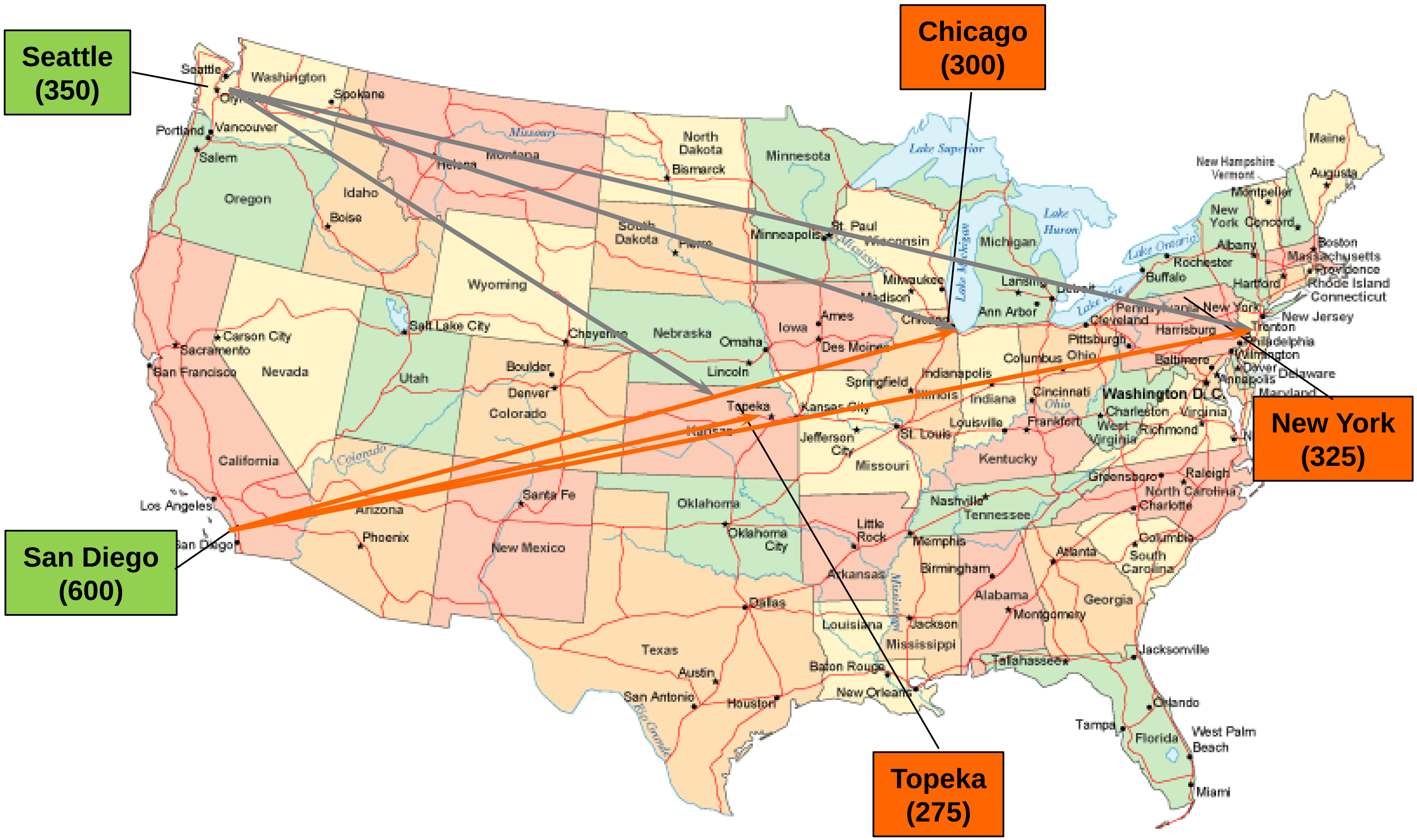
→Models benefit from

- Advancing hardware
- Enhanced / new solver technology
- Improved / upcoming interfaces to other systems

Agenda

- What is GAMS
- **What is a GAMS model**
- Roles of a Model
- Market Demands and Challenges

A Simple Example: Transportation Model



A Simple Example: Algebra

Minimize	Transportation cost
subject to	Demand satisfaction at markets
	Supply constraints

$$
\begin{array}{llll}
\text{Objective} & \sum_i \sum_j c_{i,j} \times x_{i,j} & \longrightarrow \min & \\
\text{Observe supply limit at plant } i\text{:} & \sum_j x_{i,j} & \leq a_i & \forall i \\
\text{Satisfy demand at market } j\text{:} & \sum_i x_{i,j} & \geq b_j & \forall j \\
 & x_{i,j} & \geq 0 & \forall i, j
\end{array}
$$

A Simple Example: Declarative Model

C:\Users\Franz\Documents\gamsdir\projdir\trnsport.gms

data.inc | trnsport.gms | trnsport.lst

```
Sets    i   canning plants
        j   markets;
Parameters  a(i)   capacity of plant i in cases
            b(j)   demand at market j in cases
            d(i,j) distance in thousands of miles
            f      freight in dollars per case per thousand miles
            c(i,j)  transport cost in thousands of dollars per case ;
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) ..   sum(j, x(i,j))  =l=  a(i) ;
demand(j) ..   sum(i, x(i,j))  =g=  b(j) ;
Model transport /all/ ;
```

1: 3 Modified | Insert

A Simple Example: Model Data

C:\Users\Franz\Documents\gamsdir\projdir\data.inc

data.inc | trnsport.gms | trnsport.lst

```
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          2.5           1.7          1.8
      san-diego        2.5           1.8          1.4   ;

Scalar f  freight in dollars per case per thousand miles  /90/ ;
```

11: 44 | Insert

A Simple Example: Results

- Compilation
  - Equation Listing SOLVE transport Usin
  - Equation
  - Column Listing SOLVE transport Usir
  - Column
  - Model Statistics SOLVE transport Usin
  - Solution Report SOLVE transport Usin
  - SolEQU
  - SolVAR
- Execution
  - Display

```
**** REPORT SUMMARY :        0     NONOPT
                             0 INFEASIBLE
                             0  UNBOUNDED
GAMS Rev 238  WEX-WEI 23.8.1 x86_64/MS Windows          03/29/12 13:28:06 Page 6
A Transportation Problem (TRNSPORT,SEQ=1)
E x e c u t i o n


----     68 VARIABLE z.L                   =      153.675  total transportation
                                                           costs in thousands of
                                                           dollars

----     68 VARIABLE x.L  shipment quantities in cases

            new-york     chicago      topeka

seattle       50.000     300.000
san-diego    275.000                 275.000
```

C:\work\gdxxrw\results.gdx

farmsp.gms | farmsp.lst | nbsimple.gms | nbsimple.lst | results.gdx | trnsport.gms | trnsport.lst

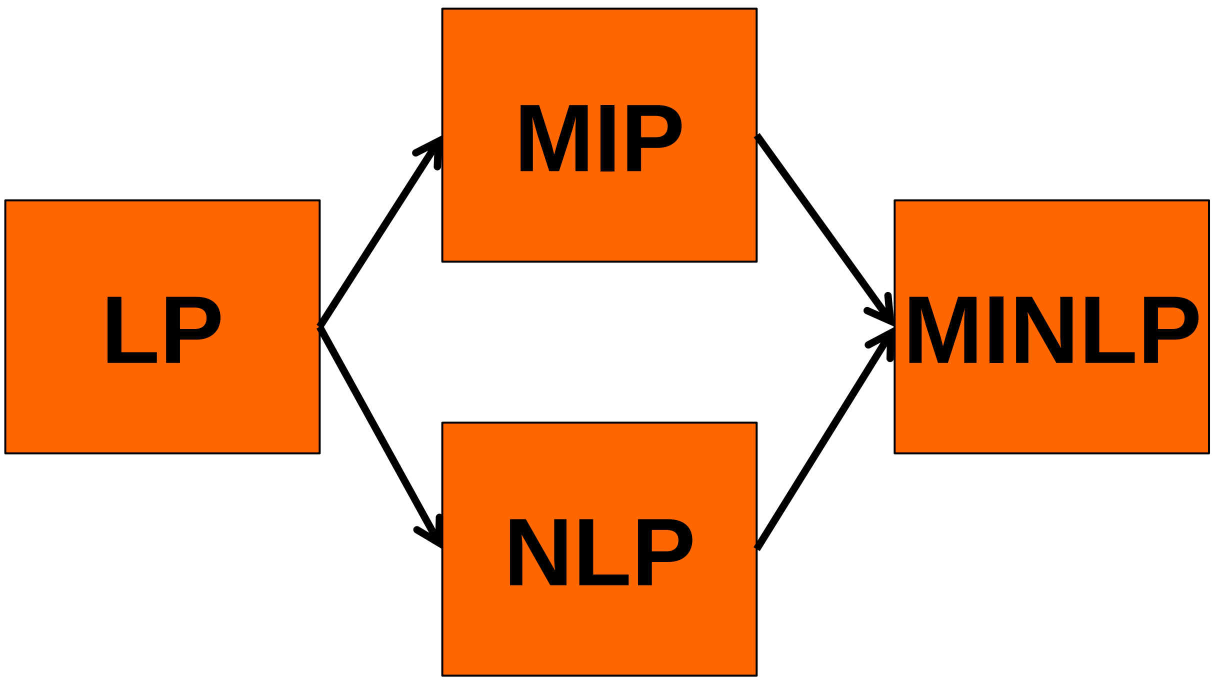
Entr	Symbo	Type	Dim	Nr Elem
3	a	Par	1	2
4	b	Par	1	3
7	c	Par	2	6
10	cost	Equ	0	1
5	d	Par	2	6
12	deman	Equ	1	3
6	f	Par	0	1
1	i	Set	1	2
2	j	Set	1	3
11	supply	Equ	1	2
8	x	Var	2	6
9	z	Var	0	1

x: shipment quantities in cases

Level
Marginal

	new-york	chicago	topeka
seattle	50	300	
san-diego	275		275

A Simple Example: Modifications



GAMS

A Simple Example: Minimum Shipment

- Extension: Minimum Shipment
  - Ship at least 100 units or don't ship

- Continuous variable x(i,j)
- Binary variable ship(i,j)

- Coupling constraints:
  - if *ship* = 1 → $x \geq 100$: $x \geq 100 * ship$
  - *If ship* = 0 → $x = 0$: $x \leq \text{bigM} * ship$

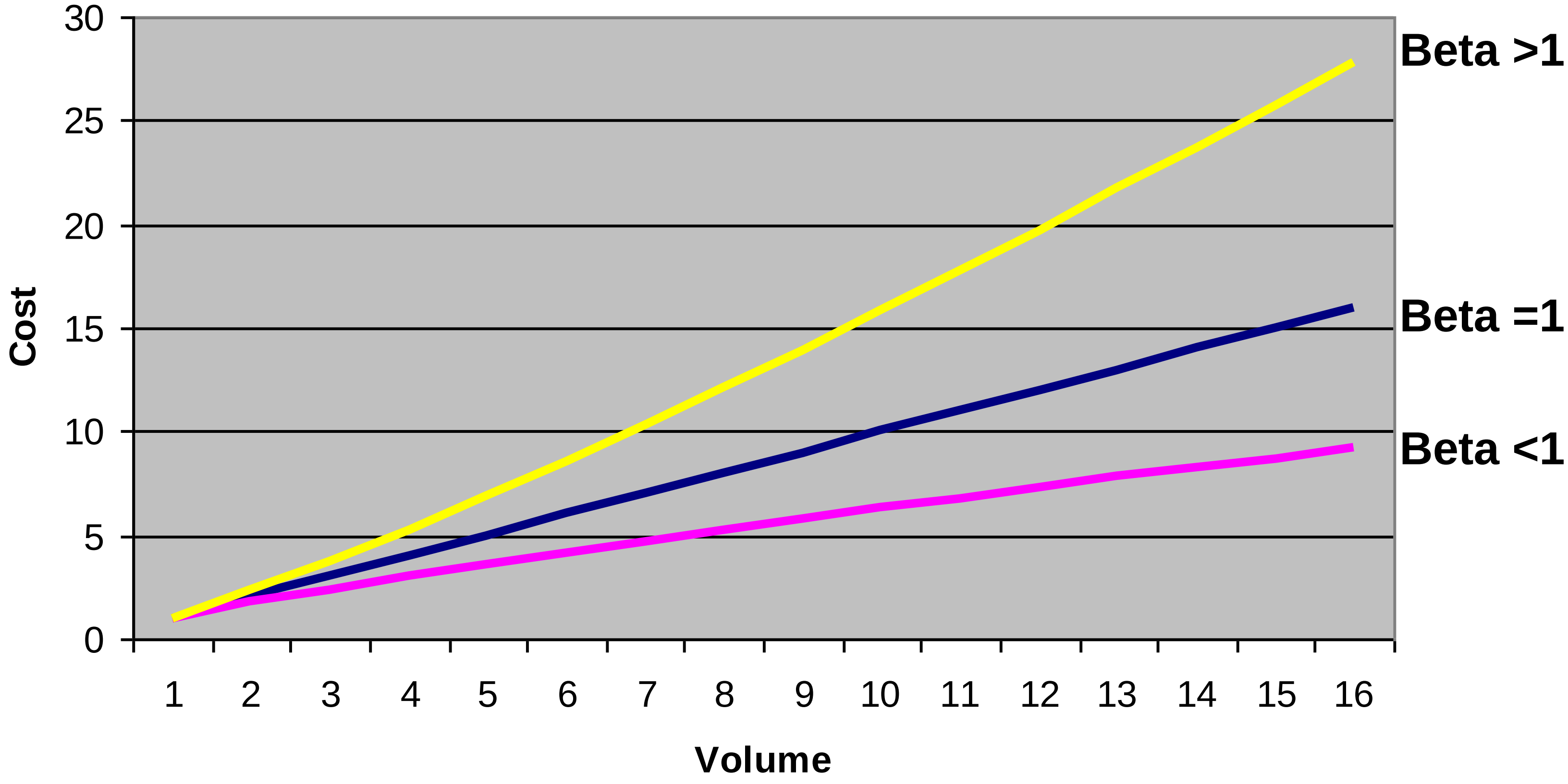
A Simple Example: Min/Max Shipments

```
Parameter rep1(i,j,*)    Shipments between plants and markets
          rep2(*)        Objective value;
rep1(i,j,'lp') = x.l(i,j);
rep2('lp')     = z.l;

scalars xmin / 100 /
        xmax / 325 /;
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 shipments / all /;
solve m2 using mip minimizing z;
rep1(i,j,'mip') = x.l(i,j);
rep2('mip')     = z.l;

option mip=coincbc
solve m2 using mip minimizing z;
rep1(i,j,'mip-coincbc') = x.l(i,j);
rep2('mip-coincbc')     = z.l;
display rep1,rep2;
```

```
----    100 PARAMETER rep1  Shipments between plants and markets

                           lp         mip  mip-coinc~

seattle  .new-york      50.000
seattle  .chicago      300.000     300.000     300.000
san-diego.new-york     275.000     325.000     325.000
san-diego.topeka       275.000     275.000     275.000


----    100 PARAMETER rep2  Objective value

lp        153.675,    mip         153.675,    mip-coincbc 153.675
```

A Simple Example: Economy of Scales

Cost = Volume^{beta}



A Simple Example: Nonlinear Costs (NLP)

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

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

model m3 / transport -cost +nlcost /;

beta = 1.5;
solve m3 using nlp minimizing z;
rep1(i,j,'nlp-convex') = x.l(i,j);
rep2('nlp-convex')     = z.l;

beta = 0.6;
solve m3 using nlp minimizing z;
rep1(i,j,'nlp-concave') = x.l(i,j);
rep2('nlp-concave')     = z.l;

option nlp=baron;
solve m3 using nlp minimizing z;
rep1(i,j,'nlp-baron') = x.l(i,j);
rep2('nlp-baron')     = z.l;

display rep1,rep2;
```

```
----    127 PARAMETER rep1  Shipments between plants and markets

                             lp  nlp-convex  nlp-conca~   nlp-baron

seattle  .new-york       50.000     142.384
seattle  .chicago       300.000     130.930     300.000     300.000
seattle  .topeka                     76.686
san-diego.new-york      275.000     182.616     325.000     325.000
san-diego.chicago                   169.070
san-diego.topeka        275.000     198.314     275.000     275.000


----    127 PARAMETER rep2  Objective value

lp           153.675,    nlp-convex  1983.555,    nlp-concave   15.585
nlp-baron     15.585
```

A Simple Example: MIP and Nonlinear

```
* min/max and nonlinear objective

model m4 / m3  +minship +maxship/;

option minlp=baron;
solve m4 using minlp minimizing z;
rep1(i,j,'minlp-bar') = x.l(i,j);
rep2('minlp-bar')     = z.l;

option minlp=lindoglobal;
solve m4 using minlp minimizing z;
rep1(i,j,'minlp-lin') = x.l(i,j);
rep2('minlp-lin')     = z.l;

display rep1,rep2;
```

```
----    142 PARAMETER rep1  Shipments between plants and markets

                          lp         mip  mip-coinc~  nlp-convex  nlp-conca~

seattle  .new-york    50.000                             142.384
seattle  .chicago    300.000     300.000     300.000     130.930     300.000
seattle  .topeka                                          76.686
san-diego.new-york   275.000     325.000     325.000     182.616     325.000
san-diego.chicago                                        169.070
san-diego.topeka     275.000     275.000     275.000     198.314     275.000

               +   nlp-baron   minlp-bar   minlp-lin

seattle  .chicago    300.000     300.000     300.000
san-diego.new-york   325.000     325.000     325.000
san-diego.topeka     275.000     275.000     275.000


----    142 PARAMETER rep2  Objective value

lp          153.675,    mip          153.675,    mip-coincbc  153.675
nlp-convex 1983.555,    nlp-concave   15.585,    nlp-baron     15.585
minlp-bar    15.585,    minlp-lin     15.585
```

Agenda

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?

Academic Researcher

- Most of model source is algebra
- Declarative modeling
- Performance of the solver is important
- Set of (benchmark) problem instances
- Taste (Syntax, development environment, solver,…)
- Data in most cases less important
- No maintenance issues

Consultants

- Model is tool for problem analysis
- Only a small fraction 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, …)

End-User (Black Box Models)

- ***Innocent user***
- Bulletproof optimization application
- No failures (e.g. no infeasible models)
- Model embedded in larger systems
- Optimization
  - takes longer than one is willing to wait
  - will eventually fail
- Application
  - Real time
  - Always needs a solution

Communication Vehicle

- Defining scope of a (part of a) project/model
- IT, analysts, managers, model builders have different views
- Misunderstandings common with verbal descriptions
- Use a model to define the scope
- Requirements for such a model
  - Rapid prototyping
  - Standard I/O interface (Excel)

Analytic Framework

- Optimization models do not allow for any type of vagueness
  - Input data requirements
  - Objectives and constraints
  - Results

- Misunderstandings result in failure of the model
  - Compilation/execution errors
  - Infeasible/unbounded MP models

- Model as a *contract*

Model as a Contract

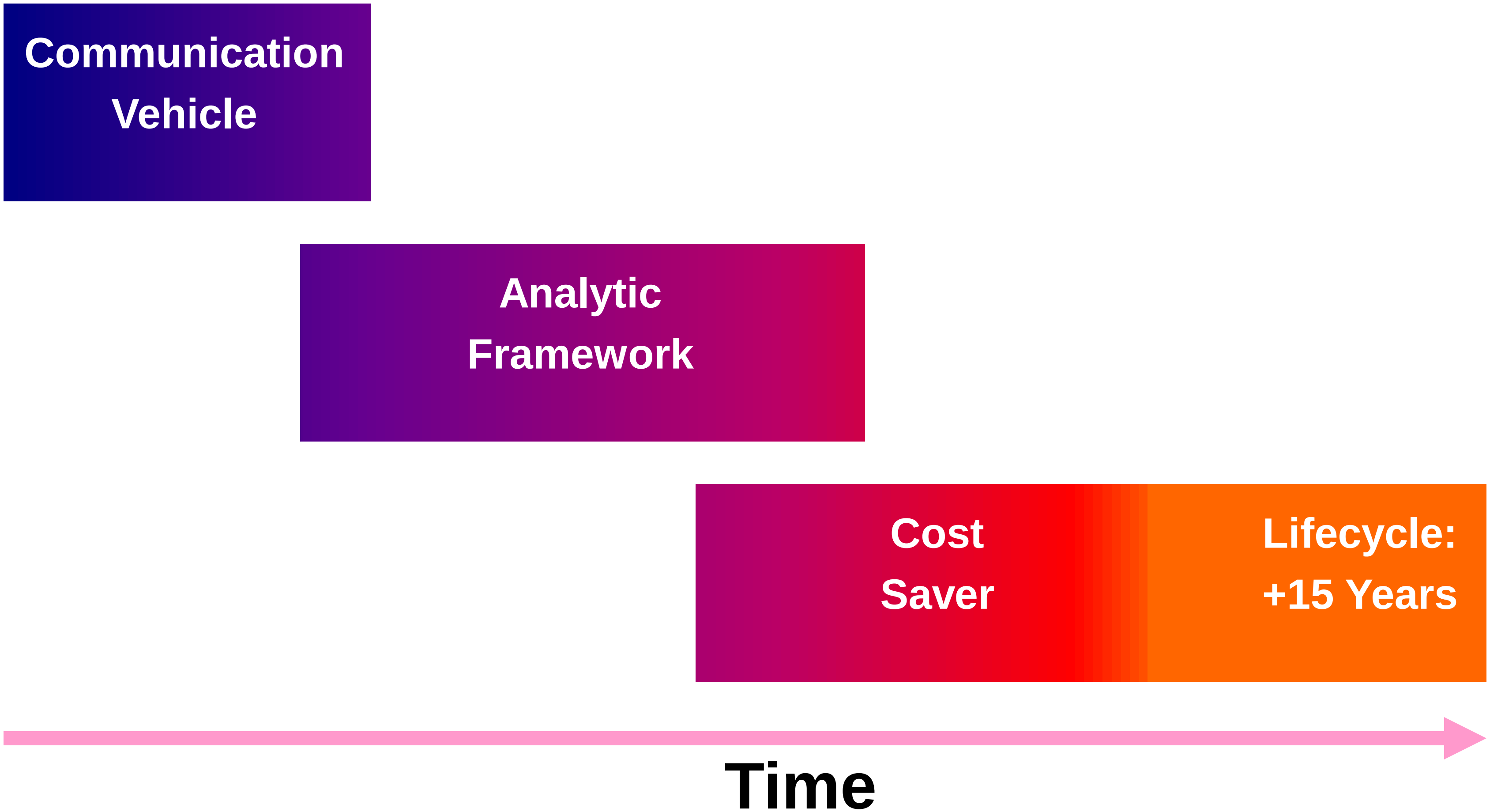
- Good models do not rely on contract (input data)
- Input Module (handles bad data)
  - Simple error checks
  - Analyzing and reporting complex data problems
- Good models (modeling systems) provide access to results via independent result analyzers for non model experts
- Analytic framework helps to define a result metric
  - e.g. violations of soft constraints

Cost Saver

- Most convincing and obvious reason for using an optimization model
- *Science of better (INFORMS)*
- Often exaggerated/difficult to estimate
- More reasons:
  - Institutionalize personal knowledge
  - Scientific foundation (economic models)
  - Get “*fair*” results (usually fails)

GAMS

Model Roles over Time



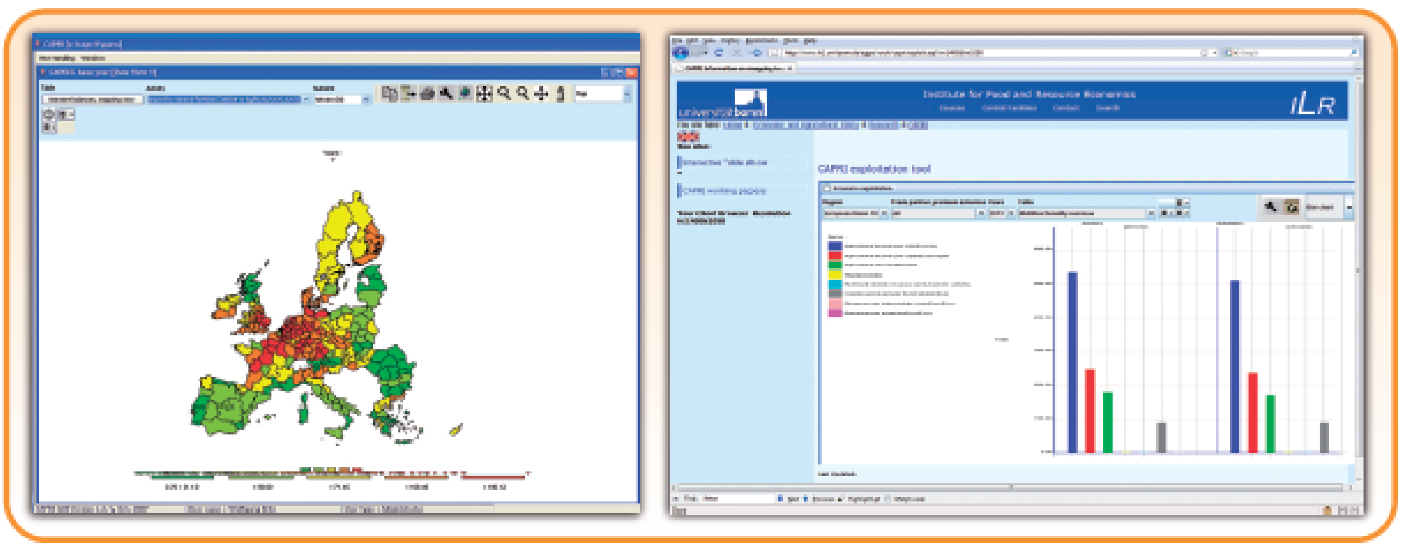
CAPRI

The CAPRI (Common Agricultural Policy Regional Impact) Modelling System

CAPRI is a global agricultural sector model powered by GAMS with focus on 27 countries of the European Union and Norway

- Global multi-commodity model for agricultural products in 18 trade blocks
- About 250 regions or even up to six farm types for each region
- Evaluates regional and aggregate impacts of trade policies on production, income, markets, trade and environment
- Used by research institutions and EU Commission services

More information and an online exploitation tool at:
http://www.ilr1.uni-bonn.de/agpo/rsrch/capri/capri_e.htm



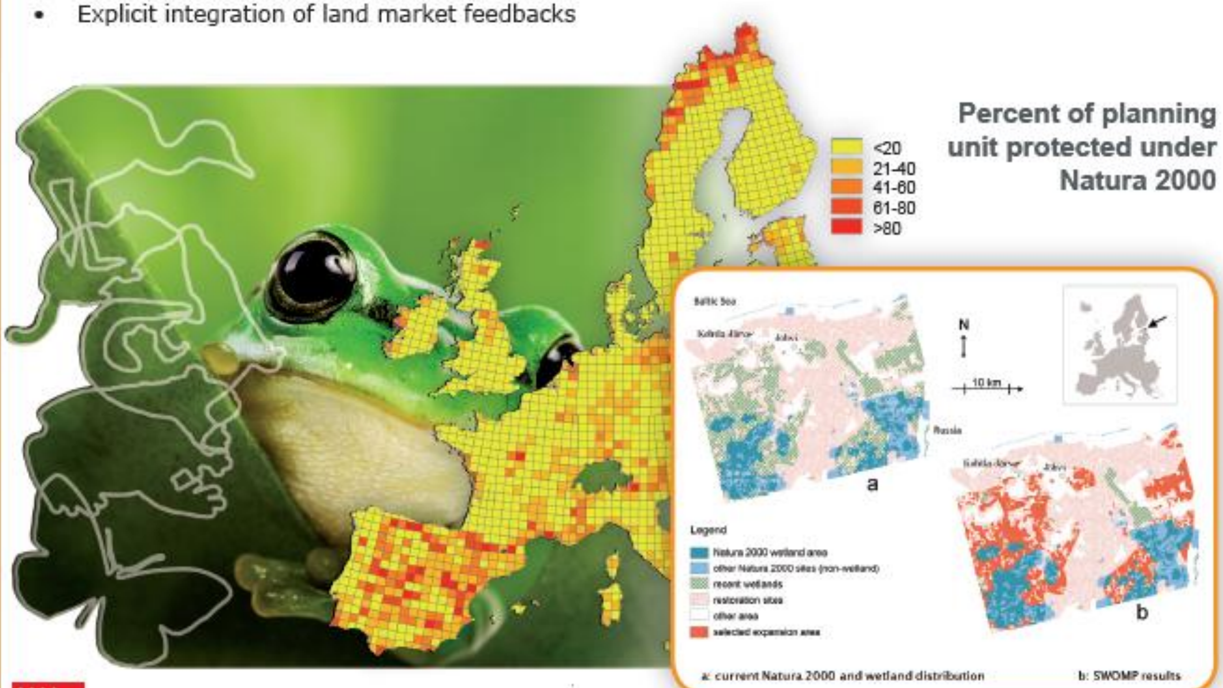
Screen shots from the CAPRI exploitation tool

HABITAT

HABITAT – a reserve selection tool for European wetland biodiversity conservation

Developed at the University of Hamburg, the HABITAT model was explicitly designed for the special requirements for conservation planning on the European continent with its fragmented habitats and high human population density. It is based on principles of systematic conservation planning and economic theory. This central component of the systematic conservation planning philosophy aims at efficiency of resource use. The objective is to find a set of conservation sites that achieves a conservation target at minimum cost.

- A set-covering problem formulated as a mixed integer program to find the cost-efficient allocation of nature reserves
- Integration of representation and persistence principles in the „conservation target" approach
- Endogenous calculation of reserve sizes
- Explicit integration of land market feedbacks



Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

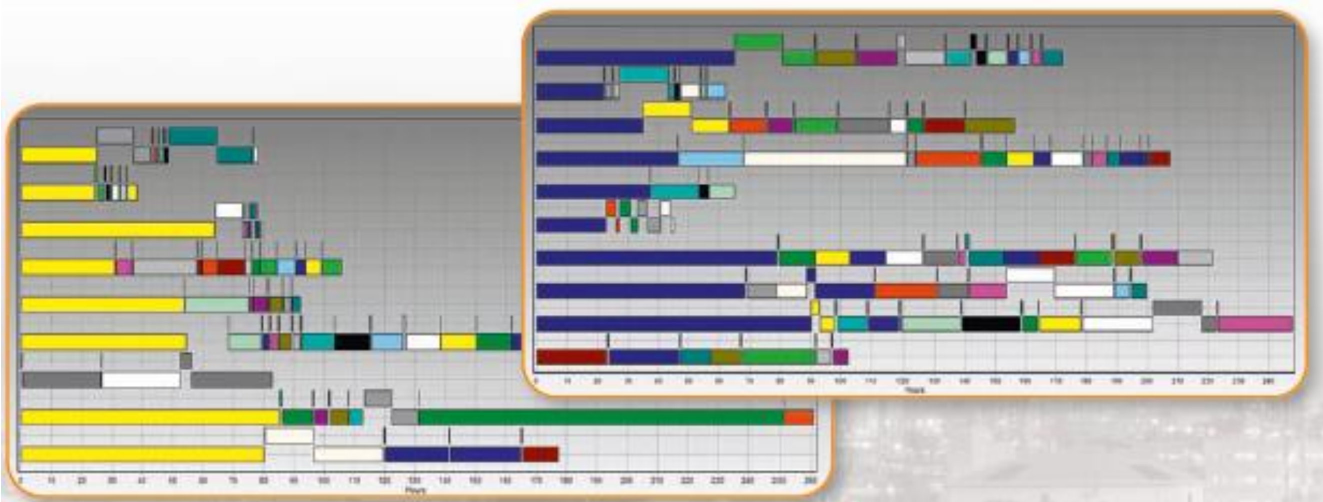
For further information about this application please contact Kerstin Jantke <kerstin.jantke@zmaw.de>, Uwe Schneider <uwe.schneider@zmaw.de >, or visit: http://fnu.zmaw.de/

Scheduling and Planning at BASF

Scheduling and Planning at BASF

Close cooperation between logistics, information services and the scientific computing group of BASF, Prof. Dr. C. A. Floudas (Princeton University), Dr. A. V. Eremeev and Dr. P. A. Borisovski (Omsk Branch of Sobolev Institute of Mathematics SB RAS), SAP AG, and Mathesis GmbH led to a number of successfully deployed applications based on exact and hybrid optimization techniques. One of the results is a novel modeling approach of batch and continuous plants:

- State-task network formulation resulting in mixed-integer linear program
- Unit-specific, event-specific continuous-time formulations
- Hybrid methods and decomposition schemes to handle large instances
- Tight lower bounds derived from auxiliary models
- Implementation in GAMS with parallel GAMS/CPLEX
- New interfacing technology and integration approaches to connect to SAP-APO
- Used on a daily basis to improve planning and scheduling



Cutting Stock Optimization at GSE

Cutting Stock Optimization at GSE

GSE-TRIM is a fully integrated module of the ERP-System GSE-PPS for Cutting Stock Optimization. Close cooperation of our in-house specialists with scientists in the area of discrete optimization has led to a number of successfully deployed applications used by the paper industry. Exact and hybrid optimization techniques coded in GAMS and Fortran have been implemented in our software package GSE-TRIM.

Our clients in various Mid-European paper industry companies benefit from:

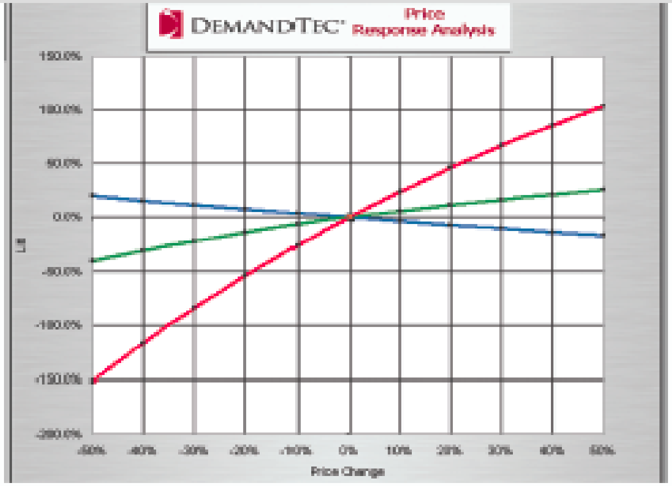
- Exact waste minimization in roll production
- Non-standard objective functions
- Considering detailed operational restrictions
- Multi-stage format production

Based on a daily basis GSE-TRIM improves our clients key indicators and has been proven very stable over 7 years.

For more information please contact: www.gse-software.de

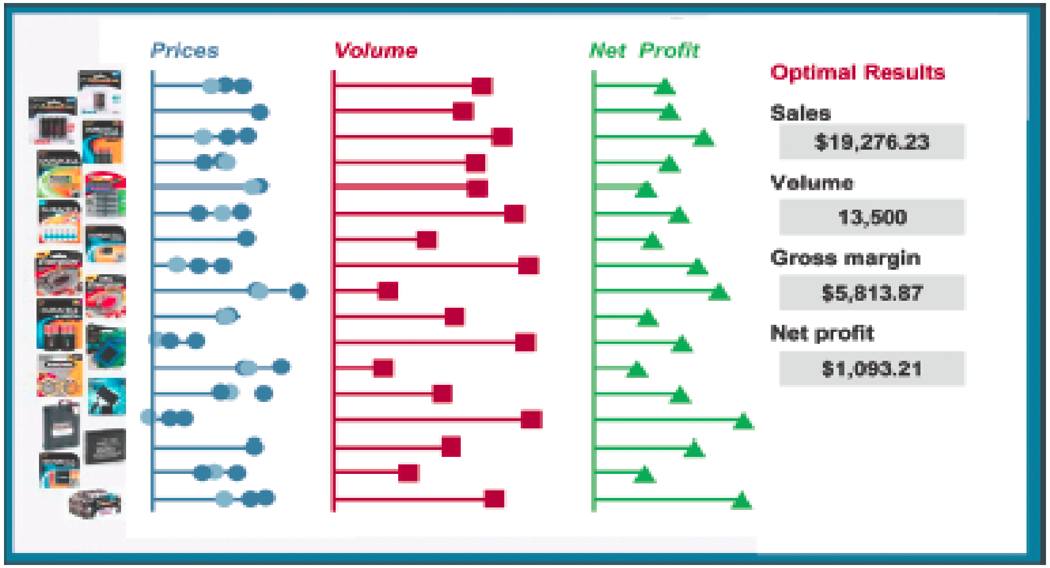
DemandTec

DemandTec Leverages GAMS to Drive Innovation in Retail and CPG Industries



DemandTec uses sophisticated econometric and optimization models to help retailers and manufacturers make merchandising and marketing decisions based on a quantified understanding of consumer demand. DemandTec's applications are used to:

- Model price elasticity, cross-price elasticity, and other merchandising causals to predict and influence demand given different merchandising conditions and strategies.
- Optimize prices and promotions to maximize sales, volume, or profit, while operating within the constraints of competitive pricing and other business rules.
- Accurately forecast the impact of merchandising strategies and tactics, taking into account cannibalization, halo effects, seasonality, trend, and other factors.



GAMS

Agenda

- What is GAMS
- What is a GAMS model
- Roles of a Model
- Market Demands and Challenges

Market Demands

- **Minimize risks** for (new) clients / management
- **Provide cutting edge technology**
- **Protect user investments**

Minimize Risks

- Support rapid prototyping
- Increase productivity
- Deliver (expected) results
- **Do not lock users into a certain environment**

Provide cutting edge technology

- **Industry:** Reliable, high performance system for developing and deploying optimization applications

- **Academia (research tool):**
  - New modeling paradigms (e.g. SDP, bilevel, SP,…)
  - Emerging solution technology (e.g. MPEC)
  - New computing environments

Bridging the Gap

GAMS serves both worlds (synergy):

- Large user base in industry and academia
- Dissemination of research ideas
- Challenging/relevant problems from industry

➡ **30% of revenue invested in research and product development**

GAMS

Protect User Investments

- Life time of a model: 15+ years:
  - New maintainer, platform, solver, user interface
  - Protection of investment in a model
- Blessing for the user (mostly) – curse for developers
  - Old concepts in new situations
    - Example: GAMS listing file
  - Language additions have to be supported in the future
  - GAMS is conservative when it comes to syntax additions
- Danger of becoming a barrier for innovation

Quality Assurance at GAMS

Quality Test Models Library

- Include tests to verify proper behavior of the system
- More than 550 quality test models (included in the distribution), each containing numerous pass/fail tests
- Continuous quality improvement using automated and reproducible tests (> 20.000 solves for each platform)
- Automatic generated test summaries with different levels of information

Quality Assurance at GAMS

http://builds.gams.com/

GAMS

[Home | Support | Sales | Solvers | Documentation | Model Library | Search | Contact Us]

Latest GAMS System Builds and Test Results

Thursday 12Apr12 13:10 (UTC)

[Latest Builds | Alpha Builds | Beta Builds | Nightly Builds | System Codes | History]

Comments?

nightly α	System	Libraries	Build	Rev	Status and Time (UTC)		Initial Tests		Full Tests	
Wednesday	lnx	Download	23.9.0	32515	Test started	12Apr2012 01:32:39	708 runs 3 failures (q=3,s=0)	Report	results pending	
Wednesday	vs8	Download	23.9.0	32517	Test done	12Apr2012 10:11:52	710 runs 3 failures (q=3,s=0)	Report	9112 runs 20 failures (q=19,s=1)	Report
Wednesday	wei	Download	23.9.0	32522	Test done	12Apr2012 09:29:15	688 runs 3 failures (q=3,s=0)	Report	8581 runs 19 failures (q=19,s=0)	Report

nightly β	System	Libraries	Build	Rev	Status and Time (UTC)	Initial Tests	Full Tests

GAMS System Builds and Test Results Archive

Thursday 12Apr12 13:13 (UTC)

[Latest Builds | Alpha Builds | Beta Builds | Nightly Builds | System Codes]

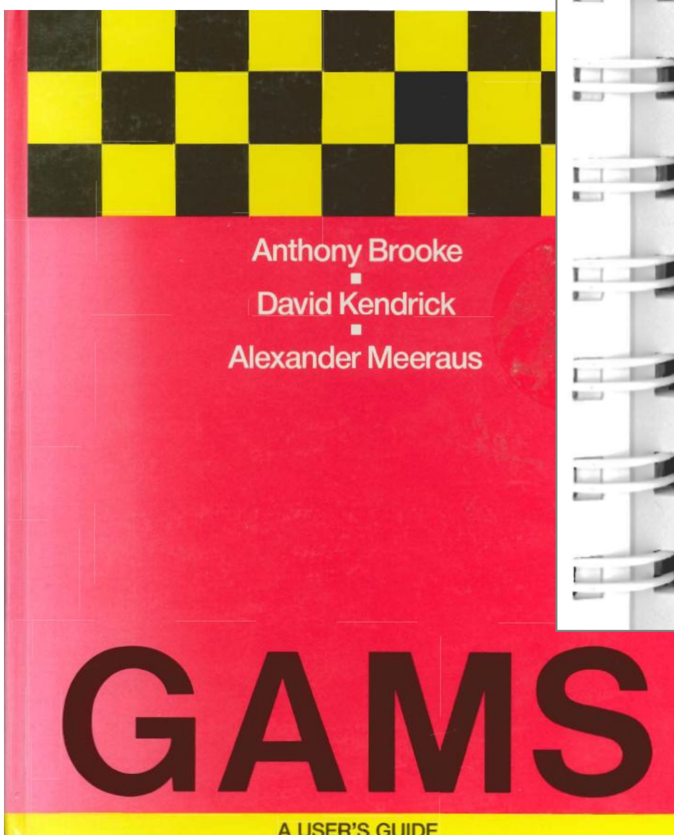
Comments?

```
Total:          9112 runs         20 failures
Quality:        1538 runs         19 failures
Slvtest:        7378 runs          1 failures
EMP:             126 runs          0 failures
Data:             56 runs          0 failures
API:              14 runs          0 failures

**** QUALITY TEST FAILURES (failures_qa.gms)
$call  =gams quality --DEMOSIZE=1 lo=2 --prefix=vs8 --fail=failures_qa.tmp --test=BADPT2 --ftrace=1
$call  =gams quality --DEMOSIZE=1 lo=2 --prefix=vs8 --fail=failures_qa.tmp --test=BADPT3 --ftrace=1
$call  =gams quality --DEMOSIZE=1 lo=2 --prefix=vs8 --fail=failures_qa.tmp --test=PFMAPTST --ftrace=1
$call  =gams quality --DEMOSIZE=1 lo=2 --prefix=vs8 --fail=failures_qa.tmp --test=LP01 --solver=baron --ftrace=1
$call  =gams quality --DEMOSIZE=1 lo=2 --prefix=vs8 --fail=failures_qa.tmp --test=LP02 --solver=baron --ftrace=1
$call  =gams quality --DEMOSIZE=1 lo=2 --prefix=vs8 --fail=failures_qa.tmp --test=LP11 --solver=baron --ftrace=1
$call  =gams quality --DEMOSIZE=1 lo=2 --prefix=vs8 --fail=failures_qa.tmp --test=LP12 --solver=baron --ftrace=1
```

Client Model Testing

- Requires changes to the model of the clients to allow automated pass/failure tests
- Includes:
  - Ability to solve (= no bugs)
  - Returns the same solution back
  - Similar or better performance
- Gives clients assurance that their application will also work with new GAMS releases
- Improves communication between development team and clients (specific wishes)

Then …



In Table 17.1 we list sizes and attributes of representative models that are "large" in the sense that they are near the limit of what is practical on a personal computer, along with the model generation time (GAMS) and solution time (solver), both in minutes. These examples were run on an 8 MHz AT with an 80287 coprocessor and 640K of RAM. The times shown are to give you a rough idea of what is possible: these are not precisely controlled benchmarks, and we have a host of performance improvements in mind for the near future.

Table 17.1: Problem Characteristics

Name	*Number of Rows*	*Number of Columns*	*Number of Nonzeroes*	*Generation Time*[a]	*Solution Time*[a]	*Iterations*	*Solver*
DINAMICO	318	425	4156	3.0	30.1	628	MINOS
SARF	532	542	3949	37.7	115.8	2775	MINOS
FERTD[b]	458	2968	7252	11.4	28.3	1368	ZOOM
CAMCGE[c]	243	280	1356	0.8	7.0	189	MINOS
GANGES[d]	274	357	1405	1.8	7.3	187	MINOS
YEMCEM[e]	168	258	953	0.9	7.6	600	ZOOM
EGYPT[f]	281	618	3168	4.0	25.3	1551	ZOOM

[a] Measured in minutes.
[b] The problem is too big for MINOS. ZOOM was used instead.
[c] A nonlinear problem. 63% of the non-zeroes are nonlinear.
[d] A nonlinear problem. 58% of the non-zeroes are nonlinear.
[e] A mixed binary problem, with 55 binary variables (solved with a relative termination criterion of 10%).
[f] A linear problem, solved using XMP which is contained within ZOOM.

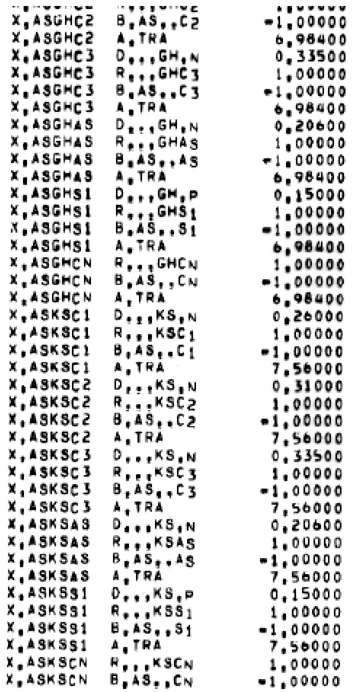
GAMS Users Guide (1988)

… and now

	Type	s in 1988	s in 2008	Improvement Factor
camcge	NLP	468	0.031	15097
dinamico	LP	1986	0.125	15888
egypt*	MIP	1758	0.015	117200
fertd*	MIP	2382	0.062	38419
ganges	NLP	546	0.109	5009
sarf	LP	9210	0.139	66259
yemcem*	MIP	510	0.140	3643

* MIP 1988 solver ZOOM, 2008 solver CPLEX

Change in Focus: Past



```
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
```

Computation	*Model*	*Application*
→ Users left out	*→ Users involved*	→Users hardly aware of model

Change in Focus: Now

C:\Users\Franz\Documents\gamsdir\projdir\trnsport.gms

data.inc | trnsport.gms | trnsport.lst

```
Sets     i    canning plants
         j    markets;
Parameters  a(i)    capacity of plant i in cases
            b(j)    demand at market j in cases
            d(i,j)  distance in thousands of miles
            f       freight in dollars per case per thousand miles
            c(i,j)  transport cost in thousands of dollars per case ;
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) ..    sum(j, x(i,j))  =l=  a(i) ;
demand(j) ..    sum(i, x(i,j))  =g=  b(j) ;
Model transport /all/ ;
$include data.inc
c(i,j) = f * d(i,j) / 1000 ;
Solve transport using lp minimizing z ;
Display x.l, x.m ;
```

Computation

→ Users left out

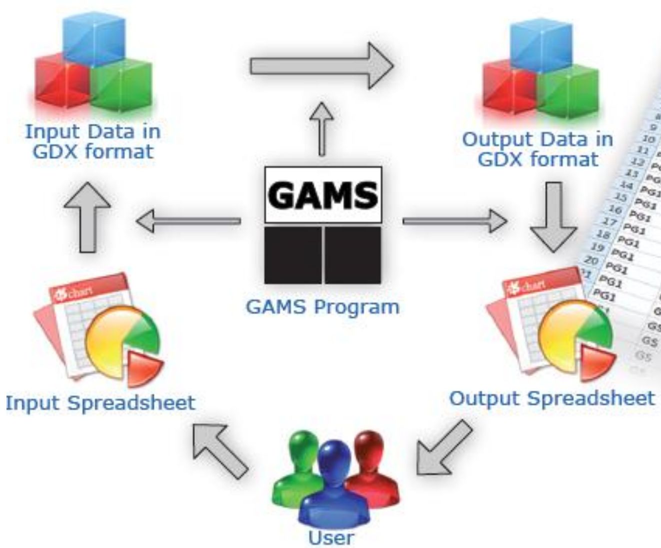
Model

→ Users involved

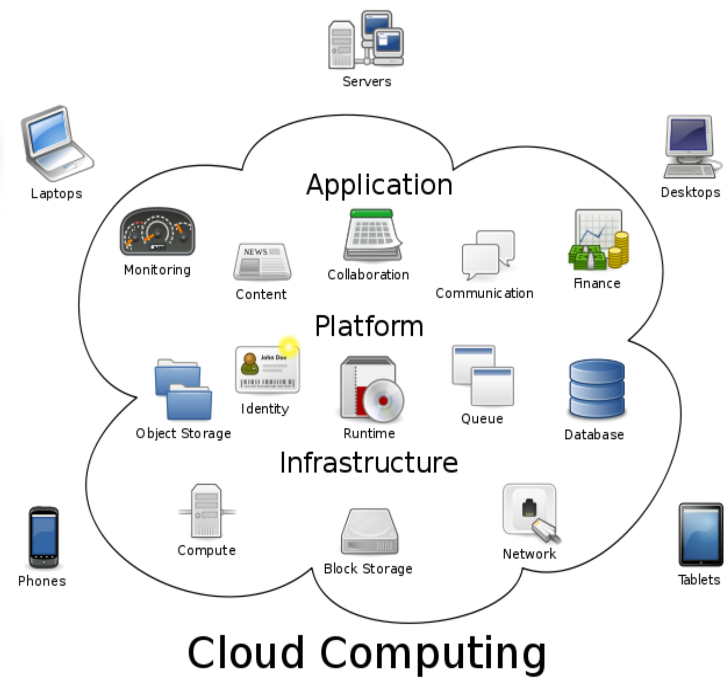
Application

→Users hardly aware of model

Change in Focus: *Future*



?



Computation	*Model*	*Application*
→ Users left out	*→ Users involved*	*→Users hardly aware of model*

Summary

What is GAMS

- Algebraic Modeling Language
- Balanced mix of declarative and procedural elements
- Platform and solver independence
- Open architecture and independent layers

Role of a Model

- Communication Vehicle
- Analytic Framework
- Cost Saver

Market Demands:

- Minimize Risks
- Provide cutting edge technology
- Protect user investments

Thank You !

<u>USA</u>

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