Models and Their Roles
Or
“"A Model is a Model is a Model"

Franz Nelissen  FNelissen@gams.com  
GAMS Development Corp. /  GAMS Software GmbH
www.gams.com

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

<table>
<thead>
<tr>
<th>What is GAMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is a GAMS model</td>
</tr>
<tr>
<td>Roles of a Model</td>
</tr>
<tr>
<td>Market Demands and Challenges</td>
</tr>
</tbody>
</table>
Matrix Generator
MPS Output

<table>
<thead>
<tr>
<th>NUMBER</th>
<th>NAME</th>
<th>TYPE</th>
<th>STATUS</th>
<th>COL ACTIVITY</th>
<th>OBJ COEF</th>
<th>D UPPER</th>
<th>MARGINAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>G1</td>
<td>PL</td>
<td>LOWER</td>
<td></td>
<td>-47.800000</td>
<td>INF</td>
<td>-8,44851</td>
</tr>
<tr>
<td>102</td>
<td>G2</td>
<td>PL</td>
<td>ACTIVE</td>
<td>0.00087</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>103</td>
<td>G3</td>
<td>PL</td>
<td>ACTIVE</td>
<td>-701.000000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>104</td>
<td>G4</td>
<td>PL</td>
<td>ACTIVE</td>
<td>-10330.60000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>105</td>
<td>G5</td>
<td>PL</td>
<td>LOWER</td>
<td>-2424.70000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>106</td>
<td>G6</td>
<td>PL</td>
<td>LOWER</td>
<td>-9416.00000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>107</td>
<td>G7</td>
<td>PL</td>
<td>LOWER</td>
<td>-5116.00000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>108</td>
<td>G8</td>
<td>PL</td>
<td>LOWER</td>
<td>-13.20000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>109</td>
<td>G9</td>
<td>PL</td>
<td>LOWER</td>
<td>-231.57000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>110</td>
<td>G10</td>
<td>PL</td>
<td>LOWER</td>
<td>-139.87000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>111</td>
<td>G11</td>
<td>PL</td>
<td>LOWER</td>
<td>-139.47000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>112</td>
<td>G12</td>
<td>PL</td>
<td>LOWER</td>
<td>-76.71000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>113</td>
<td>G13</td>
<td>PL</td>
<td>LOWER</td>
<td>-76.71000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>114</td>
<td>G14</td>
<td>PL</td>
<td>LOWER</td>
<td>12.91000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>115</td>
<td>G15</td>
<td>PL</td>
<td>LOWER</td>
<td>180.74000</td>
<td>INF</td>
<td>INF</td>
<td>-87,1934</td>
</tr>
<tr>
<td>116</td>
<td>G16</td>
<td>PL</td>
<td>LOWER</td>
<td>167.63000</td>
<td>INF</td>
<td>INF</td>
<td>-256,3963</td>
</tr>
<tr>
<td>117</td>
<td>G17</td>
<td>PL</td>
<td>LOWER</td>
<td>121.35000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>118</td>
<td>G18</td>
<td>PL</td>
<td>LOWER</td>
<td>91.60000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>119</td>
<td>G19</td>
<td>PL</td>
<td>LOWER</td>
<td>109.74000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>120</td>
<td>G20</td>
<td>PL</td>
<td>LOWER</td>
<td>77.46000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>121</td>
<td>G21</td>
<td>PL</td>
<td>LOWER</td>
<td>77.46000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
<tr>
<td>122</td>
<td>G22</td>
<td>PL</td>
<td>LOWER</td>
<td>77.46000</td>
<td>INF</td>
<td>INF</td>
<td>INF</td>
</tr>
</tbody>
</table>
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**
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 was the first algebraic modeling language (AML) and is formally similar to commonly used fourth-generation programming languages. GAMS contains an integrated development environment (IDE) and is connected to a group of third-party optimization solvers. Among these solvers are BARON, CONI 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.
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
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
  • …
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

10+ Supported Platforms

- Solaris 64
- Solaris Sparc
- AXU
- AIX
- Linux 32
- Linux 64
- HP
- Mac
- Windows 64
- Windows 32
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
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

- ASCII
- **Gams Data eXchange** (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: Algebra

Minimize Transportation cost

subject to Demand satisfaction at markets

Supply constraints

Objective

Observe supply limit at plant $i$:

\[ \sum_j x_{i,j} \leq a_i \quad \forall i \]

Satisfy demand at market $j$:

\[
\begin{align*}
\sum_i x_{i,j} & \geq b_j \quad \forall j \\
x_{i,j} & \geq 0 \quad \forall i, j
\end{align*}
\]
A Simple Example: Declarative Model

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/ ;
A Simple Example: Model Data

```
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/ ;
```
A Simple Example: Results

**** REPORT SUMMARY : 0 NONOPT
0 INFEASIBLE
0 UNBOUNDED

GAMS Rev 238 WEX-WEI 23.3.1 X86_64/MS Windows 03/29/12 13:28:06 Page 6
A Transportation Problem (TRANSPORT,SEQ=1)

Execution

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

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

<table>
<thead>
<tr>
<th></th>
<th>new-york</th>
<th>chicago</th>
<th>topeka</th>
</tr>
</thead>
<tbody>
<tr>
<td>seattle</td>
<td>50.000</td>
<td>300.000</td>
<td></td>
</tr>
<tr>
<td>san-diego</td>
<td>275.000</td>
<td>275.000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Entry</th>
<th>Symbol</th>
<th>Type</th>
<th>Dim</th>
<th>Nr Elen</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>a</td>
<td>Par</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>b</td>
<td>Par</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>c</td>
<td>Par</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>cost</td>
<td>Equ</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>d</td>
<td>Par</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>demand</td>
<td>Equ</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>f</td>
<td>Par</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>i</td>
<td>Set</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>j</td>
<td>Set</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>supply</td>
<td>Equ</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>x</td>
<td>Var</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>z</td>
<td>Var</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

X: shipment quantities in cases

<table>
<thead>
<tr>
<th></th>
<th>new-york</th>
<th>chicago</th>
<th>topeka</th>
</tr>
</thead>
<tbody>
<tr>
<td>seattle</td>
<td>50</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>san-diego</td>
<td>275</td>
<td>275</td>
<td></td>
</tr>
</tbody>
</table>
A Simple Example: Modifications

- LP
- MIP
- NLP
- MINLP

Diagram showing the relationships between LP, MIP, NLP, and MINLP.
A Simple Example: Minimum Shipment

• Extension: Minimum Shipment
  – Ship at least 100 units or don’t ship

• Continuous variable $x(i,j)$
• Binary variable $\text{ship}(i,j)$

• Coupling constraints:
  – if $\text{ship} = 1 \rightarrow x \geq 100: x \geq 100 \times \text{ship}$
  – If $\text{ship} = 0 \rightarrow x = 0: x \leq \text{bigM} \times \text{ship}$
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;
A Simple Example: Economy of Scales

Cost = Volume^{\text{beta}}

- **Beta >1**
- **Beta =1**
- **Beta <1**
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;
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

<table>
<thead>
<tr>
<th></th>
<th>lp</th>
<th>mip</th>
<th>mip-ccinc</th>
<th>nlp-convex</th>
<th>nlp-conca</th>
</tr>
</thead>
<tbody>
<tr>
<td>seattle</td>
<td>50.000</td>
<td>300.000</td>
<td>300.000</td>
<td>142.384</td>
<td></td>
</tr>
<tr>
<td>seattle</td>
<td>300.000</td>
<td>300.000</td>
<td>300.000</td>
<td>130.930</td>
<td>300.000</td>
</tr>
<tr>
<td>seattle</td>
<td>76.686</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>san-diego</td>
<td>275.000</td>
<td>325.000</td>
<td>325.000</td>
<td>182.616</td>
<td>325.000</td>
</tr>
<tr>
<td>san-diego</td>
<td>169.070</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>san-diego</td>
<td>198.314</td>
<td>275.000</td>
<td>275.000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

+ nlp-baron minlp-bar minlp-lin

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>seattle</td>
<td>300.000</td>
<td>300.000</td>
<td>300.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>san-diego</td>
<td>325.000</td>
<td>325.000</td>
<td>325.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>san-diego</td>
<td>275.000</td>
<td>275.000</td>
<td>275.000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

--- 142 PARAMETER rep2 Objective value

<table>
<thead>
<tr>
<th></th>
<th>153.675</th>
<th>153.675</th>
<th>153.675</th>
<th>153.675</th>
</tr>
</thead>
<tbody>
<tr>
<td>nlp-convex</td>
<td>198.355</td>
<td>nlp-concave</td>
<td>15.585</td>
<td>nlp-baron</td>
</tr>
<tr>
<td>minlp-bar</td>
<td>15.585</td>
<td>minlp-lin</td>
<td>15.585</td>
<td></td>
</tr>
</tbody>
</table>
## Agenda

<table>
<thead>
<tr>
<th>What is GAMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is a GAMS model</td>
</tr>
<tr>
<td>Roles of a Model</td>
</tr>
<tr>
<td>Market Demands and Challenges</td>
</tr>
</tbody>
</table>
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)
Model Roles over Time

- Communication Vehicle
- Analytic Framework
- Cost Saver
  Lifecycle: +15 Years

Time
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
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

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

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 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.

Optimal Results:

- Sales: $19,276.23
- Volume: 13,500
- Gross margin: $5,813.87
- Net profit: $1,093.21
<table>
<thead>
<tr>
<th>Agenda</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is GAMS</td>
</tr>
<tr>
<td>What is a GAMS model</td>
</tr>
<tr>
<td>Roles of a Model</td>
</tr>
<tr>
<td>Market Demands and Challenges</td>
</tr>
</tbody>
</table>
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
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

Latest GAMS System Builds and Test Results

<table>
<thead>
<tr>
<th>nightly α</th>
<th>System</th>
<th>Libraries</th>
<th>Build</th>
<th>Rev</th>
<th>Status and Time (UTC)</th>
<th>Initial Tests</th>
<th>Full Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wednesday</td>
<td>Inx</td>
<td>Download</td>
<td>23.9.0</td>
<td>32515</td>
<td>Test started 01:32:39</td>
<td>798 runs 3 failures (q=3,s=0)</td>
<td>Report</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>results pending</td>
<td></td>
</tr>
<tr>
<td>Wednesday</td>
<td>vs8</td>
<td>Download</td>
<td>23.9.0</td>
<td>32517</td>
<td>Test done 10:11:52</td>
<td>710 runs 3 failures (q=3,s=0)</td>
<td>Report</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9112 runs 20 failures (q=19,s=1)</td>
<td>Report</td>
</tr>
<tr>
<td>Wednesday</td>
<td>wei</td>
<td>Download</td>
<td>23.9.0</td>
<td>32522</td>
<td>Test done 09:29:15</td>
<td>698 runs 3 failures (q=3,s=0)</td>
<td>Report</td>
</tr>
</tbody>
</table>

GAMS System Builds and Test Results Archive

| Total:  | 9112 runs | 20 failures |
| Quality:| 1638 runs | 19 failures |
| Slvtest:| 7376 runs | 1 failures  |
| EMP:    | 126 runs  | 0 failures  |
| Data:   | 56 runs   | 0 failures  |
| API:    | 14 runs   | 0 failures  |

**** QUALITY TEST FAILURES (failures_ga.m)****

```bash
scal =gams quality --DEMOFILE=1 lo=2 --prefix=vs8 --fail=failures_ga.xtm --test=BADP2 --ftrace=1
scal =gams quality --DEMOFILE=1 lo=2 --prefix=vs8 --fail=failures_ga.xtm --test=BADP3 --ftrace=1
scal =gams quality --DEMOFILE=1 lo=2 --prefix=vs8 --fail=failures_ga.xtm --test=BADP5 --ftrace=1
scal =gams quality --DEMOFILE=1 lo=2 --prefix=vs8 --fail=failures_ga.xtm --test=BADP10 --ftrace=1
scal =gams quality --DEMOFILE=1 lo=2 --prefix=vs8 --fail=failures_ga.xtm --test=BADP11 --ftrace=1
scal =gams quality --DEMOFILE=1 lo=2 --prefix=vs8 --fail=failures_ga.xtm --test=BADP12 --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

<table>
<thead>
<tr>
<th>Name</th>
<th>Number of Rows</th>
<th>Number of Columns</th>
<th>Number of Nonzeros</th>
<th>Generation Timea</th>
<th>Solution Timea</th>
<th>Iterations</th>
<th>Solver</th>
</tr>
</thead>
<tbody>
<tr>
<td>DINAICO</td>
<td>318</td>
<td>425</td>
<td>4156</td>
<td>3.0</td>
<td>30.1</td>
<td>628</td>
<td>MINOS</td>
</tr>
<tr>
<td>SARF</td>
<td>532</td>
<td>542</td>
<td>3949</td>
<td>37.7</td>
<td>115.8</td>
<td>2775</td>
<td>MINOS</td>
</tr>
<tr>
<td>FERTDb</td>
<td>458</td>
<td>2968</td>
<td>7252</td>
<td>11.4</td>
<td>28.3</td>
<td>1368</td>
<td>ZOOM</td>
</tr>
<tr>
<td>CAMCRGc</td>
<td>243</td>
<td>280</td>
<td>1356</td>
<td>0.8</td>
<td>7.0</td>
<td>189</td>
<td>MINOS</td>
</tr>
<tr>
<td>GANGESd</td>
<td>274</td>
<td>357</td>
<td>1405</td>
<td>1.8</td>
<td>7.3</td>
<td>187</td>
<td>MINOS</td>
</tr>
<tr>
<td>YEMCSMf</td>
<td>168</td>
<td>258</td>
<td>953</td>
<td>0.9</td>
<td>7.6</td>
<td>600</td>
<td>ZOOM</td>
</tr>
<tr>
<td>EGYTFg</td>
<td>281</td>
<td>618</td>
<td>3168</td>
<td>4.0</td>
<td>25.3</td>
<td>1551</td>
<td>ZOOM</td>
</tr>
</tbody>
</table>

*Measured in minutes.
*bThe problem is too big for MINOS. ZOOM was used instead.
*cA nonlinear problem. 63% of the non-zeroes are nonlinear.
*dA nonlinear problem. 58% of the non-zeroes are nonlinear.
*eA mixed binary problem, with 55 binary variables (solved with a relative termination criterion of 10%).
*fA linear problem, solved using XMP which is contained within ZOOM.
... and now

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

* MIP 1988 solver ZOOM, 2008 solver CPLEX
Change in Focus: Past

- **Computation** → **Users left out**
- **Model** → **Users involved**
- **Application** → **Users hardly aware of model**
Change in Focus: Now

Computation → Users left out

Model → Users involved

Application → Users hardly aware of model
Change in Focus: Future

- Computation: Users left out
- Model: Users involved
- Application: 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!

USA

GAMS Development Corp.
1217 Potomac Street, NW
Washington, DC 20007
USA

Phone: +1 202 342 0180
Fax: +1 202 342 0181

http://www.gams.com
sales@gams.com
support@gams.com

Europe

GAMS Software GmbH
Eupener Str. 135-137
50933 Cologne
Germany

Phone: +49 221 949 9170
Fax: +49 221 949 9171

http://www.gams.com
info@gams.de
support@gams.com