Supply Chain Planning and Management:
A Software Architecture

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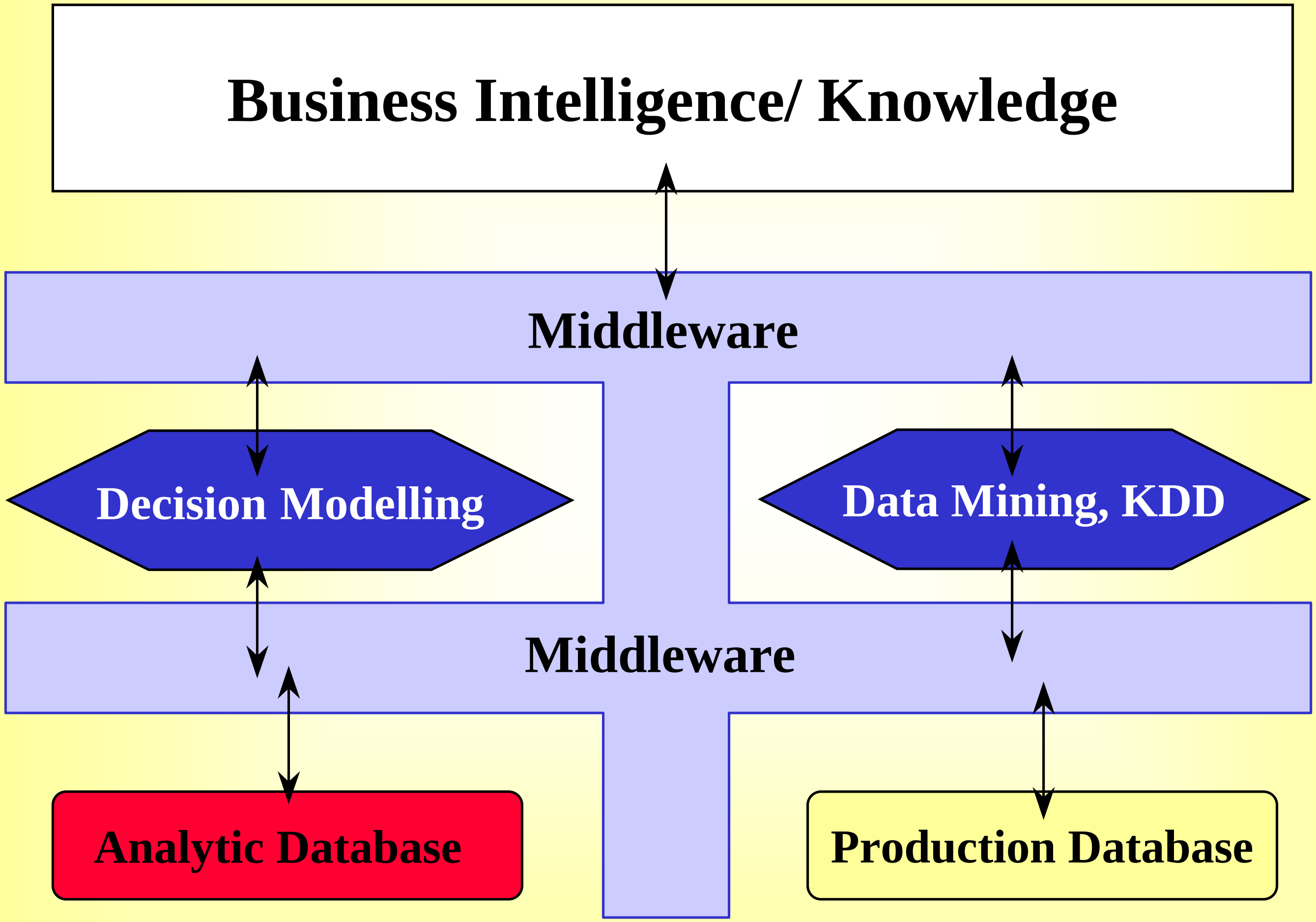
IBERINCO

Outline

- Information Systems and Analytical Solutions
- Scope of the Models
  - Planning
  - Scheduling
- Software Architecture
- Investigation of a Planning Model
- Unique Selling Points

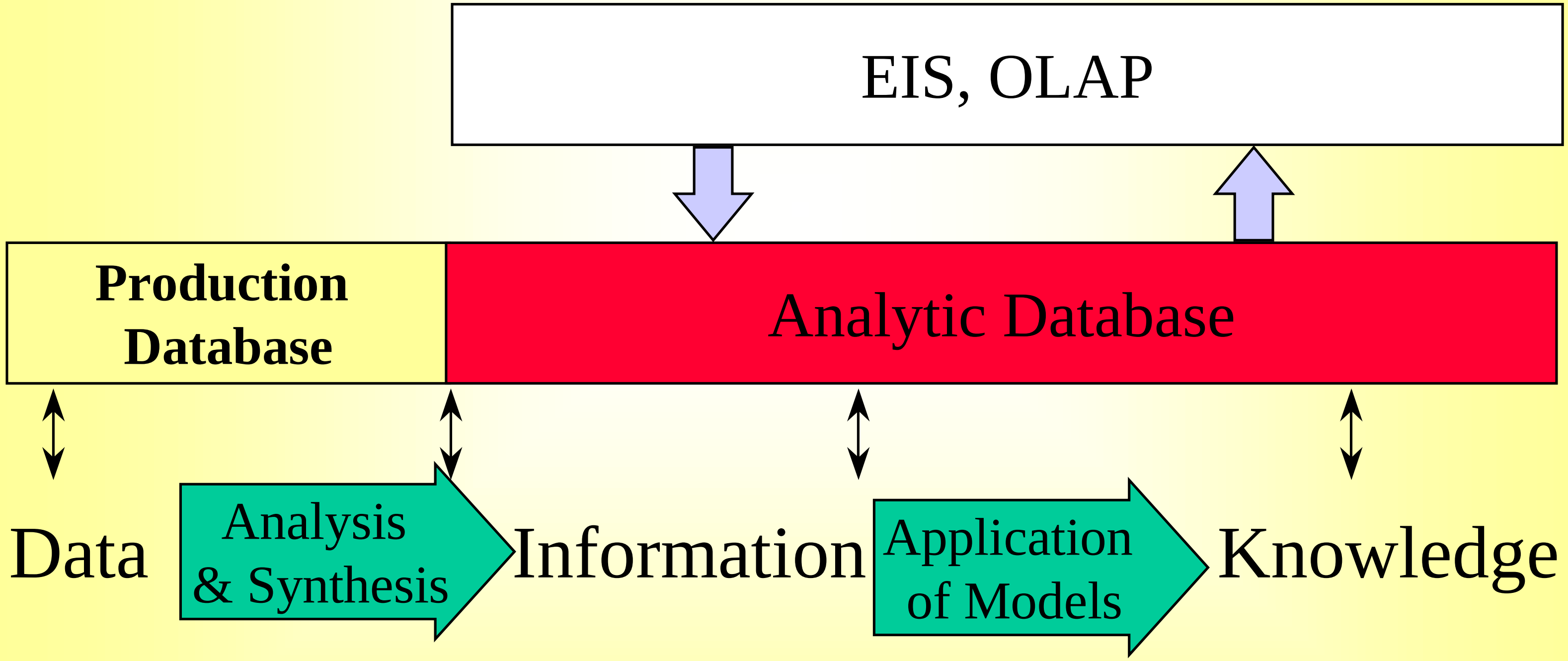
Information Systems and Analytical Solutions

Information and Decision Technologies

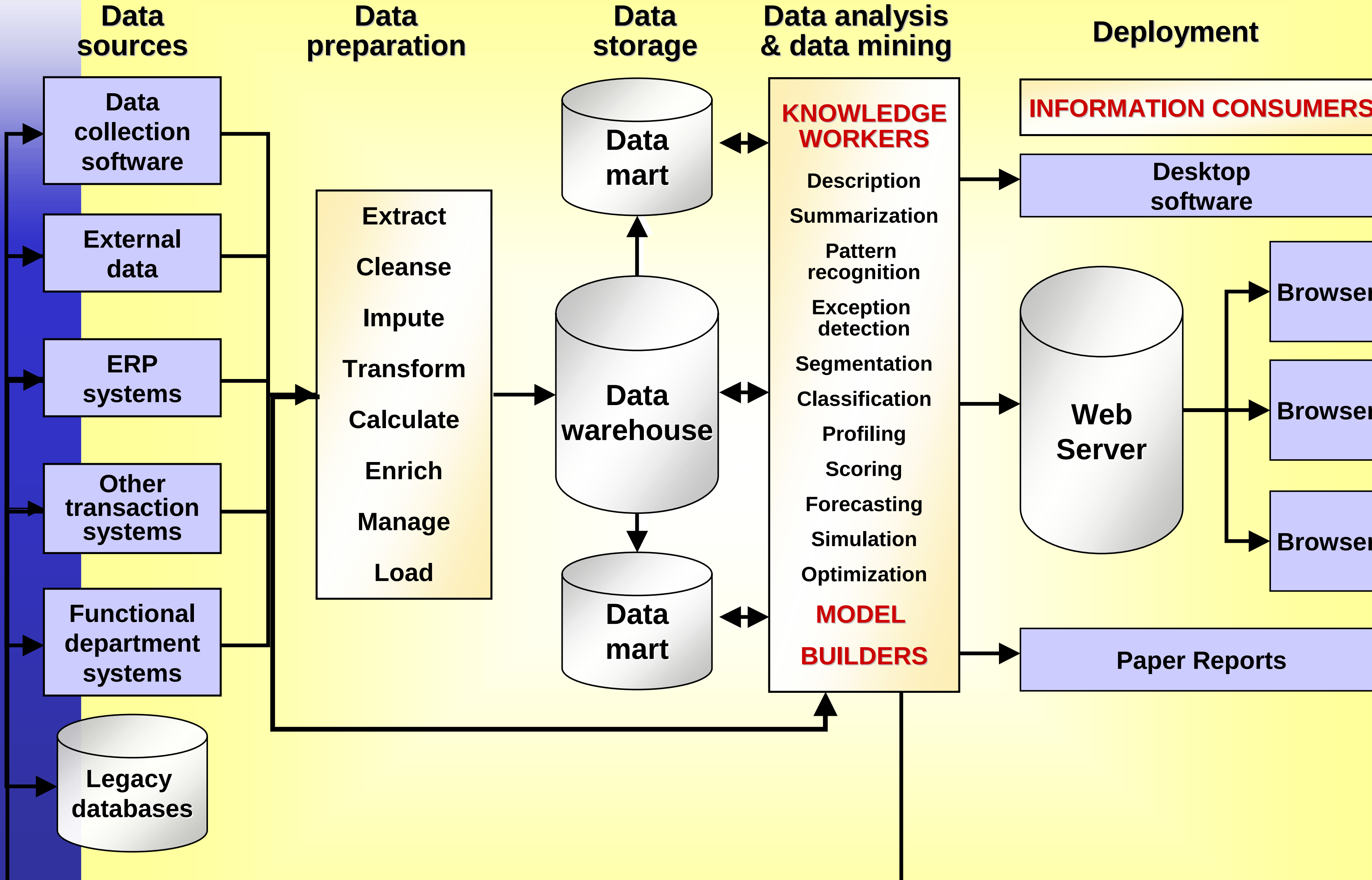


Middleware includes: Client/Server, Agents, Internet, Intranet,...

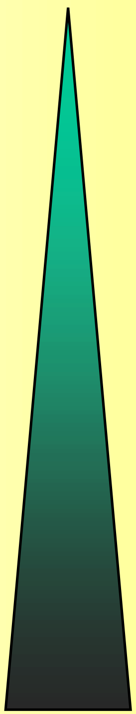
Information and Knowledge:
The Value Chain



Alternative View



Hierarchy of Tools and their Interaction

Function(s)	DSS Interaction	Software Tool	User Interaction
Model Solving	Solver	Optimisation Solver (FortMP)	
LP-Optimisation Forecast	Symbolic (Decision) Modelling	Modelling Tool (MPL)	
Roll-Up Drill-Down Slice What if Graphs	Analytic DB - Data Modelling	MDDB	
	Interface for the Analysis of data, Decision Models, Solutions	User Interface GUI, IUI	

Scope of the Models

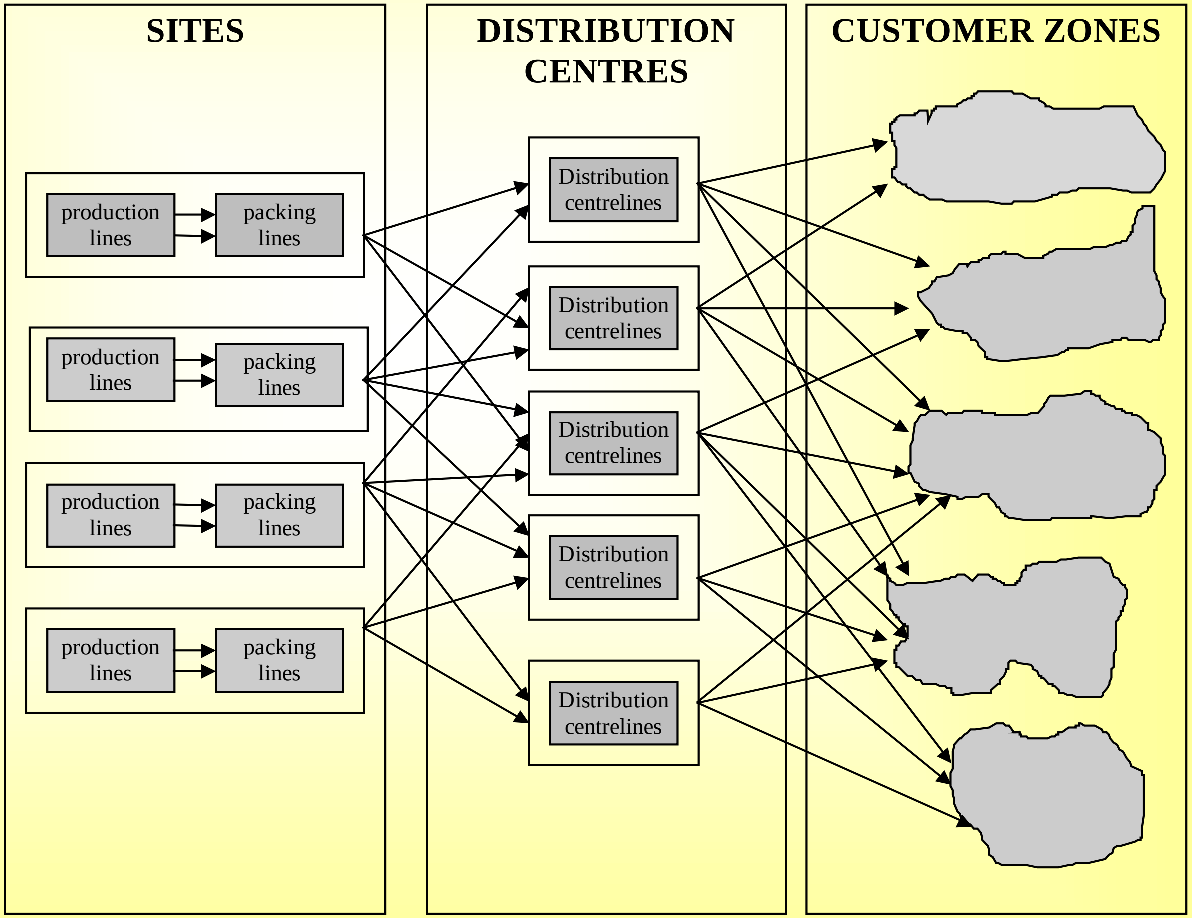
- Strategic ***Planning*** for a large multinational manufacturing company
- Production ***Scheduling*** for a Large Automobile Manufacturer

Investigation of a Planning Model

A Planning Problem

Capacity Planning Problem

- Sites
- Factories
- Lines
- Production
- Distribution
- …
- Uncertainty



Declarative Model

- Logical constraints
  - Open/Close plant
  - Line capacities at plants
  - Special ordered set constraints
  - Budget constraints
- Operational Constraints
  - Production Balances
  - Meeting Demand accounting for shortfalls
  - Linking constraints

Modelling Issues

- Manufacturing line technologies can be installed, removed or switched to other sites in any year
- Lines can be removed from the system at a number of points in the future
- Rules for Line Start/Shut Down are difficult to model declaratively

Application Objectives

- To determine where, when and what size of new plant to install
- To decide how to configure each plant with different technology lines
- Incorporating uncertainty in the data
  - demand
  - exchange rates
  - ...

Why Stochastic Programming?
Planning Under Uncertainty

Uncertainty $\rightarrow$ may lead to Risk
but,
Uncertainty $\neq$ Risk

Time plays a key role
We do not know the future … it unfolds
We capture possible future events or realizations as “Scenarios”

To “immunize” our plans against “risk”, we must:

- identify the risk event
- assign a likelihood/probability/weight
- know its “impact”
- compute mathematical expectation “*likelihood* x *impact*”

Unscheduled maintenance, delays in deliveries, changes in forecasted demand ...

Nature of Planning Decisions

- The decisions concerning investments in assets … made now
- As the future unfolds ... corrective action is taken to:
    - manage for better results
    - mitigate risk

Of course using the "Wait and See" model we can find "what should have been" the best decision:

But "Here and Now" is a two stage decision model …

it captures the very nature of "time phased decisions"

Strategic Planning Model

$$\begin{aligned} \text{Min} \quad & Z = cx + f^s y^s \\ \text{s.t.} \quad & Ax = b \\ & Bx + D^s y^s = d^s \\ & x \geq 0, \quad y^s \geq 0 \end{aligned}$$

First Stage Decisions *x* (Strategic)	**Second Stage Decisions *y*** (Operational)	
Manufacturing Sites, Distribution Centres, Production Lines, Packing Lines, …	Production Level, Packing, Distribution, Shortage, Quantities,…	
Ax		$= b$
Bx	$+ D^S y^S$	$= d^s$
$x = 0,1$	$y^S \geq 0$	

First and Second Phase

FIRST PHASE

$$s = 1,\ldots,100 \quad \text{Scenarios}$$

$$P_{MIP}(s): \quad \text{Min } Z^s = cx + f^s y^s$$

$$\text{s.t.} \quad Ax = b$$

$$Bx + D^s y^s = d^s$$

$$x \in \{0,1\}, \quad y^s \geq 0$$

$$Solve\ P_{MIP}(s) \rightarrow (sub)optimal\ \bar{x}_s$$

SECOND PHASE

$$P_{LP}(s,j): \quad s = 1,\ldots,100 \quad \text{designs/configurations}$$

$$j = 1,\ldots,100 \quad \text{scenarios}$$

$$\text{Min} \quad Z = c\bar{x}_s + f^S y^S$$

$$\text{s.t.} \quad D^S y^S = d^j + B\bar{x}_s$$

$$y^S \geq 0$$

Model Statistics for a Single Scenario

Model Dimensions		
Network Dimensions	**Prototype Model**	**Planning Model**
The number of Sites, I :	2	8
The types of packing line technology, Y_C:	1	4
The types of production line technology, Y_R:	1	2
The number of distribution centres , J :	3	15
The types of DC line technology types, Y_D:	1	2
The number of Customer Zones , H :	4	30
The number of Products , P :	2	13
The number of time periods, T :	6	6
Model Statistics		
Logical Constraints: Sites, DCs opening and closing, Limit on number of Sites, DCs, and Lines	268	1460
Continuous Constraints: Production, Packing, Ordering, Transportation, Balance, Demand, and also Production and Packing Capacities.	347	4520
Discrete Decision Variables: Sites, DCs, Production lines, Packing lines, DC lines.	172	1195
Continuous Variables: Production, Packing, Ordering, Transportation, and Shortage quantities.	226	44021
Non-zeros	2265	118884
Density	1.4%	0.05%
Scenarios	50	100

Investigation of a Scheduling Model

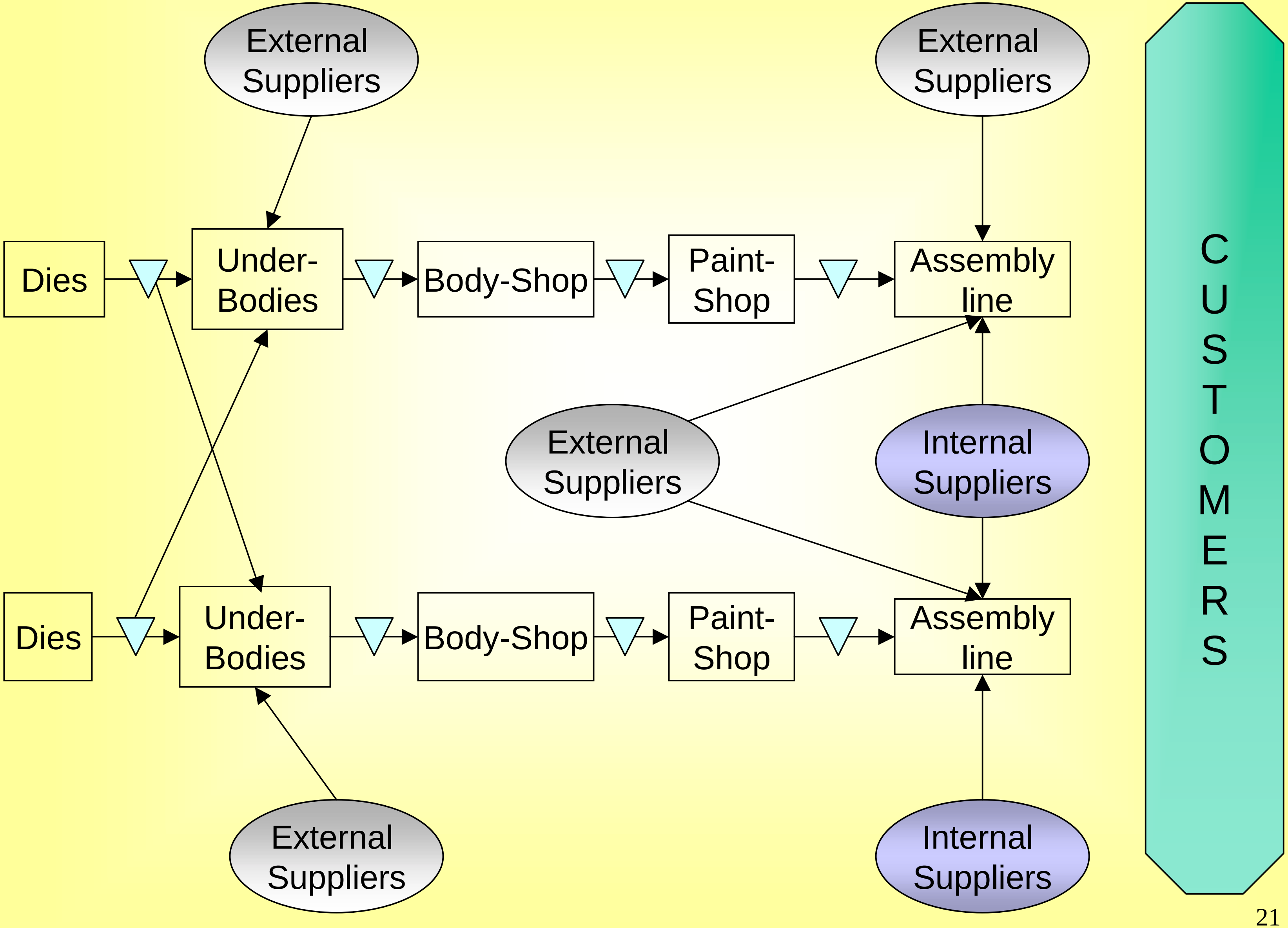
A Scheduling Problem

Target:

A Multi-product, Multi-Level, Multi-Plant, Multi-Period Model for Production Planning with:

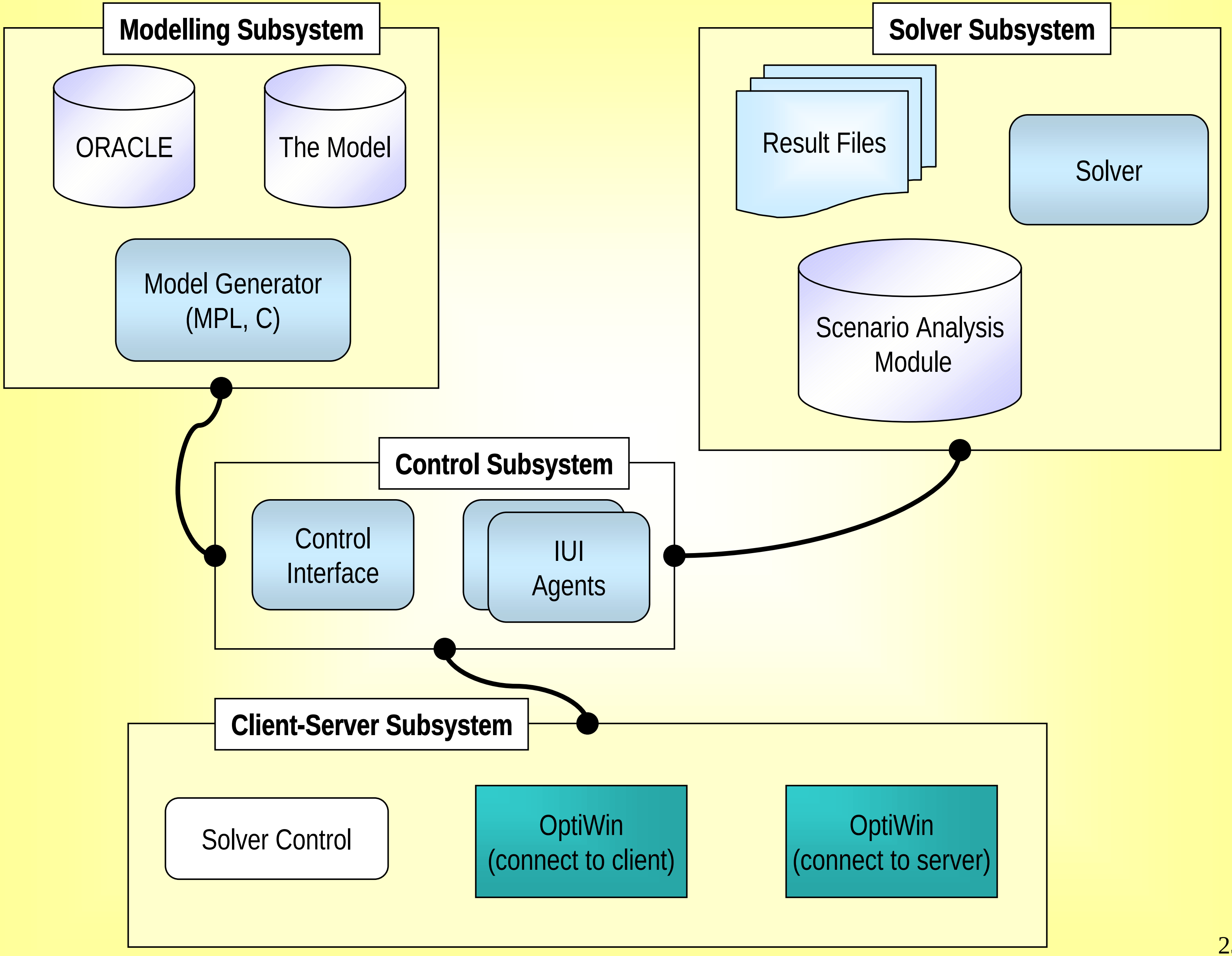
- Multiple Demand Sources
- Alternate Bills of Materials
- Alternate Parts
- Effective Period Segments
- Capacity Constraints
- Standard and Expediting Components
- Procurement Models

Sub-Assembly Line Flow

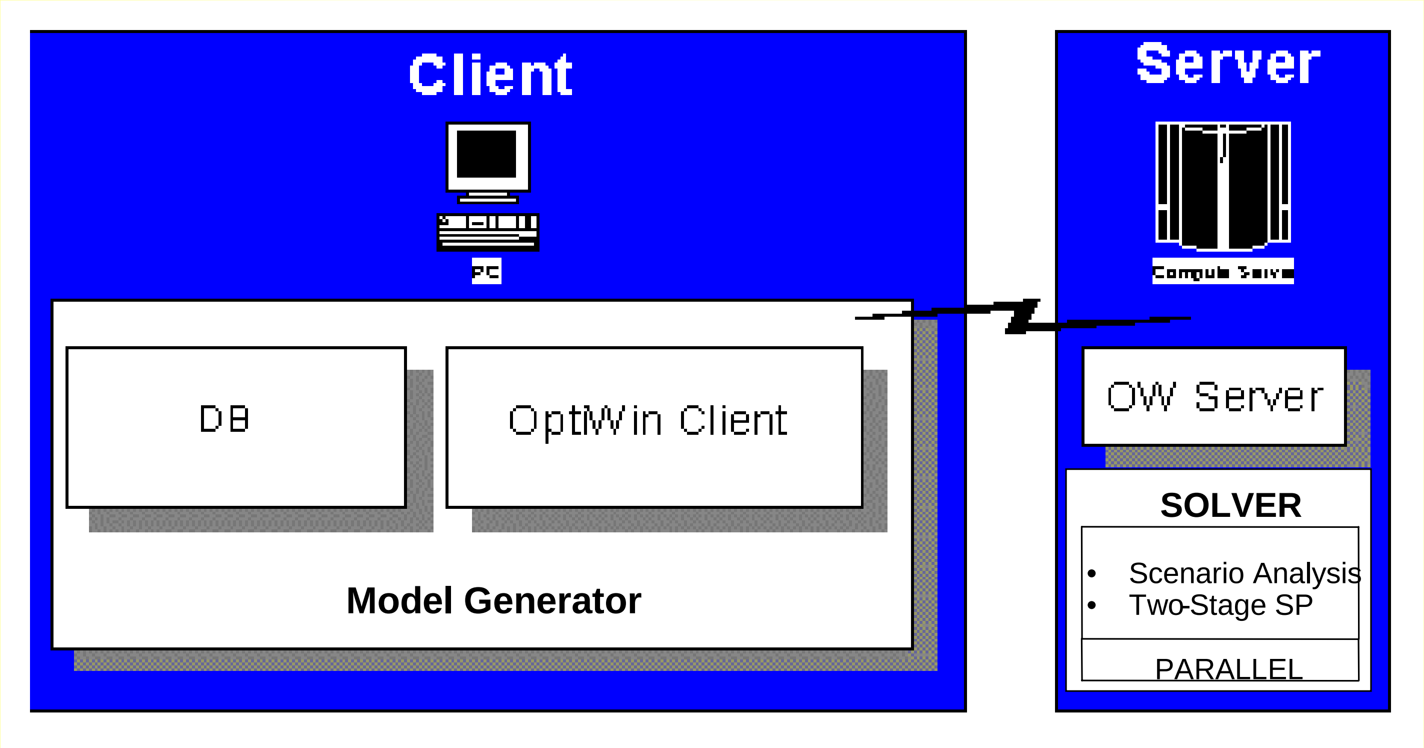


Software Architecture

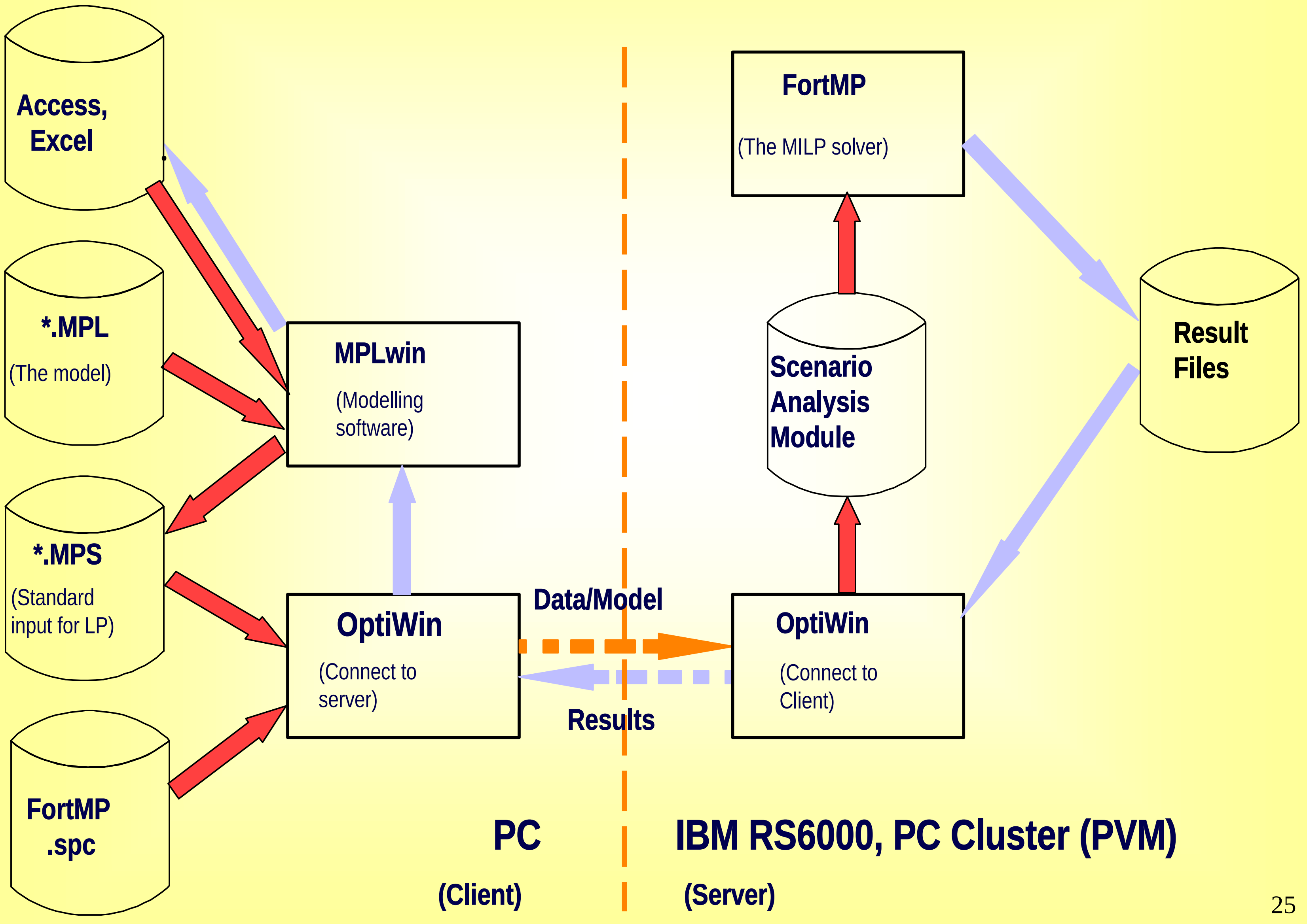
Software Architecture



Fat Client Architecture



The "OSIRIS" Computational System



Scenario Analysis

Phase 1

Solve a "Wait-and-See" Model for each Scenario

… Configuration (Design) Generator

Phase 2

Stochastic evaluation of Design Configurations against All Scenarios

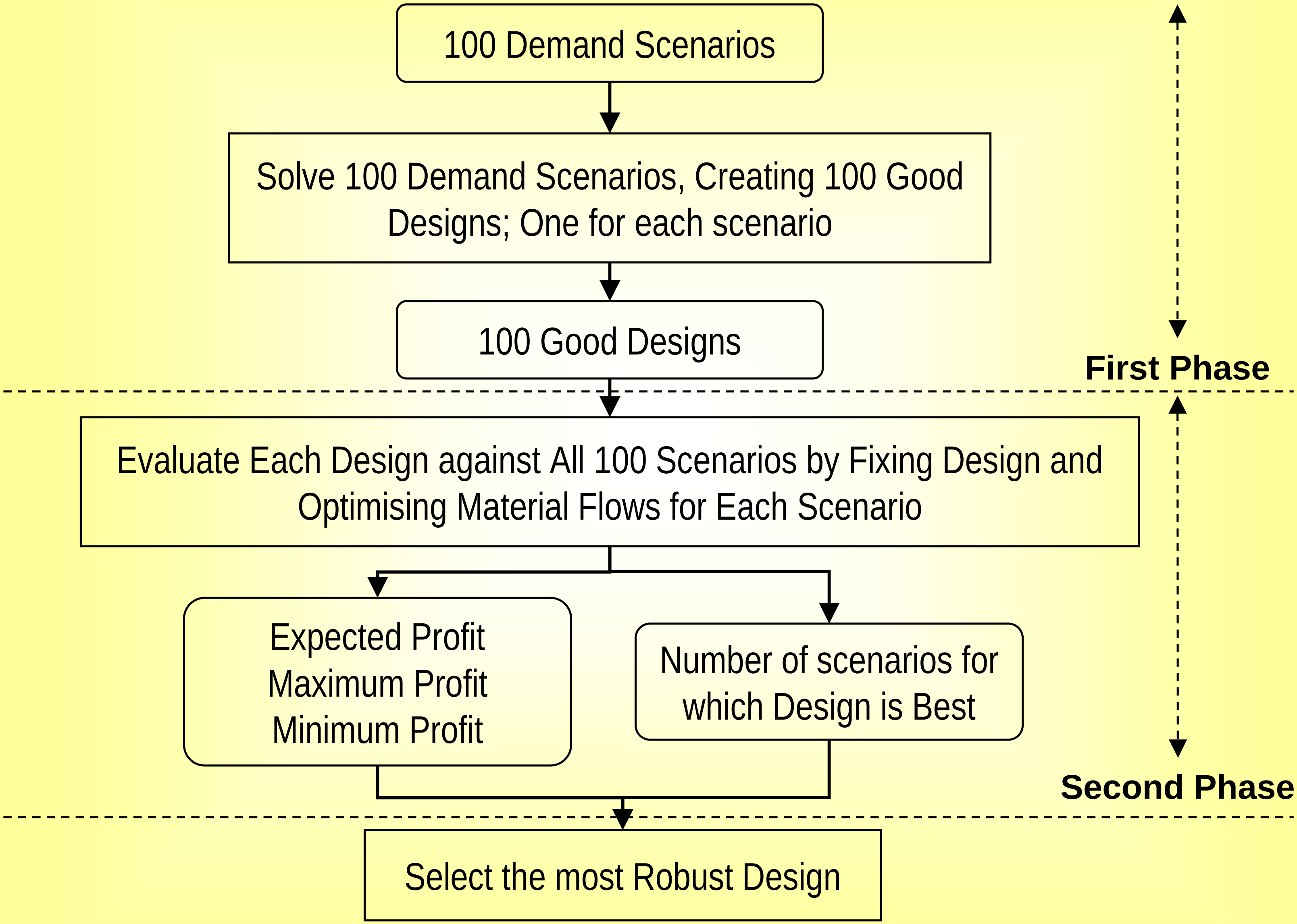
… Quality of Decision

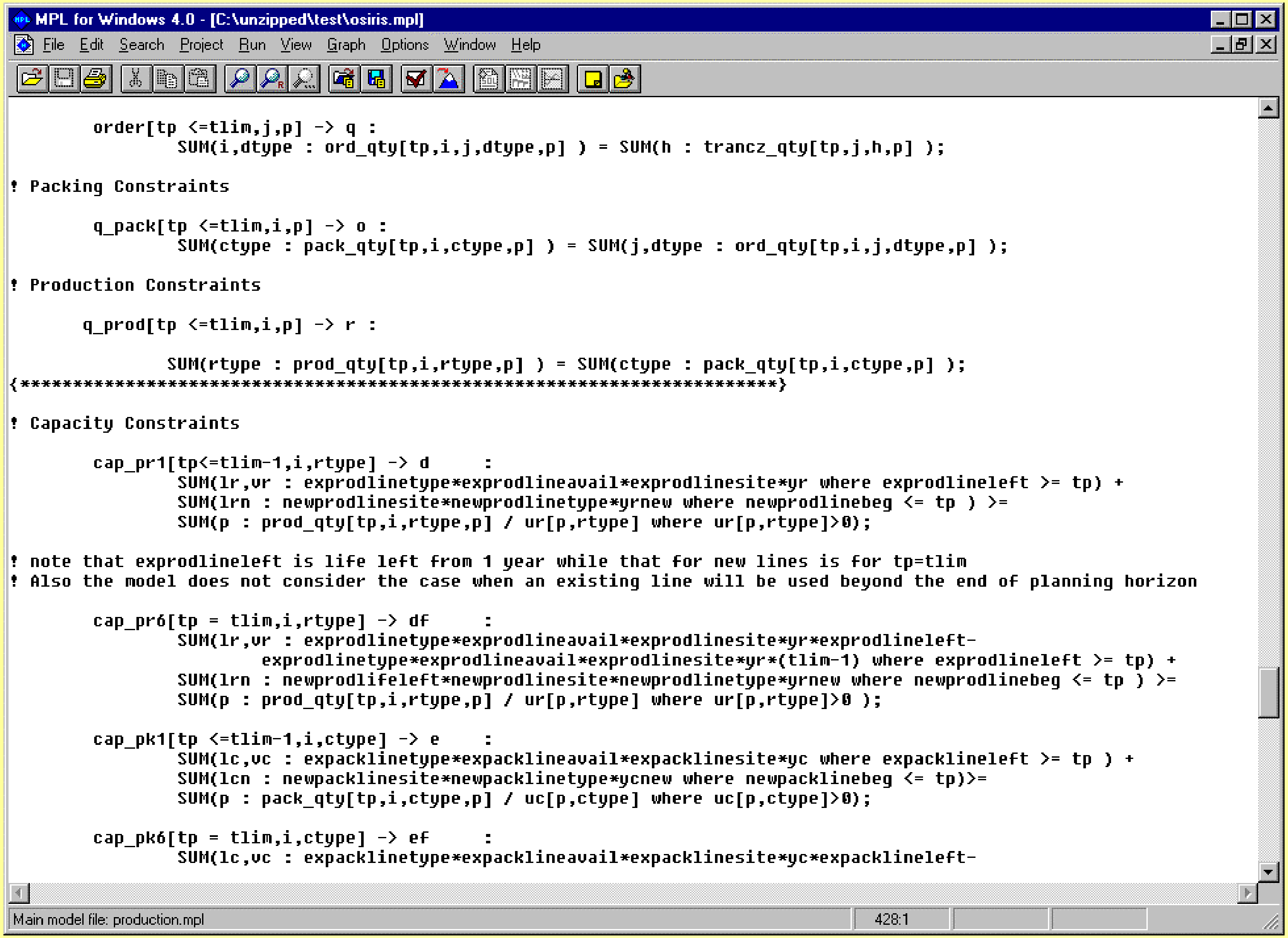
Phase 3

Match Common Decisions

… Good Quality Design

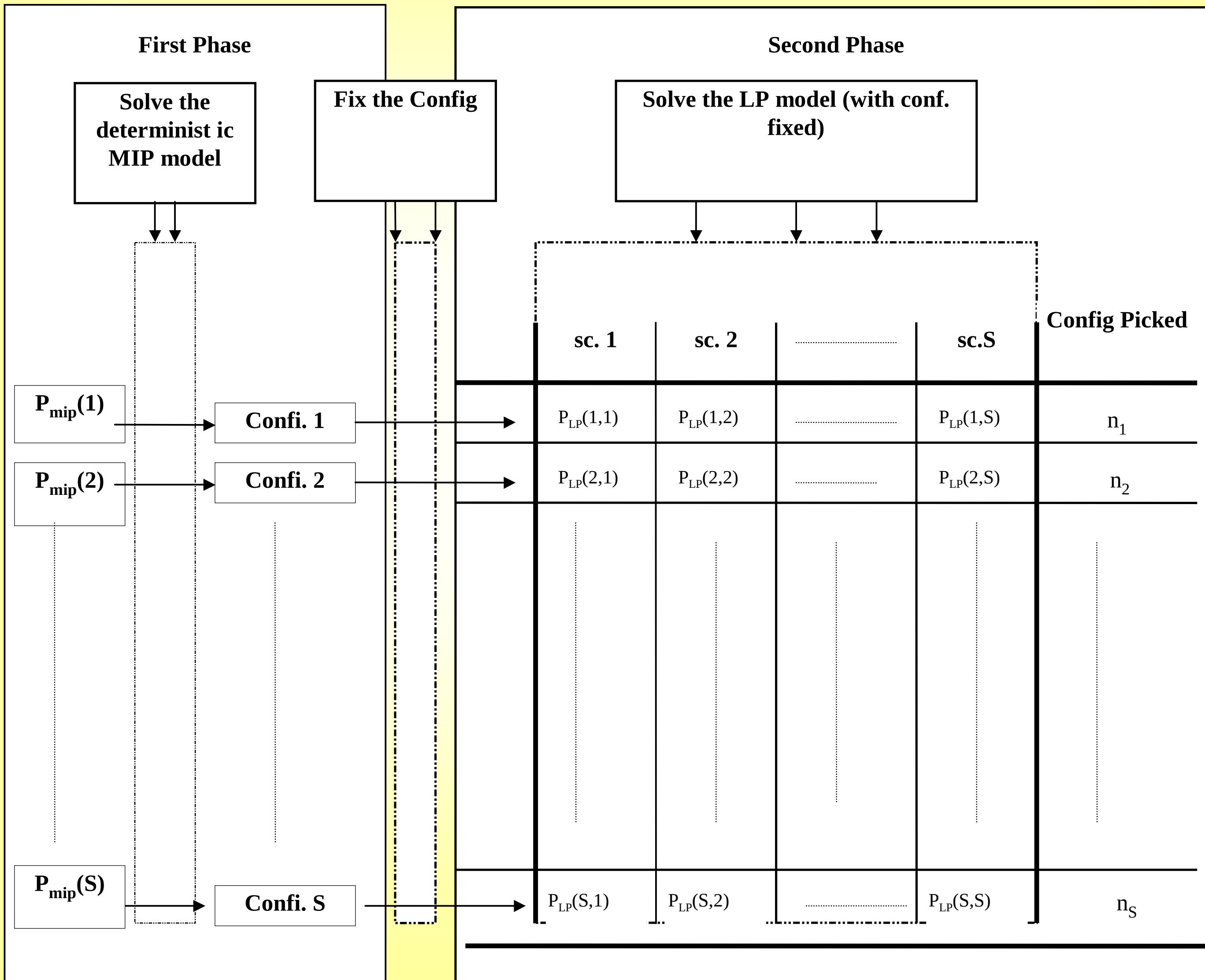
The “Scenario Analysis” Approach



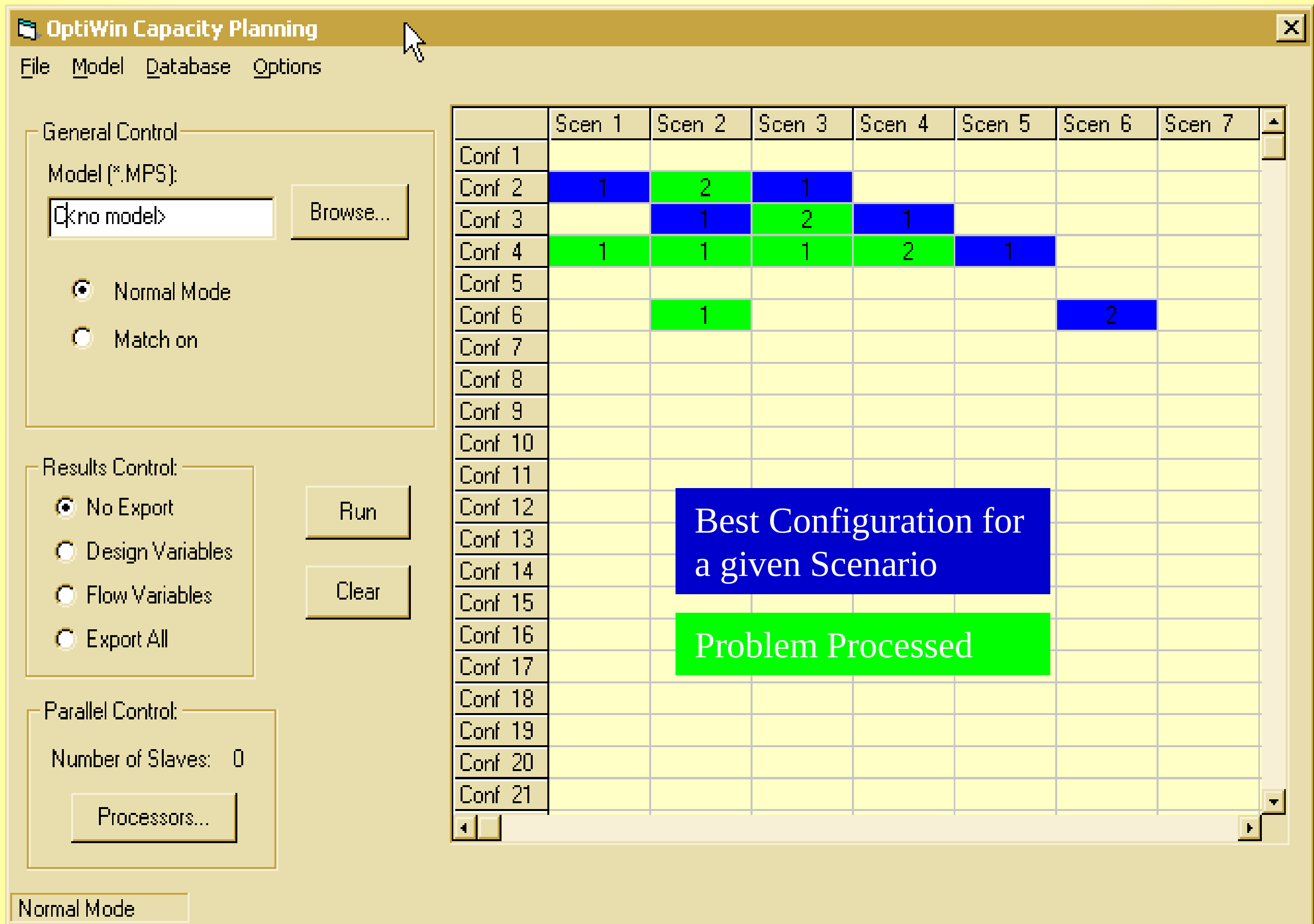



```
       order[tp <=tlim,j,p] -> q :
               SUM(i,dtype : ord_qty[tp,i,j,dtype,p] ) = SUM(h : trancz_qty[tp,j,h,p] );

! Packing Constraints

       q_pack[tp <=tlim,i,p] -> o :
               SUM(ctype : pack_qty[tp,i,ctype,p] ) = SUM(j,dtype : ord_qty[tp,i,j,dtype,p] );

! Production Constraints

      q_prod[tp <=tlim,i,p] -> r :

              SUM(rtype : prod_qty[tp,i,rtype,p] ) = SUM(ctype : pack_qty[tp,i,ctype,p] );
{**************************************************************************}

! Capacity Constraints

       cap_pr1[tp<=tlim-1,i,rtype] -> d     :
               SUM(lr,vr : exprodlinetype*exprodlineavail*exprodlinesite*yr where exprodlineleft >= tp) +
               SUM(lrn : newprodlinesite*newprodlinetype*yrnew where newprodlinebeg <= tp ) >=
               SUM(p : prod_qty[tp,i,rtype,p] / ur[p,rtype] where ur[p,rtype]>0);

! note that exprodlineleft is life left from 1 year while that for new lines is for tp=tlim
! Also the model does not consider the case when an existing line will be used beyond the end of planning horizon

       cap_pr6[tp = tlim,i,rtype] -> df     :
               SUM(lr,vr : exprodlinetype*exprodlineavail*exprodlinesite*yr*exprodlineleft-
                       exprodlinetype*exprodlineavail*exprodlinesite*yr*(tlim-1) where exprodlineleft >= tp) +
               SUM(lrn : newprodlifeleft*newprodlinesite*newprodlinetype*yrnew where newprodlinebeg <= tp ) >=
               SUM(p : prod_qty[tp,i,rtype,p] / ur[p,rtype] where ur[p,rtype]>0 );

       cap_pk1[tp <=tlim-1,i,ctype] -> e    :
               SUM(lc,vc : expacklinetype*expacklineavail*expacklinesite*yc where expacklineleft >= tp ) +
               SUM(lcn : newpacklinesite*newpacklinetype*ycnew where newpacklinebeg <= tp)>=
               SUM(p : pack_qty[tp,i,ctype,p] / uc[p,ctype] where uc[p,ctype]>0);

       cap_pk6[tp = tlim,i,ctype] -> ef     :
               SUM(lc,vc : expacklinetype*expacklineavail*expacklinesite*yc*expacklineleft-
```

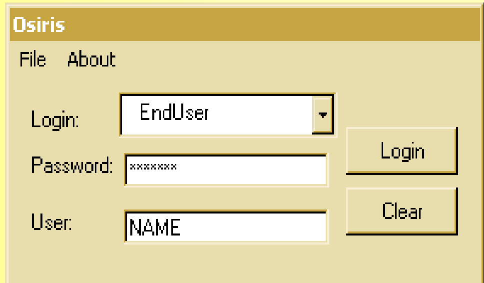
Scenario Analysis Methodology

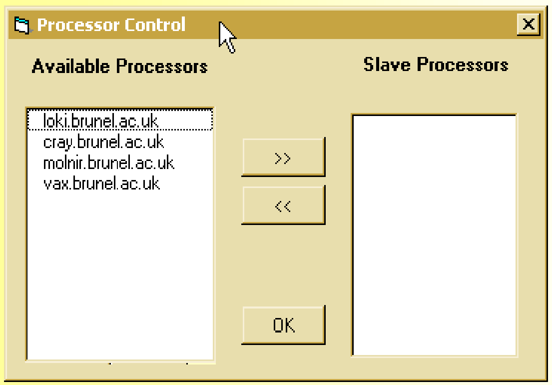


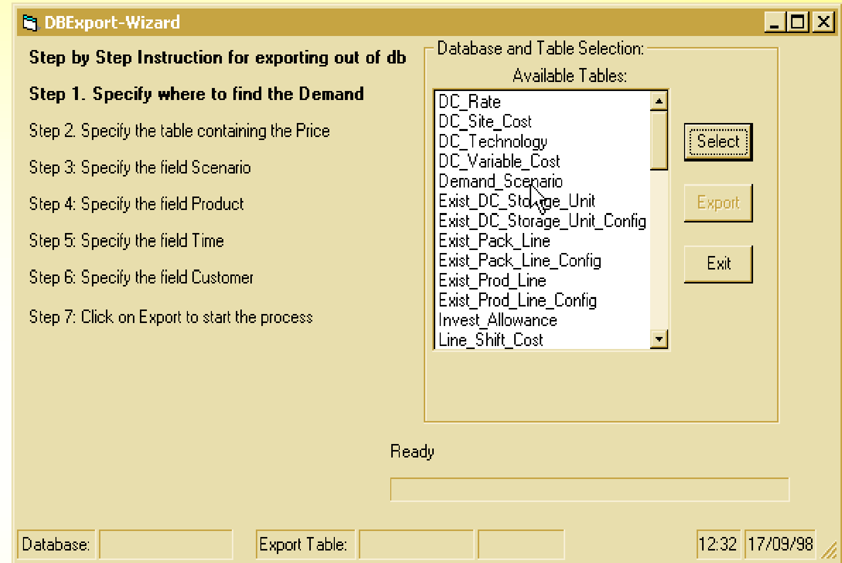
User-Interface

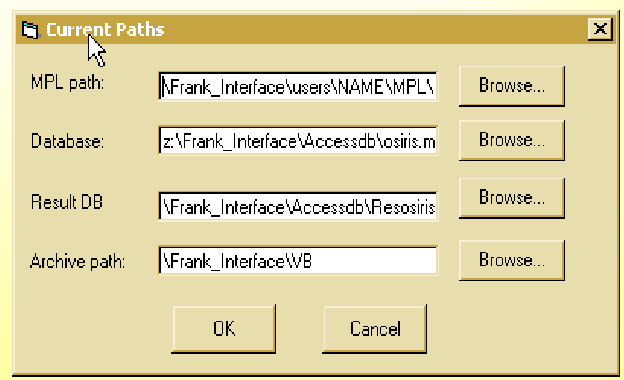


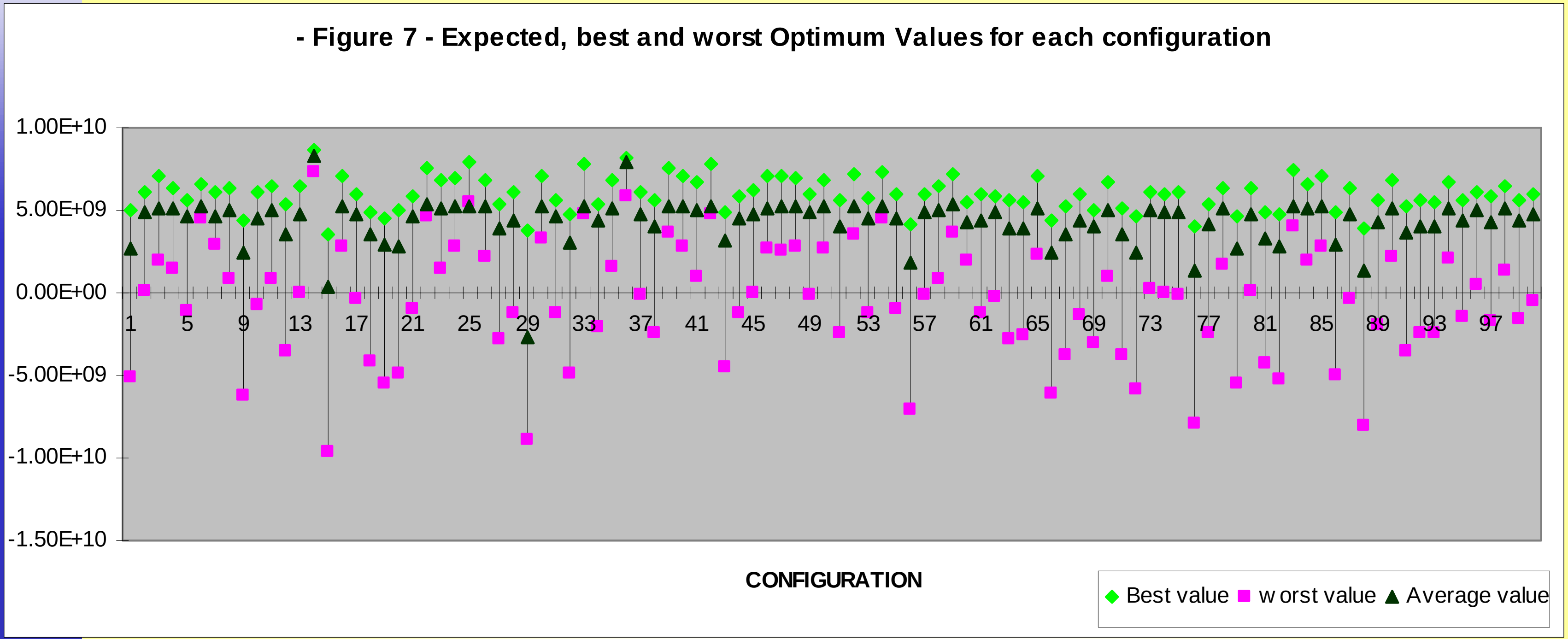
Control Panels

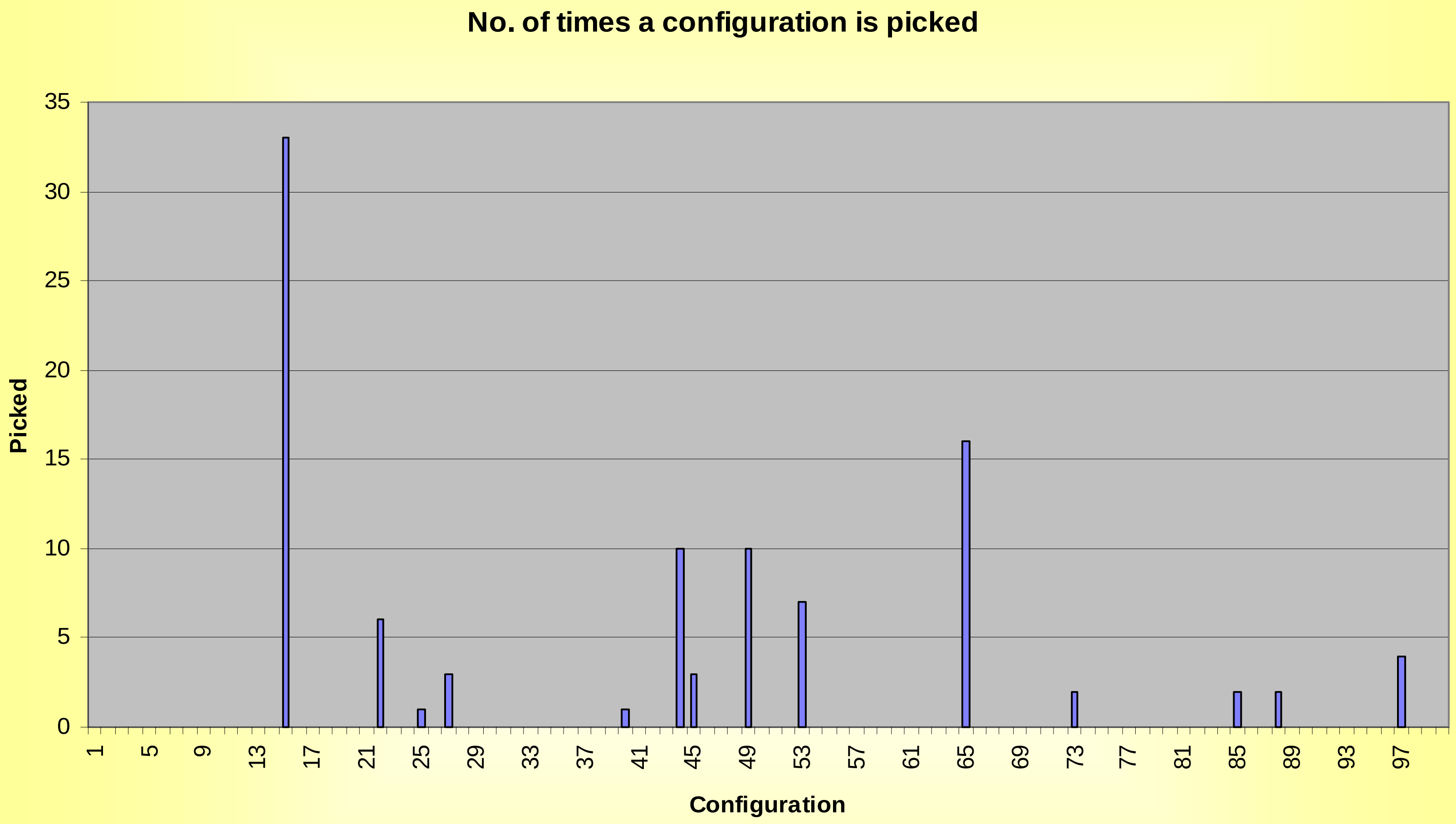









- Figure 7 - Expected, best and worst Optimum Values for each configuration
1.00E+10
5.00E+09
0.00E+00
-5.00E+09
-1.00E+10
-1.50E+10
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97
CONFIGURATION
Best value
worst value
Average value



No. of times a configuration is picked
Picked
Configuration
0
5
10
15
20
25
30
35
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97

Unique Selling Points

- Large Scale Discrete Optimisation Model
- Representation of Uncertainty
- Use of Cluster Technology
  - Portable
  - Continual Upgrade Path
- Web Compliant
  - Thin Client
  - Any Server

Discussion