Stochastic Programming and Scenario Generation within a Simulation Framework :

An Information Systems Perspective

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Outline

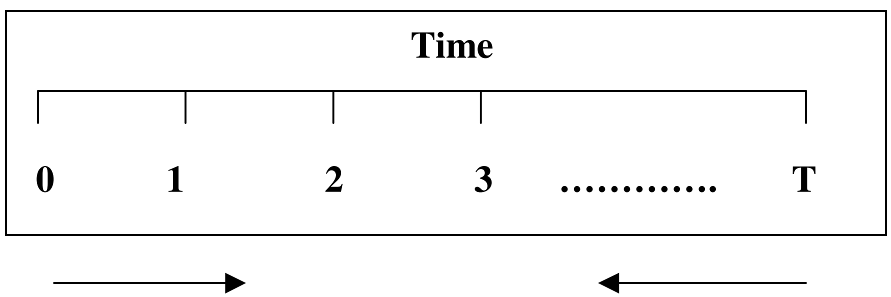
- Scope and Objectives
- SP & SG Background
- Data Types
- Data Viewing : OLAP
- SP and OLAP Integration
- Generation of Scenarios
- Integrating SP, SG and Simulation
- Conclusions

Scope and Objectives (1)

- Optimisation Models and Scenario Generation Methods Integration
- SP and DSS (Decision support System) Applications
- Integration of Optimisation Tools and Information Systems
- Simulation

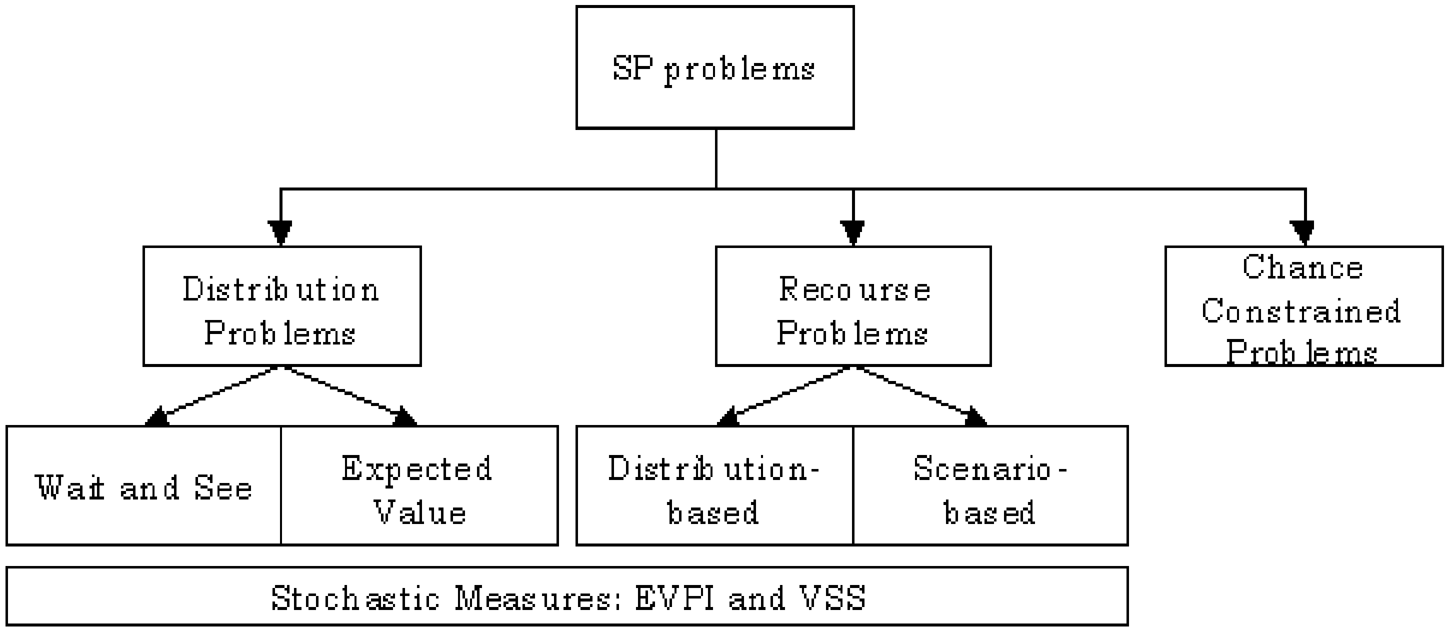
Scope and Objectives (2)

- Data Model
- Decision Model
  - Constrained optimisation
- Descriptive Model
  - Simulation and Evaluation

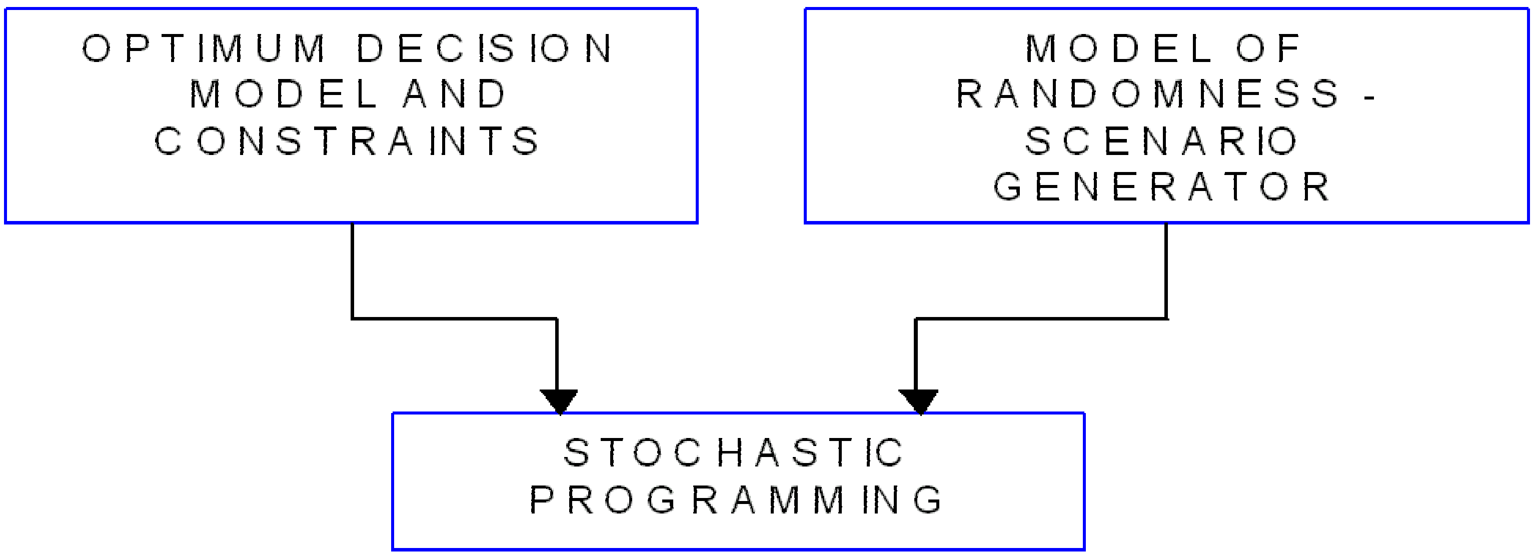


- Ex ante decision Ex post evaluation (simulation)

Classes of SP Problems



SP Paradigm


OPTIMUM DECISION MODEL AND CONSTRAINTS
MODEL OF RANDOMNESS - SCENARIO GENERATOR
STOCHASTIC PROGRAMMING

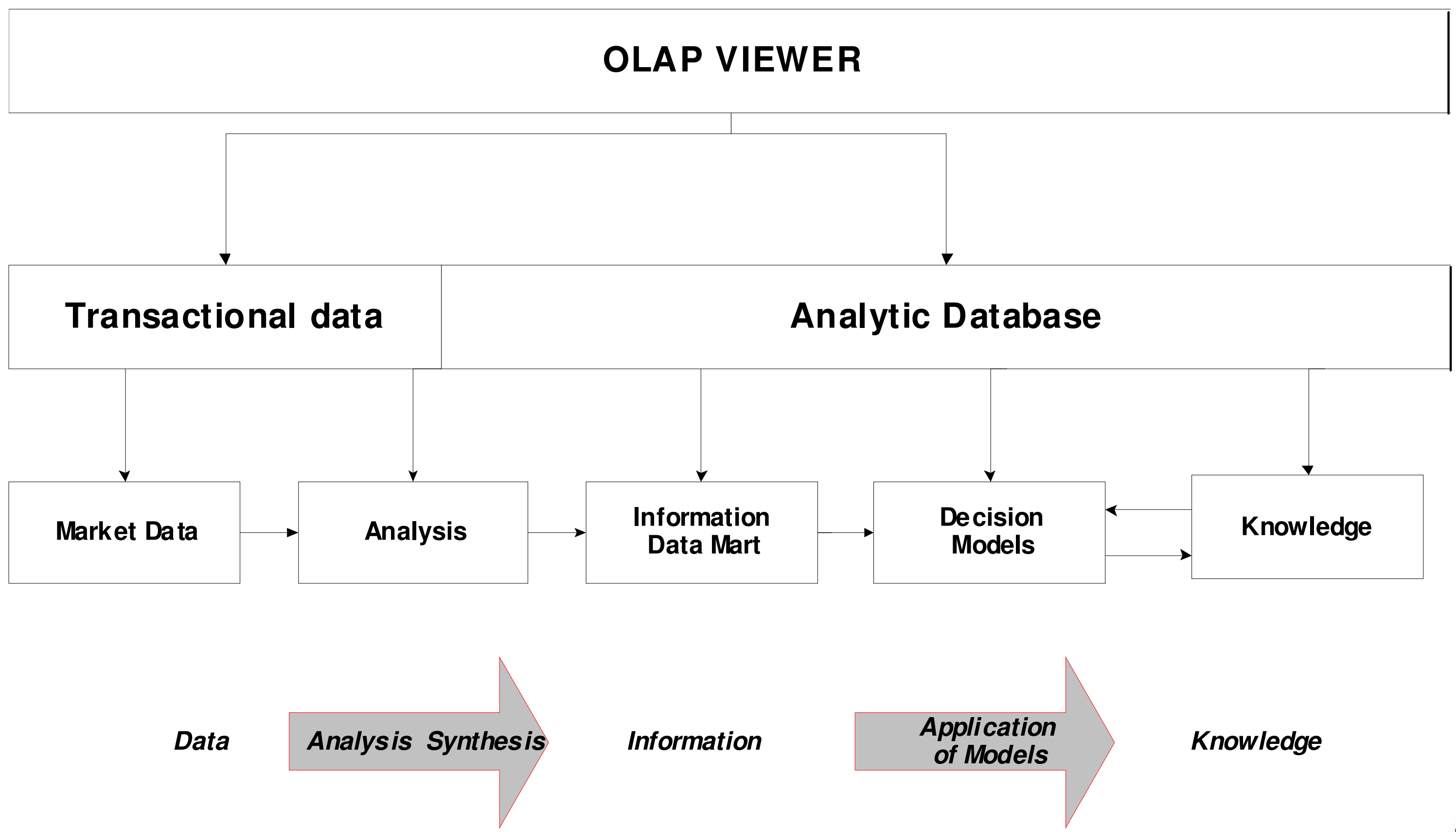
SP Software Tools

Name	Affiliation	System Name	Type
JJ Bisshop, et al.	Paragon Decision Tech.	AIMMS	Modelling System
A Meeraus, et al.	GAMS	GAMS	Modelling System
B Kristjansson	Maximal Software	MPL	Modelling System
R Fourer, et al.	Northwestern University	AMPL	Modelling System
MAH Dempster, et al.	Cambridge University	STOCHGEN	Modelling System
E Fragniere, et al.	University of Geneva	SETSTOCH	Modelling System
A King, et al.	IBM/COIN-OR	OSL/SE, SMI	Solver
HI Gassmann, et al.	Dalhousie University	MSLiP	Solver
G Infanger et. Al.	Stanford University	DECIS	Solver
P Kall, et al.	University of Zürich	SLP-IOR	Modelling System / Solver
G Mitra, et al.	Brunel University	SPInE	Modelling System / Solver

Data Modelling

- Transactional Data
- Analytic Data
- Decision Data

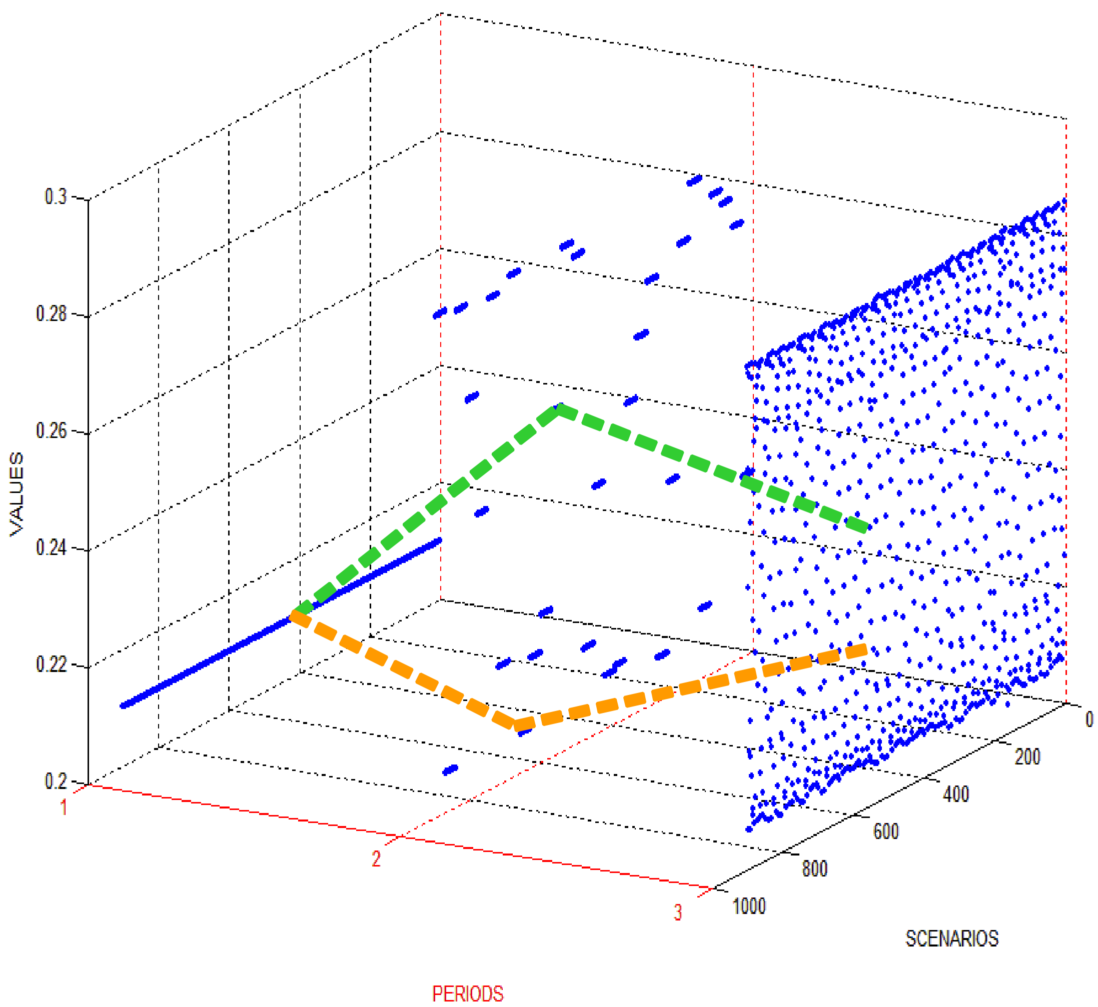
OLAP and Information Value Chain



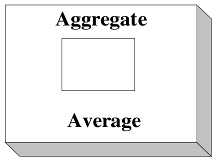
OLAP

- **Model investigation**: Summarise, Detail, or Filter data before model instantiation
  - Requires careful data preparation and database design (e.g. alternative summary functions may be required for model consistency)
  - May require dynamic changes in the model
  - Industry standard connectivity with OLAP tools
- **Data Analysis**: Summarise, Detail, or Filter data following model instantiation
  - Most typical use of OLAP (e.g. Pivot tables)
  - Requires basic preparation at the data level

OLAP Data cube

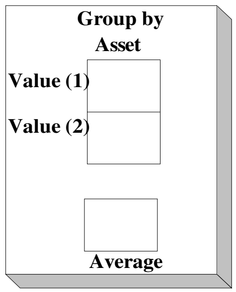


OLAP Cuboids



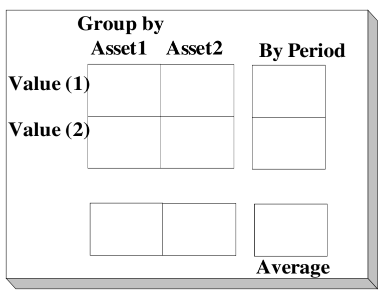
0 - D Data Cube

Asset	Period	Scenario	Price
ALL	ALL	ALL	5.15



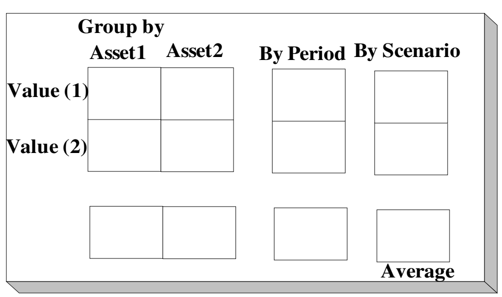
1 - D Data Cube

Asset	Period	Scenario	Price
1	ALL	ALL	0.24
2	ALL	ALL	10.162069
3	ALL	ALL	2.4108309
4	ALL	ALL	4.0341134
5	ALL	ALL	9.3705672
6	ALL	ALL	3.7087038
7	ALL	ALL	13.445068
8	ALL	ALL	6.0159124
9	ALL	ALL	1.4141097
10	ALL	ALL	0.6728426



2 - D Data Cube

Asset	Period	Scenario	Price
1	1	ALL	0.21
1	2	ALL	0.25
1	3	ALL	0.25
2	1	ALL	9.84
2	2	ALL	10.32
2	3	ALL	10.32
…	…	…	…
10	1	ALL	0.67
10	2	ALL	0.67
10	3	ALL	0.67



3 - D Data Cube

Asset	Period	Scenario	Value
1	1	1	0.21
1	1	2	0.21
1	1	3	0.21
…	…	…	…
10	3	898	0.727029
10	3	899	0.665327
10	3	900	0.670015

SG Methods (1)

- Analytic Methods
- Scenario Reduction Methods
- Internal Sampling Methods

SG Methods (2)

- Moment Matching (Kaut & Wallace)
- Diffusion Processes
  - Wiener Processes (Brownian Motion)
  - Generalised Wiener Processes (Brownian motion with drift)
- Time Series
  - Autoregressive Models : AR(p)
  - Moving Average Models : MA(q)
  - Autoregresssive Moving Average Models : ARMA(p,q)
  - Generalised Autoregressive Conditional Heteroscedasticity : GARCH (p,q)
- Barycentre Approximation
- Stratified Sampling
- Optimal discretization

Moment matching

Fixing the target values: using historical data series we specify the first four moments which should characterise the distribution of each asset price and their correlations.

Minimize the distance between moments of the generated outcomes and their target values

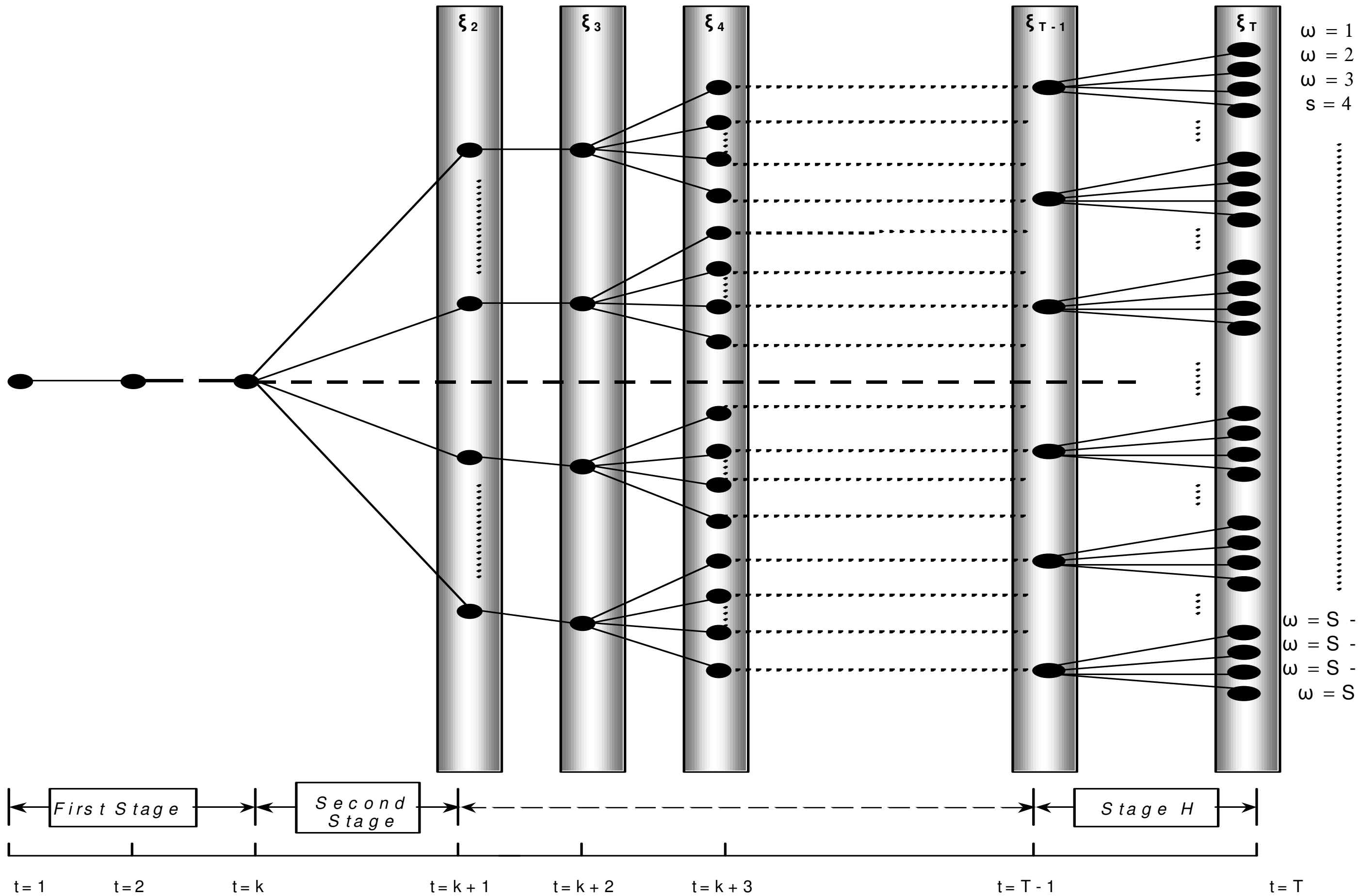
Conditional Moment Matching

At the first stage we sample several values using the moment matching approach

Then, at every node of a scenario tree:

we insert the actual random vector value as the last element of the data series (using a moving window approach) and
compute the new target values in order to generate the next sample vector values

Multistage Tree

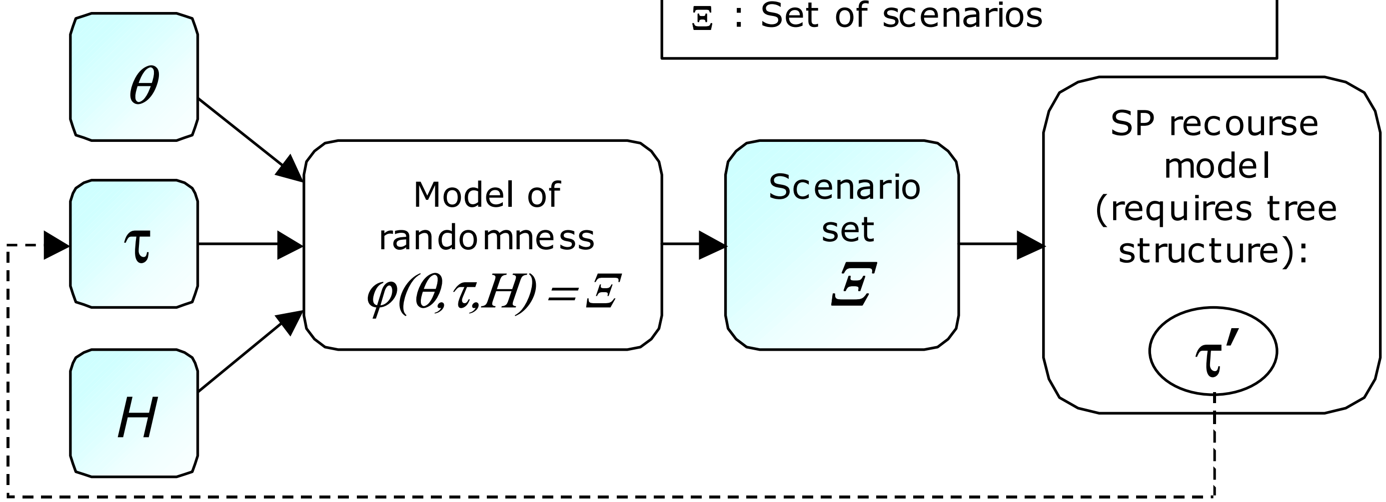


SG Integration

Consistency condition:

$$\tau = \tau'$$

τ : Scenario tree structure
τ' : SP model tree structure
φ : Model of randomness
θ : Other parameters of φ
$\boldsymbol{H}$: Historical data
Ξ : Set of scenarios



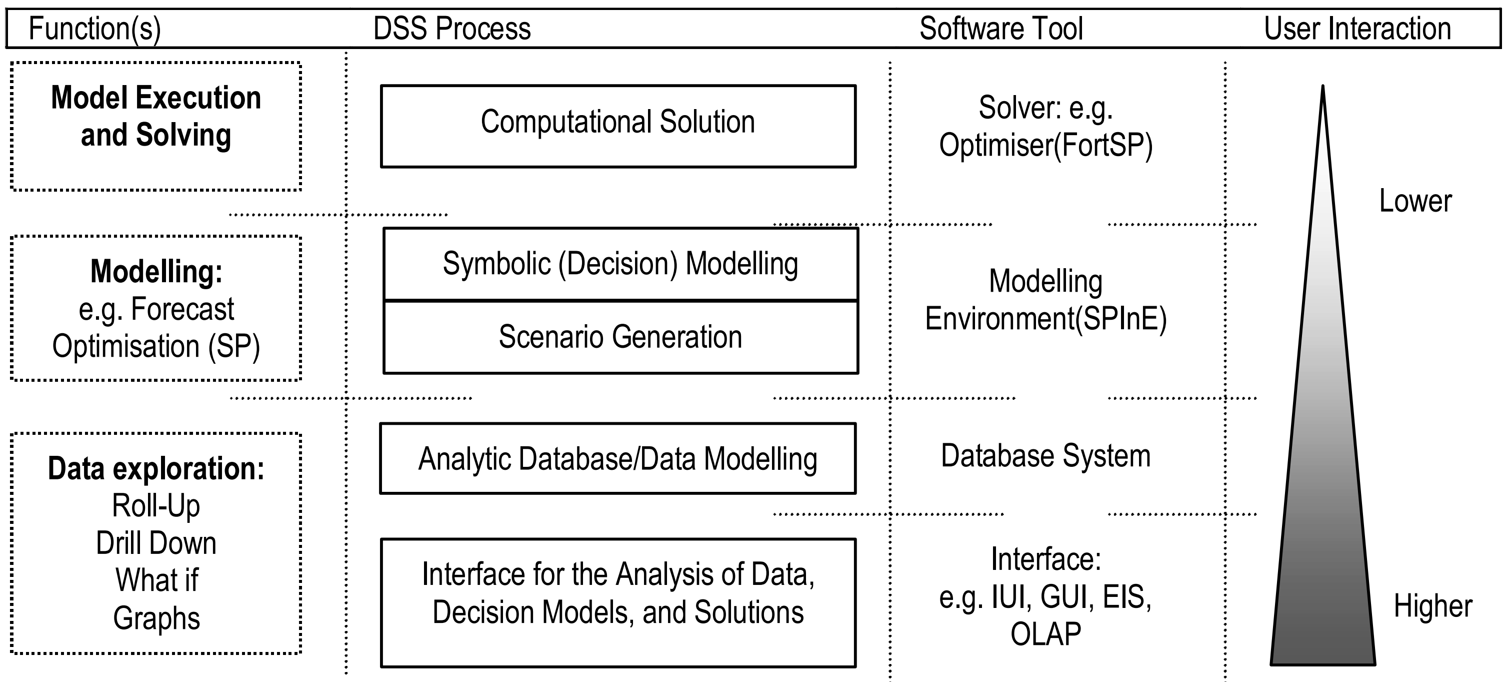
SG Integration Issues

- Data Consistency
- Data Communication (XML)
- OLAP, Modelling System and SG Interoperability
- Standard Interface

Integrated Environment for SP

- Multistage SG based on Moment Matching method
- SPInE : Stochastic Programming Integrated Environment
- Integration of SG, OLAP in SPInE

Software and User Interaction



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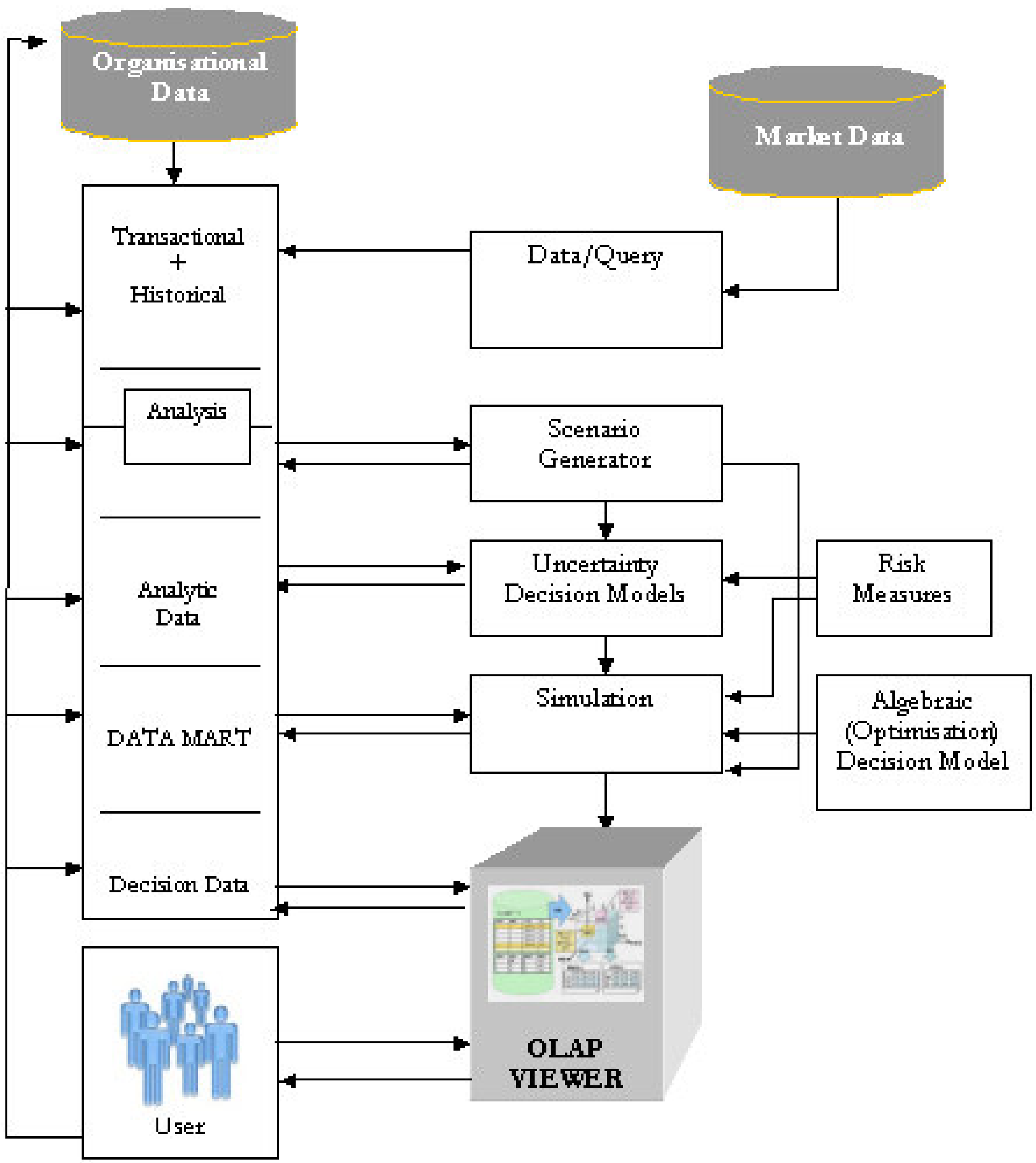
System Overview



Simulation and SP

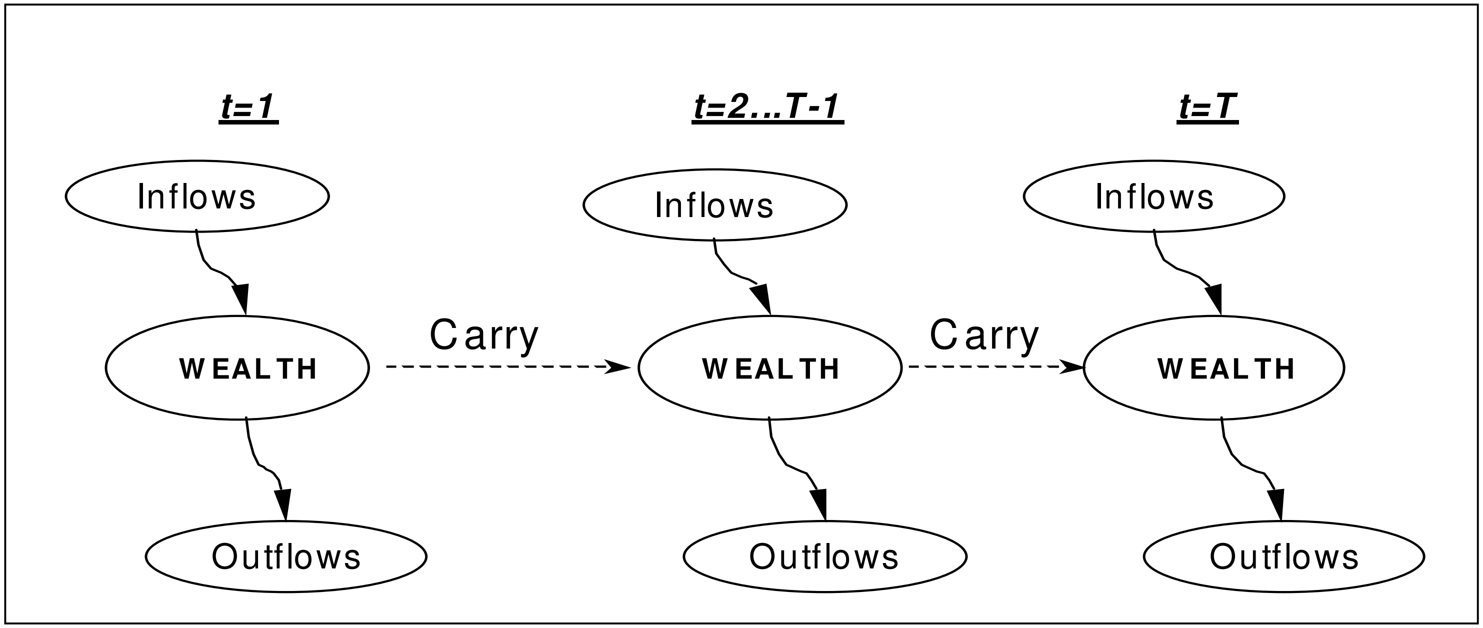
- Scenario generation (for the approximation of distributions and stochastic processes by discretisation)
- Scenario generation method evaluation
- Solution algorithm (Benders, Lagrange, also Stochastic Decomposition methods)
- Evaluation of solutions (robustness of a model or the robustness of a set of decisions)
- Analysis of the risk associated with a given set of decisions.

Case Study

1. ALM model Optimisation
2. Stochastic Measures (EVPI, VSS)
3. In-Sample Stability
4. Risk Measures (VaR, CVaR)

An ALM Stochastic Programming Model

Surplus Wealth = assets – PV(liabilities) – PV(goals)

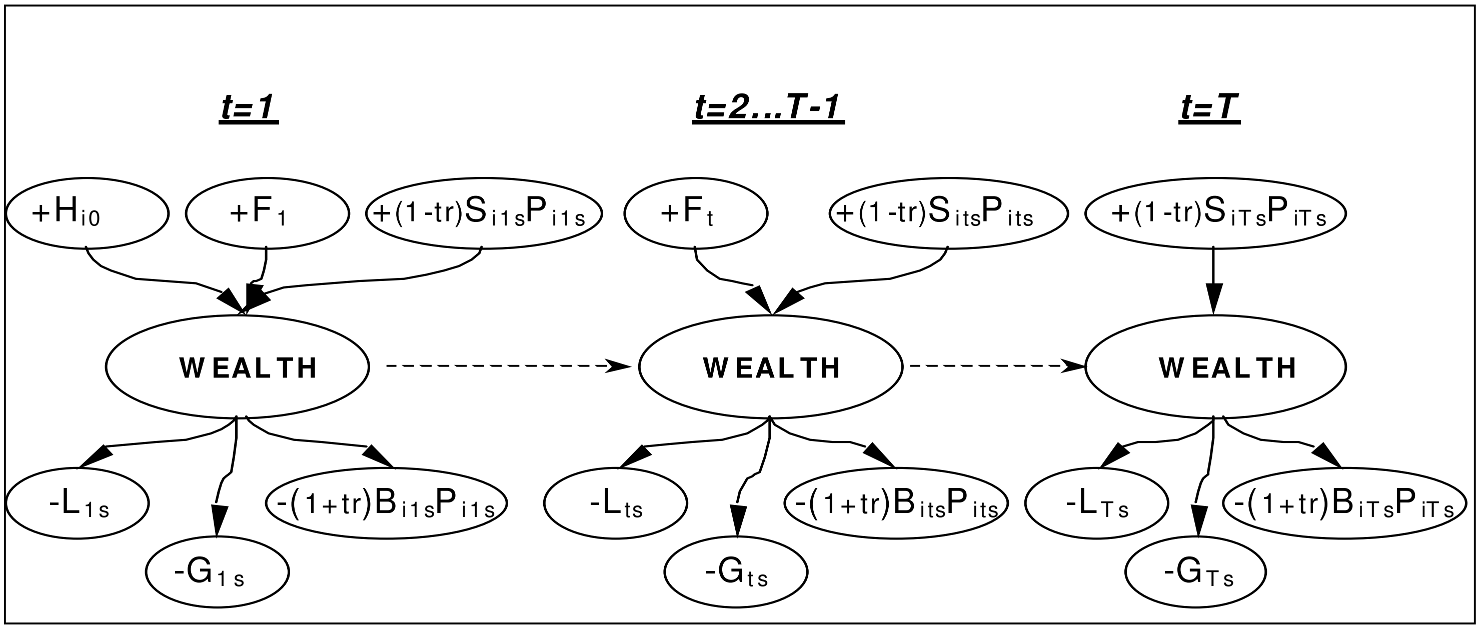


Model Components

	NOTATION	EXPLANATION	
INDEX	i.	**Assets**	i=1..n
	s.	**Scenarios**	s=1…S
	.t	**Timeperiod**	t=1..T
	.k	**RiskGroup**	k=1..K
MODEL PARAMETERS	P_{ist}	**Prices**[assets,scenarios,timeperiod]	
	L_{ts}	**Liability**[timeperiod,secenario]	
	π_s	**Probability**[scenario]	
	H_{i0}	**Initial_Holdings**[assets, timeperiod=0]	
	F_t	**Funding**[timeperiod]	
	1+tr	**Transaction_Buy**	
	1- tr	**Transaction_Sell**	
	ρ_κ	**RiskGroup_Holdings**	
DECISION VARIABLES	H_{ist}	**Amounthold**[assets, scenarios,timeperiod]	
	B_{ist}	**Amountbuy**[assets, scenarios,timeperiod]	
	S_{ist}	**Amountsell**[assets, scenarios,timeperiod]	

An ALM Stochastic Programming Model

Surplus Wealth = assets – PV(liabilities) – PV(goals)



Optimisation and Stochastic Measures

- **WS**: 67189.4
- **HN**: 61354.4
- **EV**: 54846
- **EEV**: 60567.2

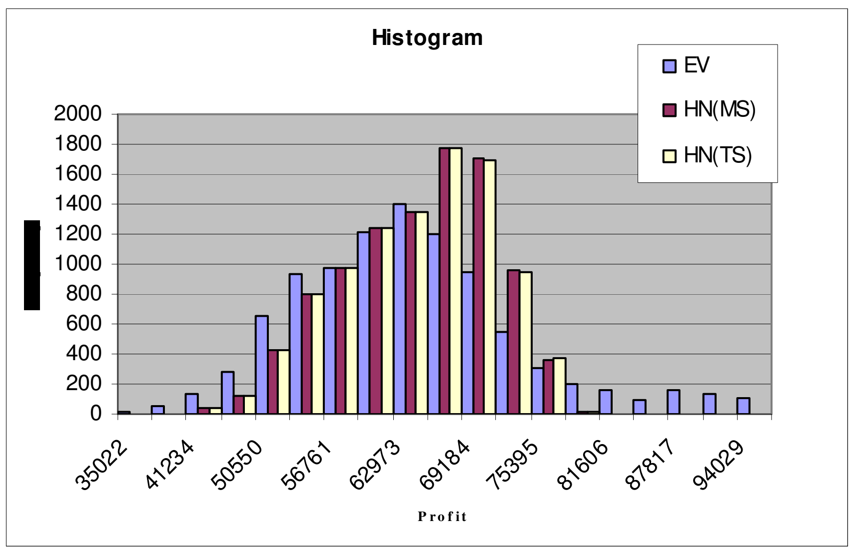
- **EVPI =** (WS-HN) = 5834.91774172
- **VSS** = (HN-EEV) = 787.229642443

Stability Measures

Stability measured by :	Value
Min	57344.52844
Max	60055.20384
Range	2710.675393
Mean	59419.04298
Stdev	492.7932547
Relative Max Deviation	4.56%
Relative Mean Deviation	0.83%

Risk Measures

	EV	HN (MS)	HN (TS)
VaR	44537.35	48370.01	48358.62
CvaR	41419.95	45054.09	45065.22
Variance	113806893.41	52421392.19	52374316.20
Mean	60798.51	61413.73	61413.96



Conclusions

- Emergence of Risk Modelling
- Ex-ante decisions coupled with ex-post evaluation (combined paradigm: optimisation and simulation)
- How to bring together :
  - Quantitative Modelling and Financial engineering Skills
  - Information Engineering Skills
  - Algorithm and Software Engineering Skills

Thank You

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