Risk Measurement
Risk Architecture
and the
Bank of the Future

Ron Dembo
Founding Chairman
Algorithmics Incorporated
May, 2004
Overview

1. Measuring Risk: The scale of the problem
2. State of the Market
3. Risk Architecture
4. Simulation, Static and Dynamic (Mark-to-Future)
5. Optimization
6. Potential topics for research
1. Scenario Generation
2. Portfolio Compression
3. Pricing in Illiquid Markets
4. Near-Time Risk for a Large Institution
Measuring Risk
Coherent Measures & Credit Risk

Single Corporate 8% zero bond, 1 year maturity

Payoff (1 year): $108 99.89% (no default)
                 $ 54 .. 0.11% (default)

VaR (99%) = $ 0.00
Coherent Measures & Credit Risk

Portfolio of 10 independent bonds same characteristics

Payoff (1 year): $108 / 10  98.9%  (no default)
                   $ 54 / 10  ..  1.1%  (default)

VaR (99%) = $ 5.40  More diversified  ===>  More Risk  ???

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“The only thing we understand is that we don’t understand how much risk the institution is running.”

Warren Buffet
Fortune, March 17, 2003
Enron

“…..we have a liability of 350 million due April……”

or……….

….we have a liability of 350 million due April…..

….drop 2 notches is credit rating and this becomes

9 Billion!
Know your Risk

JP Morgan (Enron)

Day 1: Exposure = $500 Million
Day 5: Exposure = $1 Billion
Day 12: Exposure = $1.9 Billion

What is the real exposure?
Nortel
Largest company in Canada by Market Cap (= Mutual Funds)

30% drop in a day!
> 10 Billion Market Loss

Compensation Risk!
Know your Risk

HSBC
One of the largest banks in the world

> 60 trading floors

> 90 countries

> 4000 traders

> 300 “Enron” sized counterparties

Each with many subsidiaries, trading with any part of the bank
“Simple” Questions

What is my exposure, expected loss and regulatory capital for United Airlines?

What is my exposure and regulatory capital against tech sector for our Asian sub?

What is my regulatory capital associated with Brazil?

What is my exposure and regulatory capital to non-investment grade products?

What is my economic capital for North American subsidiary?

What is my exposure and regulatory capital on retail mortgages for UK division?

What is my total Capital requirement for the bank?
State of the Enterprise Risk Market
(Banks) Mapped to Products

Innovators
Early Adopters
Early Majority
Late Majority
Laggards (Skeptics)

Operational Risk
Risk Architecture
Collateral
Credit risk
Market risk

Maturity
Market
State of the Enterprise Risk Market
(Asset Managers) Mapped to Products

- **Innovators**
- **Early Adopters**
- **Early Majority**
- **Late Majority**
- **Laggards (Skeptics)**

**Risk Architecture**
- **Credit risk**
- **Operational Risk**
- **Collateral**
- **Market risk**

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State of the Enterprise Risk Market
Mapped to Regulations

- Innovators
- Early Adopters
- Early Majority
- Late Majority
- Laggards (Skeptics)

- Maturity

- Patriot Act
- FSA 195
- Sarbanes-Oxley
- FAS 133
- Basel I
- Basel II

Market
The Regulatory Environment

Basel II is a regulatory framework for risk measurement

- Market Risk (as in previous accord)
- Credit Risk (a fundamental change)
- Operational Risk (new)

Just think back to the fundamental changes to risk management practice brought about by Basel I.

Basel II will result in much bigger changes.
“institutions wishing to qualify . . . will have to prove . . . that the internal ratings system and its component parts are all used in the active day-to-day granting of credit.”

From the New Basel Accord.

- pricing of credit risk
- incorporation of credit mitigation
- setting of credit limits
- calculation of economic capital
The biggest change will occur in the measurement and management of credit:

• credit touches all aspects of banking
• significant amount of new sophistication in credit measurement infrastructure
• usage criteria will require banks to re-engineer their IT architecture
Basel II ..some quotes

“….Basel II is nice, but we are re-architecting our credit infrastructure because it is good for business!”

...Tim Howell, Head Group Treasury, HSBC

In the first day of operation of its new credit risk system, HSBC saved more than the cost of the software!
“The thrust of Basel II will disadvantage entities that do not prepare themselves by adopting innovative [risk management] techniques. New technologies and techniques must be adopted.

Unfortunately, measuring credit risk is not easy, nor will applying the new techniques be cheap, especially for those institutions that need it the most – the large internationally active banks with their complex structures and operations.”

Roger W Ferguson, Vice Chairman of the US Fed.
“…In coming years, and we can start very soon, we look forward… to find ways to move Basel in the direction of full credit risk models. Likewise, the Committee must continue to monitor developments in the industry to be prepared to harness other improvements in risk management practices…”

Jaime Caruana., Basel Committee Chairman
A Fundamental Change

Today:

Banks do business and *then* compute risk

Tomorrow:

They will compute risk and then do business!
Risk Architecture
A bank wants to build its new headquarters

• The CEO has nothing to do with the vision or architecting of the building

• A manager buys a piece of land, digs a big hole and starts pouring concrete for a foundation

• By the time the first floor is built, the building committee decides to enlarge the building and double its height, they hope the foundations are adequate

• By the time the third floor is built, someone suggests the need for an underground garage. The current efforts are scrapped, demolished and a new hole is dug……
The tailor’s children has no clothes!

- We can learn a lot from some famous architects
- Frank Gehry

…. Bilbao
Debugging an Architecture
Guggenheim at Bilbao

• 3 bids for construction
• Quotes within $100,000 of each other
• Built on time and on budget

• How many banks can claim this for their risk system?
A single risk architecture must be able to handle business needs ranging from overnight batch to real-time.
Risk Computation Needs
e.g. Counterparty credit exposures

- Overnight
- Baseline exposure profile
- "Round robin" 24x7 updating

- Intraday

- Real-time
- Pre-deal checking
Risk Architecture

Monolithic vs Distributed

Inherently slow vs Intraday possible
Distributed Architecture

Multiple data sources
communicating with multiple risk engines
producing output in multiple locations

*all interconnected!*
Mark-to-Future
An Architectural Vision

www.mark-to-future.com
Scenario based

Links all risk types

Full forward valuation, no shortcuts

Separates simulation and reporting
An example of the complexities

The floating leg of a swap:

- Bond
- age
- now
- value date
An example of the complexities

The floating leg of a swap:

- Present value
- Reset rate
- Value date
- Reset date
- Indexing
- Monte Carlo generation
- Now
The “Cube”

The Mark-to-Future “Cube”

Scenario

Security

Time
MtF of a Portfolio

Scenarios

3 5 16 45

All Instruments (MtF)

Any Portfolio MtF

sort

statistics
MtFCube Mapping

Netting, Credit Mitigation Collateral, etc.

Scenarios

Mark-to-Future Instruments

Mark-to-Future Credit Portfolio
Mapping to Basis Instruments

<table>
<thead>
<tr>
<th>Product</th>
<th>Basic Instrument</th>
<th>Risk Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond</td>
<td>3M Zero</td>
<td>3 month rate</td>
</tr>
<tr>
<td></td>
<td>6M Zero</td>
<td>6 month rate</td>
</tr>
<tr>
<td></td>
<td>1Y Zero</td>
<td>1 year rate</td>
</tr>
<tr>
<td></td>
<td>5Y Zero</td>
<td>5 year rate</td>
</tr>
</tbody>
</table>

e.g.
## Maps for Equities

<table>
<thead>
<tr>
<th>MtM</th>
<th>Scenarios</th>
<th>MtF</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_1 \theta_1 + f_2 \theta_2 + f_3 \theta_3$</td>
<td>$\begin{pmatrix} m_{11} \ m_{21} \ m_{31} \end{pmatrix} \theta_1$ + $\begin{pmatrix} m_{11} \ m_{21} \ m_{31} \end{pmatrix} \theta_2$ + $\begin{pmatrix} m_{11} \ m_{21} \ m_{31} \end{pmatrix} \theta_3$</td>
<td>$\begin{pmatrix} d_1 \ d_2 \ d_3 \end{pmatrix}$</td>
</tr>
</tbody>
</table>

**Stock or portfolio of stocks**  
Is mapped into  
a portfolio of factors  
Factor MtF (done once!)
A Swap Portfolio

Single Currency; 40,000 (Vanilla) Swaps
20 points on yield curve; 1000 scenarios; 10 time periods

\[1000 = 200,000!\]

Swap Portfolio \( = F(m_1, \ldots, m_{20})\)

Risk in an instant!
Counterparty portfolio:
• 2000 positions
• FRAs, FX Forwards & Options, IRS, Caps/Floors, Swaptions etc… (long & short positions)
• 83 risk factors
• 1000 scenarios across 50 time steps
• netting agreements & collateral

Pre-deal ‘what-if’ for new interest rate swap with a counterparty:
Total simulation and aggregation time to derive a full montecarlo updated profile:
13 seconds!!!!
Consistency

Consistent Measurement of Earnings and Value at Risk

Scenarios

Growth and re-investment assumptions

Cash flow generation

Valuation Models

Pre-cube

Earnings-at-Risk

Value-at-Risk

Post-cube
Without the “cube”, scalability to 20,000 users in real time would be prohibitive!
Only a few scenarios are relevant!

Mean of Distribution (10,000 scenarios)

Mean of a Bucket

11 “Bucket Scenarios” reproduce the distribution for 1/1000th the work!

Single scenario result
Liquidity and the true simulation of dynamic portfolio risk
Dynamic Portfolios

Portfolio changes

Function of the scenarios and strategy

Time

Events
A Regime

If (margin on the derivatives book is below s, liquidate sufficient bonds to raise it to S)

Apply to all marked nodes
Funding Liquidity Risk

Multi-period Simulation

Cash / Collateral Account
Risk and Return

talk ended here
after 50 min
At the end of the day….

Mark-to-Market

Mark-to-Future

Upside

Downside
The Upside has the payoff of a Call option on net exposure!

\[ \max\{0, (M_x - \text{eq}´x)\} \]
The Downside is a Put option on net exposure!

\[
\text{Max}\{0, -(Mx - eq \cdot x)\}
\]
Decomposing a Risky Decision

Inherently forward-looking!

Call: \((Mx - eq’x)_+\)

Put: \((Mx - eq’x)_-\)
Risk-Adjusted Performance

\[ \text{Upside} - \lambda \text{Downside} \]

(Call) (Put)

(Equity) (Debt)
The “Put / Call” Efficient Frontier

Maximize: **Upside**    Subject to: **Limited Downside**
Risk-Adjusted Performance

Concave function of net exposure

+  +  -

Call - $\lambda$ Put

$\lambda > 1$

Exposure
The “Put / Call” Efficient Frontier

Max: \( p' u \)

Subject to: \( p' d \leq k \) \((\mu)\)

where: \( u - d - (Mx - rq'x) = 0 \) \((\pi)\)
\( u \geq 0; \ d \geq 0 \)

\( u'd = 0 \)
Dual of “Put / Call” Trade-off

Max: \[ p' u \]
Subject to: \[ p' d \leq k \] \[(\mu)\]
where: \[ u - d - (M - rq')x = 0 \] \[(\pi)\]
\[ u \geq 0; d \geq 0 \]

Min: \[ k\mu \]
Subject to: \[ (M - rq')\pi = 0 \] \[(x)\]
\[ p \leq \pi - \mu p \leq 0 \] \[(u,d)\]
\[ \mu \geq 0 \]
Dual of “Put / Call” Trade-off

Min: \( k\mu \)

Subject to:

\[
(M - rq\)\pi = 0 \quad (x)
\]

\[
p \leq \pi - \mu p \leq 0 \quad (u,d)
\]

\[
\mu \geq 0
\]

Dual feasibility \((r = 1)\) implies:

\[
M(\pi/\Sigma\pi) = q
\]
Complementarity

Max: \( p'u \)
Subject to: \( p'd \leq k \quad (\mu) \)
where: \( u - d - (M - rq')x = 0 \quad (\pi) \)
\( u \geq 0; \quad d \geq 0 \)

Min: \( k\mu \)
Subject to: \( (M - rq')\pi = 0 \quad (x) \)
\( p \leq \pi - \mu p \leq 0 \quad (u,d) \)
\( \mu \geq 0 \)

\( \pi'\{u - d - (M - rq')x\} = 0 \)
Complementarity

\[ \pi'(u - d - (M - rq')x) = 0 \]

\[ \left(\frac{\pi}{\Sigma\pi}\right)'u - \left(\frac{\pi}{\Sigma\pi}\right)'d = \left(\frac{\pi}{\Sigma\pi}\right)'(Mx - q'x) \]

Call - Put = Future Gain/Loss

Complementarity iff Put / Call parity!
Price vs. Quantity is piecewise linear

\[ x = x_1 + x_2 + x_3 \]

\[(x_1)_L \leq x_1 \leq (x_1)_U\]
\[0 \leq x_2 \leq (x_2)_U\]
\[0 \leq x_3 \leq (x_3)_U\]

“fill” \(x_1\)
before \(x_2\)
before \(x_3\)
The Put/Call Efficient Frontier

\[ k\mu \quad (\mu > 1; \text{infinite liquidity}) \]

\[ k\mu^* - (\omega_U)'x_U + (\omega_L)'x_L \]

Adjustment for liquidity
Distribution \((t_n) = F\{\text{price, yields (many currencies), correlations, growth rates, exchange rates, volatility surfaces, etc.}\}\)
Replication
Single Period, Multi State Security Prices

\[ q_1, q_2, q_3 \]

Probabilities

\[ \pi_1, \pi_2, \pi_3 \]

State Values

\[ \tau_1, \tau_2, \tau_3 \]

portfolio

benchmark

m_{11}, m_{21}, m_{31}

m_{12}, m_{22}, m_{32}

m_{13}, m_{23}, m_{33}
MR(\(K\)) = Minimize \(x \quad .. \quad E ( \left\| (M^T x - \tau) \right\| \) Regret

Subject to: \[E \{M^T x\} - q^T x - [E \{\tau\} - c] \geq K\]

portfolio gain - target gain
“…I should have computed the historical covariance of the asset classes and drawn an efficient frontier….Instead I visualized my grief if the stock market went way up and I wasn’t in it…or if it went way down and I was completely in it. My intention was to minimize my future regret, so I split my contributions 50/50 between bonds and equities..”

Harry Markowitz

(Money Magazine 1997)
Images of a Portfolio

Inverse problems

- Implied Views
- Stability of Optimal solutions
- No-arbitrage (risk-neutral) parameters (implied discount factors, distributions)

Portfolio

$p_1$

$p_2$

$p_3$

$t$

Value

Time
eg: US Govt. Bond Portfolio

Ranges

Govt. Book

Scenario Opt. Hedge

PV01 Hedge
99% Confidence

US Govt Book $6,480,000

.. With PV01 Hedge $2,275,344

.. With Scenario-Optimal Hedge $353,634
### Portfolio Compression

<table>
<thead>
<tr>
<th>Portfolio:</th>
<th>1,025 Positions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition:</td>
<td>Options on Bond Futures 4.9%</td>
</tr>
<tr>
<td></td>
<td>Callable Bonds 4.8%</td>
</tr>
<tr>
<td></td>
<td>Caps/Floors 32.3%</td>
</tr>
<tr>
<td></td>
<td>Bond Futures 1.6%</td>
</tr>
<tr>
<td></td>
<td>Interest Rate Swaps 15.5%</td>
</tr>
<tr>
<td></td>
<td>Treasury Bills, Bonds, Strips 40.9%</td>
</tr>
</tbody>
</table>

*Replication with hypothetical Treasury Strips, European Options on long-dated Treasury Bonds, spanning monthly periods from January 1995 to December 2025*
Compressed Portfolio

Compressed Portfolio: 51 Positions (simple)
Scenario Set: 50 randomly generated
Composition:
- 17 puts on long-dated Treasury Bonds
- 32 calls on long-dated Treasury Bonds
- 2 Treasury Strips

Replication with hypothetical Treasury Strips, European Options on long-dated Treasury Bonds, spanning monthly periods from January 1995 to December 2025
Compression Results

VaR Original (95%)       14,963,188
VaR Compressed (95%)     14,981,115

Error < 5 basis points!

\[
\frac{\text{TIME (Compressed)}}{\text{TIME (Original)}} < \frac{1}{1000}
\]
The End