RISK MANAGEMENT

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CONTENTS

- Some trends
- Operational risks
- Program and project risks
- General Quantitative risk assessment
- Real options, contracts, spiral development
- Flexibility Engine™

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A FAST DEVELOPING DOMAIN

- Chief Risk Officer
  Emerging as one of the most important positions in the executive management team, but not spreading as effectively as possible due to agency issues.
- Integrated Risk Management & Enterprise Risk Management
  New tendencies within corporations
- Motivation
  - ✓ **Regulatory compliance**
  - ✓ **Monitoring emerging risks and encompass a wider range of enterprise risks**
  - ✓ **Enabling corporations to make better decisions**

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CHALLENGES AND DIFFICULTIES

- I.T. challenge of consolidating risk systems and processes.
- Difficulty of measuring operational risks
- Difficulty of managing risks across globally dispersed operations
- Lack of data on event risks
- Difficulty of keeping up with a fast-changing regulatory environment
- Difficulty of managing risk posed by business partners (e.g. suppliers, outsourced service providers)

The Economist, Report from the Economist Intelligence Unit, 2005

SOME CONTRADICTIONS IN THE EVOLUTION

- In the past, risk management has been a relatively focused technical area:
  - ✓ Quantifying and offsetting financial risks
  - ✓ Quantifying reliability of equipments and quality of products
- It is becoming more strategic, with less quantifiable aspects.
- However, remaining purely qualitative cannot be sufficient: a more scientific approach is needed; new concepts and methods are necessary.

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NEW CONCEPTS IN RISK MANAGEMENT

- **Financial Risk Management has progressed thanks to three essential reasons:**
  - ✓ **Pricing risks (through Risk finance)**
  - ✓ **Growth of financial products and trading through financial markets**
  - ✓ **Predominance of external risks**
- **A key issue(and a two edge sword) in the progress of risk management outside finance resides in the possibility of extending these concepts to the "real" world**
  - ✓ **Pricing real assets, real project financing and management, real options**
  - ✓ **Ethics and responsibilitition due to risk intermediation**
- **Moreover one manipulates probabilities and not numbers**
  - ✓ **Non normality, Fat tails and co-dependence of risk probabilities**
  - ✓ **Risk predictability , and chaos," when the unlikely becomes likely"**

ORMS, February 2006: Probability Management, Chief Probability Officer, Savage, Scholtes, Zweidler

NEW CONCEPTS IN RISK MANAGEMENT

- How to interact with a probability distribution
  - ✓ Interactive simulation
- Warnings
  - ✓ Quantification has limits: e.g. political risks
  - ✓ Better no numbers than wrong numbers
  - ✓ How to quantify risks which never occurred (new types of terrorist attacks) or are very rare.
  - ✓ Feeling of protection might lead to rash behavior.

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AN INTERESTING COMPARISON: CHALLENGE OF FINANCIAL SERVICES

- Managing the risk from mismatches between assets and liabilities
- Solutions adopted by commercial and investment banks
  - ✓ Large portfolios of assets and liabilities with values tied to financial variables such as interest rates, foreign exchange rates and stock prices
  - ✓ Sophisticated methods and models for managing uncertainty
- A new discipline has emerged with multiple names; i.e., Financial Engineering, Mathematical Finance, Computational Finance
- A similar phenomenon is highly likely for risk and decision analysis in general
- GOAL: A new "academic" discipline has to be developed.

OPERATIONAL RISKS

Technical Risks: Risks of failure of products, equipments, infrastructure

- **Reliability assessment: Computation of failure probability**
- **Example of remarkable development of methods: Standards for buildings to resist seismic hazards**
- **Life data analysis: interestingly, default of firms is modeled in a similar way**

RISKS OF FAILURE OF SYSTEMS

- **Failure Mode, Effects and Criticality Analysis: FMECA**
  - ✓ **Components are characterized by "Failure Modes" called risks. A failure mode is characterized by its probability and its severity (scoring system).**

- **Most equipments have controls to detect failure causes or mitigate their effects. They are characterized by detection ratings.**
  - ✓ **RPN = Risk Priority Number =**
    Probability x Severity x Detection Rating

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TECHNIQUES

- Event trees
- Fault trees
- Bayesian networks
- Cause and Effect diagrams
- Cause and Consequence diagrams
- Influence diagrams

These techniques extend to general systems (not just complex equipments) and are the basis of PRA (Probabilistic Risk Assessment).

MITIGATING TECHNICAL RISKS

- Maintenance Management
- Inspections and tests

These problems can be treated by Stochastic Control and Dynamic Programming Techniques. An important source of complexity stems from lack of sufficient resources. One cannot perform all desired maintenance actions simultaneously. Ranking of maintenance actions is necessary.

RISKS DUE TO THE PROCESS

- Traditional approach of Operations Management: 3 major variables, time to delivery, cost and quality. Efficiency and competitiveness are the main preoccupation.
- Supply chains are considered as value streams. Lean processes, Just in Time, Push and Pull systems, Kanban, MRP.
- These common practices eliminate waste. Risks considered are those related to the variability of the service time, which affects the cycle time and the performance of the system.

REDUCING VARIABILITY

- Reducing variability in the performance is addressed by Six Sigma and QFD (Quality Function Deployment) methodologies. Statistical process control permits to detect abnormal variability.
- The existing methodologies and concepts of operations management are adapted to in house manufacturing.
- They underestimate new risks , like outsourcing a substantial part of the supply chain.
- Vulnerabilities have been introduced as a consequence of JIT approaches.

RISKS DUE TO THE DEMAND

- A natural way to address variability of the demand is to improve forecasting.
- Safety inventories are used to mitigate variability of lead times. Cycle time is deteriorated by safety inventories, but it is not a waste since it guarantees a level of risk.
- Safety capacity: alternative or complement to safety inventories. One maintains a sufficient capacity to process customer orders.

NEW RISKS IN SUPPLY CHAINS

- **Increasing possibilities of disruptions in supply and demand: Third-party interference, labor strikes, natural hazards, human errors, changes in customer taste, technological failures, financial distress partners**
  - ✓ **Examples: consequences of dot.com crash, financial scandals, terrorist attacks, etc.**
- **Increasing intrinsic uncertainties in predicting supply of key inputs and demand of products**
  - ✓ **Demand: market acceptance of new products changes in technology and technological standards; change in competitor's offerings**
  - ✓ **Supply: insufficient in house capacity; uncertainties in availability and price of outsourced components**

SOURCES OF DISRUPTION RISK

- **Operational Contingencies**
  - ✓ Equipment malfunctions
  - ✓ System failures
  - ✓ Unforeseen discontinuities in supply
  - ✓ Bankruptcy and other forms of financial distress
  - ✓ Human-centered issues such as strikes and fraud
- **Natural Hazards**
  - ✓ Earthquakes, Hurricanes and Storms
- **Terrorism and Political Instability**

Source: Kleindorfer & Saad, POM, 2005

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MITIGATION STRATEGIES FOR DISRUPTION RISKS

- Comprehensive Tracking & Monitoring
- Total Supply Network Visibility
- Flexible Sourcing Strategies
- Product and Process Redesign

Source: Hau L. Lee, Michael Wolfe, Supply Chain Management Review, Jan/Feb 2003

SUPPLY ALLIANCE NETWORK
A WAY TO REDUCE DISRUPTION RISK

- **In addition to having the buyers develop flexible supply bases, suppliers (contract manufacturers, airlines cargo companies, trucking companies, logistics providers) can proactively form strategic alliances with other suppliers in different countries. These alliances can serve as a safety net for each member, who will receive help from other members if a disruption happens.**

Source: Christopher S. Tang, UCLA Working Paper, 2005

INNOVATION

- Efficiency is less important than innovation
- Shift towards design
- Adapt supply chain techniques to project and program management.
- What are the risks of failures in program and project management.

PROGRAMMATIC RISK MANAGEMENT

- The challenges are more and more at the design and development phases.
- Several projects are carried out within programs. Risks are technical and managerial (not meeting schedules and costs).
- The issue is to allocate in the best way the resources to projects in order to minimize failures of projects or programs.
- Techniques like Decisions Trees and optimization are used.

SPECIFIC ISSUES IN DESIGN AND DEVELOPMENT

- **Design Paradox: Commit costs early, while the knowledge of the system is limited. One needs to close the gap between knowledge and commitment.**
- **Most of project failures are Process Management failures: Systems engineering practices and principles can improve project success rate and reduce risk.**
- **System Engineering is the "discipline" of designing systems properly.**
- **It is an "interdisciplinary approach" which considers the complete problem, from customer needs to design synthesis and system validation, then manufacturing and operations.**
- **The amount of system engineering depends on the amount of risk.**

QUANTITATIVE RISK ASSESSMENT: A GENERAL APPROACH

- **General procedure to analyze all kinds of risks. A risk is a scenario leading to failure or degradation (like failure modes). QRA involves assessment of probability of occurrence and consequences (impact, severity).**

- **Steps of QRA:**
  - ✓ **Knowledge of the system: in a supply chain, what characterizes the expected performance? All interdependencies among operation steps must be known.**
  - ✓ **Risk Identification: May be the most informative and constructive element of the whole process. The goal is to be as exhaustive as possible and to anticipate potential problems that have not yet occurred.**

RISK QUANTIFICATION

- For each scenario S_i, one must estimate P (S_i), its probability of occurrence. One must also estimate the consequences (impact-severity). There may be several types of consequences (cost, delay, quality…)

- It is important to summarize these consequences into an aggregated indicator of performance V (the value). The consequences are combined into a percentile P ($V \leqslant v|S_i$). Influence diagrams and Bayesian networks are used to facilitate those computations.

- <u>Difficulty:</u> The risk scenarios may be dependent.

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RISK MANAGEMENT

- At this stage one studies the approaches to reduce risks, at two levels.
  - ✓ Probability of occurrence of external risk factors
  - ✓ Conditional probability of performance given a risk scenario
- To choose among scenarios, an aggregate utility function has to be defined. Decision Analysis provides a framework for rational choices.

Reference: Quantitative Risk Assessment of Supply Chain Performance, Léa A. Deleris *et al.*, Working paper, Stanford University

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VARIABILITY AND UNCERTAINTY

- The relevance of risk analysis depends on the accuracy of the probability distributions of the risk factors. After preliminary risk reduction treatments remains a structural risk.
- If the probability distribution is known, the randomness is called variability.
- But models (at least parameters) are uncertain. Uncertainty is overlaid onto the variability.
- A lot of research in Risk Analysis concerns the treatment of uncertainties.
- Prior information comes often in the form of Experts' Opinion. Posterior probability distributions are obtained by Bayesian or other updating techniques. Research combines statistics and risk management.

VALUE AT RISK AND RELATED RISK MEASURES

- Risk management involves comparing random performances.
- Following the concept of VaR in Finance, an active research exists on risk measures.
- An important aspect concerns modeling the attitude to risk of the decision maker (risk averse, risk-neutral, risk loving).
- Utility functions are the main tool when random dominance does not occur.

REAL OPTIONS

- Real options bring to “real” projects and assets what financial options bring to “financial” securities and assets.
- They allow the re-design of investment strategies along two key dimensions, time and scope.
- Postponing costly investments permits one to acquire more information and thus to mitigate “downside” risk in the process.
- Possibility of Abandonment.
- The scope dimension introduces a wider array of choices for future decisions.

REAL OPTIONS IN SUPPLY CHAINS

- Sales Options
  - ✓ **Offer a set of product choices to consumers**
  - ✓ **Create consumer value**
  - ✓ **Give information on the demand, reducing risks**
  - ✓ **Postpone procurements**
  - ✓ **Match supply and maximize profit**

REAL OPTIONS IN SUPPLY CHAINS

- Manufacturing Options
  - ✓ **Introduce modularity**
  - ✓ **Delay final customization**
  - ✓ **Adapt to better demand forecasts**
  - ✓ **Replace inventory by careful staging of the manufacturing process**
  - ✓ **Use alternative types of capacity or processes adapted to demand**

PROCUREMENT OPTIONS

- Long term contracts and short term flexible contracts
- Use of spot markets; e.g., electronic components, commodities, etc.
- How to build portfolios: Like portfolios of financial investments, the issue is to trade off increase of value (or reductions in cost) with decrease of risk exposure. One can define procurement portfolios, as well as product and services portfolios.
- Contract engineering, similar to financial engineering is needed.
- Difficulty: Analysis of costs and risks in much more complex, since the analogue of financial markets does not exist or is limited.

NEW BUSINESS MODELS

- Outsourcing will extend, this requires new organization (shifting from vertical integration to negotiation, trading and contracting with external manufacturers). Spot markets will appear. It requires new organization at the supply side.
- New information infrastructure is needed, which must incorporate risk management techniques, real options approaches, new performance metrics. The equivalent of Financial Engineering will emerge in the supply chain context.

SERVICE SUPPLY CHAIN

- Evolution of support and maintenance logistics, in aerospace and defense.
- Performance Based Logistics: Instead of buying set levels of spares, repairs, tools and date, the new focus is on buying a predetermined level of availability.
  - ✓ DOD Acquisition Guidebook
  - ✓ Cohen, Kim, Netessine (Performance Contracting in Service Supply Chain, Oct 2005)
  - ✓ Acquisition in U.K. of defense satellites (PARADIGM)
  - ✓ Management of the space shuttle
  - ✓ Key Issue → Risk Sharing
- How to combine cost savings with performance goal, in situations where competition is limited.

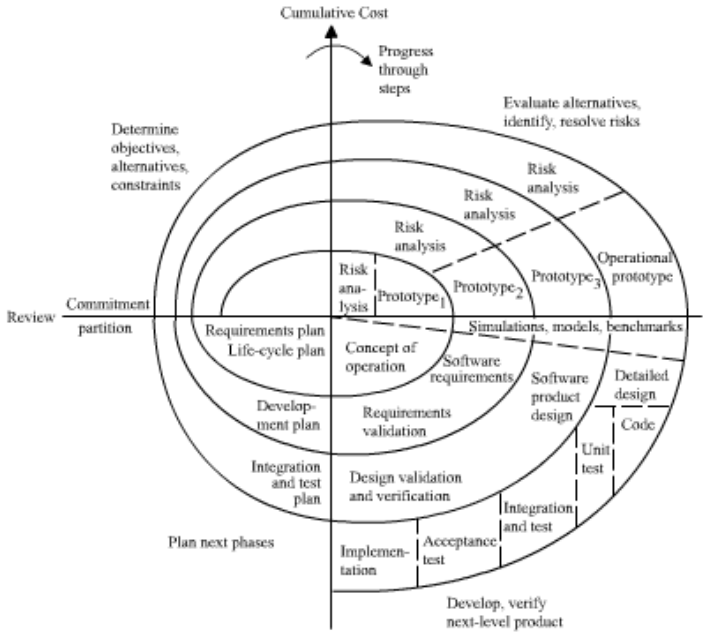
CONTRACTS: PRINCIPAL-AGENT MODELS

- Relation between a prime and suppliers are governed by contracts. The benefits of outsourcing may be offset by risks. Contracts must incorporate a treatment of risks.
- Economists have studied similar problems under the terminology Principal-Agent Theory. They have developed an interesting conceptual framework.
- Supply chains experts make use of this theory to develop efficient contracts between primes and suppliers. Adequate incentives must be introduced. The level of information that the Principal has on suppliers is a key element of the model. A lot of efforts remain necessary to adapt the framework of economists to supply chain contracts.
- The presence of spot markets is an element to be considered.

SPIRAL DEVELOPMENT

- Large innovative development programs in aerospace and defense are procured following spiral development principles. This concept started in software development.
- The terminology comes from a graphic representation of all development and implementation phases of a system. The successive phases expand like a spiral, not a purely sequential process. At each phase an analysis is conducted.
- Flexibility of choices is allowed at early stages.
- In the spirit of real option → delay decision and utilize maximum flexibility.

ORIGINAL SPIRAL MODEL



The Spiral Model

Boehm, Barry (1988) "A Spiral Model of Software Development and Enhancement," *IEEE Computer 21*, 5, 61-72.

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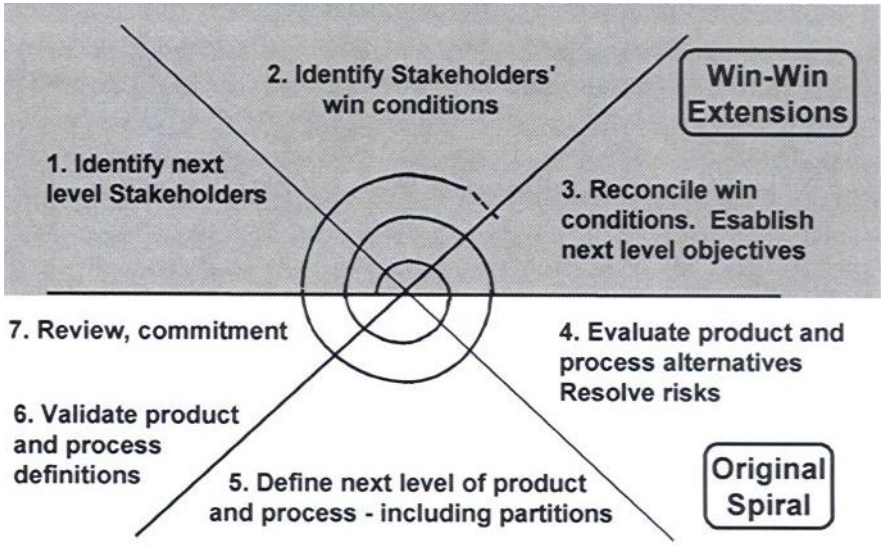
WINWIN SPIRAL MODEL
A REFINED SPIRAL MODEL

- The original spiral model has difficulty determining the roots of elaborated objectives, constraints, and alternatives.
- The WinWin spiral model resolves this by adding three activities to the front of each spiral cycle:
  - ✓ Identify the system or subsystem's key stakeholders
  - ✓ Identify the stakeholders' win conditions for the system or subsystem
  - ✓ Negotiate win-win reconciliations of the stakeholders' win conditions

WINWIN SPIRAL MODEL



Boehm, Barry (2000) "Spiral Development: Experience, Principles, and Refinements," Carnegie Mellon University.

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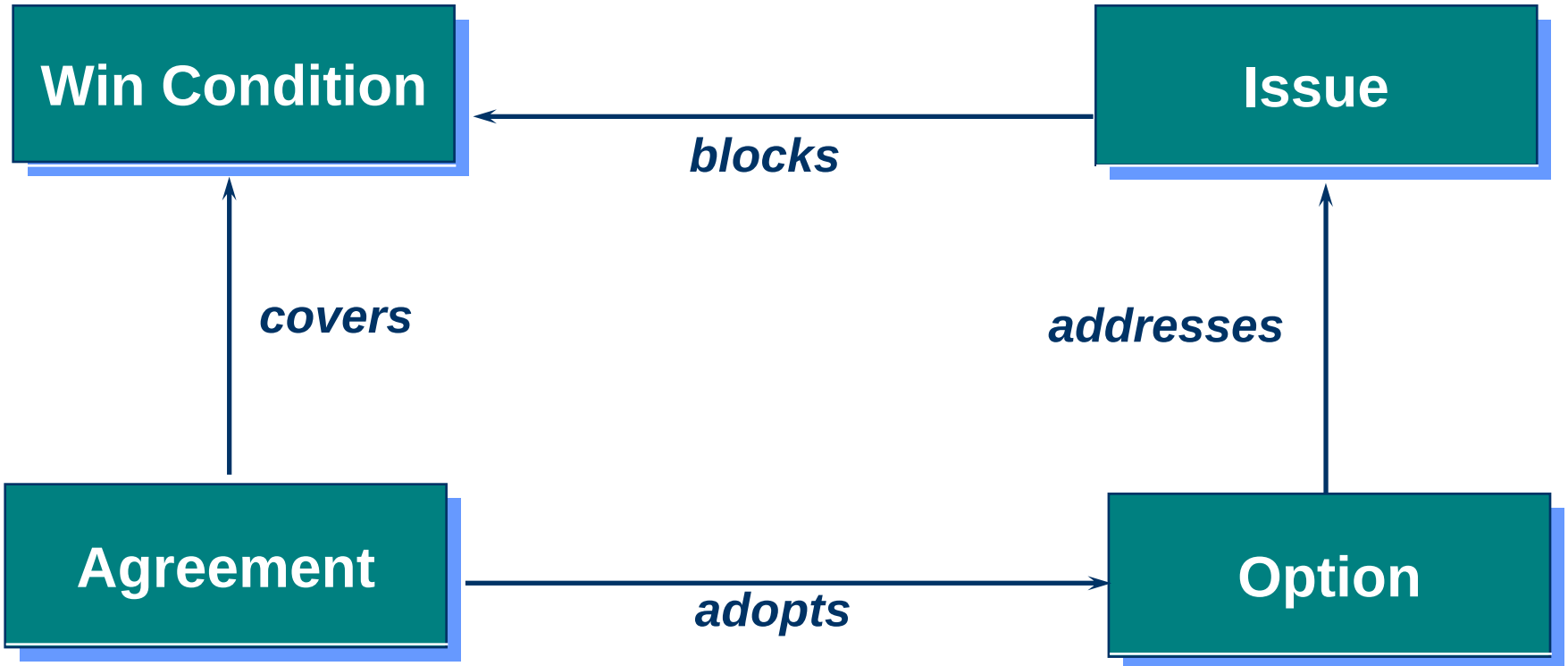
WINWIN SPIRAL MODEL
A NEGOTIATION FRAMEWORK



From the lecture notes of Prof. Larry Bernstein at Stevens Institute of Technology

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THE FLEXIBILITY ENGINE™
A NEW WAY OF THINKING

- **Framework to incorporate long-term implications of current decision alternatives: how would each alternative behave over time and what kind of triggers could be needed?**
- **Process to proactively capitalize on relevant, available and value-added synergies, and come up with new ones in a dynamic and complementary manner.**
- **System to exploit and cope with uncertainties of the exogenous and endogenous kind explicitly.**
- **Methodology to identify key elements of decision making at the executive level of the corporation, and impose performance yardsticks for sustainable growth.**

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THE FLEXIBILITY ENGINE™
TYPOLOGY FOR EFFECTIVE DECISION MAKING

- Flexibility in time → American Options, Optimal Stopping
- Flexibility in scope → Portfolio Optimization, Stochastic Control
- Flexibility in means and ends → Spiral Development →WinWin Spiral Model
- Flexibility in concept → Concept Maps, Causal Maps →Knowledge maps
- Flexibility in design →Influence Diagrams, Bayesian Networks → Dynamic Decision Networks
- Flexibility in strategy →Opportunity Development →Uncertainty Exploitation
- Flexibility in extreme events → Disruptive Risk Management (Kleindorfer & Saad, 2005)

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THE FLEXIBILITY ENGINE™
BEYOND REAL OPTIONS ANALYSIS

- When target markets and technical agendas are flexible, that is,
  - ✓ demarcation between investment stages is blurry,
  - ✓ the scope for possible modifications in the initial stages is vast,
  - ✓ opportunities are linked to the actions of the corporation; i.e., endogenous,

  and actors at different levels of the corporation have different perspectives on the attractiveness of a given opportunity due to psychological biases, cognitive issues, and different incentive structures, the discrete logical framework of real options breaks down.

- There is a need for more generic path-dependent processes:
  - ✓ Probe and learn (Lynn et al., 1996)
  - ✓ Incremental search (March & Simon, 1958)
  - ✓ Innovation journeys (Van de Ven et al., 1999)

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SOCIAL AND CULTURAL IMPLICATIONS

- **Flexible Human Beings**
- **Flexible Educational System**
- **Flexible Communities and Societies**
- **A Flexible Generation (*FlexGen*)**
- **A Sustainable Future for the Human Race**

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CONCLUDING REMARKS

- Risks → here to stay
- External risks → growing in importance
- Network risks dependence → a challenging conceptual and technical problem
- Risk intermediation → what are the limits of sharing risks and using market approaches? Is there a possibility of global chaos?
- Risk and Decision Analysis → a strategic new scientific discipline
- Risk Management → a strategic profession
- Flexibility Theory → to be formalized soon…