TECHNOLOGY INVESTMENT PORTFOLIO PLANNING

A SYSTEMS APPROACH WITH APPLICATIONS TO LARGE ORGANIZATIONS

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PERSONAL BACKGROUND
Systems Thinker and Technology Planner

Education:
Ph.D., Operations Research, Stanford University; MSEE, Georgia Tech; BSEE, Taiwan University

Experience:
1974-1989: Manager, Planning Analysis, Electric Power Research Institute
Origination and application of *Technology Investment Portfolio Planning Process* to over 3000 technology research project a year.
1989-2000: Director, Energy and Technology Strategies, SRI International
Combining *Technology Investment Portfolio Planning Process* with *Scenario Analysis* and applying it to over 200 projects around the world.
2000-present: President, STARS Group;
Application of the *Systems Approach Based Technology Investment Portfolio Planning Process* to companies and governments around the world.

Related Activities in the Last Decade:
12 technical papers, a regular MBA course, 16 training programs, and a book on *Technology Portfolio Planning and Management,* Springer Publisher.

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METHODOLOGY BACKGROUND

Technology advances have been the driving forces for human civilization and economic developments.

Effective technology investment portfolio planning is essential for the *growth and competitiveness* of not only a corporation but also a country.

It can also be useful for *increasing the productivity* of a non-profit organization like a university or even for an individual.

This presentation introduces a *systems* approach for technology investment portfolio planning that has been *successfully applied to large corporations as well as government agencies around the world*. In addition to the basic approach and the overall planning process, we will use applications to technology investments by an Asian government as examples.

THE SYSTEMS APPROACH: Key Characteristics

The *systems* approach views technology investment portfolio planning as a *total-system decision process* that involves:

- A *systematic decision framework* for *optimally* allocating limited financial, technical, and human resources of an organization *among* alternative technology portfolios.
- A *holistic understanding of decision-maker's values.*
- An *organized identification of alternative technology portfolios.*
- A *scenario-based forecasting process* for the relationships between alternative portfolios and organizational values.
- The use of simple management tools to generate *strategic insights*.
- A *modern portfolio theory-based investment planning process* for the optimal portfolio by balancing the perceived expected returns and risks of long-term technology investments.

METHODOLOGY EMPHASIS: Diversity, Reasoning, and Transparency

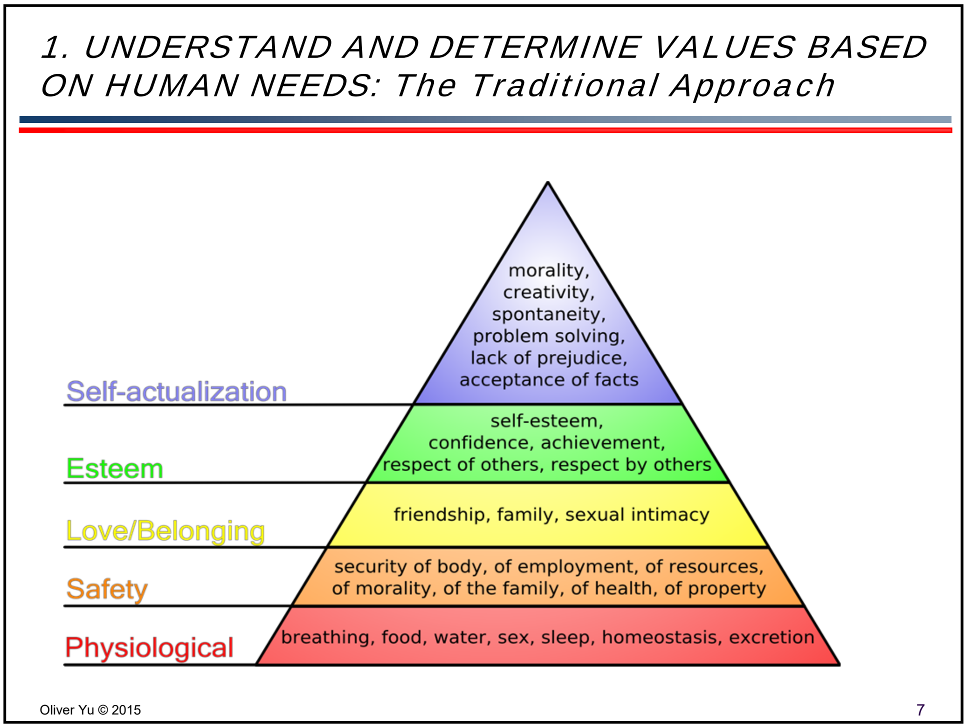
Planning is *both a rational and a creative* ***decision process***.
The systematic approach emphasizes a *structured framework* to systematically and iteratively *integrate* reasoned and informed judgments and build consensus among diverse, intelligent, and knowledgeable professionals to provide a *systematic and supportable* basis to the technology investment decision-maker.
Specifically, it strives to:

- ❖Reduce bias, broaden perspective, and stimulate creativity through *diversity*
- ❖Develop logical and structured reasoning and informed judgments through *intelligent and knowledgeable professional interactions and in-depth technical analysis*
- ❖Provide *transparency and accountability* through an open and iterative process

TEHCNOLOGY INVESTMENT DECISION: A Systematic Framework

A systematic technology investment portfolio decision framework includes the following six key steps:

1. Understand and determine the *values* of the decision-maker, which are the motivation for decision-making and the basis for evaluating alternatives.
2. Identify major available *alternative portfolios*.
3. Forecast the *relationships between alternatives and values.*
4. Generate *strategic insights*.
5. Find the *optimal portfolio*.
6. Explore *policy implications* for plan implementation.


1. UNDERSTAND AND DETERMINE VALUES BASED ON HUMAN NEEDS: The Traditional Approach
morality, creativity, spontaneity, problem solving, lack of prejudice, acceptance of facts
Self-actualization
self-esteem, confidence, achievement, respect of others, respect by others
Esteem
friendship, family, sexual intimacy
Love/Belonging
security of body, of employment, of resources, of morality, of the family, of health, of property
Safety
breathing, food, water, sex, sleep, homeostasis, excretion
Physiological
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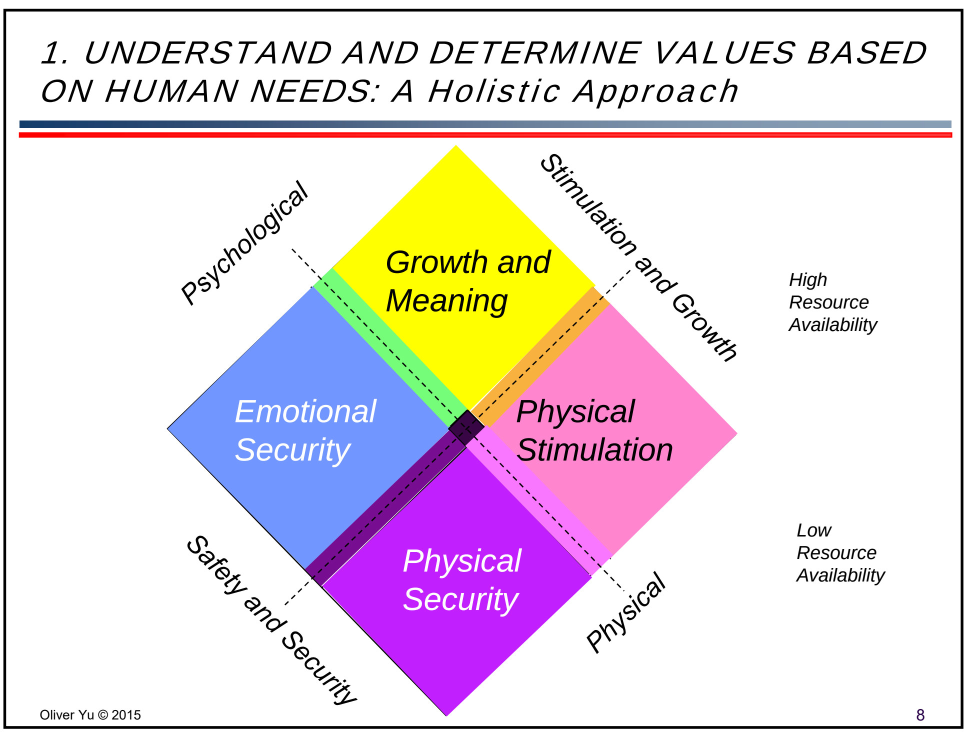
1. UNDERSTAND AND DETERMINE VALUES BASED ON HUMAN NEEDS: A Holistic Approach
Psychological
Stimulation and Growth
Growth and Meaning
High Resource Availability
Emotional Security
Physical Stimulation
Physical Security
Safety and Security
Physical
Low Resource Availability
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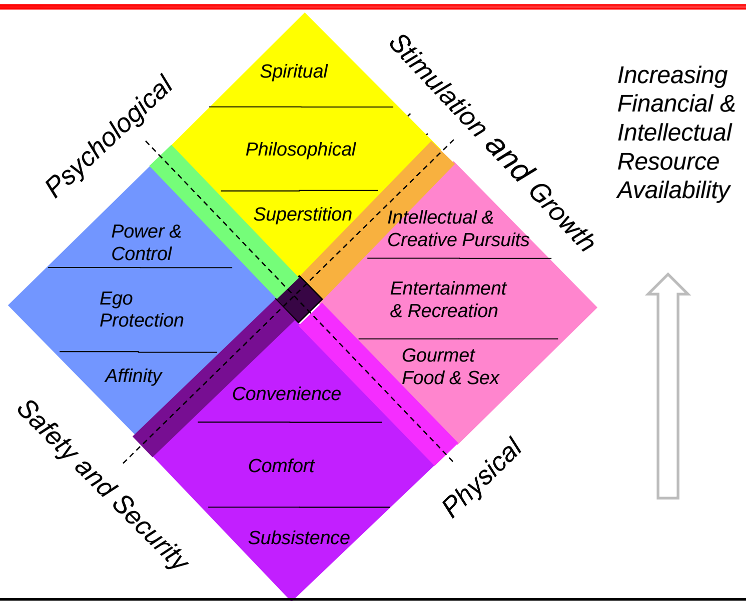
1. UNDERSTAND AND DETERMINE VALUES: The Holistic Approach for Individuals



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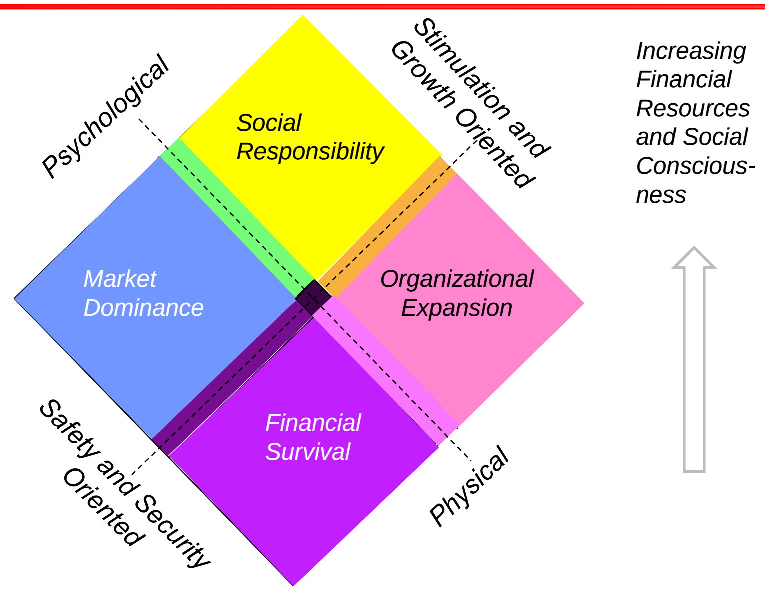
1. UNDERSTAND AND DETERMINE VALUES: The Holistic Approach for Corporations



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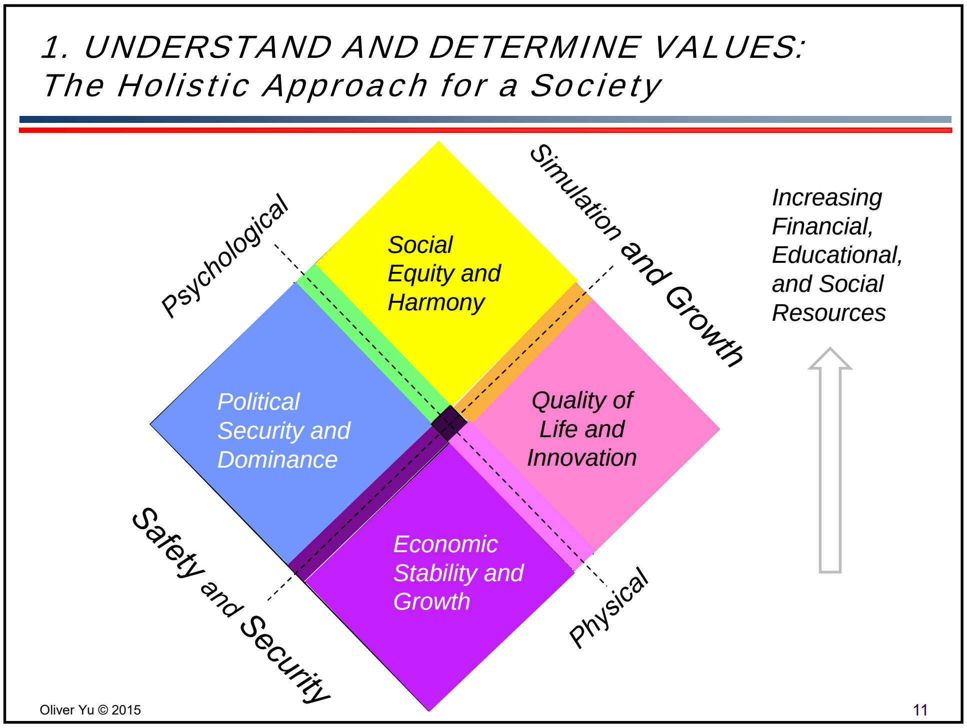
1. UNDERSTAND AND DETERMINE VALUES:
The Holistic Approach for a Society
Social Equity and Harmony
Political Security and Dominance
Quality of Life and Innovation
Economic Stability and Growth
Psychological
Simulation and Growth
Safety and Security
Physical
Increasing Financial, Educational, and Social Resources
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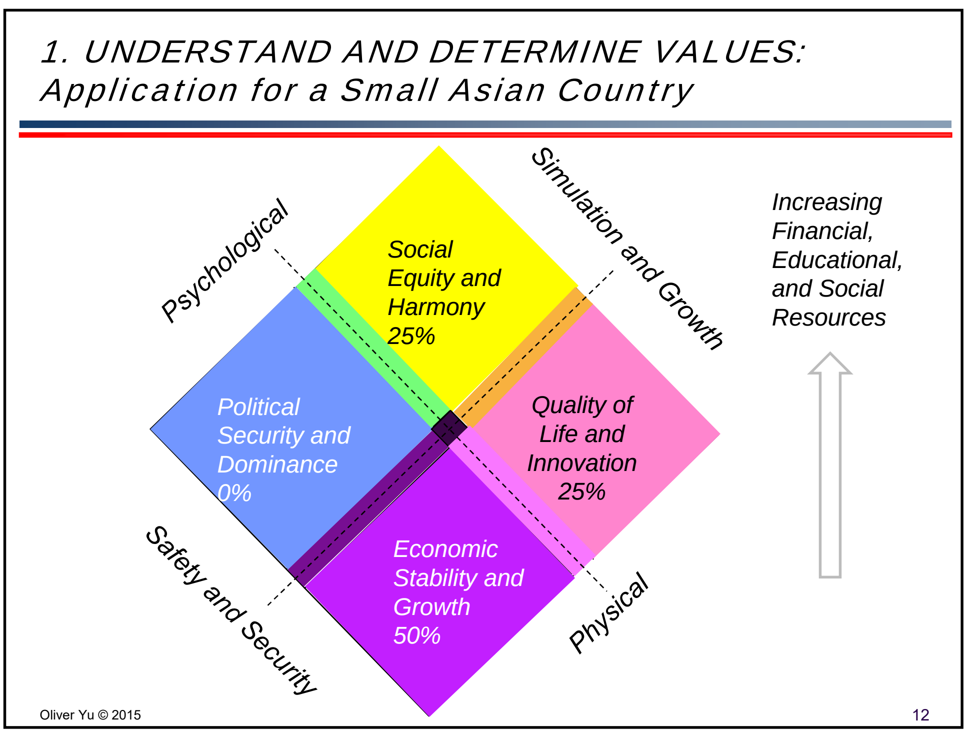
1. UNDERSTAND AND DETERMINE VALUES:
Application for a Small Asian Country
Social Equity and Harmony 25%
Political Security and Dominance 0%
Quality of Life and Innovation 25%
Economic Stability and Growth 50%
Psychological
Simulation and Growth
Safety and Security
Physical
Increasing Financial, Educational, and Social Resources
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1. DETERMINE SOCIETAL VALUES: Details for a Small Asian Country

For government technology investment portfolio decisions of a small Asian democratic country, *Societal Values* were obtained from a large group of opinion leaders in the society, including top public officials, key industry and business executives, senior technology researchers and social scientists, major educators, top media representatives and artists:

❖ Economic prosperity (50%)
  -Economic growth
  -Economic stability
  -Increase in value added
❖ Social equity (25%)
  -Narrowing of income gaps
  -Social welfare improvement
    -Low unemployment rate
    -Care of aged and disabled population
❖ Life quality (25%)
  -Environmental quality and sustainability
  -Balance of work and leisure
  -General quality of life

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2. IDENTIFY ALTERNATIVE PORTFOLIOS: Organized Formation of Clusters & Portfolios

There are generally a large number of alternative technologies available for consideration, which are often difficult to differentiate and compare. Thus, a useful step is an *organized grouping of these alternative technologies to form a manageable number of clusters and portfolios* (i.e., complementary combinations), which once selected can be decomposed in the future to yield individual technologies for further evaluation.

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2. TECHNOLOGY CLUSTERING: Overview

The objective of technology clustering is to integrate the large number of potential individual technologies into *meaningful, insightful, and manageable* clusters.

There are two basic approaches:
Top-down: In this case, the participants, through their knowledge and experience, identify the relevant and important technology clusters
Bottom-up: In the case, the participants are given a large list of technologies to be integrated into various major clusters.
In the application to the small Asian country, the Bottom-up approach was used.

To initiate cluster formation, we first divided the list of technologies into major areas: biotech, materials, energy, semiconductors, and information and communications.

To further facilitate clustering, we asked the experts to sort technologies by
- Shared technology root or developmental processes
- Common practical application or market demand
- Integrated support to societal values and visions

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2. TECHNOLOGY CLUSTERING: Results of Bottom-Up Process

❖ Over 250 technologies were initially sorted into 6 bins:
– Biotech
– Materials Technology
– Energy Technology
– Semiconductor Technology
– Information and Communications Technology
– Other

❖ Each bin yielded multiple clusters (groupings of several technologies).

The initial technology clusters were reviewed again by technology experts to ensure definition clarity and content agreement. Through iterative discussion, differences of expert judgments were reduced and unified. Finally, the process resulted in a total of 42 technology clusters, with *29 top clusters* appearing to be particularly attractive to the societal values of the Country.

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3. FORECASTING RELATISHIPS: Traditional Methods All Assumption-based

	Power of collective wisdom	Potential leading indicators	Continuation of historical patterns	Analogies to well known phenomena	Structural relations	Causal Methods
Underlying Assumption	There is power in collective wisdom about the technology development and adoption process	There are potential signs or leading indicators about the technology development and adoption process	Historical patterns or trends will continue due to inherent nature or momentum of the process	The technology development and adoption process is analogous to some well known phenomena	Technology development and adoption follows a plausible set of structural relations	Causal relations can be mapped for technology development and adoption
Examples	•Delphi –expert opinions •Executive judgments	•Patent analysis •Citation and innovation search	•Trend extrapolation •Growth models •Substitutions	•Technology life cycle •Growth models •Diffusion models	•Relevance tree •Cross-impact matrix	•Techno-economic models •Simulation
Advantages	Good credibility Low cost	Plausibility Relatively low cost	Empirical Short term momentum	General acceptability and credibility	Systematic and logical	Sophisticated and impressive
Pitfalls	Inherent bias, blind leading the blind	Indicators may be misleading, may miss isolated development	Patterns or trends may not continue as assumed	May be different with the well known phenomena	Difficult to include feedback loops	Complex, Often incomplete, and incorrect
Applicability	Far-out technologies with little knowledge	Early warning signs for gradual technology developments	Short term forecasting with ample data to support validity	Wide applications to forecasting of technology development	Longer term technology forecasting	An idealistic goal for technology forecasting

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3. FORECASTING RELATIONSHIPS: Planning Scenarios for Managing Future Uncertainty

Many factors in the external business environment, such as global and local socio- economic, technological, and ecological trends, industry structure, government policies, and international relations, can significantly affect the relationships between alternatives and their values to the decision-maker.

Long-term future changes and uncertainties of these factors are generally difficult to forecast. Systematic construction of *decision-focused planning scenarios* can provide:

- ❖ an *effective envelope for these changes and uncertainties*
- ❖ the basis for a *robust* technology investment strategy.

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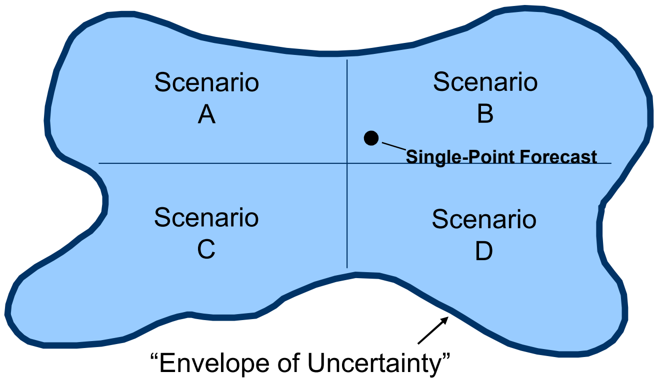
3. PLANNING SCENARIOS: Overview

Constructing planning scenarios is *conceptually different* from traditional forecast or sensitivity analysis for managing future uncertainties. Strictly speaking, it does *not* develop a single forecast but a set of *structurally different but plausible alternative* scenarios that provides an *envelope to uncertainty* in the future environment.



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3. PLANNING SCENARIOS: Key Characteristics

Decision-focused planning scenarios are not

- Predictions
- Variation around a mid-point/base case
- Generalized views of feared or desired futures
- Product of outside futurists

Rather, they are

- Descriptions of alternative plausible futures
- Significantly, often structurally different views of the future
- Specific decision-focused views of the future
- Result of management insight and perceptions

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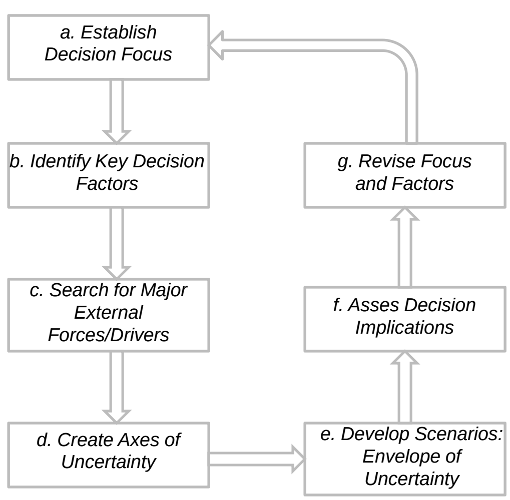
3. PLANNING SCENARIOS: Major Advantages

In a complex and dynamic business environment, the construction of decision-focused planning scenarios can be an effective technology forecasting technique with the following advantages:

- *Focus on decision objectives*
- *A total system view of the decision*
- *Rich context of alternative futures*
- *Effective management of uncertainty*

On the other hand, local system-oriented single realization point forecast, even with sensitivity analysis, is almost always not only wrong but also misleading

3. PLANNING SCENARIO DEVELOPMENT: Major Iterative Steps



3. PLANNING SCENARIO DEVELOPMENT: a,b. Decision Focus and Factors

- Decision Focus and Elements pinpoint the *choices* we need to make.
- We initially assume that our decision will *not* significantly affect external environment, which is the focus of the scenario development process.
- Key Decision Factors are the *key issues in the external environment* that directly affect out decision and we want to forecast—they often include
  - Technology development - Market demand growth - Industry structure
  - Government regulations - Resource requirements - International relations
- Micro and Macro Forces are *major drivers of changes* in the external environment and basic causes of future uncertainty based on which we develop scenarios.
- Scenario Implications are *preliminary assessment of the general impacts* of the scenarios on Key Decision Factors and eventually our Decision.
- Scenarios of the external environment may be refined by our decision through *iterations* of the scenario development process.

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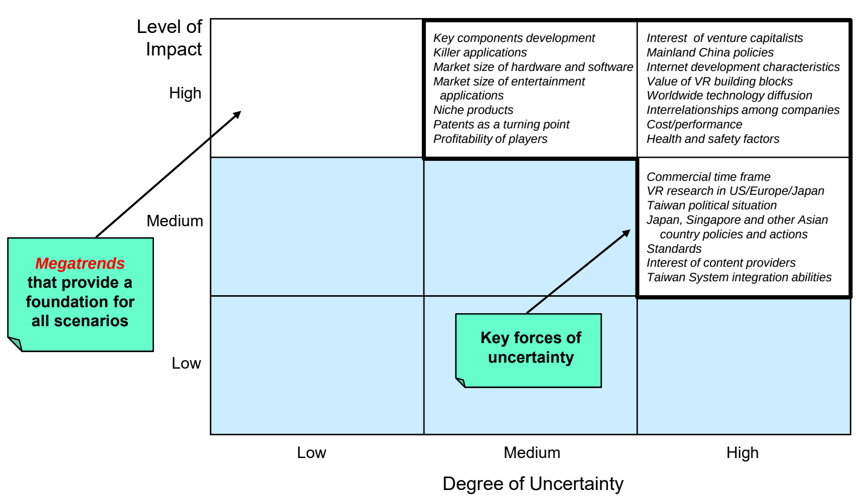
3. PLANNING SCENARIO DEVELOPMENT: c. External Forces by Impact and Uncertainty



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3. PLANNING SCENARIO DEVELOPMENT: c. Global Mega-trends

Global Mega-trends:

❖ Society:
- -Knowledge society
- -Aging population
- -Continued urbanization
- -Urban crowding
- -Income polarization

❖ Politics:
- -Regional competition & cooperation
- -International organizations
- -Terrorism

❖ Technology:
- -Global environmental pollution
- -Biotechnology
- -Information and communications technology
- -Nanotechnology
- -Intelligent materials

❖ Economy:
- Expansion of multi-nationals
- Revolution of industrial processes
- Rise of miniaturization industry
- Shifting sources of human skills
- Changes in consumption patterns

❖ Environment:
- Environment without political boundaries
- Global climatic changes
- Limitations of natural resources
- Widespread of diseases and plagues

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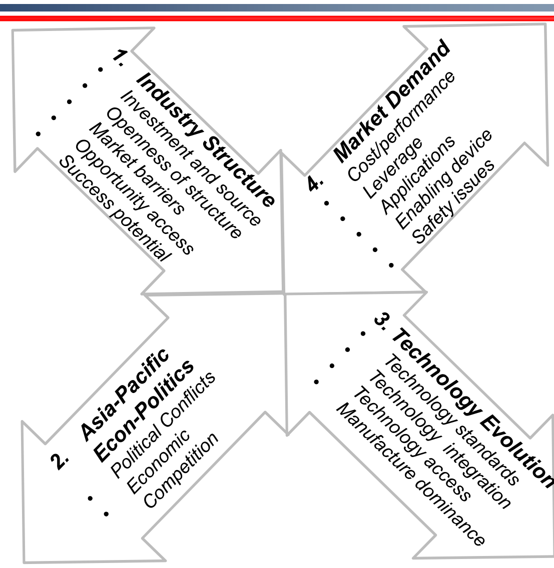
3. PLANNING SCENARIO DEVELOPMENT: d. Create Axes of Uncertainty



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3. PLANNING SCENARIO DEVELOPMENT: d. Plausible Extreme Futures of Axis

Virtual Reality Industry Structure Axis	
Alternative	**Rationale**
Combative Fragmented	• Low investment mainly from corporations • Protective structure with high market barriers • Limited access to opportunities
Cooperative Integrated	• Heavy investments and many from venture capitalists • Open structure with international cooperation • Full access to opportunities and many small companies have major successes

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3. PLANNING SCENARIO DEVELOPMENT: d. Plausible Extreme Futures of Axis

Technology Evolution Axis	
Alternative	**Rationale**
Stuck/Disjointed	• Fragmented development • No standards • Disjoint development • Dominance by component manufacturers and patent barriers
Breakthrough	• Coordinated development • Standards achieved • System integration works • Easy access to technology

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3. PLANNING SCENARIO DEVELOPMENT: e. Candidate Scenarios

All the possible combinations of the two extremes of the Uncertainty Axes are "Candidate Scenarios". . .

Candidate Scenario	Uncertainty Axes			
	1. Industry Structure	2. Asia Pacific Eco-Politics	3. Technology Evolution	4. Market Demand
1	Combative Fragmented	Closed	Stuck Disjointed	Expensive Specialized
2	C/F	Closed	S/D	Cheap Mass Market
3	C/F	Closed	Breakthrough	E/S
14	Cooperative Integrated			
15	C/I	Open	Breakthrough	E/S
16	C/I	Open	Breakthrough	CMM

. . .In this case, 16 possibilities

3. PLANNING SCENARIO DEVELOPMENT: f. Guidelines for Final Scenarios

- Each should be *"structurally" different.*
- Each should be *internally consistent*
  - Natural fit of components into a "story line."
- Each should be *plausible.*
- Each must have *decision making utility* as a "test bed" for assessing alternative future actions.
- Together, the cases selected should span the realm of plausible future worlds, or the *"envelope of uncertainty."*

3. PLANNING SCENARIO DEVELOPMENT: f. Final Scenarios

After eliminating redundancy and inconsistency and being responsive to the decision focus, the following final scenarios were selected.

Scenario	**Uncertainty Axis** 1. Industry Structure	2. Asia-Pacific Econ-politics	3. Technology Evolution	4. Market Demand
(5) Life in Hell	Combative Fragmented	Closed	Stuck Disjointed	Expensive Specialized
(12) Left Behind	Cooperative Integrated	Closed	Breakthrough	Cheap Mass Market
(14) Waiting for Technology Spring…	Cooperative Integrated	Open	Stuck Disjointed	Cheap Mass Market

4a. STRATEGIC INSIGHTS BY FACTOR ANALYSIS: Factor Selection

Select a set of important attributes of an alternative as *factors*. Using a technology cluster as an example, the major factors may include the following:

- Strategic Importance
- Commercial Value
- Commercial Timing
- Risks - Business and Technical
- Current Position in Technology Competition
- Technology Availability

4a. STRATEGIC INSIGHTS BY FACTOR ANALYSIS: Factor Definition

For each factor, there needs to be a *clear definition*, albeit qualitative. Again using the technology cluster as an example:

Strategic Importance - Importance of the technology development as a sustained competitive advantage to the business area

Commercial Value - Size of the financial impact to the company if the technology is successful

Commercial Timing - Time at which the market will adopt or buy this technology at an acceptable business level and at which the competitor will use it commercially

Risks - Likelihood that the technology will fail to accomplish its technical objectives, and that, if technical successful, it will fail commercially

Current Position - Strength and ability of the company versus competitors in developing the technology today

Technology Availability - Availability of technology from any source for commercialization

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4a. STRATEGIC INSIGHTS BY FACTOR ANALYSIS: Factor Measures

Based on the definition, develop for each factor a set of measures. Again using the technology cluster as an example, typical measures include the following:

Strategic Importance - Degree of impact based on market share, product differentiation, cost efficiency, and market entry speed

Commercial Value - Net present value, return on investment, revenue from increased sales, and other financial measures

Commercial Timing - Calendar time in years with estimated probability

Risks - Probabilities of technical and commercial failures based on internal capability and resource availability and external market size, position, and future uncertainty

Current Position - Degree of strength based on past experience, existing patents, and current capability of the company versus competitors

Technology Availability - Number of sources and their willingness to license

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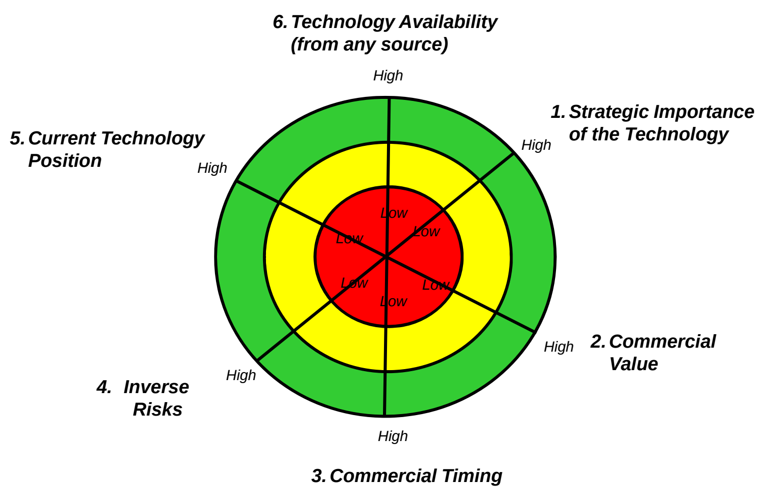
6a. FACTOR ANALYSIS: Factor Measures (example)

The following are some typical factor measures:

Factors						
Measure	*Importance (Market Impact)*	*Value (NPV)*	*Timing (Years)*	*Inverse Risks (Probability of Success)*	*Position*	*Availability*
High	Major, broad	>$500 M	0-2	>60%	World leader	Readily
Medium	Significant in some key segments	$50-$500 M	3-7	30-60%	Credible follower	Limited
Low	Minor or isolated	<$50 M	>8	<30%	Not Competitive	None

4a. STRATEGIC INSIGHTS BY FACTOR ANALYSIS: Graphical Representation



4a. STRATEGIC INSIGHTS BY FACTOR ANALYSIS: Methodological Emphases

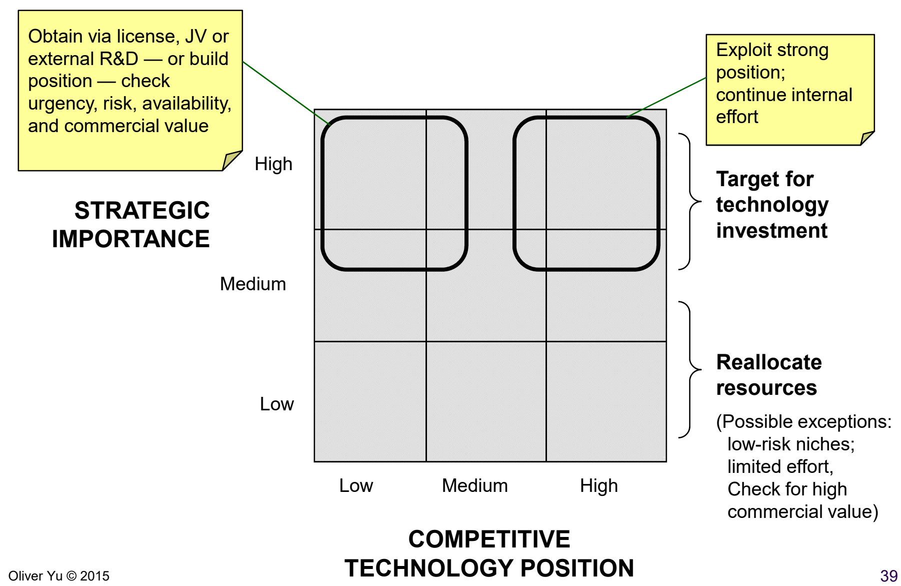
Effective factor analysis has the following emphases:

- To avoid double-counting of their effects, the factors should be as *uncorrelated* with each other as possible.
- To be strategic, the definitions should be made with the perspective of the overall *corporate objective, market conditions, and competitive environment.*
- To avoid ambiguity but without undue effort, the measure should be specified *as clear and quantifiable as practical.*
- Factor analysis should be applied to evaluate each alternative *in a given scenario*.
- Analytic Hierarchy Process can be applied if *more precision* is desired.

4b. GENERATE INSIGHTS BY STRATEGY MAP: Factor Interactions and Balances

Strategy map is a useful tool for examining the *interactions and balances* between two factors for each alternative in a given scenario. These interactions and balances can provide strategic directions for technology development. The following are a number of illustrative examples based on technology clusters.

4b. GENERATE INSIGHTS BY STRATEGY MAP: Illustrative Example 1



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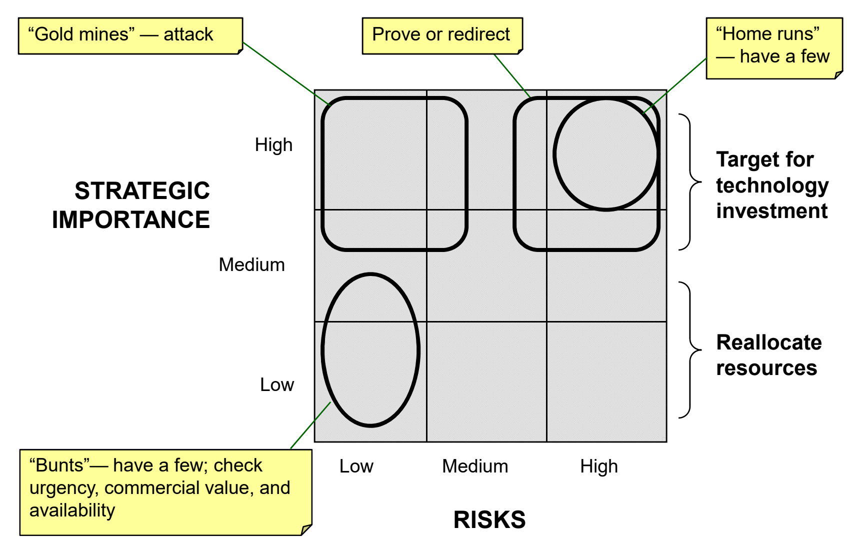
4b. GENERATE INSIGHTS BY STRATEGY MAP: Illustrative Example 2



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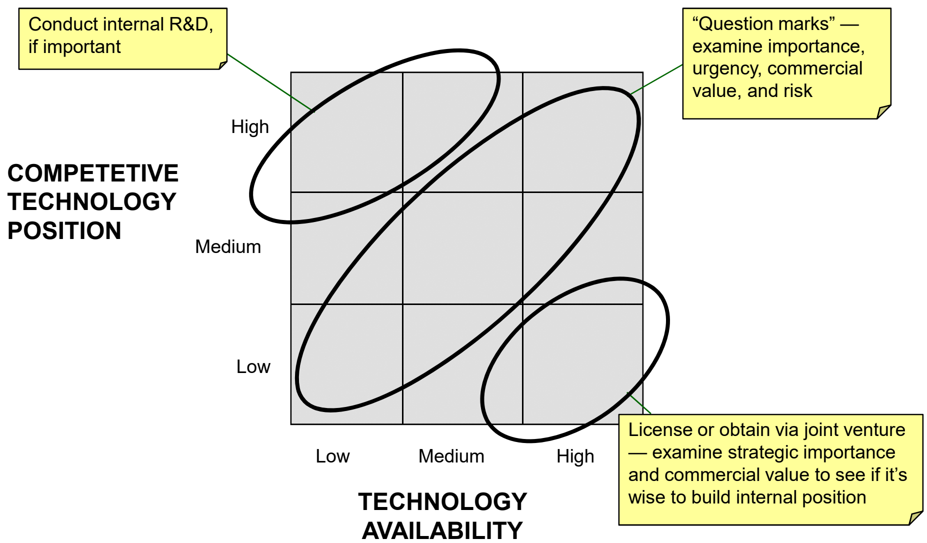
4b. GENERATE INSIGHTS BY STRATEGY MAP: Illustrative Example 3



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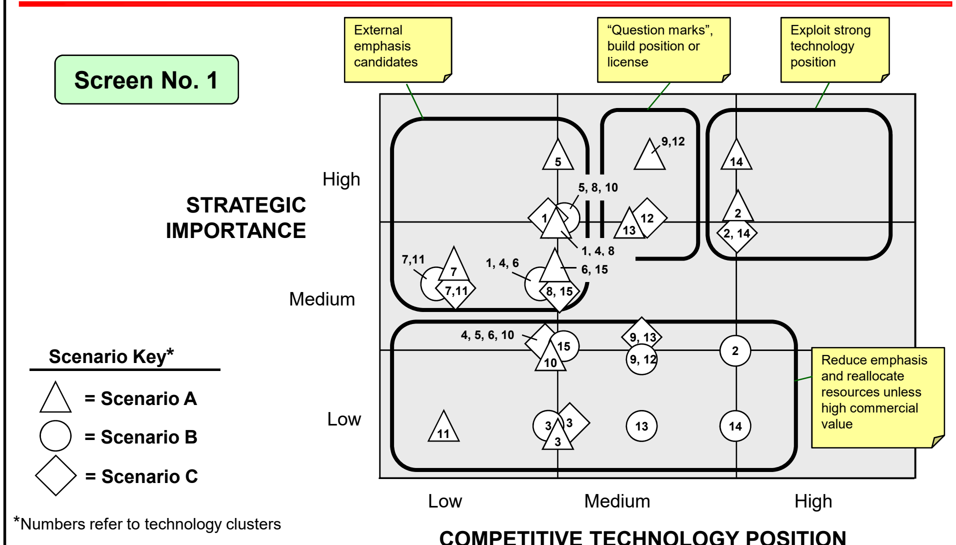
4b. GENERATE INSIGHTS BY STRATEGY MAP: Illustrative Example 1 for Qualitative Portfolio Evaluation



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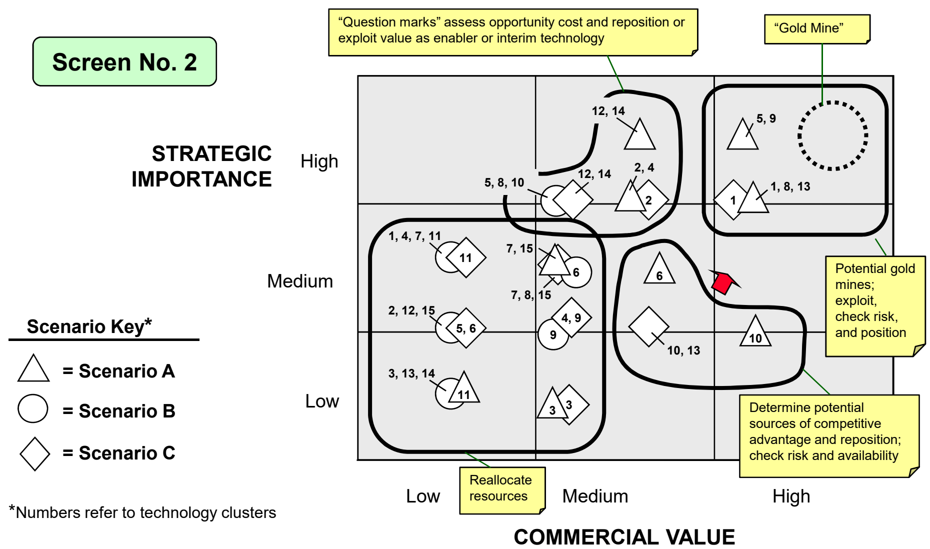
4b. GENERATE INSIGHTS BY STRATEGY MAP: Illustrative Example 2 for Qualitative Portfolio Evaluation



4b. GENERATE INSIGHTS BY STRATEGY MAP: Illustrative Example 3 for Qualitative Portfolio Evaluation

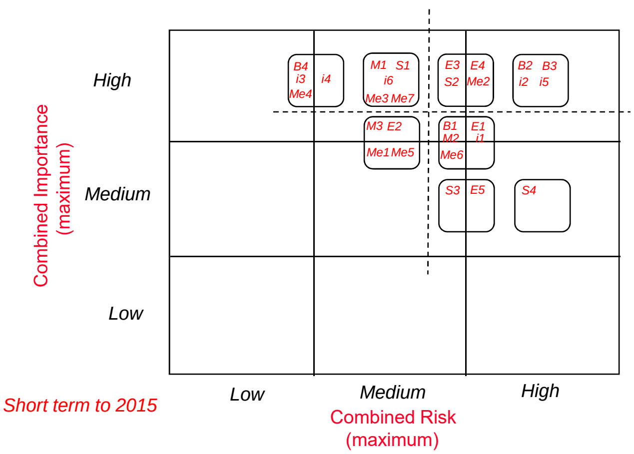
Integrated factor analysis can reveal the *robustness* of technology clusters across scenarios and the *strength* of the portfolio within each scenario.

Example: Factor #1 - Strategic Importance of the Technology

Technology Cluster	Scenario A	B	C	Overall Rating
1	MH	MM	MH	MH
2	HL	LH	MH	MM
3	LM	LM	LM	LM
4	MH	ML	LH	ML
Etc				
Overall Portfolio	MM	LH	ML	ML

The strategy maps can also provide insights about how the portfolio may be *strengthened and improved*.

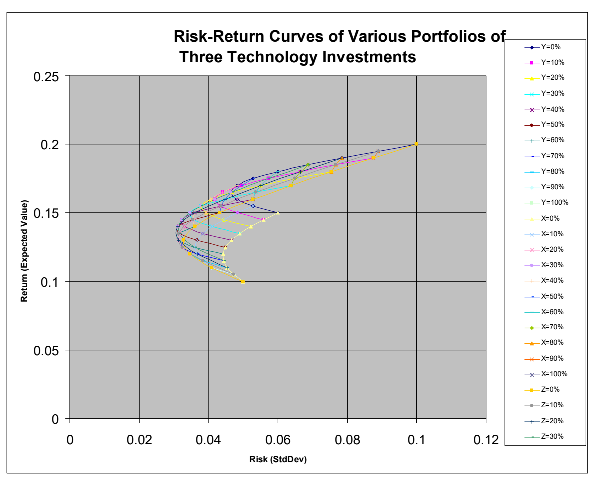
4b. SUMMARY STRATEGY MAP: Combined Importance vs. Combined Risk



Top Clusters:

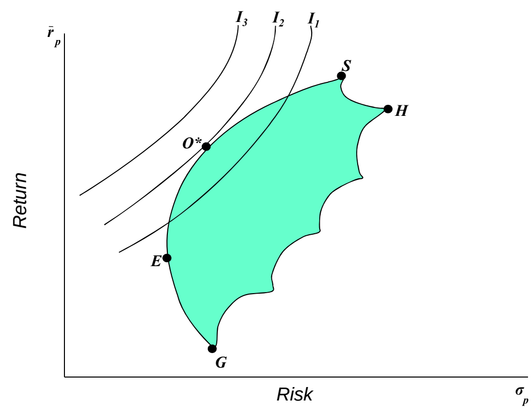
B1 Prevent, Predict, Personal Molec. Diagnostic
B2 Emerging Infect. Disease Management
B3 Regenerative Medicine & Well Being for Aging Population
B4 Agricultural Biotechnology
M1 Nano Materials and Systems
M2 Smart Materials and Systems
M3 Materials for Advanced Energy Systems
E1 Clean Fossil Fuel Conversion & Emission Reduction
E2 Next Generation Solar Energy
E3 Green Vehicles & Alternative Fuels
E4 Efficient Energy End Use device
E5 Advanced Fuel Cells for Non-Propulsion
S1 High Complexity IC's
S2 Next Gen. Semiconductor Fabrication & Process Tools
S3 Flexible Electronics
S4 Future Computing devices
I1 Recognition and Interpretation Software
I2 Smart Enterprise Computing
I3 Networked Multi-Media
I4 Broadband Communications
I5 Intelligent Transportation System
I6 Digital Home
Me1 Ubiquitous Wireless Technologies
Me2 Distributed Health Care Systems
Me3 Advanced Optical Display Systems
Me4 Sustainable Buildings
Me5 Robotics
Me6 Environmental & Resources Management
Me7 Precision Machining Tools & Products

5. FINDING THE OPTMAL PORTFOLIO: Modern Portfolio Theory



5. FINDING THE OPTIMAL PORTFOLIO: Modern Portfolio Theory

In a simplified way, optimal portfolio selection is the *best balance* between return and risk for a decision-maker, which occurs at the *tangential point of the indifference curves and the efficient frontier* as shown below.



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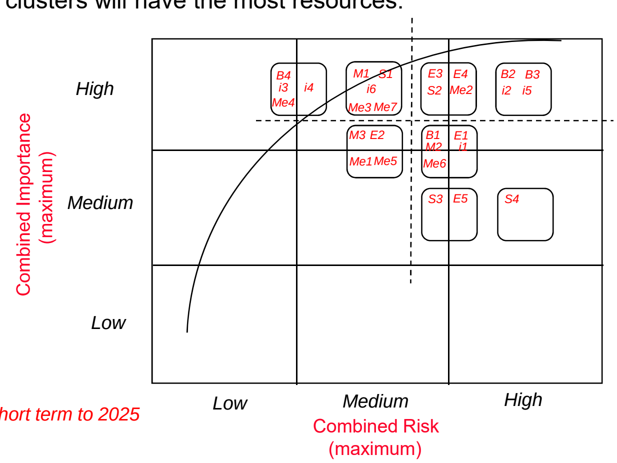
5. FINDING THE OPTIMAL PORTFOLIO: Application to a Small Asian Country

If the government is willing to make large investment for the high risk home runs, then high importance and high risk clusters will have the most resources; if the government is interested in mainly base hits and commercialization, then medium importance and risk clusters will have the most resources.



Top Clusters:

B1 Prevent, Predict, Personal Molec. Diagnostic
B2 Emerging Infect. Disease Management
B3 Regenerative Medicine & Well Being for Aging Population
B4 Agricultural Biotechnology
M1 Nano Materials and Systems
M2 Smart Materials and Systems
M3 Materials for Advanced Energy Systems
E1 Clean Fossil Fuel Conversion & Emission Reduction
E2 Next Generation Solar Energy
E3 Green Vehicles & Alternative Fuels
E4 Efficient Energy End Use device
E5 Advanced Fuel Cells for Non-Propulsion
S1 High Complexity IC's
S2 Next Gen. Semiconductor Fabrication & Process Tools
S3 Flexible Electronics
S4 Future Computing devices
I1 Recognition and Interpretation Software
I2 Smart Enterprise Computing
I3 Networked Multi-Media
I4 Broadband Communications
I5 Intelligent Transportation System
I6 Digital Home
Me1 Ubiquitous Wireless Technologies
Me2 Distributed Health Care Systems
Me3 Advanced Optical Display Systems
Me4 Sustainable Buildings
Me5 Robotics
Me6 Environmental & Resources Management
Me7 Precision Machining Tools & Products

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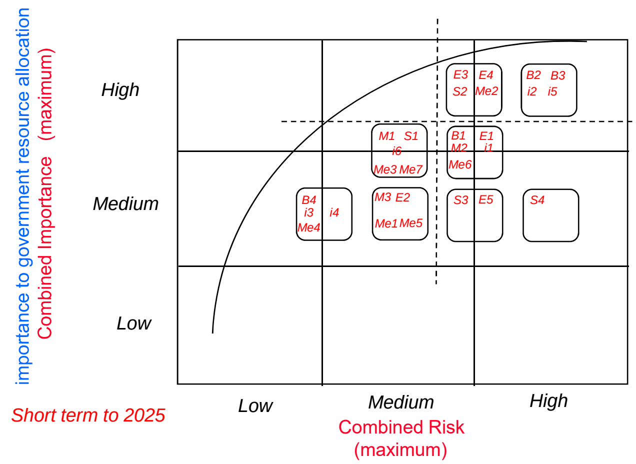
5. FINDING THE OPTIMAL PORTFOLIO: Revised for Government Investment

For government viewpoint, it will be more meaningful to use the importance to *government* resource allocation.



Top Clusters:

- B1 Prevent, Predict, Personal Molec. Diagnostic
- B2 Emerging Infect. Disease Management
- B3 Regenerative Medicine & Well Being for Aging Population
- B4 Agricultural Biotechnology
- M1 Nano Materials and Systems
- M2 Smart Materials and Systems
- M3 Materials for Advanced Energy Systems
- E1 Clean Fossil Fuel Conversion & Emission Reduction
- E2 Next Generation Solar Energy
- E3 Green Vehicles & Alternative Fuels
- E4 Efficient Energy End Use device
- E5 Advanced Fuel Cells for Non-Propulsion
- S1 High Complexity IC's
- S2 Next Gen. Semiconductor Fabrication & Process Tools
- S3 Flexible Electronics
- S4 Future Computing devices
- I1 Recognition and Interpretation Software
- I2 Smart Enterprise Computing
- I3 Networked Multi-Media
- I4 Broadband Communications
- I5 Intelligent Transportation System
- I6 Digital Home
- Me1 Ubiquitous Wireless Technologies
- Me2 Distributed Health Care Systems
- Me3 Advanced Optical Display Systems
- Me4 Sustainable Buildings
- Me5 Robotics
- Me6 Environmental & Resources Management
- Me7 Precision Machining Tools & Products

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5. FINDING OPTIMAL PORTFOLIO: Scenarios and Investment Time Horizons

Selection of optimal portfolio will also consider:

- The *robustness* under different scenarios
- The *risk tolerance* of the decision-maker for different time horizons.

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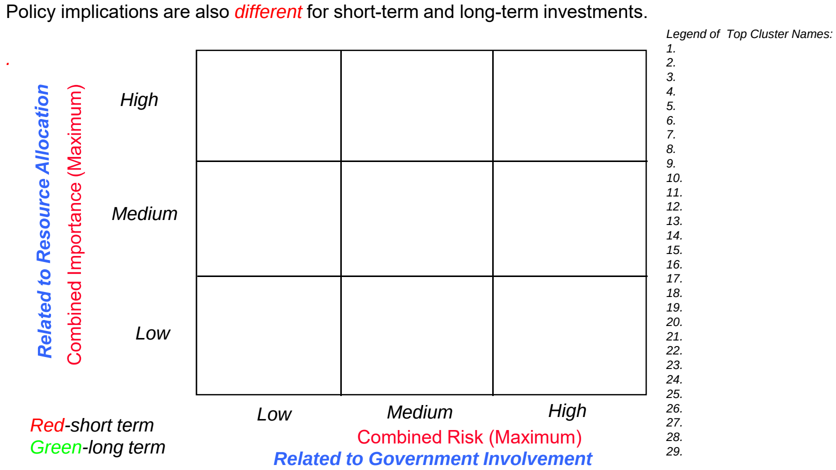
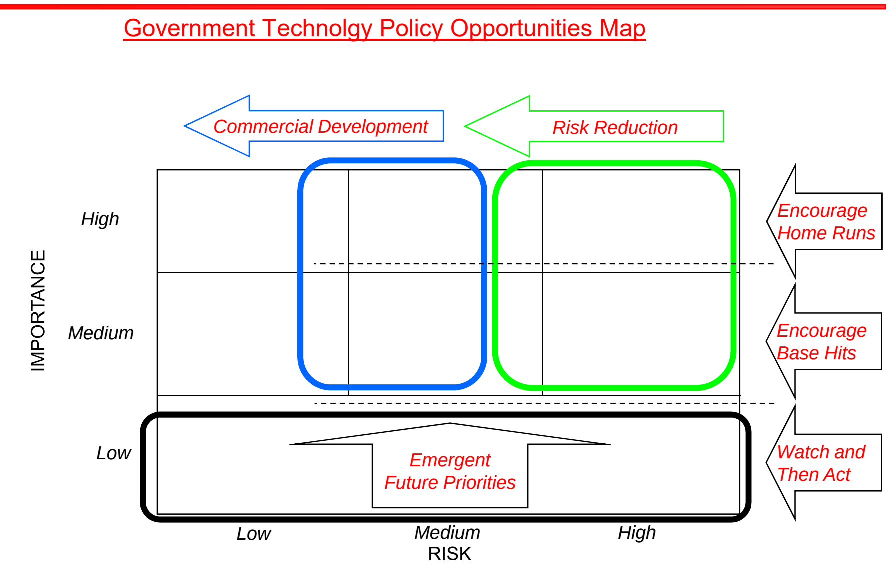
6. IMPLEMENATION POLICY IMPLICATIONS: General

The horizontal axis relates to the *degree of government involvement* needed to reduce technology development risk and promote technology commercialization.
The vertical axis relates to *level of resources* required to achieve the return from the technology development.
Policy implications are also *different* for short-term and long-term investments.



6. IMPLEMENTATION POLICY IMPLICATIONS: Government Policy Opportunities



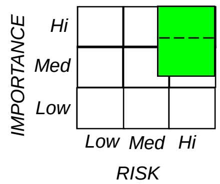
6. POLICY LEVERS: Risk Reductions for High Risk Clusters

Risk Reduction Portfolio (16 Clusters)

High Risk Clusters:

B2 Emerging Infect. Disease Management
B3 Regenerative Medicine & Well Being for Aging Population
E3 Green Vehicles & Alternative Fuels
E4 Efficient Energy End Use device
S2 Next Gen. Semiconductor Fabrication & Process Tools
i1Recognition and Interpretation Software
I2 Next generation Solar Energy
I5 Intelligent Transportation System
Me2 Distributed Health Care Systems

B1 Prevent, Predict, Personal Molec. Diagnostic
E1 Clean Fossil Fuel Conversion & Emission Reduction
E5 Advanced Fuel Cells for Non-Propulsion
M2 Smart Materials & Systems
S3 Flexible Electronics
S4 Future Computing Devices
Me6 Environmental & Resources Management



Government Technology Strategy for High Risk Clusters

	Support Innovator Vision	Support Integrator Vision

Top Impact Tech. Policy Levers:

- Recruit foreign talent
- Government Support/ sponsored R&D/ Center of Excellence / National R&D center
- International Joint Research & Cooperation
- Market Intelligence / Technology Foresight
- IP Planning & Development

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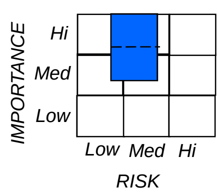
6. POLICY LEVERS: Commercialization of Medium Risk Clusters

Commercial Development Portfolio (15 Clusters)

Medium Risk Clusters:

B4 Agricultural Biotechnology
M1 Nano Materials and Systems
S1 High Complexity IC's
I3 Networked Multi-Media
I4 Broadband Communications
I6 Digital Home
Me3 Advanced Optical Display Systems
Me4 Sustainable Buildings
Me7 Precision Machining Tools & Products

M3 Materials for Advanced Energy Systems
E2 Next Generation Solar Energy
I2 Smart Enterprise Computing
I5 Intelligent Transportation System
Me1 Ubiquitous Wireless Technologies
Me5 Robotics



Government Technology Strategy for Medium Risk Clusters

	Support Innovator Vision	Support Integrator Vision

Top Impact Tech. Policy Levers:

- Infrastructure building
- Regulation/Deregulation
- Active Incubators
- Tax incentives /Tax holidays
- Promote local industry alliance
- Grant to enterprise for R&D or technology transfer

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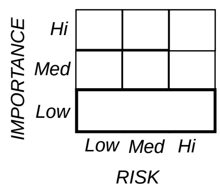
6. POLICY LEVERS: Observing and Assisting Low Importance Clusters

Emergent Opportunities Portfolio (11 Clusters)

Low Importance Clusters:
B5 Implant. & Min. Invasive Medical Devices
M5 Medical Materials
M6 Fibers
M7 Catalysts
E6 Advanced Batteries for Non-Propulsion
E7 Alternative Liquid Fuel Production
E8 Wind and Ocean Power
S5 Energy Semiconductor
S6 Trusted System
I7 Pervasive Learning
Me7 Exotic Transportation



Government Technology Strategy for Emergent Clusters

	Support Innovator Vision	Support Integrator Vision
Top Impact Tech. Policy Levers:		
- Market Intelligence / Technology Foresight		
- Public education sites/ Public awareness (K-12 Curriculum & Teacher development & Science education for public)		
- Support for small business start-ups		
- International Cooperation		
- Recruit foreign talent		

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SUMMARY

- A *systems approach* has been used to develop a step-by-step technology investment portfolio planning process that has been successfully applied to large corporations and government agencies around the world.
- Major advantages of the process includes:
  - *Systematic and transparent* approach.
  - *Holistic* approach to understand values of the decision-maker.
  - *Expert-based* identification and formation of alternative technology clusters and portfolios.
  - *Scenario-based* assessment of the uncertain relationships between alternative portfolios and values.
  - Use of *simple management tools* for strategic insights.
  - *Modern portfolio theory-based* selection of the optimal portfolio.
- Potential future extensions include *simplified* processes for
  - VC investment planning and due diligence analysis
  - Personal technology purchase planning.
- Constructive criticism and suggested improvements will be greatly appreciated.

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Thank you very much for your attention!

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A SYSTEMATIC PLANNING PROCESS

1. Societal/Organizational Values

⇩

2. Major Technology Portfolio Alternatives

⇩

3a. Global/regional Mega-Trends

3b. Uncertainty Analysis and Scenarios Development for Relationships between Alternatives and Values

⇩

4. Factor analysis and Strategy Map Assessment by Major Stakeholders and Experts for Strategic Insights

⇩

5. Optimal Technology Portfolios

⇩

6. Implementation Policy Implications for Plan Execution