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.
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*

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**TECHNOLOGY 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*.
1. UNDERSTAND AND DETERMINE VALUES BASED ON HUMAN NEEDS: The Traditional Approach

- **Physiological**
  - breathing, food, water, sex, sleep, homeostasis, excretion
- **Safety**
  - security of body, of employment, of resources, of morality, of the family, of health, of property
- **Love/Belonging**
  - friendship, family, sexual intimacy
- **Esteem**
  - self-esteem, confidence, achievement, respect of others, respect by others
- **Self-actualization**
  - morality, creativity, spontaneity, problem solving, lack of prejudice, acceptance of facts

1. UNDERSTAND AND DETERMINE VALUES BASED ON HUMAN NEEDS: A Holistic Approach

- **Psychological**
  - Growth and Meaning
- **Emotional Security**
- **Physical Security**
- **Physical Stimulation**
- **Stimulation and Growth**
- **High Resource Availability**
- **Low Resource Availability**
1. UNDERSTAND AND DETERMINE VALUES:
The Holistic Approach for Individuals

- Spiritual
- Intellectual & Creative Pursuits
- Comfort
- Substitute
- Affinity
- Entertainment & Recreation
- Gourmet Food & Sex
- Power & Control
- Ego Protection

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

- Social Responsibility
- Organizational Expansion
- Financial Survival
- Market Dominance
- Safety and Security
- Physical
- Psychological
- Social
- Intellectual & Emotional Resource Availability

Increasing Financial & Intellectual Resource Availability
1. UNDERSTAND AND DETERMINE VALUES:
The Holistic Approach for a Society

- **Social Equity and Harmony**
- **Economic Stability and Growth**
- **Quality of Life and Innovation**
- **Increasing Financial, Educational, and Social Resources**

1. UNDERSTAND AND DETERMINE VALUES:
Application for a Small Asian Country

- **Social Equity and Harmony**: 25%
- **Economic Stability and Growth**: 50%
- **Quality of Life and Innovation**: 25%
- **Political Security and Dominance**: 0%
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

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.
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

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.
3. FORECASTING RELATIONSHIPS:
Traditional Methods All Assumption-based

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

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.
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.

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
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

Diagram showing the iterative steps:

- a. Establish Decision Focus
- b. Identify Key Decision Factors
- c. Search for Major External Forces/Drivers
- d. Create Axes of Uncertainty
- e. Develop Scenarios: Envelope of Uncertainty
- f. Assess Decision Implications
- g. Revise Focus and Factors
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 the 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 our 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.

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

<table>
<thead>
<tr>
<th>Degree of Uncertainty</th>
<th>Key forces of uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level of Impact</th>
<th>Key components development</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Killer applications</td>
</tr>
<tr>
<td></td>
<td>Market size of hardware and software</td>
</tr>
<tr>
<td></td>
<td>Market size of entertainment applications</td>
</tr>
<tr>
<td></td>
<td>Meme products</td>
</tr>
<tr>
<td></td>
<td>Patents as a turning point</td>
</tr>
<tr>
<td></td>
<td>Profitability of players</td>
</tr>
<tr>
<td>Medium</td>
<td>Interest of venture capitalists</td>
</tr>
<tr>
<td></td>
<td>Megatrends that provide a foundation for all scenarios</td>
</tr>
<tr>
<td></td>
<td>Investments in US/Europe/Japan</td>
</tr>
<tr>
<td></td>
<td>Taiwan political situation</td>
</tr>
<tr>
<td></td>
<td>Japan, Singapore and other Asian country policies and actions</td>
</tr>
<tr>
<td></td>
<td>Standards</td>
</tr>
<tr>
<td></td>
<td>Interest of content providers</td>
</tr>
<tr>
<td></td>
<td>Taiwan System integration abilities</td>
</tr>
<tr>
<td>Low</td>
<td>Commercial time-frame</td>
</tr>
<tr>
<td></td>
<td>VR research in US/Europe/Japan</td>
</tr>
<tr>
<td></td>
<td>Taiwan political situation</td>
</tr>
<tr>
<td></td>
<td>Japan, Singapore and other Asian country policies and actions</td>
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<td></td>
<td>Interest of content providers</td>
</tr>
<tr>
<td></td>
<td>Taiwan System integration abilities</td>
</tr>
</tbody>
</table>
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

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

**Virtual Reality Industry Structure Axis**

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combative</td>
<td>* Low investment mainly from corporations</td>
</tr>
<tr>
<td>Fragmented</td>
<td>* Protective structure with high market barriers</td>
</tr>
<tr>
<td></td>
<td>* Limited access to opportunities</td>
</tr>
<tr>
<td>Cooperative</td>
<td>* Heavy investments and many from venture capitalists</td>
</tr>
<tr>
<td>Integrated</td>
<td>* Open structure with international cooperation</td>
</tr>
<tr>
<td></td>
<td>* Full access to opportunities and many small companies have major successes</td>
</tr>
</tbody>
</table>

**Technology Evolution Axis**

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stuck/Disjointed</td>
<td>* Fragmented development</td>
</tr>
<tr>
<td></td>
<td>* No standards</td>
</tr>
<tr>
<td></td>
<td>* Disjoint development</td>
</tr>
<tr>
<td></td>
<td>* Dominance by component manufacturers and patent barriers</td>
</tr>
<tr>
<td>Breakthrough</td>
<td>* Coordinated development</td>
</tr>
<tr>
<td></td>
<td>* Standards achieved</td>
</tr>
<tr>
<td></td>
<td>* System integration works</td>
</tr>
<tr>
<td></td>
<td>* Easy access to technology</td>
</tr>
</tbody>
</table>
3. PLANNING SCENARIO DEVELOPMENT: e. Candidate Scenarios

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

<table>
<thead>
<tr>
<th>Candidate Scenario</th>
<th>Uncertainty Axes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Industry Structure</td>
</tr>
<tr>
<td>1</td>
<td>Combative</td>
</tr>
<tr>
<td>2</td>
<td>Fragmented</td>
</tr>
<tr>
<td>3</td>
<td>C/F</td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Cooperative</td>
</tr>
<tr>
<td>15</td>
<td>Integrated</td>
</tr>
<tr>
<td>16</td>
<td>C/I</td>
</tr>
</tbody>
</table>

...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:  
\textit{f. Final Scenarios}

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

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Uncertainty Axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5) Life in Hell</td>
<td>Combative Fragmented</td>
</tr>
<tr>
<td>(12) Left Behind</td>
<td>Cooperative Integrated</td>
</tr>
<tr>
<td>(14) Waiting for Technology</td>
<td>Cooperative Integrated</td>
</tr>
<tr>
<td>Spring</td>
<td></td>
</tr>
</tbody>
</table>

4a. STRATEGIC INSIGHTS BY FACTOR ANALYSIS:  
\textit{Factor Selection}

Select a set of important attributes of an alternative as \textit{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

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
### 6a. FACTOR ANALYSIS:
Factor Measures (example)

The following are some typical factor measures:

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

### 4a. STRATEGIC INSIGHTS BY FACTOR ANALYSIS:
Graphical Representation

The graphical representation illustrates the strategic insights derived from factor analysis, with axes for Technology Availability, Current Technology Position, Inverse Risks, Commercial Timing, Commercial Value, and Strategic Importance of the Technology.
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

- **Competitive Technology Position**
  - **Strategic Importance**
    - High
    - Medium
    - Low
  - **Risks**
    - Low
    - Medium
    - High

- **Target for Technology Investment**
  - Exploit strong position; continue internal effort
  - Reallocate resources
    - (Possible exceptions: low-risk niches; limited effort, Check for high commercial value)

- **Resources**
  - Obtain via license, JV or external R&D — or build position — check urgency, risk, availability, and commercial value

- **Actions**
  - "Gold mines" — attack
  - "Home runs" — have a few
  - "Bunts" — have a few; check urgency, commercial value, and availability

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

- **Competitive Technology Position**
  - **Strategic Importance**
    - High
    - Medium
    - Low
  - **Risks**
    - Low
    - Medium
    - High

- **Target for Technology Investment**
  - "Gold mines" — attack
  - "Home runs" — have a few

- **Actions**
  - Prove or redirect
  - Reallocate resources
    - "Bunts" — have a few; check urgency, commercial value, and availability

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

Conduct internal R&D, if important

“Question marks” — examine importance, urgency, commercial value, and risk

License or obtain via joint venture — examine strategic importance and commercial value to see if it's wise to build internal position

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

Screen No. 1

Scenario Key*

= Scenario A
= Scenario B
= Scenario C

*Numbers refer to technology clusters

Reduce emphasis and reallocate resources unless high commercial value

Explicit strong technology position

“Question marks”, build position or license

External emphasis candidates

Strategic Importance

Competitive Technology Position

Technology Availability

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

**Screen No. 2**

<table>
<thead>
<tr>
<th>STRATEGIC IMPORTANCE</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMMERCIAL VALUE</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Scenario Key**
- △ = Scenario A
- ○ = Scenario B
- ◊ = Scenario C

*Numbers refer to technology clusters

"Question marks" assess opportunity cost and reposition or exploit value as enabler or interim technology
"Gold Mine"

**Scenario Key**
- △ = Scenario A
- ○ = Scenario B
- ◊ = Scenario C

*Numbers refer to technology clusters

Reallocate resources

Potentially gold mines: exploit, check risk, and position

Determine potential sources of competitive advantage and reposition, check risk and availability

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

<table>
<thead>
<tr>
<th>Technology Cluster</th>
<th>Scenario A</th>
<th>Scenario B</th>
<th>Scenario C</th>
<th>Overall Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MH</td>
<td>MM</td>
<td>MH</td>
<td>MH</td>
</tr>
<tr>
<td>2</td>
<td>HL</td>
<td>LH</td>
<td>MH</td>
<td>MM</td>
</tr>
<tr>
<td>3</td>
<td>LM</td>
<td>LM</td>
<td>LM</td>
<td>LM</td>
</tr>
<tr>
<td>4</td>
<td>MH</td>
<td>ML</td>
<td>LH</td>
<td>ML</td>
</tr>
<tr>
<td>Etc</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Portfolio</td>
<td>MM</td>
<td>LH</td>
<td>ML</td>
<td>ML</td>
</tr>
</tbody>
</table>

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

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

Top Clusters:
- B1 Prevent, Predict, Personal Molec. Diagnostics
- 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 ICs
- 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 & Resource Management
- Me7 Precision Machining Tools & Products

5. FINDING THE OPTIMAL PORTFOLIO: Modern Portfolio Theory

![Risk-Return Curves of Various Portfolios of Three Technology Investments](image-url)
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.

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 Molecular 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 ICs
- S2 Next Gen. Semiconductor Fabrication & Process Tools
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- I5 Intelligent Transportation System
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- Me1 Ubiquitous Wireless Technologies
- Me2 Distributed Health Care Systems
- Me3 Advanced Optical Display Systems
- Me4 Sustainable Buildings
- Me5 Robotics
- Me6 Environment & Resource Management
- Me7 Precision Machining Tools & Products
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.

Selection of optimal portfolio will also consider:

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

Legend of Top Cluster Names:
1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29.

Red-short term
Green-long term

Combined Risk (Maximum)
Related to Government Involvement

6. IMPLEMENTATION POLICY IMPLICATIONS:
Government Policy Opportunities

Government Technology Policy Opportunities Map

High
Medium
Low

High
Medium
Low

Commercial Development
Risk Reduction

Encourage Home Runs
Encourage Base Hits
Watch and Then Act

Emergent Future Priorities

Low Medium High

Low

RISK

IMPORTANCE

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6. POLICY LEVERS: Risk Reductions for High Risk 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 devices
- S2 Next Gen. Semiconductor Fabrication & Process Tools
- I7 Recognition and Interpretation Software
- I2 Next generation Solar Energy
- I5 Intelligent Transportation System
- M2 Distributed Health Care Systems
- B1 Prevent, Preheat, Personal Medical Diagnostic
- E5 Advanced Fuel Cells for Non-Propulsion
- M6 Smart Materials & Systems
- S3 Flexible Electronics
- S1 Advanced Optical Display Systems

Risk Reduction Portfolio (16 Clusters)

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

6. POLICY LEVERS: Commercialization of Medium Risk Clusters

Medium Risk Clusters:
- B4 Agricultural Biotechnology
- M1 Nano Materials and Systems
- S1 High Complexity IC's
- I8 Networked Multi-Media
- H Broadband Communications
- M5 Advanced Optical Display Systems
- M6 Sustainable Buildings
- M7 Precise Manufacturing Tools & Products
- M3 Materials for Advanced Energy Systems
- E2 Next Generation Solar Energy
- I1 Smart Enterprise Computing
- I3 Intelligent Transportation System
- M8 Unmanned Aerial Vehicles
- M9 Robotics

Commercial Development Portfolio (15 Clusters)

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
6. POLICY LEVERS: Observing and Assisting Low Importance Clusters

Emergent Opportunities Portfolio (11 Clusters)

<table>
<thead>
<tr>
<th>Low Importance Clusters:</th>
</tr>
</thead>
<tbody>
<tr>
<td>B5 Implant &amp; Min. Invasive Medical Devices</td>
</tr>
<tr>
<td>M5 Medical Materials</td>
</tr>
<tr>
<td>M6 Fibers</td>
</tr>
<tr>
<td>M7 Catalysts</td>
</tr>
<tr>
<td>E6 Advanced Batteries for Non-Propulsion</td>
</tr>
<tr>
<td>E7 Alternative Liquid Fuel Production</td>
</tr>
<tr>
<td>E8 Wind and Ocean Power</td>
</tr>
<tr>
<td>S5 Energy Semiconductor</td>
</tr>
<tr>
<td>S6 Trusted System</td>
</tr>
<tr>
<td>I7 Pervasive Learning</td>
</tr>
<tr>
<td>M7 Exotic Transportation</td>
</tr>
</tbody>
</table>

Government Technology Strategy for Emergent Clusters

<table>
<thead>
<tr>
<th>Support</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovator Vision</td>
<td>Integrator Vision</td>
</tr>
</tbody>
</table>

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

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!
A SYSTEMATIC PLANNING PROCESS

1. Societal/Organizational Values
2. Major Technology Portfolio Alternatives
3. Global/regional Mega-Trends
   - Uncertainty Analysis and Scenario 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

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