Addis Ababa University
New Mexico State University
in collaboration with the
Metal Engineering Corporation

Systems Engineering Initiative

July 15, 2013
Purpose of the Systems Engineering Initiative...

Using the *Systems Engineering Process*, demonstrate the development of a Policy Portfolio that has the potential to significantly enhance the quality of life of the citizenry of Ethiopia.
Qualitative Architecture...

Policy Options

Non-Anthropogenically Induced "Stress"

Quality of Life

Anthropogenically Induced "Stress"
The Classical Systems Engineering Process…

Stage I ~ *Define* the Problem
Stage II ~ *Design* the System Solution.
Stage III ~ *Develop and Build* the Integrated System.
Stage IV ~ *Produce and Release* the System.
Stage V ~ *Support Post-Release Life-Cycle Management* of the System.
The Classical Systems Engineering Process...

Stage I ~ Define the Problem.
   Identify the need.
   Develop and verify\(^1\) requirements.
   State the problem.
Stage II ~ Design the System Solution.
   Identify alternative concepts [this can be goods (eg. software, hardware, or both) as well as services].
   Conduct basic and applied science and engineering research to explore the concepts.
   Develop and test a preliminary model\(^2\) of the system\(^3\).
   Choose the concept to develop into a system solution including post-release life-cycle management.
Stage III ~ Develop and Build the Integrated System.
   Develop and test a final model of the system.
   Construct and test a prototype of the system.
      Integrate the components.
      Verify with the customer.
      Secure authorization\(^4\) to test the system.
      Assess system performance.
   Test, refine, and validate the prototype.

---

1 Verification is carefully vetting requirements with the customer.
2 The model can be either numerical or physical or both.
3 A system is a set of entities, real or abstract, comprising a whole where each entity interacts with at least one other entity and collectively they serve a common objective.
4 Ensure due diligence on proceeding by securing authorization from the appropriate level.
The Classical Systems Engineering Process (Cont’d)...

Stage IV ~ *Produce and Release* the System.
- Secure authorization to create and deploy the system.
- Create a deployable system.
- Assess performance.
- Develop the logistics of delivering the system to the end-user(s).
- Deploy the system.

Stage V ~ *Support Post-Release Life-Cycle Management* of the System.
- Develop and implement a plan for ensuring system operations that satisfy requirements.
- Provide system support as per system requirements.
- Develop and implement a plan for ensuring appropriate end-of-life disposition of the system and associated programmatic infrastructure.
- Assess performance.
Define

Design

Develop And Build

Test

Produce and Release

Manage

Abort System

Post-Release Support

Engineering Stages and Associated Dynamics
During all phases of the engineering project...

- Use physical and computational simulation to understand the design and performance of the product.  
  - Don’t forget the Janus faced perspectives of reductionism and reverse-reductionism

- Identify project documentation and records and ensure they are adequately controlled and maintained.

- Identify and apply lessons learned and feedback.

- It is recognized that engineering projects may move fluidly in and among all stages.

- An engineering process should be defined for each project.

- It is important that this process be appropriate for the project's deliverables, constraints, scope and complexity.
The SEI has been designed to address the first two stages; i.e…

Stage I ~ *Define* the Problem.
- Identify the need.
- Develop and verify requirements.
- State the problem.

Stage II ~ *Design* the System Solution.
- Identify alternative concepts [this can be *goods* (eg. software, hardware, or both) as well as *services*].
- Conduct basic and applied science and engineering research to explore the concepts.
- Develop and test a preliminary model of the system.
- Choose the concept to develop into a system solution including post-release life-cycle management.
The Methodological Approach

- Stage I ~ Define the Problem.
  - This will be the focus of the Vital Issues Panels (VIP)

- Stage II ~ Design the System Solution.
  - This will be the explored via modeling and analysis (M&A) of the case study in the Systems Engineering survey class.

VIP → M&A
Modeling and Analysis Methods to be Explored…

• Dynamic Simulation
  – System Dynamics
  – Monte-Carlo/Discrete-Event Simulation
  – Agent-Based Simulation

• Decision Making
  – Decision Theory
  – Game Theory
  – Social Movement Theory
Feedback from you…

• Introduce yourself.
• What is your educational background?
• What is your current professional position and responsibilities?
• What are your specific expectations of this course?

...please provide a response that is 30 seconds in duration.
What is the Vital Issues Process???

• The Vital Issues Process (VIP) is a strategic planning tool that identifies a portfolio of programmatic activities for an organization, aimed at satisfying its overall goals and objectives.

• The VIP is typically a multi-stage process, involving a series of daylong, intensive workshops, each of which builds on the results of the previous.

• The first workshop focuses on definitions, identifying target goals and objectives, describing the type of issues or topical areas addressed by the sponsoring organization, and identifying criteria for issue or problem selection.

• The following workshop(s) uses the selection criteria and the definition of the topical area or problem to identify and rank a set of vital issues.
Characteristics of the Vital Issues Process...

- Stakeholder driven
- Cost effective
- Qualitative (synthesis) & quantitative (analysis)
- Produces measures for both prioritization of issues and level of agreement
- The VIP has been applied in over 80 applications during the past 20 years
Stakeholder Template...

- Government
  - Branch
    - Legislative
    - Executive
  - Level
    - Local
    - State
    - Federal

- Private Sector
- Academe
- Citizens’ Interest Groups
Initial, draft Policy Objective...

A portfolio of policy options that has the potential to significantly enhance the quality of life of the citizens of Ethiopia.
Initial collection of Quality of Life Dimensions…

- Human Health
- Cultural Heritage Preservation
- Human Rights
- Economic Well-Being
- Environmental Quality
- Availability of Services
- Confidence in Government
Initial collection of Quality of Life Dimensions and Associated Measures...

- Human Health
  - Life expectancy at birth
- Cultural Heritage Preservation
  - Risk to both physical and intangible cultural resources
- Human Rights
  - Equal access to education for all
- Economic Well-Being
  - GDP per capita
- Environmental Quality
  - Air quality indices
- Availability of Services
  - Accessibility of water resources
- Confidence in Government
  - Public perception of the ability of government to provide for their security

...associated measures/criteria will be used to assess relative importance of the Vital Issues.
The Quantification Process...

- Point
- CounterPoint
- Panel Arguments
- Score

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Likelihood</th>
<th>Magnitude</th>
<th>Time Frame</th>
<th>DOE Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Likelihood</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Magnitude</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Time Frame</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Robustness</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Feasibility</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>
Assignments...

- **Individual Dimensions**
  - Lead: Champion
  - Lead: CounterPoint

- **Collection of Dimensions**
  - Lead: Champion
  - Lead: CounterPoint
Meta Criteria...

• For individual criteria:
  – **Necessary**...elimination of this criterion from the list would allow some important aspect of the associated goal to go unrecognized.
  – **Operational**... this criterion can be used by the next panel to assess the relative importance of vital issues.

• For the collection of criteria:
  – **Sufficient**...this collection of criteria recognizes all important aspects with regard to determining the issues that are vital to addressing the goal.
  – **Orthogonality**...this collection of criteria is nonredundant.
In preparing your arguments, to ensure operationality, use the SMART guidelines for the measures for each criterion…

• Specific
• Measurable
• Actionable
• Realizable
• Time-Driven
**Assessment Matrix…**

Legend:
1 ~ row is *much less important* than column
2 ~ row is *less important* than column
3 ~ row has the *same importance* as the column
4 ~ row is *more important* than column
5 ~ row is *much more important* than column

<table>
<thead>
<tr>
<th>Rows</th>
<th>Measure 1</th>
<th>Measure 2</th>
<th>…</th>
<th>Measure N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure 1</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Measure 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>…</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measure N</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

E.g., measure 1 is more important than measure 2.
Addis Ababa University
New Mexico State University
in collaboration with the
Metal Engineering Corporation

Systems Engineering Initiative

VIP₂
July 17, 2013
Purpose of the SEI...

Identify and begin the analysis of a Policy Portfolio that is “quality driven, rapid development at the national level through resource utilization and optimization.”
The SEI Plan...

Exemplary Policy Portfolio

VIP

Objective, Dimensions, Vital Issues

VIP

Objective, Dimensions & Vital Issues

VIP

Stage I

Policy Research

Stage II

Dynamic Simulation

MCS → SD → ABM

Modeling and Analysis

GT → DT → SMT

Decision Making

Initial Policy Options

Objective

Dimensions

VIP

VIP

VIP

Exemplary Policy Portfolio
Qualitative Architecture...

Non-Anthropogenically Induced “Stress”

Policy Options

Quality of Life

Anthropogenically Induced “Stress”
End Result…

A consistent, non-conflicting, synergistic composite Policy Portfolio addressing issues that are vital to Ethiopia

<table>
<thead>
<tr>
<th></th>
<th>Issue 1</th>
<th>Issue 2</th>
<th>• •</th>
<th>Issue M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiscal Incentives</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Info, Education, Outreach</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technology Development</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inter/Intra Government Relations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enforcement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stage II Product

Stage III Product

Composite of Issues
Final Policy Objective...

To achieve quality-driven, rapid development at the national level through resource utilization and optimization.

...developed during VIP₁ on July 15, 2013
Final collection of Quality of Life Dimensions…

1 Human Health
2 Confidence in Government
2 Economic Well-Being
2 Availability of Services
5 Human Rights
6 Cultural Heritage Preservation

…developed during VIP on July 15, 2013
VIP\(_1\) Results for Scoring of QoL Dimensions…

- **Human Health**: 3.8
- **Human Rights**: 2.8
- **Cultural Heritage Preservation**: 2.4
- **Confidence in Government**: 3.1
- **Availability of Services**: 3.0
- **Economic Well Being**: 3.0

Relative Importance

Most Important

Least Important

Hypothetical Average
Description of the QoL Dimensions…

1 Human Health
2 Confidence in Government
2 Economic Well-Being
2 Availability of Services
5 Human Rights
6 Cultural Heritage Preservation

…provided by the original Champions.
What is a Vital Issue???

An Ethiopian Vital Issue is a significant problem or concern the resolution of which is essential to achieve quality-driven, rapid development at the national level through resource utilization and optimization.
Hypothetical Vital Issues…

- Insufficient number of trained health care professionals per capita
- Inadequate manufacturing base
- Excessive inflation
- Inequitable distribution of wealth
- Inadequate supply of electrical power
Meta Criteria...

• For individual issues:
  – *Necessary*...elimination of this issue from the list would allow some important aspect of the overall goal to go unrecognized.
  – *Operational*... this issue can be resolved with appropriate policies.

• For the collection of issues:
  – *Sufficient*...this collection of issues reflects the most pressing concerns of the citizenry of Ethiopia.
  – *Nonredundancy*...each issue in this collection of issues represents a concern that is fundamentally different from the others in the collection.
In preparing your arguments, to ensure operationality, use the SMART guidelines for the measures for each criterion…

- Specific
- Measurable
- Actionable
- Realizable
- Time-Driven
The Quantification Process...

Point → CounterPoint → Panel Arguments → Score

Criteria
- Likelihood
- Magnitude
- Time Frame
- Robustness
- Feasibility

Likelihood:
- 2
- 3
- 4
- 4

Magnitude:
- 4
- 5
- 5
- 5

Time Frame:
- 3
- 2
- 4
- 5

Robustness:
- 2
- 1
- 1
- 3

Feasibility:
- 2
- 1
- 1
- 3
### Point/Counter-Point Guidelines...

#### Vital Issues

<table>
<thead>
<tr>
<th></th>
<th>HH</th>
<th>CiG</th>
<th>AoS</th>
<th>EWB</th>
<th>HR</th>
<th>CHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Issue 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Issue N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### QoL Dimensions

**Guidelines...**

**Champions:** Ensure that you have highlighted how the resolution of your VI will result in substantive improvements in the QoL dimensions.

**CounterPointers:** Look for impacts of resolutions for this VI that have the potential to result in a degradation in one or more of the QoL dimensions.

**Panelists:** Take notes throughout the Point/Counter-Point arguments to help you with your scoring decisions.
Assessment Matrix...

<table>
<thead>
<tr>
<th></th>
<th>Issue 1</th>
<th>Issue 2</th>
<th>...</th>
<th>Issue N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issue 1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Issue 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Issue N</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
1 ~ row is **much less important** than column
2 ~ row is **less important** than column
3 ~ row has the **same importance** as the column
4 ~ row is **more important** than column
5 ~ row is **much more important** than column

e.g., issue 1 is much less important than issue 2.
### Assessment Matrix

<table>
<thead>
<tr>
<th>Issues</th>
<th>QE</th>
<th>SU</th>
<th>LA</th>
<th>BD</th>
</tr>
</thead>
<tbody>
<tr>
<td>QE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SU</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Discussion for Friday, July 19, 2013

• What is your Vital Issue? This should be stated very concisely and clearly. It should be stated so that most lay people can understand it.

• What are the measures that you believe will provide a means to determine if progress is being made. These measures should be closely related to one or more of the six dimensions of Quality of Life.

• What is the time frame for observing significant progress toward the resolution of your Vital Issue?
Discussion for Friday, July 19, 2013 (cont’d)

• What are policy options that are currently in place that have some impact on your Vital Issue? What are impacts of these existing policy options on the attainment of the overall objective that we defined for this initiative; i.e. “To achieve quality-driven, rapid development at the national level through resource utilization and optimization.” These impacts should be stated in terms of one or more of the six QoL dimensions.

• Describe if you would…
  – Eliminate any of the existing policies (if so then why)
  – Modify any of the existing policies (if so then how)
  – Add any new policies (if so then what)???
**End Result…**

A consistent, non-conflicting, synergistic composite Policy Portfolio addressing issues that are vital to Ethiopia

<table>
<thead>
<tr>
<th>Regulations</th>
<th>Issue 1</th>
<th>Issue 2</th>
<th>• •</th>
<th>Issue M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiscal Incentives</td>
<td>• •</td>
<td>• •</td>
<td>• •</td>
<td>• •</td>
</tr>
<tr>
<td>Info, Education, Outreach</td>
<td>• •</td>
<td>• •</td>
<td>• •</td>
<td>• •</td>
</tr>
<tr>
<td>Technology Development</td>
<td>• •</td>
<td>• •</td>
<td>• •</td>
<td>• •</td>
</tr>
<tr>
<td>Inter/Intra Government Relations</td>
<td>• •</td>
<td>• •</td>
<td>• •</td>
<td>• •</td>
</tr>
<tr>
<td>Enforcement</td>
<td>• •</td>
<td>• •</td>
<td>• •</td>
<td>• •</td>
</tr>
</tbody>
</table>

Stage II Product

Stage III Product

Composite of Issues
AnyLogic
Addis Ababa University
New Mexico State University
in collaboration with the
Metal Engineering Corporation

Systems Engineering Initiative

VIP$_3$
July 19, 2013
The SEI has been designed to address the first two stages; i.e…

Stage I ~ *Define* the Problem.
- Identify the need.
- Develop and verify requirements.
- State the problem.

Stage II ~ *Design* the System Solution.
- Identify alternative concepts [this can be *goods* (eg. software, hardware, or both) as well as *services*].
- Conduct basic and applied science and engineering research to explore the concepts.
- Develop and test a preliminary model of the system.
- Choose the concept to develop into a system solution including post-release life-cycle management.
SEI VIP 2 & VIP 3 Panelists
Purpose of the SEI...

Identify and begin the analysis of a Policy Portfolio that is “quality driven, rapid development at the national level through resource utilization and optimization.”

...defined during VIP₁, July 15, 2013
The Classical Systems Engineering Process...

Stage I ~ *Define* the Problem
Stage II ~ *Design* the System Solution.
Stage III ~ *Develop and Build* the Integrated System.
Stage IV ~ *Produce and Release* the System.
Stage V ~ *Support Post-Release Life-Cycle Management* of the System.
The Need...

To achieve quality-driven, rapid development at the national level through resource utilization and optimization.

…developed during VIP₁ on July 15, 2013
Final collection of Quality of Life Dimensions...

- Human Health
- Confidence in Government
- Economic Well-Being
- Availability of Services
- Human Rights
- Cultural Heritage Preservation

...developed during VIP₁ on July 15, 2013
Ordinal Ranking of Quality of Life Dimensions…

1 Human Health
2 Confidence in Government
2 Economic Well-Being
2 Availability of Services
5 Human Rights
6 Cultural Heritage Preservation

…determined during VIP₁ on July 15, 2013
Results for Scoring of QoL Dimensions…

Most Important

Human Health (3.8)

Human Rights (2.8)

Cultural Heritage Preservation (2.4)

Confidence in Government (3.1)

Availability of Services (3.0)

Economic Well Being (3.0)

Relative Importance

Least Important

Hypothetical Average

…assessed during VIP₁, July 15, 2013
The Vital Issues…

• The *Brain Drain* in certain critical areas is too great to support sustainable development.
• *Sustainable business startups* are inadequate to absorb (engage) the Ethiopian youth.
• *Agricultural productivity* is inadequate in both quantity and quality.
• The locally instituted *quality of education* at all levels is insufficient to provide for the needs of the students.

…defined during VIP₂, July 17, 2013
## Dominant Vital Issues per Quality of Life Dimension...

<table>
<thead>
<tr>
<th>Dominance:</th>
<th>HH</th>
<th>HR</th>
<th>CHP</th>
<th>AoS</th>
<th>CiG</th>
<th>EWB</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weak</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Brain Drain**
- **Business Startups**
- **Agricultural Productivity**
- **Educational Quality**

...assessed during VIP₂, July 17, 2013
Human Health Scoring Results for Vital Issues…

- Quality Education (3.9)
- Business Startups (2.7)
- Agricultural Productivity (2.5)
- Brain Drain (2.9)

...assessed during VIP₂, July 17, 2013
Human Rights Scoring Results for Vital Issues...

...assessed during VIP, July 17, 2013
Cultural Heritage Preservation Scoring
Results for Vital Issues…

…assessed during VIP₂, July 17, 2013
Availability of Services Scoring Results for Vital Issues…

...assessed during VIP_2, July 17, 2013
Confidence in Government Scoring
Results for Vital Issues…

...assessed during VIP, July 17, 2013
Economic Well-Being Scoring Results for Vital Issues…

...assessed during VIP², July 17, 2013
Composite Scoring Results for Vital Issues…

...assessed during VIP₂, July 17, 2013
Presentations per team...

• Vital Issue
• Measures of Progress
  – Identify the QoL Dimension(s) that are impacted and describe the impact.
  – How will you quantify these impacts?

• Existing Policies
  – Regulations
  – Fiscal Incentives
  – Information, Education, & Outreach
  – Technology Development & Deployment
  – Inter Organizational Relations
  – Enforcement

• Timeframe(s) for impacts from each of the existing policies.
Examples of measures for Quality of Life Dimension…

• Human Health
  ➢ Life expectancy at birth

• Cultural Heritage Preservation
  ➢ Risk to both physical and intangible cultural resources (number of professionals engaged in CHP per capita)

• Human Rights
  ➢ Equal access to education for all (enrollment/graduation data per demographic group)

• Economic Well-Being
  ➢ GDP per capita

• Availability of Services
  ➢ Accessibility of water resources (consumption per capita per demographic group)

• Confidence in Government
  ➢ Public perception of the ability of government to provide for their security
Presentations per team (cont’d)…

• Would you
  – Eliminate any of the existing policies (if so then why)
  – Modify any of the existing policies (if so then how)
  – Add any new policies (if so then what)???

• Describe the impact(s) that your suggested changes to the policy portfolio would have
  – Always refer to the quantitative measures.
  – Always provide a time-frame
  – Always identify related costs
The SEI Plan...

Exemplary Policy Portfolio

Stage I

VIP 1

Objective
Criteria

VIP 2

Objective, Criteria & Vital Issues

VIP 3

Stage II

Dynamic Simulation

MCS

SD

ABM

Modeling and Analysis

Decision Making

Initial Policy Options

Policy Research

GT

DT

SMT
Examples of measures…

• Internal
  ➢ METEC’s rate of return on investment
  ➢ METEC’s cash flow; i.e., net income + depreciation + amortization – capital expenditures - changes in working capital

• External
  ➢ METEC’s impact on the Gross Domestic Product of Ethiopia
  ➢ METEC’s impact on vital services provided to Ethiopians such as transportation, energy, telecommunications and water
Agriculture...

- Policies
  - Technology development, deployment, and utilization
  - Information Education and Outreach
  - Value chain modeling
- Good measures (key indicators)
- Focus on export market
- Good list of existing policy options
- Good list of impacts on the QoL dimensions
  - Teamwork – CHP connection
Brain Drain…

- Gave good stats on where the brains are going
- Gave a good list of the reasons for leaving
- Great format with existing policy and proposed policy

Me: I can see a role for decision theory here. Do a sensitivity analysis on the branch probabilities as a function of varying levels of incentives.
Sustainable Business

• Good success indicators
• Need references
• Need better measures

All of the presentations more Need Graphics
Quality Education

• Good list of policies and suggestions
• Format