FAMES

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THE CLIOS PROCESS

DISPLAYS

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CLIOS System

Complex(ity)

- Structural
- Behavioral
- Nested
- Evaluative

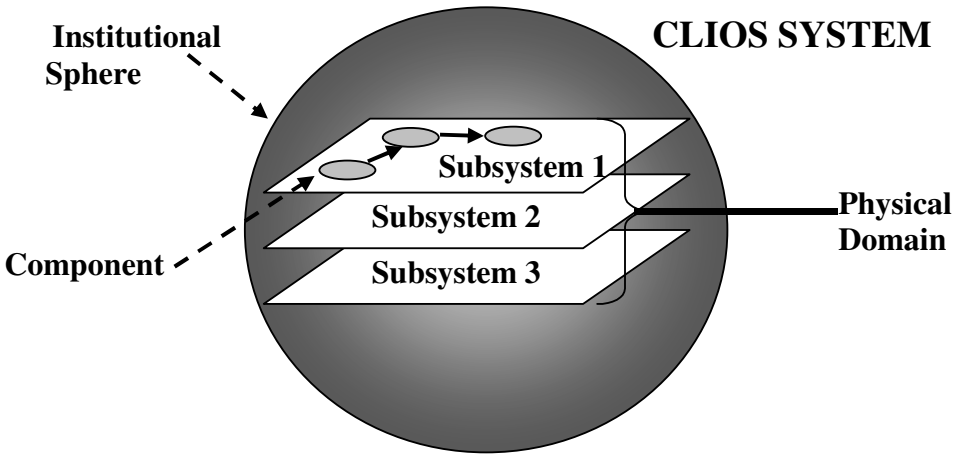
Large-scale

Interconnected

Open

Sociotechnical

The CLIOS System World View



CHARACTERIZING OUR STUDY ENVIRONMENT (1)

CLIOS Systems require interdisciplinary approach

- Huge Decision Space
- Consideration of a large set of simultaneously applied strategic alternatives of various kinds
- Development of robust and flexible bundles of strategic alternatives, recognizing the high degree of uncertainty we face
- preparing decisionmakers for recognizing different posible futures
- Explaining the findings/ recommendations to non-specialists
- Formulating strategic alternatives of value to decisionmakers

CHARACTERIZING OUR STUDY ENVIRONMENT (2)

- Understanding
  - The Science/Technology
  - The Strategic Alternatives and Their Interaction
  - The Institutional Situation
  - The Political Imperatives
- Implementation -- Instruments and Barriers
- Institutional Change as a Strategic alternative

THE
CLIOS PROCESS

THE NEED FOR A STRUCTURED METHOD FOR STUDYING COMPLEX SYSTEMS

- We need a disciplined way of studying a CLIOS System.
- Linear, yet iterative mechanism.
- It is pretty easy to miss something. Routinizing the process can help (but is not a guarantee).
- The CLIOS Process *one* (but only one) way.

KEY SYSTEMS QUESTIONS (1)

- What are the technical, economic, social and political aspects involved?
- What is the degree and nature of the interaction among components, and where are the important feedback loops?
- What is the nature and primary source of the system's complexity – is the complexity mainly internal to the technological 'artifact' or related to the social components of the system? [e.g., space program vs. the "big dig" (see Tom Hughes' *Rescuing Prometheus*)]
- What is the nature of the uncertainty of the system? When are the subsystems inherently unpredictable, and when is the uncertainty due to the interaction of the subsystems?
    - *"Uncertainty is everywhere" -- deal with it.*
- What is the scale (geographic, temporal, etc.) of the system; what is the magnitude and scope of its impacts? Is this an "important" problem?

KEY SYSTEMS QUESTIONS (2)

- What is the issue (problem)?
- What are the competing values and interests?
- Who are the stakeholders and what is their ability to change things?
- How do we negotiate a "solution" that appropriately weighs the competing interests?
- What models and frameworks are appropriate to study the issue?
- What is the process by which the system is changed?
- How does one implement the changes and make sure they work in practice?

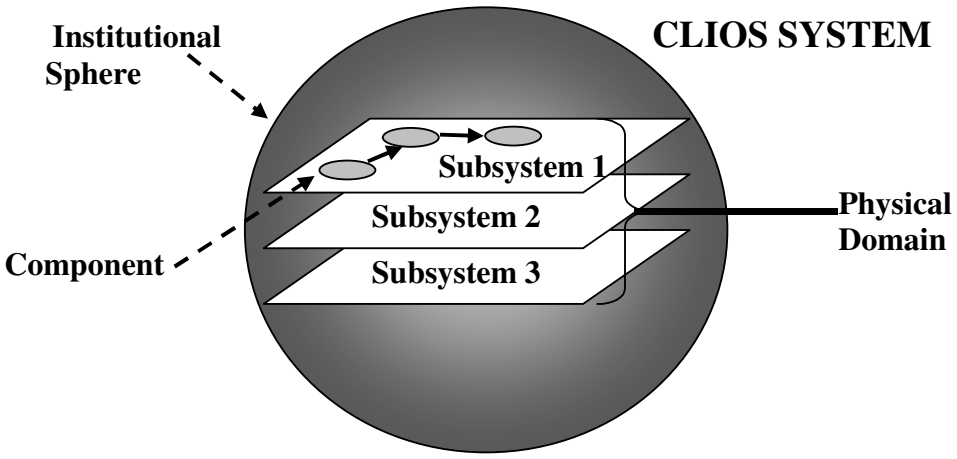
CLIOS PROCESS

- The CLIOS Process captures the key characteristics of a CLIOS System in an organized systematic manner, so as to help the analyst avoid the omission of salient factors in both its physical manifestation and its organizational/institutional manifestation.
- We make an explicit distinction between the physical system and institutional sphere*

but also

- Explicitly represent the connection between the physical domain and institutional sphere, so as to understand the sources of nested complexity.

The CLIOS System World View



CLIOS STAGE CHARACTERISTICS

Stage 1 **Representation**	Primarily Qualitative *Key Idea:* Understanding the CLIOS System Establishing Preliminary Goals
Stage 2 **Design, Evaluation, and Selection**	Both Qualitative and Quantitative Aimed at improvement of the CLIOS System *Key Idea:* Developing bundles of strategic alternatives
Stage 3 **Implementation**	Pragmatic in nature. How to implement bundles of strategic alternatives *Key Idea*: Follow-through: changing and monitoring the performance of the CLIOS System

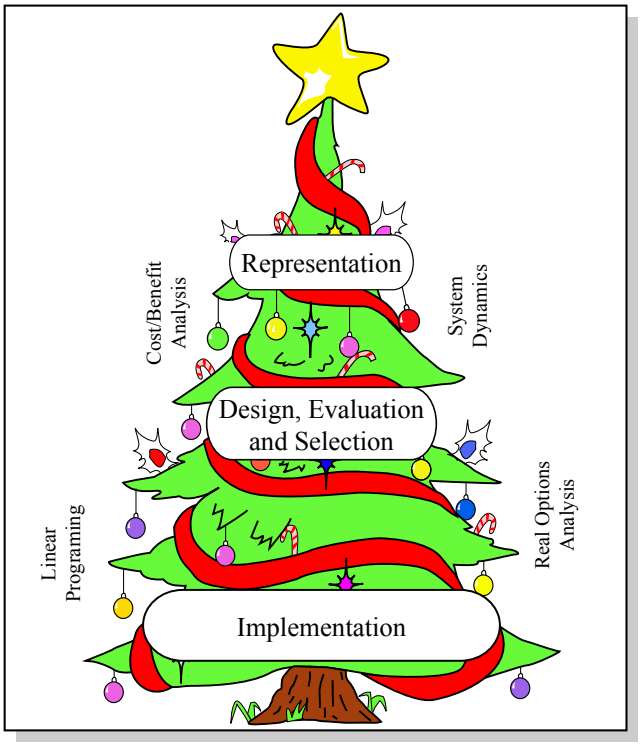


Figure by MIT OpenCourseWare.

Stage 1: Representation

- Structure
  - What are the appropriate set of subsystems to represent the physical domain?
  - How are the physical subsystems embedded in a political and institutional structure?

- Behavior
  - What is the degree and nature of the interaction between aspects of the CLIOS System?
  - Are the connections weak or strong?
  - Are there important feedback loops?
  - What insights can we gain into CLIOS System behavior?

Stage 2: Design, Evaluation and Selection

- How is performance measured for the entire CLIOS System as well as the subsystems?
- How do key stakeholders and decisionmakers' measures or rank different types of performance?
- What are the tradeoffs among the various dimensions of performance?
- How could performance be improved through strategic alternatives?

Stage 3: Implementation

- How do these performance improvements actually get implemented, if at all? What compromises have to be made in the name of implementation?
- What actors/organizations on the institutional sphere have an influence on the parts of the CLIOS system targeted for intervention?
- Do the types of actions by different actors on the institutional sphere reinforce or counter each other?
- Under the current institutional structure, can organizations manage the system to achieve reasonable performance levels?

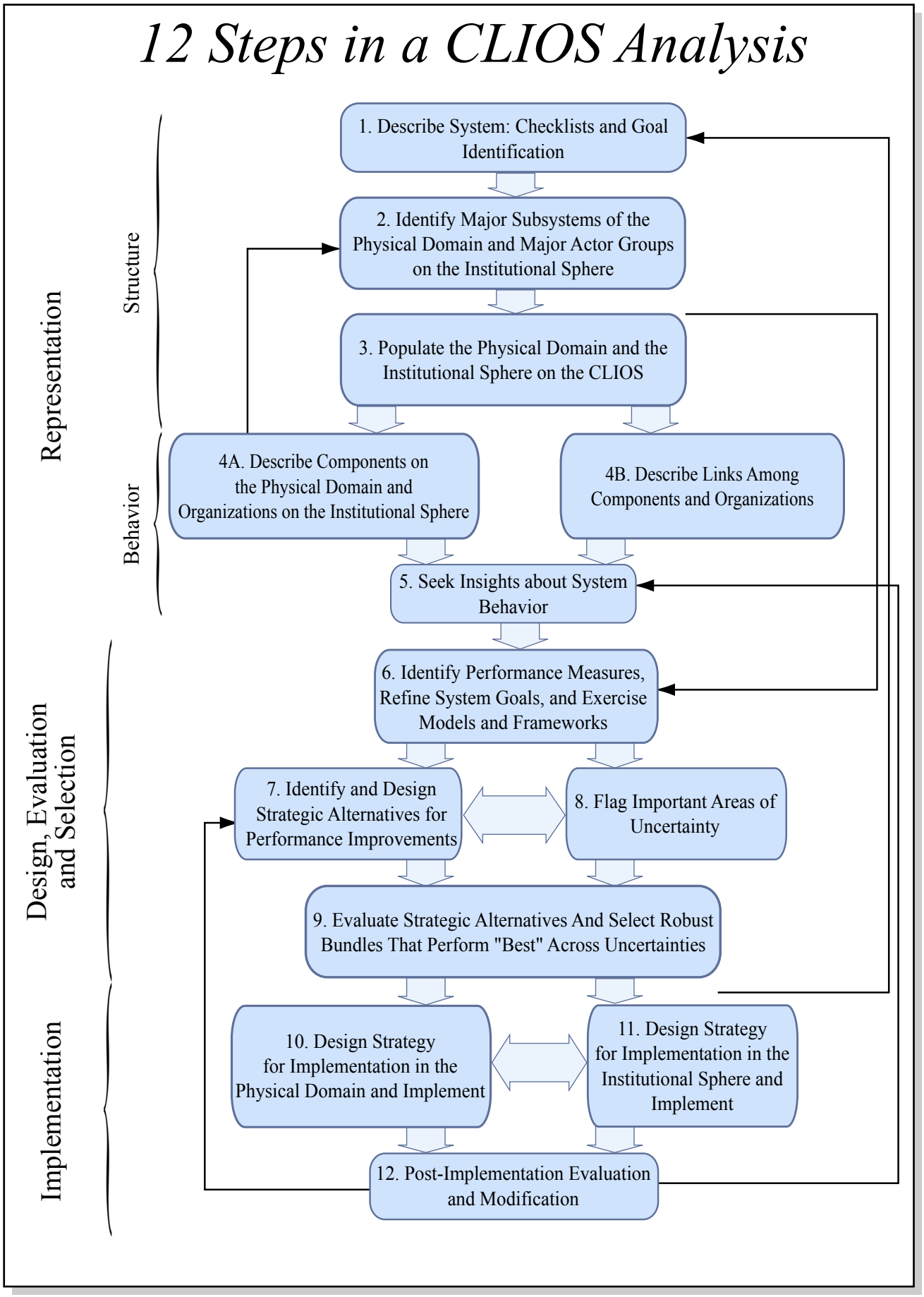
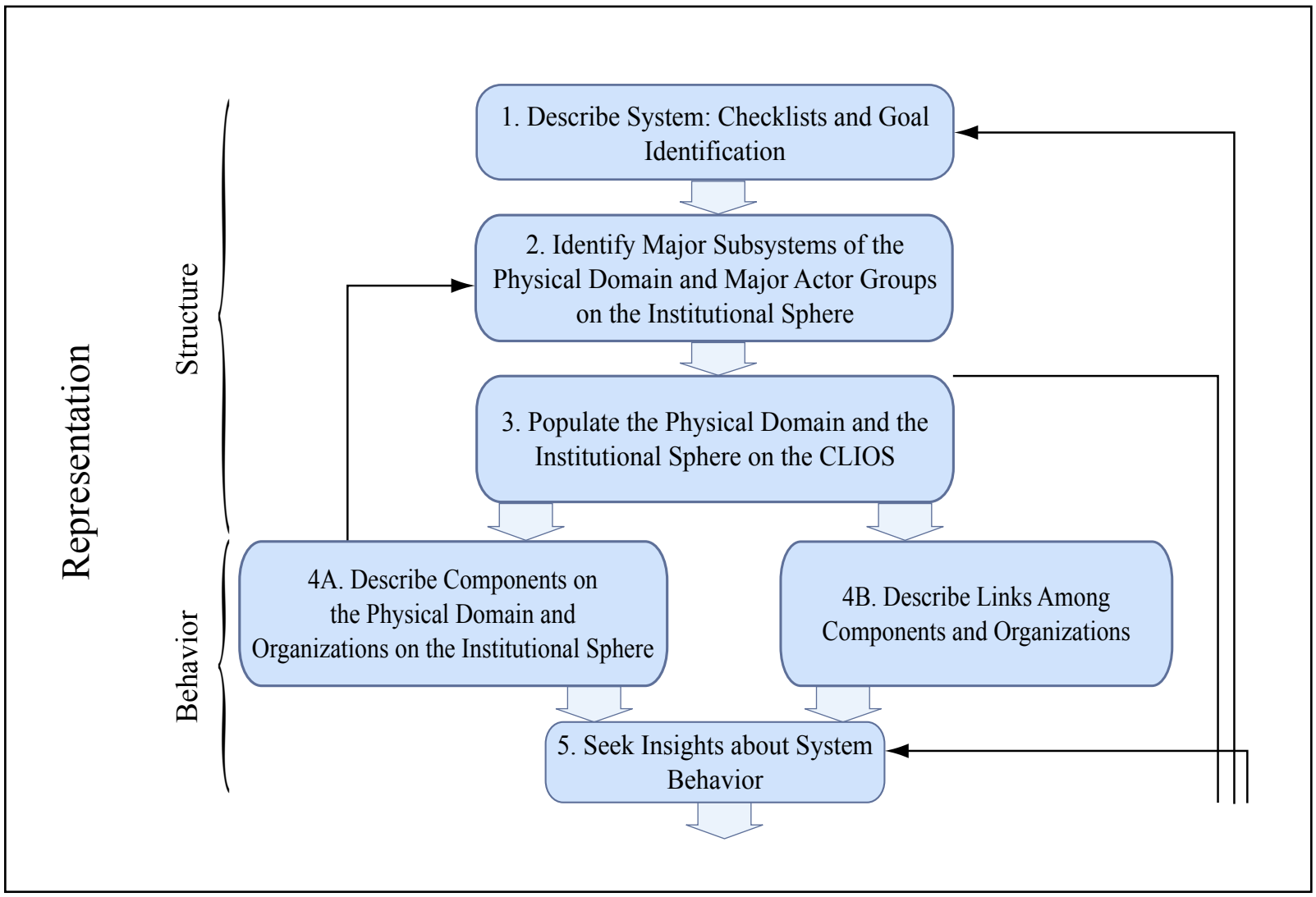


Figure by MIT OpenCourseWare.

SOME IMPORTANT CHARACTERISTICS OF THE CLIOS PROCESS

- At the representation stage, usually a diagrammatic and largely qualitative approach to understanding the CLIOS System
- Nested complexity: bi-directional relationship between the physical and the institutional
- Institutional change as a strategic alternative
- Serves to highlight key system aspects
- Step-by-step, yet iterative process: our organized structure for analysis and design

12 Steps in a CLIOS Analysis



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Step 1: Describe the CLIOS System—Various Checklists

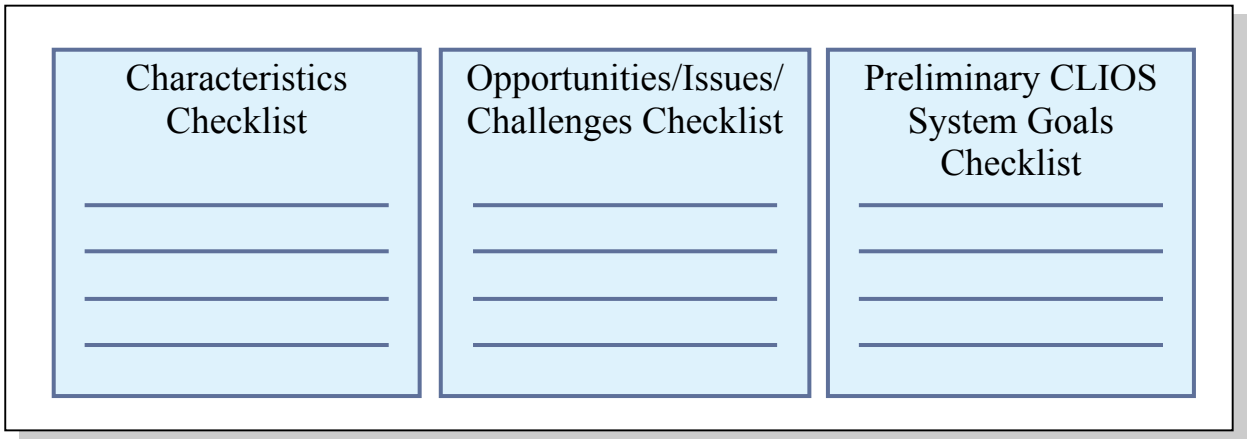


Figure by MIT OpenCourseWare.

Some Questions to Think About:

- What is the temporal and geographic scale of various aspects of the CLIOS System?
- What are the core technologies?
- What are the natural physical conditions that impact or are impacted by the CLIOS system?
- What are the key economic and market issues?
- Are there any important social or political issues or controversies that relate to this system?
- What are the persistent and difficult-to-resolve problems?

Step 1: The Mexico City Megacity Characteristics Checklist

1. "Megacity" with close to 20 million people in Mexico City Metropolitan Area (MCMA)
2. A combination of topography and meteorological conditions, together with increased auto ownership, producing an air quality problem of the first magnitude
3. As with many developing countries, a tremendous range in wealth among its citizens
4. A sprawling land use pattern fueled by both illegal settlements on the fringes and "suburbanization" and the resistance of central city "delegaciones" to densification
5. A surface transportation subject to substantial congestion – throughout the day in some parts of the city – exacerbating the air quality issue in the MCMA
6. The MCMA as institutionally complex, considering its relation to the federal government and relationship between the Federal District (DF) and the State of Mexico (EM)
7. The MCMA as the economic engine of Mexico, but dependent on the economic health of its neighbor to the north
8. Economic growth as a driving policy, with the automotive industry as an important part of the national economy
9. A changing political landscape in the past five years (since the election of President Fox in 2000, after 71 years of presidential rule by the same party).

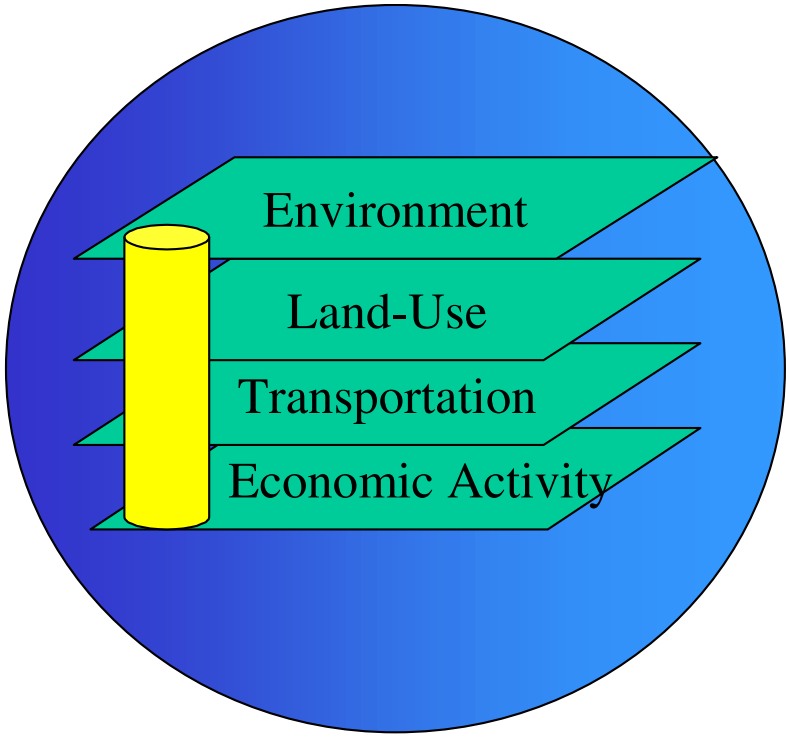
Step 1: The Mexico City Megacity Opportunities/Issues /Challenges Checklist

1. Severe air pollution leading to adverse health impacts (mortality and morbidity)
2. Productivity loss from congestion
3. Unreliability in travel times
4. High energy consumption and Green House Gas (GHG) emissions
5. Inefficient public transportation system

Step 1: The Mexico City Megacity Preliminary CLIOS Systme Goals Checklist

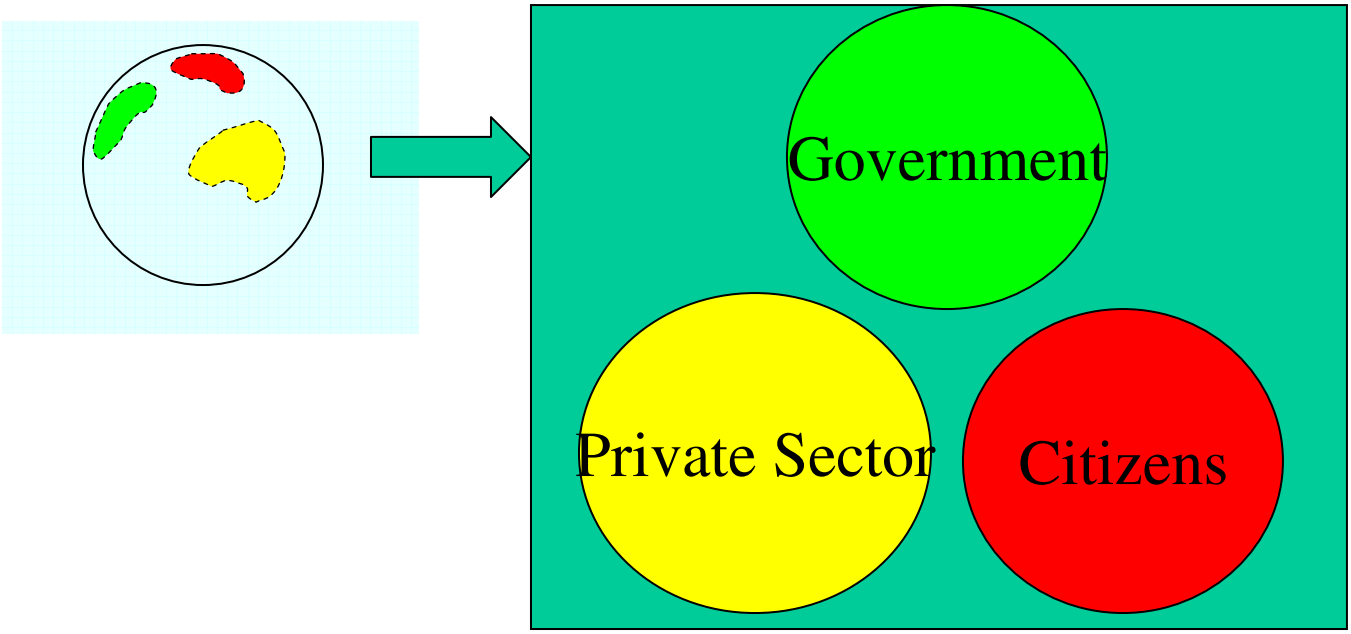
1. Reduce air pollution in the MCMA to a level that reduces the health impacts to the population significantly
2. Reduce productive time loss in congestion
3. Increase travel time reliability for passengers and freight
4. Reduce fuel consumption and reduce GHG emissions
5. Create more efficient public transportation

Step 2:Identify Major Subsystems



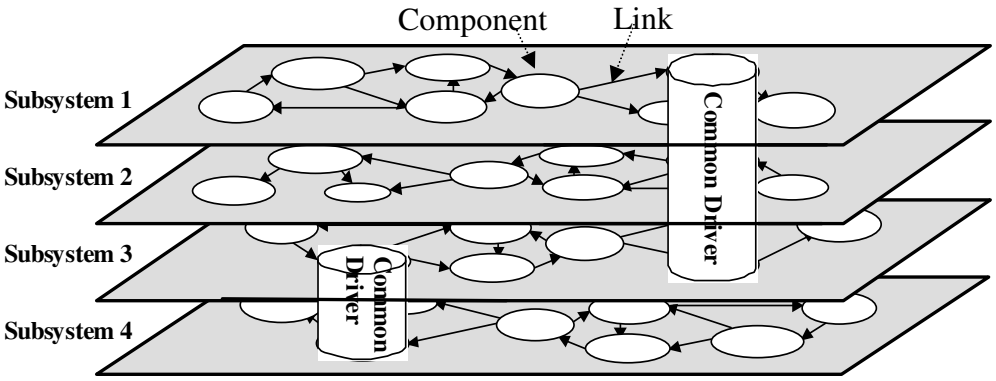
Step 2: Identify Major Actor Groups on the Institutional Sphere

Institutional Sphere consists of Organizations/actors only

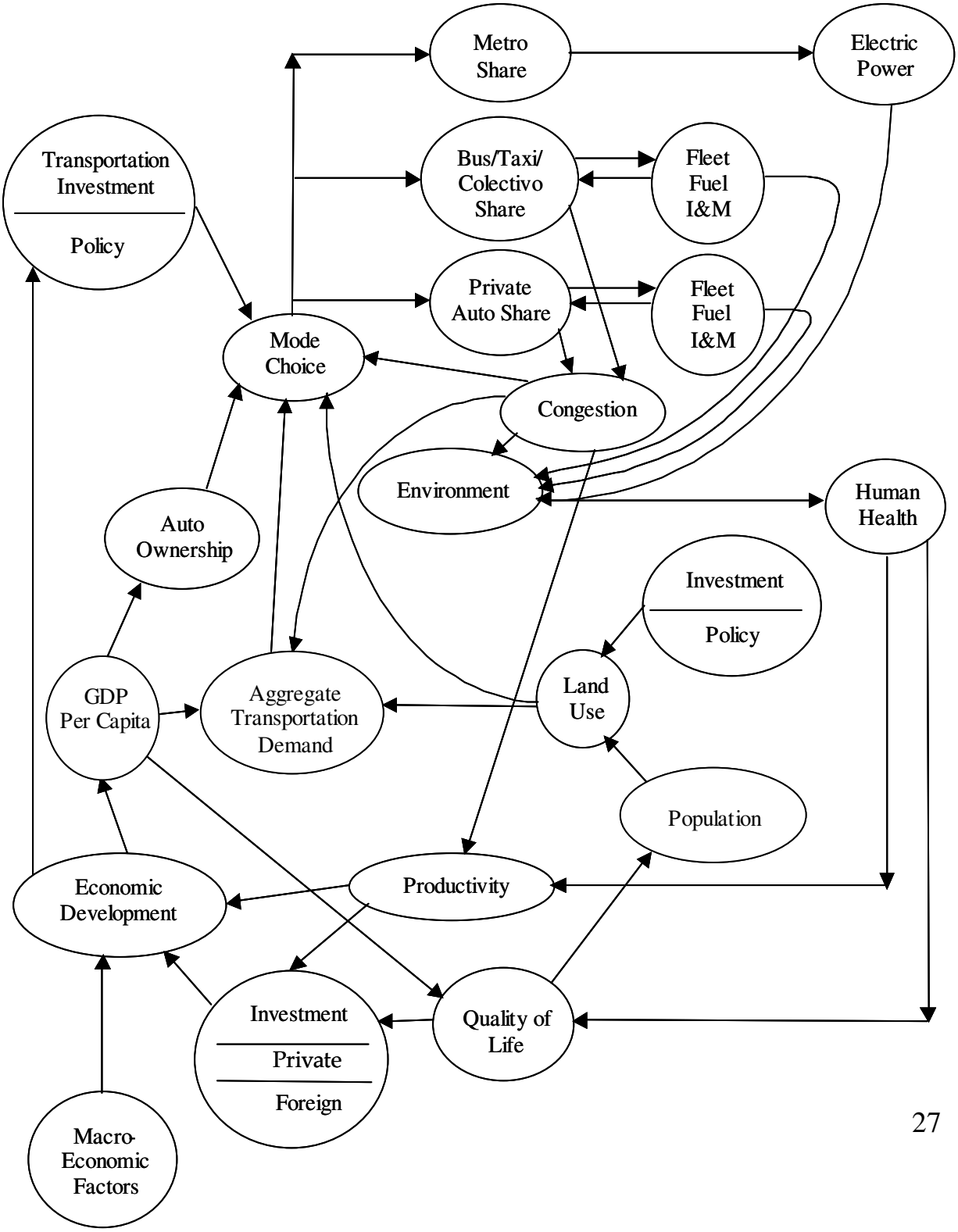


We can "map" the sphere on a plane to categorize major actor groups. Mapping is the process of flattening the Institutional Sphere into a surface in order to facilitate examination.

Step 3:Populate the Physical Domain



Populating the Mexico City CLIOS Transportation Subsystem



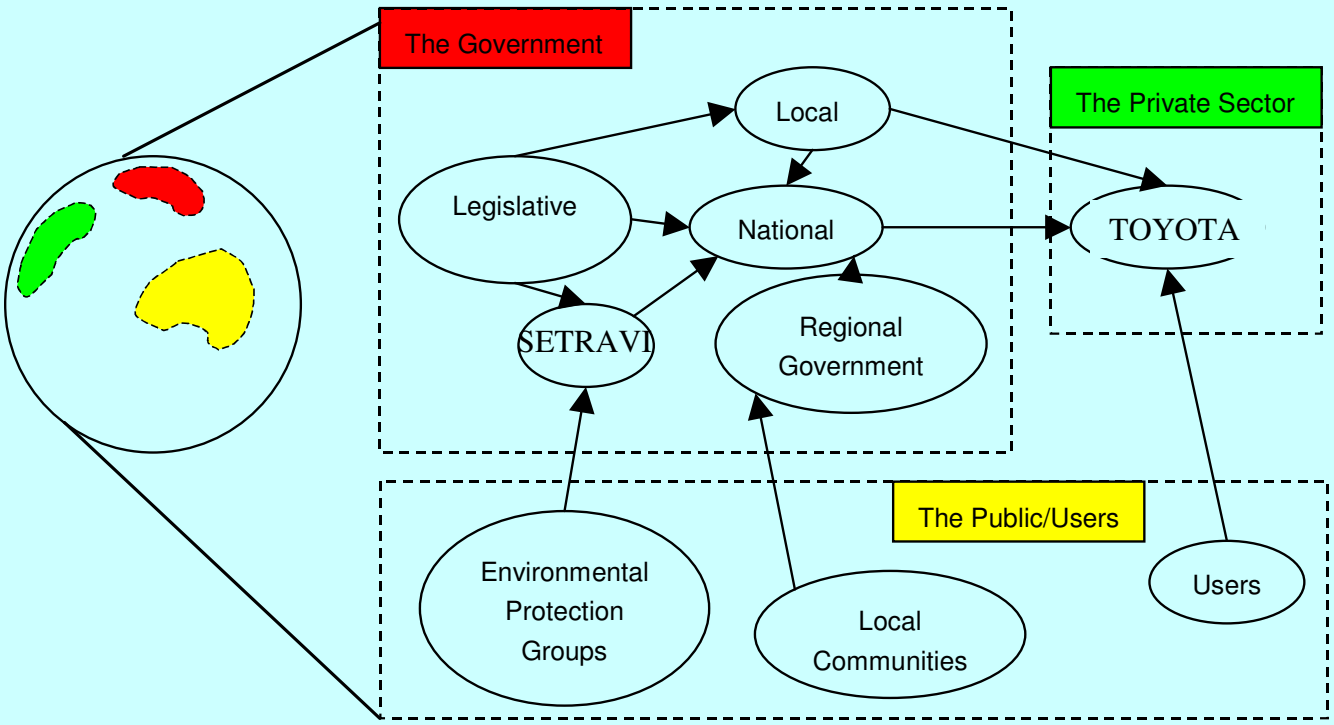
Step 3 continued

Institutional Sphere: Actor Groups

- Government
- Private Sector
- The Public/Users

On the institutional sphere there are only actors. All institutional and regulatory components (such as laws, budgets etc.) are shown in the physical domain. Actors on the institutional sphere then affect those components and thereby impact the physical system.--**This is part of our CLIOS System world view**

Step 3 Populating Actors on the Institutional Sphere



Example of Mapping of the institutional sphere

Mexico City Actor Groups/ Actors

GOVERNMENT

- The Mexican Federal Government
  - SEMARNAT, SCT, PEMEX
- Metropolitan Agencies
  - CAM, COMETRAVI
- Federal District
  - SETRAVI (Transport) , SMA (Environment)
- State of Mexico Agencies
  - SCT-EM , Secretaria de Ecologia

PRIVATE SECTOR

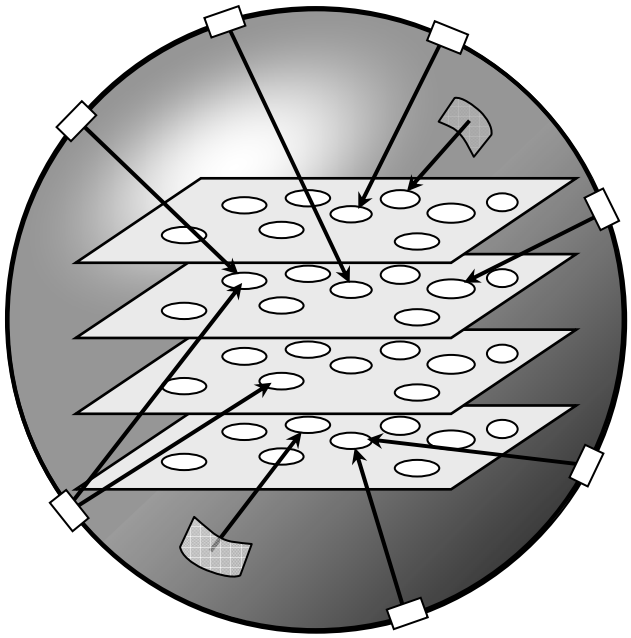
- Auto Manufacturers, Colectivo Associations

THE PUBLIC/USERS

- Mexican Environmental Groups
- Metro Riders
- Car Owners

CLIOS System World View

- *institutional sphere* of institutional, organizational, political and social **actors**
- *Physical subsystems*



Step 3 continued Expanding

Expanding is "Pulling out" a component to explore certain aspects of the CLIOS System in more detail

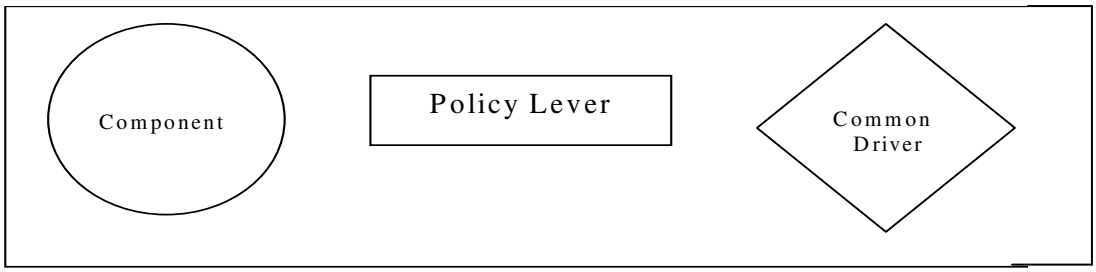
EXPANSION -- EXAMPLES

Can expand portion of transportation subsystem diagram as appropriate

- *Land Use*
  - Densities
  - Income distribution
  - Commercial development
- *Environment*
  - PM
  - HC
  - NOX
- *Fleet*
  - Growth
  - Profile -- new, old
  - Technologies

Also appropriate for actors on the institutional sphere--eg divisions of companies

Step 4A: Describe Components in the Physical Domain



Components are the basic building blocks in the physical domain

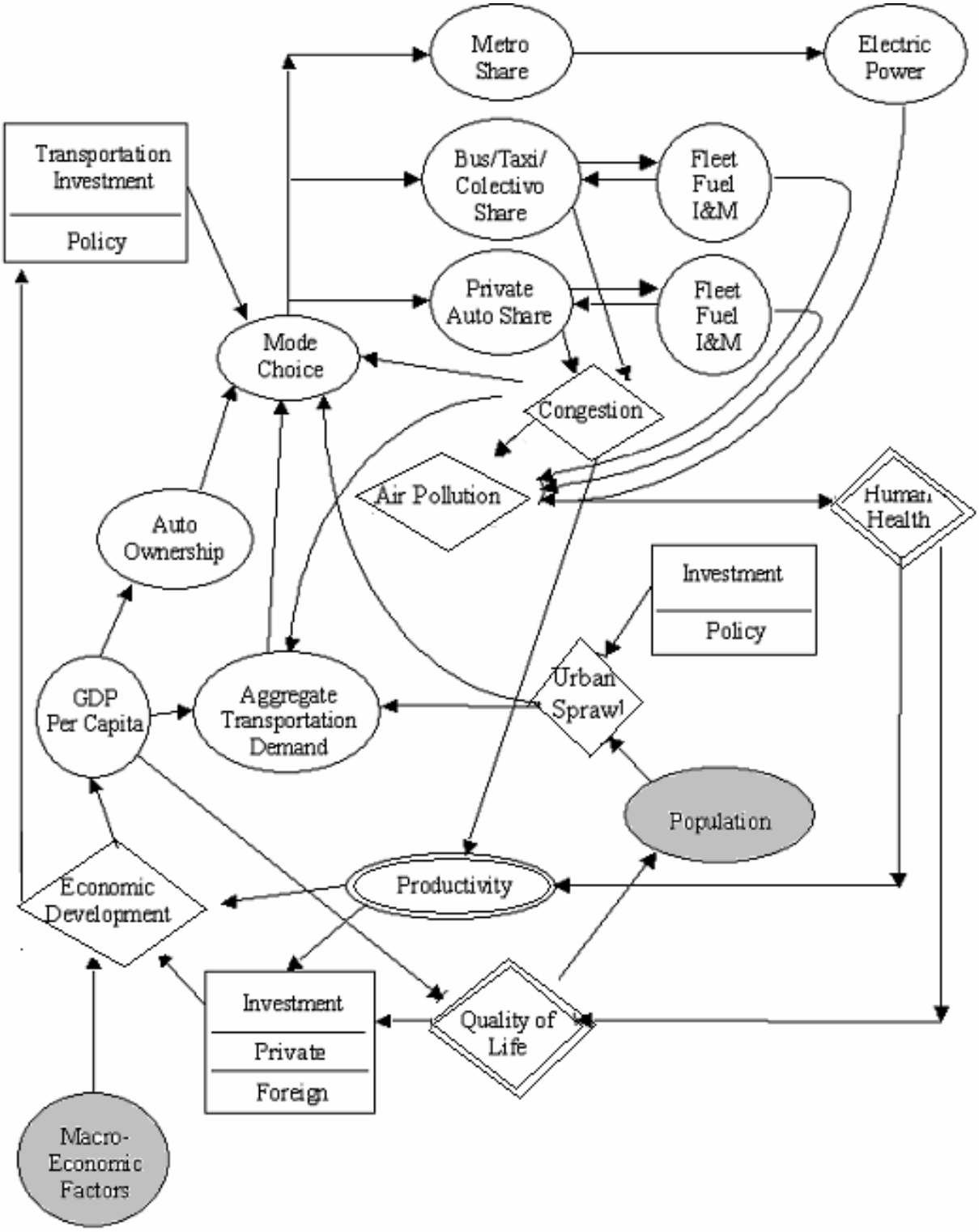
Some special kinds of components are:

Policy Levers, directly controlled or influenced by decisions by actors on the institutional sphere

Common Drivers, shared across multiple and possibly all subsystems

External Factors: Considered external to the CLIOS System-- shown by shading; can be any type of component

Enhanced Mexico City CLIOS Transportation Subsystem Representation



Step 4A: Describe Actors in the Institutional Sphere

Identify important characteristics:

- power or mandate over other actors or components of the subsystems
- interests in specific subsystems
- expertise and resources
- positions with regards to different potential strategic alternatives
- Can be considered external (shown by shading)

Three classes of links

Class 1: Between components within a physical subsystem
- Engineering- and microeconomics-based methods
- Often quantifiable

Class 2: Between actors on the institutional sphere and components within the physical domain
- Quantitative analysis is less useful
- Human agency and organizational interests come into play

Class 3: Between actors on the institutional sphere
- Organizational theory and institutional and policy analysis

"What we want is to understand how such non-physical things as purposes, deliberations, plans, decisions, theories, intentions and values, can play a part in bringing about physical changes in the physical world" (Karl Popper,1972)

Step 4B: Describe Links between Components in the Physical Domain and between Actors on the Institutional Sphere

Characterizing the nature of the links between components or components and actors, including, for example

- Directionality of influence
- Magnitude and direction of influence
- Time frame of influence (immediate, long term…)
- Uncertainty in the effect of one component upon another
- Functional form (e.g., linear, nonlinear, threshold, …)
- Adaptive

Characterizing the nature of links between actors

- Hierarchical
- Command and control
- Advisory
- Info-sharing

LINK CHARACTERIZATION -- SOME EXAMPLES

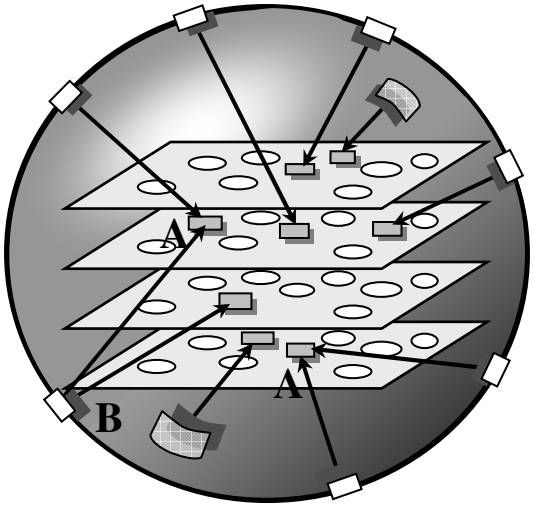
- Congestion to Aggregate Transportation Demand
  - As LOS goes down, demand decreases, often nonlinearly
- Congestion to Environment
  - Stop and go driving
  - "Stuck in Traffic"
- GDP per capita to Auto Ownership
  - Research by Gakenheimer -- empirical studies -- "threshold effect"
- Auto Ownership to Mode Choice
  - "If you have a car, you drive it"
- Electric Power (for Metro) to Environment
  - Difficult to characterize -- *where* is the power "for the Metro" generated
- Transportation Investment to Mode Choice
  - Long timeline in the case of Metro building
  - Medium timeline in the case of bus purchases
  - Short timeline in the case of bus schedule changes

Step 5: Seek Insight about CLIOS System Behavior

- Within the physical system (Class 1links):
  - Are there strong interactions within or between subsystems?
  - Are there chains of links with fast-moving, high-influence interactions?
  - Are some of the links non-linear and/or irreversible in their impact?
  - Can strong positive or negative feedback loops be identified?

Step 5: Seek Insight about CLIOS System Behavior

- Between institutional sphere and physical domain (Class 2 links):
  - Components within the physical domain influenced by many different actors on the institutional sphere ("A" in adjoining figure)?
  - Are they pushing in the same direction, or...
  - Is there competition among actors in the direction of influence?
  - Are there actors on the institutional sphere that have an influence on many components within the physical domain ("B" in adjoining figure)?



Step 5: Seek Insight about System Behavior

- On the institutional sphere

(Class 3 links):

  - Are the relationships between actors characterized by conflict or cooperation?
  - Are there any high-influence interactions, or particularly strong actors that have direct impacts on many other actors within the institutional sphere?
  - What is the hierarchical structure of the institutional sphere, and are there strong command and control relations among the actors?
  - What is the nature of interaction between actors that both influence the same subsystems within the physical domain ("A" in previous figure)?

Schematic Overview of CLIOS Process Representation Stage