Conceptual Problems with the CLIOS Framework - The Need for an Implementation Context

Briefing Note Prepared for the Malaysia Transportation Research Group, April 2004

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The purpose of this paper is to discuss the challenges of applying the CLIOS framework to the transportation research project in Malaysia. In particular, the paper uses the Malaysia research team (based at MIT) to highlight a perceived problem relating to the lack of an *implementation context* to the CLIOS framework. To be more explicit, while the 13 steps of a CLIOS analysis have been clearly defined, there is currently no guidance relating to the human resources needed to undertake a full CLIOS analysis. For example, can an individual undertake a CLIOS analysis of the transportation system in Kuala Lumpur (KL), or is this too complicated or time consuming for one person? The underlying question is whether the CLIOS framework needs some form of *management* component to help an individual researcher, or group, define a realistic scope to their research.

**THE PROBLEM WITH HAVING SUSTAINABILITY AS AN OVERARCHING DESIGN PRINCIPLE**

The challenge facing the Malaysia research team is how to operationalize the principles of sustainable development to create legislation, policies, programs, and planning activities - along with appropriate institutional structures - that will transition the *provision* and *use* of transportation services in Malaysia towards sustainability.

To enable the Malaysia research team to work towards these goals, its first task should be to create a set of *overarching design principles* that could be used to guide research on the Malaysian transportation sector. An example set of designed principles is show in Box 1. Here, sustainability is seen as an *ongoing process of change* as opposed to an *end state* - i.e., sustainability could be described as being a state of mind which guides decision-making processes.

The broad focus of the overarching design principles means that the Malaysia research team will need to consider the *national* scale of the transportation sector, as opposed to only considering the transportation network in the KL region, which is the current focus. A focus on the KL region alone will not be sufficient to counter the growing negative impacts of transportation in Malaysia (such as the growth in emissions from increasing numbers of automobiles), which are likely to continue to occur outside of KL if national policies are not developed to counter the trends. Hence, it is argued that a focus on sustainability at a city/regional level will ultimately lead to nationwide focus, presenting an initial problem since the boundary, or scope, of the CLIOS analysis will need to be set at the *regional* or *national* level.
Box 1: Overarching Design Principles for the Malaysian Transportation Sector

A sustainable transportation system is one that:

- “provides for safe, economically viable, and socially acceptable access to people, places, goods, and services;
- meets generally accepted objectives for health and environmental quality, ...;
- protects ecosystems by not exceeding critical loads and levels for ecosystem integrity, ...;
- does not aggravate adverse phenomena such as climate change, stratospheric ozone depletion, and the spread of persistent organic pollutants” (Caid et. all., 2002, p. 220)
- is highly interconnected in both an intra- and inter-modal manner,
- supports, reinforces, and facilitates national policies that aim to reduce the throughput of natural and manmade resources to rates within the carrying capacity of the local, national, and global environment.

One possible way of circumventing this problem would be to consider the KL region as a test bed for city/region specific transportation policies, which if successful could be adopted by other cities/regions. This assumes, however, that change in the transportation sector would be led by regional transportation policies as opposed to national government policies or regulations - an assumption that will need to be considered carefully by the Malaysia research team.

In addition to creating a set of overarching design principles, the Malaysia research team might also develop a set of critical generic questions that could guide decision-making in the various research areas. For example, “will ... x ... increase the safety of the transportation network?” If the answer to a question is “no” or “may be” it might highlight critical points where unsustainable actions might occur. These critical questions should cover important areas such as the environment, the economy, social equity, work, and energy use. Developing these questions should be a group exercise - e.g., through a brainstorming session - which will help the research team form consensus on the direction of its combined research effort.

THE CLIOS FRAMEWORK: DEVELOPING AN OPERATIONAL CONTEXT

Scope of Research

In an ideal situation, one could argue that the CLIOS framework would enable a research team to identify, discuss, and evaluate all the major issues that affect a city/nation, and to develop robust policies (using scenarios) that could be implemented to initiate (positive) change. Therefore, it seems logical that when using such a framework, researchers could develop a portfolio of transportation, employment, business, environmental, etc., policies that are developed in an integrated manner. Hence, while transportation is a major component of the system, if the other components are not addressed simultaneously, then altering the transportation system by itself might cause adverse impacts within other system components.

Therefore, if the Malaysia research team plans to address the topic of sustainable transportation, it needs to address the economic, environmental, and social impacts of transportation, and
understand how the transportation system’s “use” is connected to issues in other sectors. To be explicit, the team needs to ensure that it does not exclude other sectors/systems from their research which might be affected by the recommendations put forward for the transportation sector. It should become clear that to do such a comprehensive analysis would require a research team that could assess critical issues across all the important sectors in Malaysia.

The last point above highlights an idea that is critical to a CLIOS research project - i.e., “a CLIOS analysis with a broad scope should be undertaken by a research team, and not an individual.” By definition, a CLIOS is a complex, large scale, integrated, and open system, implying that a single researcher would need to be an expert (or be competent) in all areas (domains) to be able to undertake both technical as well as institutional research. It seems quite easy to map a CLIOS, but it is something else to implement a full CLIOS analysis. Using a research team (or resources) approach would be one way of providing an operational scale to a CLIOS analysis. Hence, we need to give the CLIOS framework an implementation context.

Some Key Questions

- Would it be a good idea to define the CLIOS concept with more precision, for example, using the notion of a research team?
- What type of people (skills) would make a good CLIOS research team?
- Is there an organizational component to undertaking a CLIOS analysis that current research has not touched upon?
- Who manages the data and direction of the research within a CLIOS analysis?

These are difficult questions to answer. However, one way the description of a CLIOS analysis could be improved is to give the CLIOS framework an operational (human implementation) context. Emphasizing the large scale (comprehensive) aspect of the research means that using other methodologies (system dynamics, systems engineering, etc.) within a CLIOS analysis begins to make more sense. Hence, the CLIOS framework becomes a tool for keeping everything linked together and for integrating the output of very different analysis methodologies and ways of thinking.

New CLIOS Metrics

One way the Malaysia research team could advance the CLIOS framework, would be to provide an implementation context to their work. An interesting advance in the CLIOS framework might be the creation of some form of metric to describe how the scale of the data analysis requirements increases (or changes) as the size and complexity of the system increases. Figure 1 presents a graphical representation of this statement. The value of such a metric is that it provides researchers with an intuitive feeling about the amount of work they might unleash when defining the scope of research (including the system boundary) for a CLIOS analysis.

While the paper by Dodder et al. (2004) describes how existing tools and methodologies map into the CLIOS framework, there is currently no advice on how to connect the scope of research to resource requirements. Developing ways to explain how the CLIOS framework can be applied in practice will be essential to the successful deployment of the concept. It is well known that the
way we choose to *translate* our ideas to others will be critical to the success of our ideas (Latour, 1987).

Figure 1: Metric for Describing the Operational Context of a CLIOS Analysis

A fundamental problem with the metric presented above (Figure 1) is that the position of the line on such a graph is likely to depend on the **scope of research** and the **definition of the system boundaries** (which can be geographic or issue based). For example, it is possible for an *individual* to undertake a CLIOS analysis on KL; however, it is unlikely that such an analysis would gain the support of decision-makers in KL. Would you make strategically important decisions for a city/region based upon an analysis of a single researcher? To be explicit, an individual researcher is unlikely to have the intellectual ability to identify, address, and rigorously analyze all the critical issues (e.g., human health, transportation, energy, urban planning, etc.) associated with a city/region.

To complicate the discussion further, recent research into the CLIOS process suggests that engaging stakeholders early on in the representation and modeling of engineering systems using a Stakeholder-Assisted Modeling and Policy Design (SAM-PD) process (Mostashari and Sussman, 2004), may lead to recommendations that are viewed as more legitimate by decision-makers and stakeholders. Such a requirement within the CLIOS framework only strengthens the need for further guidance on how a CLIOS analysis is undertaken from a resources perspective. For example, how many people are needed to facilitate the SAM-PD process for a certain number of stakeholders? Ultimately, the answer to such questions will stem from the project scope; however, it would be useful to know how adjustments in the project scope can influence the type of human resource commitment that will be required.

It should now be clear that the CLIOS framework can be seen as a form of *management tool* designed to structure research into complex, large-scale, integrated, open systems. As such, it follows that we might even consider the option of defining key roles within a CLIOS project,
such as a CLIOS Director, Data Coordinator, etc. Hence, a missing link in the CLIOS discussions is the human factor and real examples of how CLIOS can be applied. Such information would help explain the CLIOS framework to students (or users), since it would provide them with a way of balancing the tradeoff between input resources (such as time, data requirements, extent of analysis, etc.) and expected output (such as the extent of the analysis and its potential value).

THE ORGANIZATIONAL (IMPLEMENTATION) CONTEXT OF THE MALAYSIA PROJECT

The Malaysia research team consists of nine core members (Table 1).

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<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Research Interests</th>
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</thead>
<tbody>
<tr>
<td>Prof. Joseph Sussman</td>
<td>CLIOS Director</td>
<td>Transportation system development in KL</td>
</tr>
<tr>
<td>Becky Dodder</td>
<td>Team member</td>
<td>The CLIOS framework and transportation planning</td>
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<tr>
<td>Jeff Ensor</td>
<td>Team member</td>
<td>Pricing Strategies, Measures, and Policies</td>
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<td>Ralph Hall</td>
<td>Team member</td>
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<td>Jessica Harrison</td>
<td>Team member</td>
<td>The CLIOS framework</td>
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<td>Joshua McConnell</td>
<td>Team member</td>
<td>Transportation Planning, Real options</td>
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<tr>
<td>Sgouris Sgouridis</td>
<td>Team member</td>
<td>Freight</td>
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<td>John Ward</td>
<td>Team member</td>
<td>Private Transportation</td>
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<tr>
<td>Zulina Zakaria</td>
<td>Team member</td>
<td>Public Transportation</td>
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During the initial plenary sessions, the first task of the research team was to develop a CLIOS representation of the KL metropolitan region (Figure 2). While the boundary of the CLIOS analysis was set at the regional level, it is clear that the issues identified in the diagram have a national scope. Therefore, in order to develop a more robust understanding of the transportation problems faced by KL, the team prepared a statement outlining the major policy issues driving the development of the KL region and the critical issues that need to be considered in the research (Box 2 and 3, respectively).

In addition, to help understand the institutional structure of KL, Figure 3 was developed to outline geopolitical layout of the region.
Figure 4: Malaysia KL CLIOS Diagram
BOX 2: A BRIEF INTRODUCTION TO THE KUALA LUMPUR CLIOS

In developing a CLIOS representation of the KL region, it is important to highlight the policy issues that drive the analysis.

Over the past twenty years, the KL region has experienced rapid population and economic growth. While this growth has been accompanied by significant investment in transportation infrastructure, the development of system capacity has not been sufficient to cope with the rate of traffic growth - particularly the number of automobiles and motorcycles on the road. As a result, congestion levels are rising which have had the ancillary affect of increasing accident rates, reducing the economic productivity of the metropolitan area, and increasing the emissions of particulate matter, Carbon Monoxide, NOx, VOCs, and greenhouse gases. All of these impacts have a negative effect on the quality of life for the Malaysian people living in the region and are also damaging the broader Malaysian economy. In addition, the problems of congestion are expected to worsen as the city merges with the surrounding suburban areas.

In 1991, Malaysia announced its intention to become a develop-nation by 2020 in a policy document entitled ‘Vision 2020.’ To achieve this goal the nation’s economy must transition from being an industrial economy to a service economy. The result of such a transition would be the gradual movement of heavy manufacturing facilities to overseas locations, reducing the need for substantial physical resources, but increasing the need for a knowledge based economy and society. In the recent ‘Eighth Malaysian Plan 2001-2005,’ the first phase of the government’s broader ‘Third Outline Perspective Plan 2001-2010’ (OPP3) to implement Vision 2020 was described. Both the Eighth Malaysian Plan and OPP3 emphasize the government’s desire to transition towards a service economy, by highlighting the importance of high-value service-orientated business.

The transportation problems facing the KL region combined with the Malaysian Government’s strategy for transitioning the country towards being a developed nation by 2020, means that when developing a strategy for improving the transportation sector, we must consider a wide range of stakeholders. The CLIOS framework will enable this to occur by identifying the critical stakeholders and describing how they interact with the various elements of the transportation system. Such information will be essential to understanding whether a particular transportation option is likely to support or run against the objectives of reducing congestion, health problems etc., while stimulating the transition of the Malaysian economy towards that of a service economy.
**Box 3: Critical Issues**

In order to provide a checklist for the CLIOS analysis, it is important to highlight the *critical issues* that need to be addressed when solving the transportation related problems in KL.

**Transportation:**
- Congestion is a significant and growing problem in KL. The transport system has developed in favor of private, low-occupancy modes. Intermodal trips are difficult, and integration of the public transit system seems to be fragmented, with inconvenient transfers.
- It is likely that there will be an increase in new strategic alliances with foreign interests in sea and air transport as the nation attempts to become a regional hub for sea and air transportation.

**Environment and Health:**
- Transport vehicles are the principal source of pollution. In KL, there is an extremely high motorization rate, with a vehicle population of nearly 1.5 million registered vehicles (and an additional 1 million vehicles enter the federal territory daily).
- Kuala Lumpur and the other urban centers in the Klang Valley continue to experience "unhealthy" air quality conditions.

**The Economy:**
- Economic *growth* and regional *competitiveness* are primary policy concerns. Electronics, furniture, automotive, chemical and petrochemical as well as mixed industrial activities have been identified as growth sectors. From the viewpoint of the transportation system, the focus on the automotive sector and promotion of the Proton is a key issue.
- The Malaysian government has stated that IT is likely to be one of the key foundations for growth. There are hopes that a pool of trained, skilled and IT-oriented manpower will emerge to propel the nation towards an industrialized and knowledge-based economy.
- The future development of the transportation sector within the city of KL is limited by a lack of financial resources and space.

**Equality:**
- Addressing the *inequality* in the distribution of growth also seems to be high on the policy agenda. There is a relatively small middle class. The diversity of Malaysia - ethnic, lingual, cultural and religious – needs to be taken into account. Dis advantaged groups, such as the Bumiputera, need to be better integrated into the economy to achieve a more equitable distribution of growth. Regional imbalances are also a development concern.

**Land Use:**
- The pressures of urbanization have created additional social problems related to public health, squatters, youth development and a change in the culture and lifestyle for those living and working in Kuala Lumpur.
- While Malaysian regional development policies since 1970 have been based conceptually on "balanced" growth centers (so that KL does not become a “runaway” primary city) in practice, KL and the Klang Valley continue to grow as the predominant city. Economic growth policies and land use/urban development policies do not seem to be well coordinated.
Before exploring the types of research assignments given to some of the team members, it is important to mention that the information presented above was the result of a team effort. Therefore, it is likely that it would not have been so refined if it were not for the group discussions and insights.

Once the intellectual framework had been developed within which the transportation research would be conducted, the next task was to assign research tasks to each team member. Since the research team was based at MIT, there were external pressures to align the tasks with the individual’s research interests. However, one could argue that when the students were selected for the team, their skill set was chosen to cover a certain area of the field of transportation. In a non-academic environment, one can imagine a similar situation in which team members are selected based upon skills and expertise.

The tasks assigned to each student were created by Prof. Sussman - the research or CLIOS director - in coordination with each student. During this process the research portfolio began to take shape. The intellectual framework presented above proved to be an excellent resource since each team member had a good understanding of where his/her research fitted in the larger picture and where it would influence other critical research areas. The team was also able to identify the areas which they would not be able to research due to resource constraints. To explore these interactions a little further, four of the students have provided a brief synopsis of their research areas, which are presented below.
Ralph Hall - *Sustainability as an Overarching Design Principle*

My role in the Malaysia research team is to ensure that each team member is aware of how their research is likely to impact upon the (multidimensional) sustainability of Malaysia. To help guide their research, I plan to develop a set of overarching design principles (refer to Box 1) that can be referred to when developing potential solutions to the problems facing the nation (outlined in Box 3). In addition to thinking about Malaysia, my research interests, more generally, are concerned with how to translate the concept of sustainable development to the transportation sector. Therefore, the Malaysia project will present an excellent opportunity to test ideas and develop new ways of thinking about sustainable transportation within a dynamic group of researchers.

Sgouris Sgouridis - *Regional Strategic Transportation Planning and Freight*

My task is to look at how the concept of Regional Strategic Transportation Planning can be applied using the CLIOS framework. My interests lie in considering the freight transportation planning aspect of the problem. More specifically, I am interested in relating freight transportation planning in the public sector with the supply chain management practices of the private sector and how the two could align their goals. Closely related to my research is the issues posed by a multi-dimensional sustainability perspective - i.e. how to balance the economic development/growth aspect of the plan with sound environmental and social repercussions. Here, my research will link with the overarch framework developed by Ralph Hall which will attempted to ensure that the transportation system develops in a sustainable manner. A potential problem I am facing is where to draw the line in considering the impacts of manufacturing on the economy, the environment, and society as opposed to only considering transportation.

Zulina Zakaria - *Public Transportation (Planning)*

My research objective is to evaluate the institutions that have the responsibility for planning the public transportation system in the Klang Valley Metropolitan Area (KLMA). Using methodologies from two from analytical frameworks - CLIOS and strategic organizational design - I intend to develop an institutional architecture for regional strategic planning for the deployment of advanced public transportation systems (APTS) to improve ridership levels. The analytical framework developed and data obtained will be shared with other team members with the objective of creating a regional institutional planning architecture for sustainable transportation systems.

Jeff Ensor - *Pricing Strategies, Measures, and Policies*

My research focuses on examining the role of pricing strategies, measures, and policies for the transportation system in the KLMA. Pricing is an important part of any transportation system, since it plays a role in the level of demand for transportation
services. The first step in creating a “good” transportation system is developing the necessary infrastructure. Then various services (such as bus routes and schedules) need to be provided to operate the system. Of course, the system also needs to receive some level of maintenance to keep it in adequate condition. However, an institutional system that stops at this point does not use all of the tools they have available to promote sustainable transportation. Demand will continue to grow if good quality transportation services are provided but are not managed. Pricing may be able to provide the incentives necessary to shape drivers’ behavior into something that might be described as being sustainable. Pricing can also generate substantial revenues for use in other parts of the transport system or for other objectives such as improving education or health care.

I have predominantly focused on pricing for automobile transportation in the KLMA because VMT and auto ownership seem to be one of the largest challenges for creating “sustainable transportation” in the region. There is a clear need to discuss useful policies and strategies with other team members to determine the impact that the introduction of pricing is likely to have on their research and hence the KLMA. Pricing policies are examined on a national level, while strategies and measures (such as a congestion pricing scheme) are examined on a regional level. Expressway tolling is one example of an area that has both a national policy component and a regional facilities component.

Through discussions with Zulina Zakaria, a Malaysian national and team member, I have been able to gain some valuable insights into transportation consumer preferences (to see what might be viewed as acceptable or why certain policies have been pursued in the past). To explore the issues related to potential pricing scheme in detail, it will be essential for me to talk with the group members who are looking at other aspects of the transportation system to figure out which type of technology could be considered robust and to try and conceive an architecture.

**Conclusion**

The objective of this section is to provide an operational (or implementation) context to the Malaysian research project. It should be clear from the information and discussions presented that there is a need to define, or at a minimum discuss, the management issues relating to the implementing a CLIOS analysis. A second critical point, which answers the question raised in the introduction, is that clearly one person would not be able to undertake the scope of research that is being conducted by the research team. Each team member has a specific set of objectives and is working with other members to test his/her ideas, or simply to understand how the group’s research interconnects.

It is argued that an interesting advance in the CLIOS framework might be the creation of some form of metric to describe how the scale of the data analysis requirements increases (or changes) as the size and complexity of the research scope increases. An alternative option would be to simply encourage a researcher to carefully review the scope of his/her project before commencing work. Such information, or action, would help explain the CLIOS framework to users, since it would provide them with a way of balancing the tradeoff between input resources...
(such as time, data requirements, extent of analysis, etc.) and expected output (such as the extent of the analysis and its potential value).

A final point worth mentioning relates to the sharing and use of data. During the early part of the research the team members were operating somewhat independently with regards to gathering data. It is believed that more advancement would have been made if the sharing and analysis of data was made an explicit role in a CLIOS analysis that has more that one researcher.

References


