Strategic Integrated Environmental Model for the Preliminary Design of Rapid Rail Transit Systems

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INTRODUCTION

Purpose and Scope

The Strategic Integrated Environmental Model (SIEM) is designed to assist in the evaluation of environmental parameters needed to obtain environmental approval and clearance during the preliminary design of Rapid Rail Transit Systems (RRTS). This model follows an interdisciplinary approach combining principles from a number of scientific fields, such as engineering, energy management, environmental impact, economics and communication.

SIEM ensures that the design and build approach of RRTS infrastructure projects are environmentally compliant. Further, SIEM attempts to address as early as possible in the decision making process the engineering, economic and social issues of the transit and urban areas. Overall, SIEM aims to be established as a standard tool to improve the design and build activities of RRTS infrastructures. The progress and effectiveness of the model is also related to societal aspects, such as participation, institutional capacity, and democracy. Further, SIEM sets clear environmental targets and objectives (i.e., air pollution, CO_2, land consumption), and raises the profile of key issues for rail transit and urban planning, by means of promoting better understanding of the interrelationship between land use measures and other specific plans, such as transport or waste management and their environmental, economic and social impacts.

Context and Significance

Environmental impact assessment (EIA) is a must component in the design and build of RRTS. During the preliminary design, it is necessary to identify the nature and scale of environmental effects likely to result from the construction of the railway line, and the measures that should be taken to minimize those effects. SIEM can help promote the objectives of sustainability, while it offers at the same time greater transparency in policy development and encourages public involvement and acceptance.

The traditional environmental assessment model which is used for the preliminary design of RRTS projects and subsequently for their environmental approval is divided into the following seven phases: (1) Planning model in providing alternative means of transportation. (2) Description of the environmental and socio-economic impacts. (3) Public stakeholders' attitude towards the project. (4) Environmental and Urban Planning concerns. (5) Mitigation measures. (6) Monitoring requirements. (7) Conclusion.

Many environmental assessment models were developed in the industrialized economies as a response to the various legislative control and regulatory measures as also to suit divergent environmental situations and purposes (Atchia & Shawna, 1995; Campbell, 1993; Canter, 2004; Miller, 1997). Each proposed environmental model presents a different depth of analysis to be carried out in a particular impact assessment. International conglomerates undertaking big infrastructure projects, such as Alstom (2008a, 2008b, 2008c, 2009) and Delcan (2010) explain that the choice of a methodology depends on: (a) needs of the user; (b) type of project; and (c) type of ecosystem. Depending on these factors, one model may be more useful than another. Therefore, the analyst must decide which environmental model best fits a given task or situation.

A careful review of a range of relevant industry engineering reports (EDM-Cansult, 1999; Alstom, 2008; Morrison Hershfield, 2012) reveal that the following considerations are important for making a choice on any model for preparing an environmental assessment: (1) Use: Is the EIA intended for a decision or for information? (2) Alternatives: Are alternatives fundamentally or incrementally different? (3) Resources: How much time, skills, money and data are available? (4) Familiarity: Is the analyst familiar with both the types of project proposed and the physical site? (5) Issue significance: How big is the issue? (6) Administration constraints: Are choices limited by governmental procedures and format requirements?

The impact identification and assessment can be made through several ways. Each one represents a methodology. There are five different methodologies based on the way the impacts are identified and assessed: (1) Ad Hoc: These methodologies provide a minimum guidance for impact assessment. (2) Overlays: These methodologies depend upon a set of maps on the environmental characteristics (physical, social, ecological and aesthetic) of the proposed project's vicinity. (3) Matrix: This methodology incorporates a list of project activities with a checklist of potentially impacted environmental attributes. (5) Combination computer-aided: These methodologies use a combination of matrix, networks, analytical models, and a computer-aided systematic approach.

Impact methodologies must effectively deal with four key problems: (1) Impact identification; (2) Impact measurement; (3) Impact interpretation; and (4) Impact communication to users. These criteria can be used for analyzing a methodology and determining its strengths and weaknesses. They also help in choosing methods, which are most appropriate for a particular situation.

BIBLIOGRAPHY APPRAISAL

During my secondary research I have reviewed one hundred and fifty-five academic journals, one hundred and thirty-three trade journals/magazines and fifty-three company web-sites. The conclusion of my secondary research regarding this extensive bibliography depicts that the current environmental assessment models present major weaknesses and gaps due to the fact that they are missing one or more of the following requirements:

1. **Determining the Environmental Impact as a Single Component and through Interface:** This is the central theme in any EIA (Environmental and Occupational Management Services, Trinidad and Tobago, 2007; Gauteng Department of Public Transport, Roads and Works, 2007; Jackson & Jackson, 1996). Environmental impact assessment is a very complex process. At the outset, a distinction has to be made between the environmental impact and the changes in environmental attributes. Our interest is on the "impacts" and not on the "changes", which normally take place even without the project. The determination of environmental impacts involve: (a) identification of impacts on environmental attributes and interfaces or the Environmental Resources Values (ER/Vs), (b) measurement of impacts on attributes, and (c) aggregation of impacts on attributes to reflect the total impact on environment.
2. **With and Without the Project:** The environmental impacts are measurement of attributes with and without the project or activity at a given point in time. But the changes in the attributes take place over time without the activity. Therefore, the impact must be measured in terms of "net" change in the attribute at a given point in time.
3. **Identifying the Direct and Indirect Impacts:** The number of attributes to be evaluated is practically infinite because any characteristic of the environment is considered to be an attribute. Therefore, they have to be reduced to be manageable numbers. Thus, duplicative, redundant, difficult to measure, and obscure attributes may be eliminated in favor of those that are more tractable. This implies that some attributes, which are difficult to measure or conceptualize, may still remain to be examined. In this case, bias and subjectivity are likely to emerge.

4. **Characteristics of the Base:** Conditions prior to the activity: The nature of the impact is determined by the conditions of the environment existing before the project. The assessment of the characteristics of the base is a critical factor.
5. **Role of Attributes:** Though the impacts are considered to be the effects on the definite discrete attributes of the environment, the actual impacts are not correspondingly well categorized. Nature does not necessary respect man's discrete categories. Rather, the actual impact may be the effect of varying severity on a variety of interrelated attributes. The issue is one of identifying and assessing the cause condition effect in order to work out the remedial measures.
6. **Measurement of Impact:** Ideally, all impacts must be translatable into common units. However, this is not possible because of the difficulty in defining impacts in common units (e.g. on income and on water quality). In addition, the quantification of some impacts may be beyond the state of the art.
7. **Aggregation Problem:** After measuring the project impacts on various individual attributes in accordance with the Environmental Resources Values (ER/Vs), one encounters the problem of how to aggregate all impacts (quantitative and qualitative) assessed to arrive at a single composite measure to represent the "total activity impact". This would involve expressing the various impact measures in common units, which is very challenging. Some use a weighting procedure to accomplish this, which is again subjective. There is another associated problem of summing up and comparing with the impact of an alternative activity.
8. **Secondary Impacts:** Secondary or indirect impacts on environment should also be considered particularly in relation to the infrastructure investments that stimulate or induce secondary effects in the form of associated investments and changed patterns of social and

economic activity. Such induced growth brings significant changes in the natural conditions. Similarly, there can also be significantly secondary impacts in the biophysical environment.

9. **Cumulative Impacts:** Here, accumulation refers to the similar activities spread over in an environmental setting, such as hotels, beaches, resorts, surface or underground mines, industrial estates, etc. A single individual activity may produce a negligible effect on the environment. However, a series of similar activities may produce significant cumulative effects on certain aspects of environment. This raises the question of how to deal with these significant cumulative effects. Therefore, it is suggested to prepare an environmental impact assessment (EIA) on broad programs rather than on a series of component actions (e.g. industrial estates, mining sector, tourism industry, etc.) Or, alternatively, one can prepare an EIA for a particular geographical area where a series of similar activities are located (e.g. mining areas, coastal line for beach resorts, etc.)
10. **Reporting Findings:** The result should be displayed in such a way that it makes it easy and clear to comprehend the total impacts of an activity from a brief review. It is suggested to display the impacts on a summary sheet in a matrix form.

STRATEGIC INTEGRATED ENVIRONMENTAL MODEL (SIEM)

The SIEM model aims at improving the consistency and coherence during the preliminary design stage of RRTS, as well as becoming a strategic vehicle for communicating policies, processes and solutions efficiently and effectively to the public from an environmental engineering perspective. In order to analyze the environmental engineering challenges, problems and issues of integration and application, it is required that the preliminary design of RRTS follow specific environmental policies and standards, as well as accommodate the urban-transportation needs for good governance and engineering.

The benefits of the SIEM model include the following: Achieve compliance with the existing environmental legislation, and then adopt policies, which are efficient and cost effective. Facilitate the design build process of RRTS. Enhance environmental awareness to citizens, local authority staff and stakeholders. Enhance partnership and communication between the stakeholders in order to build consensus. Introduce cost savings through efficiently designed RRTS systems by reducing resources and utilities, and improving economic competitiveness through cutting costs.

The application of SIEM can provide better accuracy than the existing models, reduce the environmental and design-build risks, and clarify the interdependencies between the various project domains. The benefits from SIEM are mainly focused on the detailed study of every identified component first independently and then in conjunction with the rest of the components and subcomponents as an integrated model. Further, SIEM helps us enhance the scope of an RRTS project, understand the social and environmental needs, identify the real source of impacts, and strengthen the qualitative and quantitative measurements by considering an integrated scaling and weighting.

SIEM PERFORMANCE SPECIFICATION

The objective of the performance specification is to identify and elaborate on the structural components of SIEM and explain how they operate as one integrated model. Figure 1 shows the architectural structure of the model, which includes its components and its interface order mechanism. This section will analyse the five different levels of decision-making and action taking relative to this process.

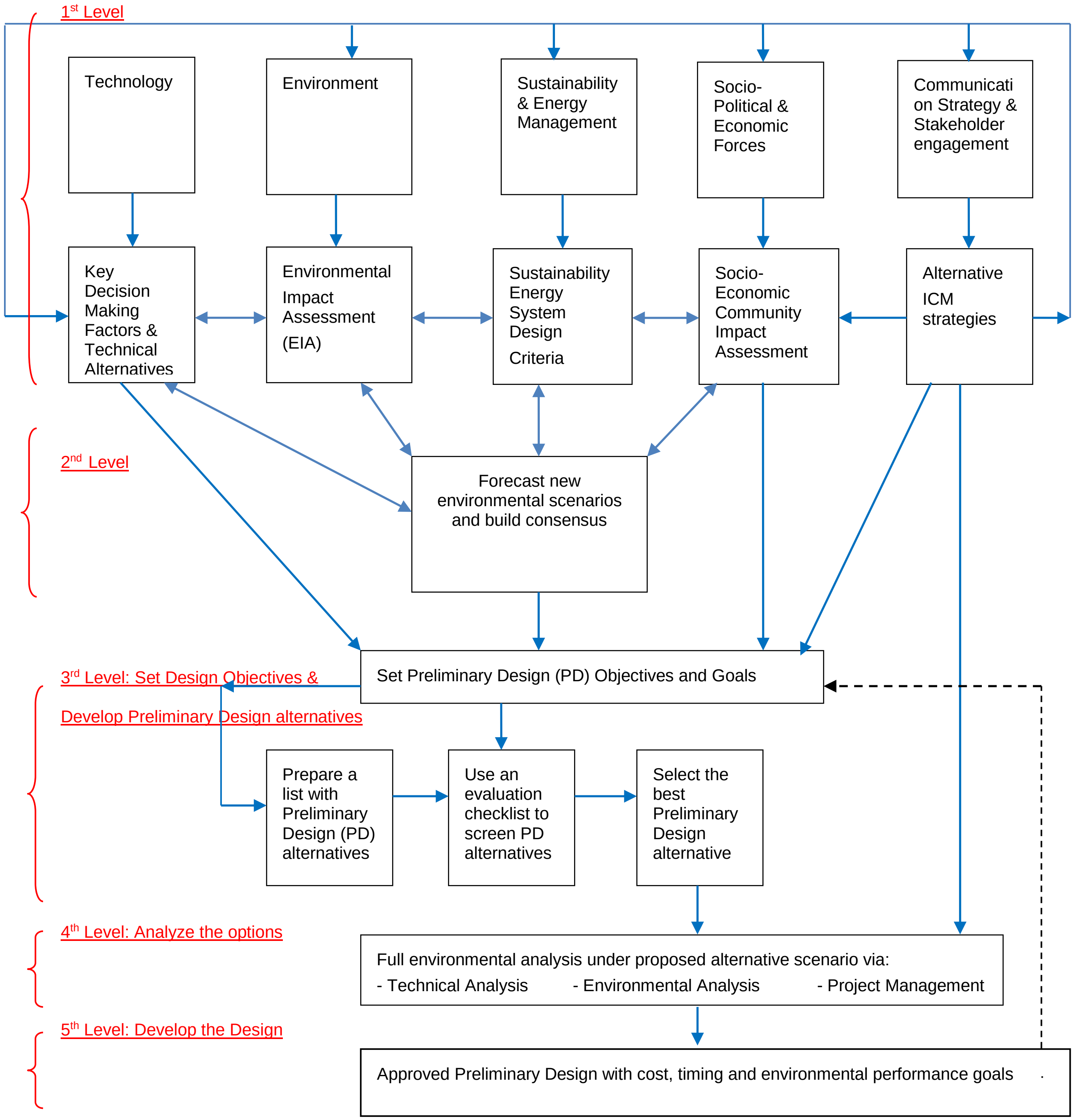

Figure 1: SIEM Architecture

SIEM-Level 1

The first level of the model identifies the five domains of environmental analysis: a) technology; b) environment; c) sustainability and energy management; d) sociopolitical and economic forces; e) communication strategy and stakeholder engagement. In addition, at level 1 the project manager should conduct quantitative and qualitative analysis of the technical specifications of each domain. More specifically:

<u>Technology</u>

As Delcan (2010), Dessau (2009) and Parsons Brinckerhoff (2012) would argue, the overriding purpose of this monitoring process is to provide the decision makers with the information needed to decide what technology will power the RRTS – using overhead catenary, third rail, or other means.

An equally important element in monitoring technology is the rolling stock assessment. The later entails the identification of a broad range of existing and future potential rolling stock technologies that could be used to provide future transit rail services (Dowling, 1991; Ford, 1992). Most industry experts would cite the following most commonly used rolling stock technologies (Jones, Robert C. 1980): (a) Diesel locomotives; (b) Diesel Multiple Units (DMU); (c) Electric Locomotives including Electric Multiple Units (EMU); (d) alternative rolling stock technologies and enhancements, including alternative locomotive fuels, hybrid drive trains, hydrogen fuel cell drive trains, maglev.

As Delcan et al. (2010) assert the power supply technology assessment will entail the identification of a broad range of existing and future potential electrification system technologies that could be used to provide power to the future transit rail services. Specifically, the electrification system technologies to be considered include the following: (a) DC electrification systems. (b) AC electrification systems at commercial frequency. (c) AC electrification systems at non-commercial frequency. (d) Combination of AC and DC electrification systems. (e) Alternative system technologies and enhancements. (f) Direct-fed system operating at 1x25 kV AC electrification voltage and commercial frequency of 60 Hz. (g) Autotransformer-fed system operating at 2x25 kV AC electrification voltage and commercial frequency of 60 Hz. (h) Direct-fed system operating at 1x50 kV AC electrification voltage and commercial frequency of 60 Hz.

Further, the key decision making factors for these train and traction power technologies must be compared and assessed by using the following screening questions: (a) Is the technology proven? (b) What are the users' total benefits? (c) Is the technology commercially viable? (d) Does the technology deliver transportation and environmental benefits? (e) Is the technology compatible with the "reference case" infrastructure and service levels? (f) Is the technology affordable? That is, does the technology present less implementation and operational risks? Thus, the key decision making factors include identification of the rail vehicle alternatives, qualitative criteria and environmental effects, quantitative criteria and environmental effects, as well as synthesis of qualitative and quantitative criteria.

Environment

The project manager must gather, collect and evaluate available information on air quality, noise, vibration, ground water pollution, and other environmental nuisances. One must also collect information on derelict vehicles and parts, especially tires and batteries disposal, and examine national environmental policy, existing regulations and guidelines. The environmental specialists must go to see the RRTS corridors in order to document the natural environment, covering such matters as land use and build environment, land communication routes at the community level, recreational, archaeological, aesthetic and cultural assets, noise, air and water quality, vegetation and wildlife, including endemic and/or endangered plant and animal species and migratory patterns, zones of exploitable natural resources, including land, water and hydrocarbon resources, and protected areas.

The analysis of the environmental data that will be collected must consider the project description, the description of the environment of the RRTS corridors, the public stakeholders' attitude towards the project, the environmental and urban planning concerns, the mitigation measures, and the monitoring requirements. With regards to the Environmental Impact Assessment (EIA) this is a systematic and structured process for identifying and assessing the potential environmental impacts of a proposed design-build project. This is an iterative process that runs in parallel with the design of the various proposals thereby allowing environmental information to be fed back into the design process. In addition, this process ensures that opportunities for mitigation and enhancement to avoid, reduce or offset environmental impacts are identified and incorporated into the design at the earliest opportunity.

Sustainability and Energy Management

Due to the increasing awareness and sensitivity of the public and scientists alike towards environmental issues, such as pollution, energy saving solutions and governmental green policies, there has been an increasing recognition of sustainability and energy management as essential components of the design methodology behind efficient rolling stock and traction power. The objectives of this component are resource conservation, climate protection and cost savings. Energy management is the proactive, organized and systematic coordination of procurement, conversion, distribution and use of energy to meet and outperform the environmental requirements, taking into account environmental and economic objectives (Sachs, 2008; Ball, 2005; Hawken, 1993).

Sustainability should become an integral part of the RRTS business strategy through corporate dedication, environment, safety, and the community. Specifically, through sustainability the RRTS should establish its environmental focus, based on CO_2 emissions and energy efficiency, waste management, and environmental shifters. The implementation of sustainability requires the development of a Sustainability Action Plan. This plan should be organized around five themes: (1) Improve rolling stock fleet fuel/traction power efficiency. (2) Improve RRTS building efficiency; (3) Invest in sustainable information technology. (4) Minimize waste and conserve a green environment. (5) Implement a clean Right of Way (ROW) policy across the corridors.

Additionally, emphasis should be placed on energy management. Energy Management in RRTS refers to the methods and techniques used to reduce the amount of energy utilized. This can be achieved by hardware design via use of energy efficient products, and people and equipment use energy management efficiently. According to Parsons Brinckerhoff (2012), the Energy Management Plan is developed in two stages: (1) The preliminary version of the Energy Management Plan, which describes the process for developing a full energy management plan, including what elements will be looked at and what strategies will be used. (2) The final version of the energy management plan, which describes what must be done to minimize energy costs and the details of how that will be achieved.

Socio-Economic Forces

This component analyzes in detail the socio-economic profile of the region where the RRTS infrastructure will be built across the proposed alignment. The monitoring of the socio-economic forces should begin the analysis of the RRTS corridor in conjunction with the national/regional economy and the key drivers of its economic growth. It should then describe the type of employment existing at the national and regional level and the breakdown of jobs by income ranges. The growth in vehicle ownership should then be examined in the context of increasing wealth, public aspirations, and environmental concerns of the population. Following this, the population distribution, land use and settlement patterns must be researched to understand the current pattern of travel demand and the future attractors and generators of travel demand.

Hence, by monitoring the socio-economic forces, the aim is to provide an overview of the historic and existing economic demographic and settlement patterns of the region and the expected direction of future growth in all these areas that would influence the transport patterns and travel demand over the next two to five decades. In order to achieve this, the SIEM model relies heavily on available documentation, such as master plans and studies, data available from authorities, such as the Central Statistical Office and international organizations, such as the United Nations and International Monetary Fund.

When monitoring the socio-economic forces of the project, it is necessary to identify the main economic drivers for the country and/or the urban area, the gross domestic product, the future GDP growth in the country, the employment and income distribution, the country's population and education, the existing land use and settlement patterns, as well as the future growth in population and employment. Of particular interest is the analysis of the population and community uses, which comprises: (a) The number of residents living alongside the RRTS. (b) The number and type of sensitive receptors located alongside the railway.

The Socieconomic Community Impact Assessment (SECIA) will be used to identify and evaluate the potential effects and impacts on the day-to-day lives of people; institutions, community and recreation features; and communities. The impacts may be positive or negative. The assessment can provide information used to assist in decision-making with respect to comparison/selection of options or alternative scenarios or the detailed assessment of a preferred option. The construction and operation of alternative rail transportation technologies can result in socio-economic community impacts – some positive, others negative. As Jorgensen et al (1996) explain, changes in noise and vibration levels, air quality and visual effects can affect the use and enjoyment of property, resulting in a change in satisfaction by residents, alteration in community character, or the operation of institutional, community and recreation features in the study area. Displacement of residents and institutional, community and recreation features may also occur if land is required for an option, with implications for residents, users and operators or community facilities and networks in the community (IGCB, 1999). However, using the data on predicted effects, examined with case study experience and professional judgement, it is possible to provide an indication of what will most likely happen.

Thus, SECIA will provide an overview of the considerations associated with the socio-economic community disciplines; assumptions for the socio-economic community impact assessment; a description of the relationship with other disciplines; criteria, indicators and data socurces for the social community impact assessment; the social community impact assessment and conclusions.

Communication and Marketing Strategy

Due to the strategic and economic significance of an RRTS project, the design and implementation of an effective communication strategy is necessary, in order to manage the public perception during the preliminary design. To achieve this, the contracting entities and the owner of the project must jointly develop a communication and marketing strategy in accordance with environmental, social and contractual requirements.

The main components for developing a successful communication strategy are: (1) Setting communication and marketing objectives that are SMART (specific, measurable, achievable, realistic and time-bound. (2) A thorough stakeholder mapping, outlining all stakeholder groupings that will be interested in and affected by RRTS during design, build, maintenance, and operational phases. (3) The strategic positioning of RRTS in the minds of the public and intended target markets and respective key messages. (4) A high level outline of communications activities and vehicles used to reach the target audiences.

Overall, the communication and marketing strategy must identify the components that will help a smooth coverage of any major infrastructure project including the design and build of a new RRTS or the upgrading of an existing one. The designer who will be nominated for the project should also be the primary promoter of the RRTS, and should retain the overall strategic communication approach. This approach should include various steps such as: (a) Setting the scene. (b) Inform and educate. (c) Build excitement. (d) Promote ridership. (e) Promote ridership and loyalty.

SIEM-Level 2

The second level of the model entails forecasting of new environmental scenarios and building consensus components. During forecasting SIEM will be developing a series of scenarios based on various inputs that will be derived from the detailed evaluation of each of the SIEM's five components and subcomponents of the first and second levels. Specifically, the derived data from the selection of the proper rolling stock and power technologies, in conjunction with the environmental, socioeconomic impact assessments, the applied design criteria for energy management and environmetal sustainability, and the development of alternative Integrated Marketing Communication (IMC) strategies will help to understand better the pros and cons in accordance with the proejct requirements and compliance standards, and therefore to forecast with further accuracy the environmental impacts and at the same time build a solid consensus towards the RRTS project. Upon formation and classification of the various forecasting scenarios the project manager will try to estimate the intencity, nature, and timing of the external forces that may affect environmental performance, disrupt plans, or force a change in the strategies for each forecasting scenario separately.

Further, a qualitative and quantitative analysis of the derived forecasting scenarios will be performed to determine the anticipated impacts to the terrestrial and aquatic ecosystems. Demand forecasting for RRTS infrastructure projects can be explained in three simple steps: (1) Identification of in-scope demand. (2) Capture the proportion of in-scope trips that will use the new service. (3) Estimate of future growth.

During this forecasting process it is necessary to build consensus, in order to establish stakeholder support towards the RRTS project, reduce risk and build the project's bench strength. Consultation and public participation is the main form of bulding consensus. This can be an extraordinary energy in a group of passionate people working on a common goal. Further, consensus building will resolve conflict, and will create and build workable solutions. Resolving conflict increases efficiency and expedites progress towards achieving project goals. Further, consutaltion and public participation can assist in the identification and mitigation of impacts, while preventing environmentally unacceptable development, controversy, confrontation and delay.

The project manager should carefully determine the stakeholders who can assist in the provision of information relevant to the project and seek their input in regards to the impact assessment process. These stakeholders would include government ministries/departments/statutory authorities, people living in the vicinity of the project, people that can be affected by the project (e.g. traditional users of the area), industrial stakeholders, environmental and other non-governmental organizations, environmental experts, and other business interests that can be affected by the project.

SIEM-Level 3

Level 3 involves setting the Preliminary Design objectives and developing preliminary design alternatives. Thus, the outcomes of the first and second levels of the SIEM models in conjunction with the forecasting outcomes from the reviewed environmental scenarios will provide us with the necessary information in order to develop the Preliminary Design objectives, which must comply with: (a) The environmental directives established by the Ministry of Environment. (b) The performance specifications established by the project's contract. Then, based on the above two considerations, the RRTS Preliminary Design will be environmentally sustainable and energy managed.

The list of goals for developing the RRTS Preliminary Design on civil works, rolling stock, and traction power is the following: (1) Efficient RRTS for users. (2) Reasonable project cost. (3) Minimal disruption during construction. (4) Aesthetically pleasing rapid rail transit system with easy access to stations, and trains. (5) Minimal environmental (air quality, noise, vibration, etc.) impact. (6) Landmark stations with Transit-Oriented Development, joint development opportunities, where feasible. (7) Minimal time taken to complete.

Thus, the project's Preliminary Design objectives and goals, requires that its designers should achieve an environmental viability in accordance with the proposed solutions. This can be achieved by implementing an integrated approach from an internal and external perspective into the RRTS design process. Further, in depth analysis of the goals and objectives can lead to a series of further aspired strategicly set engineering improvements of the RRTS.

The development of the Preliminary Design alternatives, in the third level, must follow a sequence of procedural steps in the following order. First, prepare a list with the most popular preliminary design alternatives, then use a qualitative checklist to screen the most preferable Preliminary Design alternatives, and finally select the best Preliminary Design alternative. The list of the preliminary design alternatives must be in compliance with the requirements posted by the Ministry of Environment as well as with the requirements and performance specifications identified by the technical specifications of the project's contract.

The above three components of the third level are linked to each other by a uni-directional route, as shown in Figure 1. However, there are certain occasions, such as when there is a very limited list of alternatives, that the SIEM model may proceed directly to the evaluation checklist for screening Preliminary Design alternatives and then proceed to the final step, which is the selection of the best Preliminary Design alternative.

SIEM-Level 4

Level 4 of the model entails a full environmental analysis under alternative scenarios. The scope of this component is to analyze options, which will be derived from the extensive analysis of the SIEM model, from the first level up to the third level, which is the set of the objectives and the development of the Preliminary Design alternatives. The full environmental analysis, at the fourth level, must meet the project's technical, environmental, project management requirements.

As far as the technical analysis requirements are concerned, the project manager should examine more thoroughly the potential issues and their impacts related to RRTS works and equipment related to civil, traction, and rolling stock. Additionally, emphasis should be placed on the potential issues and their impacts of the RRTS infrastructure with regards to the environment adjacent to the RRTS Right of Way (ROW). As far as the project management requirements are concerned, the project manager should examine in depth the potential issues and their impacts of the planning, scheduling, budgeting and required resources for the efficient design of the project without environmental impacts. This is very important because an integrated model has a reference period to be valid. Outside the borders of space and time the model will have other parameters of influence. In order to achieve further accuracy in the results during the process at level four, the project manager can utilize a Multi-Criteria Analysis (MCA) approach on the basis of qualitative and quantitative parameters.

SIEM-Level 5

The results from the analysis of the options in level four will be fed into level five of the SIEM model. The Preliminary Design at this level must be developed with regards to the material quantities, the timing, and the environmental performance goals. Upon validation and approval of the developed Preliminary Design, it is required to produce preliminary cost for the design and build of the RRTS project.

The approval of the Preliminary Design includes the following three stages: verification, validation and certification. During the Preliminary Design verification phase it is verified that all design outputs are in accordance with the design inputs, including the respective environmental and contractual requirements. The Preliminary Design verification is carried out during the quality control and design review. Additionally, the verification process may include inspection, comparison and performance of alternative calculations.

During the Preliminary Design validation it is demonstrated that there is the ability to fulfill specified environmental requirements. Thus, validation during the Preliminary Design phase will be assured by strict adherence to the existing design and environmental regulations and standards. In addition, pieces of work like soil improvement, drainage and noise barriers should appear on these drawings, because the study is intended to define them at the preliminary design stages.

Final Preliminary Design approval will be given by the design engineer or an independent authority after the verification and validation of the submitted design packages and will be documented in the design certificate for environmental clearance.

INTERFACE AMONG SIEM COMPONENTS

An essential function for the effective application of the SIEM model is the interface among the different SIEM components at each level. An Interfacing Impact Analysis should be conducted to identify and evaluate, not only the tangible and intangible interfacing effects of each SIEM component upon the other, but also the effects of the iteration processes between the 1st and 2nd levels, the 2nd and 3rd levels, and the 3rd and 5th levels of the model. The three cycles of iteration process are necessary in order to arrive at a decision or a desired result by repeating rounds of impact analysis and assessment. The objective is to bring the desired decision or result closer to environmental compliance standards with each iteration. The iterative process is used where the decision is not easily revocable or where the consequences of revocation could be evironmentally and economically costly.

For example, the sustainability and energy management system design criteria are directly and indirectly influenced by the Environmental Impact Assessment (EIA), the socio-economic community impact assessment, the key decision factors for technical alternatives and the communication strategy components to be implemented during the evolution of the SIEM.

In order to accurately monitor the impact analysis among the SIEM components, I have identified a list of five performance criteria for evaluating the interfacing impact analysis. The five performance criteria are: (1) Improvement of the environmental sustainability, the energy management and confinement of the environmental pollution. (2) Financial return on investment for both public and private investors. (3) Alignment efficiency. (4) Value recapture; (5) Livability/quality of life.

SIEM APPLIED METHODOLOGIES

Qualitative Evaluation Methodology and Criteria

SIEM's qualitative evaluation methodology is a thematic approach analysis. Its findings are generated through inductive processes — from detailed information to general themes (Bamberger et al. 2006). Thematic analysis involves: (a) Viewing the data several times as a whole. (b)

Identifying patterns and themes. (c) Reorganizing the data. This type of data analysis requires attention to detail and simultaneously being able to consider the data as a whole. Depending on the number and length of interviews, this process can be very time consuming.

The SIEM qualitative criteria will evaluate the impact of each of the potential environmental issues such as: pollution, noise, energy usage, visual impact, electromagnetic effects, attractiveness, and operation on the proposed infrastructure and electrical alternatives to be implemented along the railway corridor and the railway system. The first screening of infrastructure and electrical alternatives should be using a simple three-level rating system. Each alternative ought to be compared with the others and a rating should subsequently be applied, as follows: (a) Positive (identified as +). (b) Neutral (identified as 0). (c) Negative (identified as -).

Quantitative Evaluation Methodology and Criteria

Dessau (2008) suggests that the choice of the RRTS alignments and stations, and routes will be based on a quantitative analysis of various criteria. Each criterion will be assigned a unit of measure that may be dimensioned in hectares, km, and passengers-km and so on.

Routes within a given corridor may have different lengths. To avoid a bias, for instance by systematically favoring shorter routes, it is necessary to compute length-based values on a per-km basis. Also, because the units of measure are different one from the others, it is necessary to attribute a score to each criterion that will be dimension-less. In this way the scores of a given set of alternatives can be averaged to determine the final score for a given criterion.

The score can take any value from zero to 10. Usually a zero score will apply to a Yes/No choice, where the No identifies a fatal flow.

Except the case of a Yes/No alternative where a Yes scores 10 and No zero, each criterion is quantified on a measured scale. If the “best” alternative is to obtain the maximum value (for instance energy management) then a score of 10 will be attributed to that maximum value and the rest of the measured values will be pro-rated based on the best value figure as follows:

$$Score = (Value / Maximum\ Value) \times 10$$

If the "best" alternative is to obtain the minimum value (for instance cost), then the following equation will be used:

$$Score = 10 - ((Value/Maximum\ Value) \times 10)$$

Wherever possible the quantification of the criteria will be estimated for each set of alternatives on the basis of the sectors defined in the section.

<u>Multi-Criteria Analysis (MCA)</u>

SIEM Multi-Criteria Analysis (MCA) establishes preferences between options by reference to an explicit set of objectives that the decision making body has identified, and for which it has established measurable criteria to assess the extent to which the objectives have been achieved. In simple circumstances, the process of identifying objectives and criteria may alone provide enough information for decision-makers. However, SIEM MCA offers a number of ways of aggregating the data on individual criteria to provide indicators of the overall performance of options.Table 1 shows the criteria considered in the Multi-Criteria Analysis (MCA), and the measures used to evaluate each criterion.

Table 1: TRR Multi Criteria Analysis Measurements

	Criterion	**Measure**
1	Land and property acquisition	Areas in hectares
2	Construction costs	Length of Rapid Rail system in km
3	Hydrology	Length of bridges in km
4	Mobility improvements – ridership	Ridership levels
5	Mobility improvements – travel time	Average door-to-door time

6	Mobility improvements – new trips by Rapid Rail system	New trips made by Rapid Rail system
7	Environmental benefits	Reduction in trips by private cars (AM peak)
8	Environmental impacts – human	Number of rooftops within 200 m of the Rapid Rail System
9	Environmental impacts – natural, land	Surface of forest land
10	Environmental impacts – natural, water	Surface of flood-prone areas
11	Disruption during construction - traffic	Length of lane closures on adjacent existing roadway in lane-km
12	Disruption during construction – community	Population density within 200 m of the Rapid Rail system
13	Ease of construction	Number of obstacles per km of centre line of future Rapid Rail

SIEM APPLICATION FOR THE TRINIDAD RAPID RAIL'S EIA

Above I explained the purpose, the scope and the architecture of the SIEM model. Also, I presented the benefits of applying the SIEM model on Rapid Railway Transit System (RRTS) projects. It is always useful to provide examples of how theoretical models may be applied in real life and demonstrate their potential impact. As such, in this section I am applying the Strategic Integrated Environmental Model (SIEM) towards the Environmental Impact Assessment (EIA) of the Trinidad Rapid Rail project. The choice of the specific project stems from my personal involvement in the project and subsequently the ease of access to all relevant data. Further, the project in and if itself is exemplary, as it entails a Caribbean country of tropical climate, where environmental sensitivities are heightened and also presents a number of specific cultural complexities which showcase that the model is applicable in a number of international settings.

Technology – Traction Power and Rolling Stock

A comparison of the 25kV AC and 3kV DC technologies for the Overhead Catenary system was made in order to justify the choice of traction power supply voltage, independently from the selection of a rolling stock. The criteria were discussed in a matrix form, while the costs were provided for comparison purposes only, based on similar projects and they were not considered as contractual costs. The solution proposed for the Trinidad Rapid Rail (TRR) Traction Power technology was a combination of: (a) 2x25kV system from Westmoorings to Arima (which would be the most loaded section and from Junction to Chaguanas South). (b) 1x25kV system from Arima to Sangre Grande and from Chaguanas South to San Fernardo.

By applying the SIEM model the TRR project management preferred the electric over diesel trains solution, because proved to bring many advantages to the local government and to the citizens of Trinidad and Tobago. Specifically, the SIEM have shown that with regards to the:

- Capital Cost – There is a clear advantage to the electric trains even when including the traction power subsystem cost and this advantage also stands when we add possible cost of an emergency diesel generator for the traction power.
- Energy Cost – Even when considering constant process of energy, the gap was in favor of the electric solution.
- Rail Vehicle Maintenance – The cost of rolling stock maintenance is higher in diesel mode, with a lower level of rolling stock availability, two factors strongly in favor of an electric system. When was adding the cost of maintenance of the fixed electrical infrastructure (which is of course null in diesel mode), the global maintenance costs of the Diesel alternative was slightly higher than for the electric version.
- Impact on the Environment – The environmental study leaned strongly in favor of the electrification. The analysis provided show that electric systems will bring Green House Gas reduction than Diesel and could provide financial feedback through CO_2 trading (about

36Meuro for the whole network over the next 30 years). Furthermore, this would come with much less pollution damages.

- Accompanying the Growth – Electrification was the best solution to accompany the continuous growth of passenger traffic of Trinidad and to allow the Government of Trinidad and Tobago to offer a competitive alternative to cars, since electricity would be produced from gas, and Trinidad gas reserves were much more important than oil reserves.

<u>Environment</u>

Based on the SIEM model and its methodologies Table 2 was produced which shows the description of the environment as well as the potential concerns matrix of the Trinidad Rapid Rail (TRR) system. Sources of impact associated with design, and build activities were put in relation with broad categories of environmental components as described earlier.

These components were grouped into three major categories: (a) Physical environment: Erosion and slope instability, drainage, water quality, soil contamination, noise, vibration, air quality, light. (b) Biological environment: Flora and fauna. (c) Human and urban environment: Land use, roads and traffic, public networks, population.

Table 2: Potential Environmental Concerns Matrix

			Sources of Environmental Concerns										
Environmental Components			**Construction**									**Operation**	
			Land Acquisition	Demolition of Existing Buildings	Relocation of Public Utilities	Site Preparation	Earthworks, Causeway and Retaining walls	Drainage	Rail works	Road works	Buildings	Operation of System	Maintenance of System
Physical environment	Soil	Erosion and Slope Instability			✓	✓	✓	✓				✓	
		Soil Contamination		✓	✓	✓	✓		✓	✓	✓	✓	✓
	Water	Quality of surface and ground water			✓	✓	✓	✓	✓	✓	✓	✓	✓
		Drainage		✓		✓	✓	✓				✓	✓

	Air	Quality		✓	✓	✓	✓		✓	✓	✓		✓
		Noise		✓	✓	✓	✓		✓	✓	✓	✓	✓
Biological environment	Flora and fauna	Flora (species and habitat)				✓							
		Fauna (species and habitat)				✓							
Human and urban environment	Land use	Built environment	✓	✓				✓			✓		
		Agricultural Lands and Natural Resources	✓					✓					
		Archaeological and Heritage Features		✓	✓	✓	✓	✓					
	Infrastructures	Roads and traffic		✓	✓	✓	✓	✓	✓	✓	✓	✓	
		Public networks		✓	✓								
	Population	Lifestyle	✓									✓	
		Public Finances										✓	✓
		Local and Regional Economy		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Public health and safety		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

<u>Energy Management</u>

The goal of SIEM with regards to the energy management was to minimise energy costs by optimising the consumption of energy within the constraints of the TRR Baseline Service Plan. The designer evaluated, by means of the traction power simulation, what opportunity existed for the control of power demand which allowed an economically advantageous reduction in the installed substation power capacity and minimization of energy consumption. The future growth of the TRR was also considered.

Traction power was the major energy requirement. Operating voltage, substation power factor, vehicle acceleration, vehicle speed, and vehicle weight impacted energy use and assessed in the energy efficiency trade-off analysis. The current conductor cross section trade-offs of capital costs versus energy savings was also evaluated.

The energy management analysis included the traction power regeneration efficiency, as well as the acceptability and the potential benefit of bilateral power flow to the Utility system through the use of four quadrant power conversion. This encompassed power quality criteria which required significant investment and determined the economic viability.

Facility design criteria developed for all stations and buildings to minimize energy consumption. These criteria addressed heating, cooling, lighting, insulation values, energy-efficient equipment, and the use of automatic sensors, motion detectors, thermostats and similar devices with programmable computer override. Power demand at all facilities by location, time of day and time of year assessed by the design Contractor to support the preliminary design for the TRR power distribution.

Socioeconomic Forces

The general purpose of this activity was to profile the social context of communities affected along the rail corridors of the project, inform stakeholders about background and activities involved in the proposed TRR project, obtain their views on the same and take into account the concerns and issues which they believed should be addressed and taken abroad in the design of a rapid rail system. The key socioeconomic concerns associated with the selected alignment can be summarized as follows:

- Barrier Effect: Presence of the TRR fenced right-of-way may create a barrier within and between the communities, thus depriving residents of usual direct access to schools, places of worship, shopping facilities, etc. Design of the TRR will have to mitigate this impact during the construction and operation phases of the project.
- Land-use Modification: TRR may cause some transit oriented business activities located along the corridors to disappear or shift and relocate around new stations. It may also reduce quantum of agricultural and pasture lands and contribute to the permanent conversion of land to build new development and the possible introduction of incompatible land uses.

- Circulation Problems: During the construction phase, TRR is expected to potentially create circulation issues around stations location. Temporary road deviation will have to be carefully planned.
- Interference with known development projects: TRR will interfere with known development projects such as the New Port Development and the Physical Development Plan of the University of West Indies (UWI).
- Modifications in the transportation offer: TRR may affect the Public Transport Services Corporation (PTSC) by introducing competition on the East-West Corridor. TRR will require a re-organization of the traditional transportation system, including PTSC, maxi taxis, taxis, water taxis and highway network. A close and efficient collaboration is therefore a key success of the railway system.
- People care: TRR will involve relocation of people currently living in areas required for construction of the new facility.
- Noise: It will be generated during activities such as pile driving and with a lower intensity when heavy equipment is being operated. This potential impact will last only as long as the site preparation and construction phases. Noise will be of particular concern when pile driving must be undertaken in the down town area, relatively close to public buildings, and in the vicinity of houses, health facilities, schools and places of worship. Noise may also be emitted from the operation of the railroad and the maintenance facility.
- Vibration: As with noise, vibration is of particular concern where buildings are in relatively close proximity to pile driving activities and where there is continual heavy traffic. Implementation of protective measures will prevent damage to road infrastructure and buildings which may result through the cracking of foundations and the structures themselves.

Additionally, the SIEM qualitative analysis has shown that the Trinidad Rapid Rail Transit system had positive impacts to:

- The country's transport system: (a) Transportation system upgrade. (b) Reduction in travel time. (c) Improved accessibility to the capital. (d) More efficient transit services. (e) Decreased car congestion. (f) More efficient movement of goods. (g) Reduction of parking requirements in city centre.
- The National Economy: (a) Improved productivity. (b) Job creation. (c) Urban development along the TRR. (d) Stimulate economic development and GDP. (e) Positive impact for tourism.
- The Public Health: (a) Reduction of air pollution. (b) Reduction of stress and road rage. (c) Reduction of accidents. (d) Increase in leisure time. (e) Improved family and community life. (f) Improved sense of security.

<u>Communication Strategy and Stakeholder Engagement</u>

A stakeholder communication package was prepared by the contractors and after the approval of the National Infrastructure Development Company (NIDCO) it was used as part of the SIEM Communication Strategy and Stakeholder Engagement process. The package provided information on the TRR including overview information regarding the general location of the project, proposed locations of the rail alignment and stations, the organizational structure for the project and the contractual obligations of the main players: Ministry of Works (MoWT), NIDCO and the Contractors' consortium. The package concluded with the possible benefits that could be derived from the project.

The public consultations were taken the form of individual semi-structured dialogues and free flowing discussions with representatives of the targeted agencies and organizations. Presentations on the project were made by NIDCO, and the Contractors' representatives, and were followed by response and discussions with the representatives. The dialogue was guided by a series of questions, which were grouped into four key areas for feedback: (a) Their reaction to the TRR. (b) Social and environmental impacts and issues likely to ensue as a result of the TRR. (c) Measures recommended to be undertaken to mitigate any negative impacts and to address any foreseen challenges. (d) The manner in which these recommendations can be implemented.

The size and composition of the stakeholder groups provided discussions and feedback which varied in tenor, breadth of discussion and emphasis on issues for a similar set of core questions. Stakeholders generally have no difficulties in expressing themselves and some do so with passion and enthusiasm. In many public meetings, discussions between members of each group had a trend to confront issues raised by the proposed transit system and provide inputs on the basis of perceptions, knowledge of their communities, and expressed their vision for the nation's social and physical development.

CONCLUSIONS

The advent of the 21st century has brought about heightened concern and numerous discussions over environmental issues and sustainability. Mass transit is one of the most commonly cited ways to respond to the increasing commuting demands of the population in big cities, and is considered environmentally friendly, ecological, economical and time efficient. Rapid Rail Transit Systems (RRTS) designed for intra-city and inter-city commuting is thus gaining more and more attention as a main form of mass transit that can accommodate the needs of a modern society in a sustainable and eco-conscious manner.

As such, during the preliminary design of a RRTS, a designer must find the best alternative solution that is highly reliable, modern, safe, secure and above all sustainable and environmentally friendly. Presently a rather inconsistent planning process is followed by the majority of the rapid rail designers and contractors around the world, which results in design inaccuracies, miscommunication gaps, social arrest, over-budgeting, and implementation delays.

This proposed PhD thesis was undertaken in order to research and develop a Strategic Integrated Environmental Model, which would provide a consistent and solid pattern to examine all the potential environmental effects associated with the construction and operation of a RRTS. This model is aimed at ensuring that the new rail transit systems meet the environmental requirements and clearances set by local and international environmental organizations. This is becoming more and more important, as environmental assessments are becoming an accepted part of planning, especially for new and upgraded railway lines.

During the preliminary design of a rail transit system it is necessary to identify the nature and scale of environmental effects, which are likely to be brought about by the design and the construction of a railway line. Subsequently, one needs to identify what measures should be taken in order to minimize those effects. This is analyzed is two different stages of railway projects: (a) during construction, and (b) after completion. SIEM aims to be established as a standard tool to improve the planning activities of the RRTS infrastructures by the project's design and build contractors. The progress and effectiveness of SIEM are related to technical issues, as well as societal aspects, such as participation, institutional capacity, and democracy.

The architecture of SIEM encompasses the model's components and sub-components, as well as the interface among them and the impact of one component on the other. The SIEM model is not just the sum of its parts; it goes above and beyond that, creating a new architecture, which accounts for the interdependency of the model's components and therefore establishes an integrated and comprehensive model for environmental assessments. Therefore, the SIEM evaluation process must involve the qualitative assessment of schemes with regards to a checklist of environmental objectives. These may be of regional, national or international significance. The judgment criteria should include the need to minimize atmospheric pollution, noise/vibration, visual intrusion, severance, land-take, damage to the natural environment, as well as damage to archaeological sites and historic landscapes. SIEM was conceived to provide a specific framework for the management of these environmental impacts and as an initial structure for the environmental management plans when building new or upgrading existing RRTS.

The limitations of the SIEM model as it has been explained in the present study involve the lack of a thematic key performance indicator framework, which could be applied to develop indicators that are demonstrably aligned with the appropriate environmental concepts, policies and goals. Future research should focus on complementing the SIEM model with a set of key environmental indicators. The development of such a framework would involve the following tasks: (a) The development of a high level environmental goal. (b) Identification of the main environmental themes. (c) Development of objectives for each theme. (d) Indicator selection. (e) Development of targets. The components of such an environmental thematic framework could be developed from relevant legislation, government policy, current environmental reporting by boards, as well as from stakeholder and public consultation.

In conclusion, as environmental policies become more institutionalized, especially in advanced nations, it is necessary and useful to initiate the utilization of a strategic model accounting for environmental impacts of mass transit projects, such as the proposed SIEM. One of the main benefits of SIEM is that it provides logical patterns towards the seamless analysis of the inbound data, absolute integration of the various outputs, and implementation of the project schedule. Therefore, SIEM is very relevant to any transportation and non-transportation industry discussions. Further, the SIEM model can be incorporated in engineering classes and taught in engineering schools as part of the curriculum, as it prepares future mass transit engineers for the proper design, monitoring and control of the projects they will undertake.