LIFE CYCLE APPROACH TO SUSTAINABLE (ECO) URBAN SETTLEMENTS IN TROPICAL CONTEXT

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ABSTRACT: Concentration of human habitation in large scale will burden natural environment which furthermore will degrade the environment and increase poverty, in point of fact that less poverty will raise environmental protection. Sustainable development which according to Munasinghe is supposed to strictly maintain the important linkages between social and economic development and environmental protection, has been offering to prevail over the issue. Occurrence of the linkages has been manifested into several workable techniques based on a cradle to grave paradigm, in order to achieve sustainable (eco) products. The techniques are, life cycle assessment (LCA) which designated to assess product life cycle for products in general, while LCA in Sustainable Architecture designated to assess building life cycle process particularly for architecture mostly at construction stage. Both techniques carried out estimation of cost, energy, and environmental impact that will be spent and occur along the product and/or building life cycle. In favor of urban settlements, we need an approach which can meet requirements for the sustainability itself besides could possibly ease informal settlements. Life cycle approach to sustainable (eco) urban settlements, particularly in tropical context, is the most appropriate method in achieving the sustainability, though assessment should be performed seperately to each sub systems embraced by the settlements. Based on above facts, this paper will ascertain that life cycle approach is the most appropriate method to achieve sustainability of the settlements, in perspective of infrastructures which dwelling among others housing as immense part of the settlements with respect to support and services facilities.

KEYWORDS: natural environment degradation; life cycle assessment (LCA), sustainability, life cycle approach, sustainable (eco) urban settlements, tropical context

1. INTRODUCTION

In favor of products in general such as products of industrial processes and buildings as products of architectural and construction processes, Life Cycle Analysis (LCA) and LCA in Sustainable Architecture are techniques which are designated to assess cost, energy, and environmental impact that will be spent and occur along respective process, on purpose to achieve the sustainability of products. The process will incorporates not only the initial construction but also maintenance, replacement, and final demolition or reuse of systems over the useful life. Both techniques are assessment tools based on cradle to grave paradigm, as manifestation of important linkages between social and economic development and environmental protection. According to Munasinghe [4], sustainable development is supposed to strictly maintain the so called linkages.

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Urban settlements as infrastructure systems embrace many sub systems, among others residential facilities with regard to its overall support services either public or private. The state of the physical sustainability of any residential development is influenced by its spatial organization. The design most suited for the infrastructure systems which serve a particular development in turn would depend on the number of dwelling units in settlements and the number of occupants in each dwelling unit [6].

Urban settlements as broad systems which are dealing with lots of products, buildings, constructions, and systems, mainly housing, need a kind of method to assess the sustainability which is contend with. Life cycle approach has been applied to products and buildings and to systems such as water supply. With the intention that, life cycle approach could be possibly applied to broader system including urban settlements, although applied individually or seperately to every sub system embraced. Moreover, there are principles and/ or guidelines for products and buildings which were formulated based on cradle to grave paradigm. In favor of tropical context, items of the principles could be justifed according to tropical distinction, whilst in regard with housing provided a guideline for Eco-Housing in Tropical Regions [9].

2. LIFE CYCLE APPROACH

Life Cycle Analysis (LCA) as mentioned above has been designated to assess product life cycle for products in general, while LCA in Sustainable Architecture designated to asses building life cycle first and foremost for architecture and construction. Both techniques are based on cradle to grave paradigm, as materialization of the linkages between social and economic development and environmental protection in order to achieve sustainable (eco) products and buildings. In definite term, both techniques considering production processes as systems that should be assessed cyclically.

2.1 LIFE CYCLE ANALYSIS (LCA) TO SUSTAINABLE PRODUCTS

Life Cycle Analysis or Assessment (LCA), initially published in 1960, is concept to ensure the sustainability of quality and reliability of product in natural environment context by measuring its product life cycle.

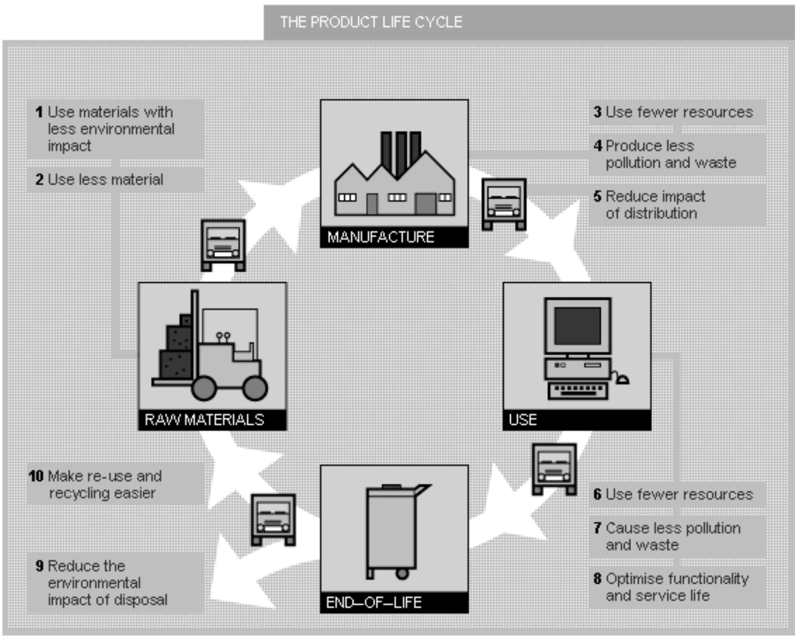

Figure 1. The Product Life Cycle [7]

Figure 1 shows overall process from Raw Materials, Manufacture, and Use, to End-of-life either reduce the environmental impact of disposal or make re-use and recycling easier, detailed as follows:

a. Raw Materials: 1. Use materials with less environmental impact; 2. Use less material;
b. Manufacture: 3. Use fewer resources; 4. Produce less pollution and waste; 5. Reduce impact of distribution;
c. Use: 6. Use fewer resources; 7. Cause less pollution and waste; 8. Optimize functionality and service life.
d. End-of-life: 9. Reduce the environmental impact of disposal; 10. Make re-use and recycling easier.

Analysis of each stage is carried out to estimate cost, energy, and environmental impact that will be spent and occur in respective stage. Similar analyses are accomplished to other stages, so that every breach will be analyzed nothing but for stakeholders' sake.

2.2 BUILDING LIFE CYCLE

Figure 2 explains impacts incurred by a building throughout its life cycle.

a. Cradle (i.e. Birth): Raw material acquisition will cause energy and cost usage besides environmental impact.
b. Products manufacture transportation: idem
c. Construction and fitting out: idem
d. Operation and maintenance: will cause operating energy and cost usage besides environmental impact as well.
e. Grave (i.e. Death): Renovation and demolition will cause energy and cost usage besides environmental impact.

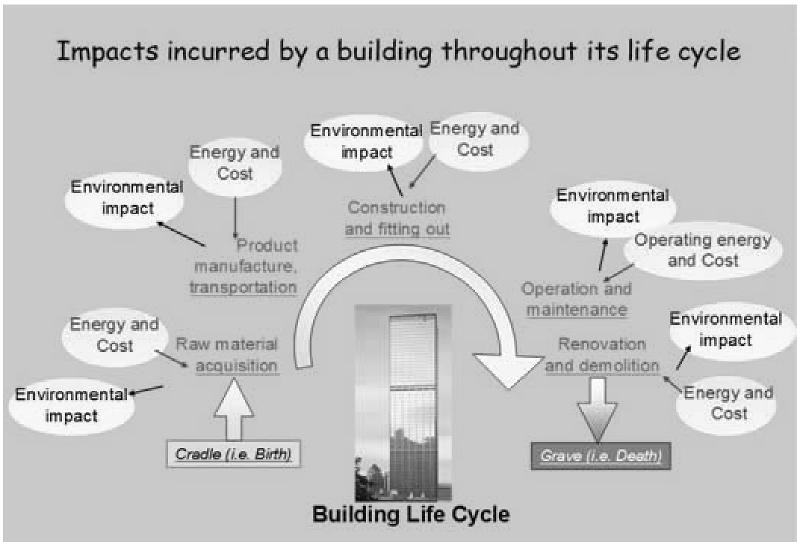

Figure 2. Building Life Cycle [5]

For estimating the amount of energy will be used, there should be analysis on both energy which is integrated into building and consumed along its life or for operational and maintenance purpose. Operation will depend on material usage and fabrication methods, whilst maintenance will depend on orientation, zone, and kind of windows, building surface sophistication, and will depend on lighting and air conditioning system, insulation, thermal characteristics of wall and roof.

For instance, a house used brick cladding on concrete slab and steel sheet on steel roof frame will need fewer energy compare to usage of energy along its life, since almost energy will be consumed for lighting, refrigerating, and/ or heating systems. Most effective way to reduce a household life cycle is by using energy conserved materials and system needed along the operational process. Solar passive design principles with energy conserved tools and lighting system is key factor that reduces energy consumption, which produced CO_2 as well as consequences of the increasing of energy production.

According to Yeang, appraisal stage of a design process is a retrospective act by which designer establish the quality of the solution. There are three basic steps in the conventional appraisal process i.e. Representation, Measurement, and Evaluation. Figure 3. Criteria for Evaluation, has been developed in order to enable effective design appraisal and evaluation, further development of criteria would involve appropriate quantitative data [10].

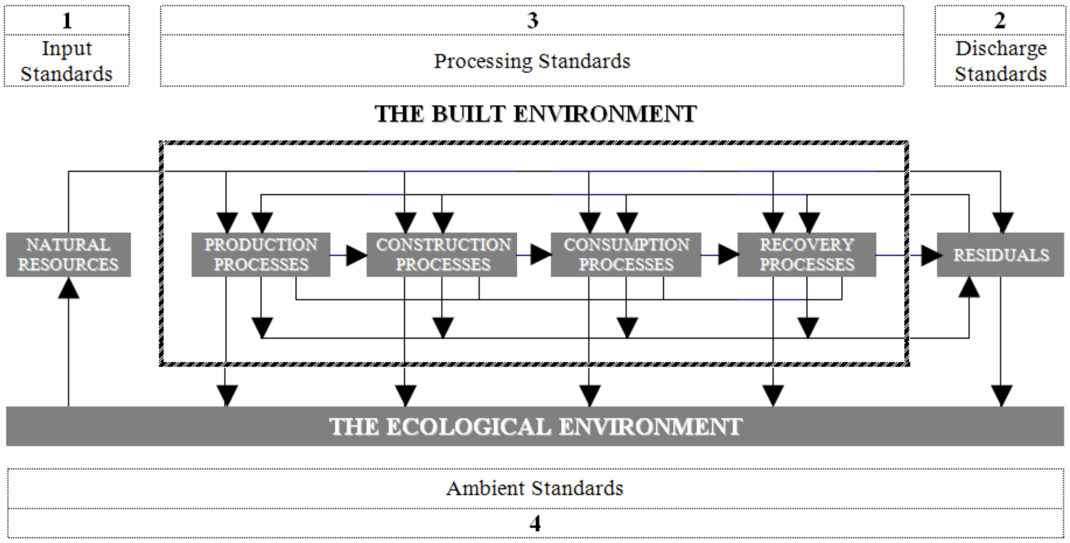

Figure 3. Criteria for Evaluation [10]

Input Criteria contend with**:**
Quantities of energy and materials used in the designed system; availability of the energy and material resources (rates of depletion); ecosystem consequences of each input used.

Output Criteria contend with**:**
The permissible quantities of output discharged by the designed system; routes taken by various outputs after discharge and their ecosystem consequences; the energy and material cost of management of the output; the ecosystem consequences of output management.

System Criteria contend with**:**
The extent of the pattern of needs and use; the efficiency of the system processes; the extent of internalization of the system processes; the ecosystem consequences of the realization of the designed system.

2.3. LIFE CYCLE ASSESSMENT IN SUSTAINABLE ARCHITECTURE (LISA)

Comparable to cradle to grave paradigm as mentioned in product life cycle, building life cycle, and design with nature, BHP Australia developed streamline computer software which is making the whole things efficient. LISA abbreviated from LCA in Sustainable Architecture is a streamlined LCA decision support tool for construction. It was developed in response to requests by architects and the industry for a simplified LCA tool to assist in green design.

LISA is designed to:

a. Identify key environmental issues mostly in construction process.
b. Provide designers or architects an easy to use tool for evaluating the environmental aspects of building design.
c. To enable designers or architects and specification officers to make informed choose based on whole of environmental life consideration, i.e. LCA.

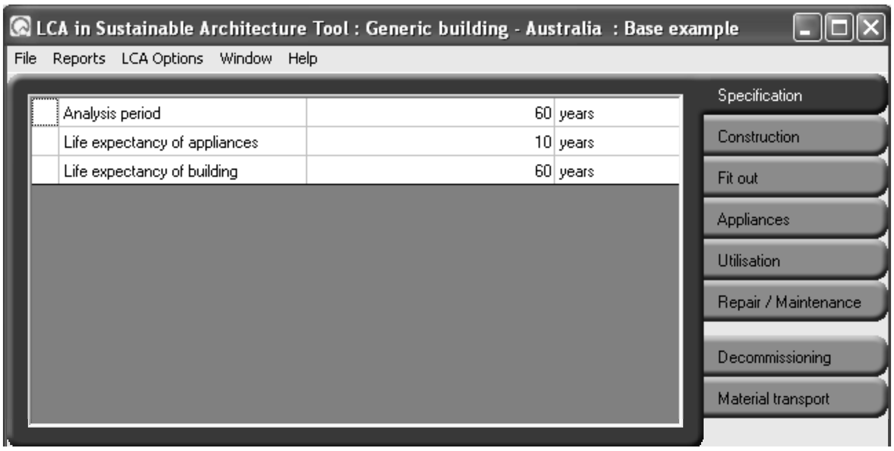

Figure 4. LISA Interface [2]

LISA has attractive, informative, and comprehensive interfaces, Figure 4. LISA Interface. LISA embraced all stages within design process, for instance designs of generic building include processes: Specification; Construction; Fit Out; Appliances; Utilisation; Repair/ Maintenance, and processes above are supported by Decomissioning and Material Transport.

Life cycle analysis, either integrated or seperately with cost analysis, are concepts and methods that have impacted remarkably on many fields i.e. products, buildings, watter supply, bridges, road networks, and many others. Analysis is formulated to consider the socio-economic effects due to operation as well as the minimisation of lifetime maintenance cost. Evaluations could be performed not only for a single product, building, or system but also for groups or network systems.

3. LIFE CYCLE APPROACH TO SUSTAINABLE (ECO) URBAN SETTLEMENTS

3.1 URBAN SETTLEMENTS

Settlements as built environment embrace organization of 4 things i.e. space, meaning, communication, and time. Based on space concept, space organization which always been dealt by planners and designers differs into built space of traditional cultures and geometric space of technological cultures mostly in urban context. Urban areas which are equipped with modern amenities and have great deal with technologies attracting people which intended for reside in urban parts of the world.

Large residential facilities, huge buildings and constructions, skyscrapers, complex mechanical and electrical, sanitary, utility, and other service systems are found in most of urban cities and areas. Majority of households in urban areas are blessed with that technological advancement. But the increasing population, majority of which prefers inhabit in urban cities and areas, has led to an imbalance in the density of human population that burden natural environment, besides excessive industrialization has invited environmental problems such as pollution.

3.2 SUSTAINABLE (ECO) URBAN SETTLEMENTS

Based on facts above, similar to many other products, designs, and systems, sustainability of settlements mainly within urban setting, nowadays turned to be necessary and need more consideration. Urban settlements as huge systems consist of buildings and infrastructures, too broad to be assessed solely on purpose to achieve its sustainability. It is needed a kind of method to approach towards the supposed sustainability. Life cycle approach hypothetically the most appropriate method, since life cycle analyses could be performed individually to respective sub systems and accomplish cumulative outcome.

The accumulation of the outcome of life cycle process of each sub system may possibly be understood as final examination. Nevertheless there are still breeches that need to be examined in favor of its sustainability. The breeches will occur since there are interdependencies between sub systems. Problems could be solved as long as the influence of interdependency includes into matters to be analyzed instead of disregard them on purpose simplification.

3.3 LIFE CYCLE APPROACH TO SUSTAINABLE (ECO) URBAN SETTLEMENTS IN TROPICAL CONTEXT

Figure 5 mentioned above illustrates proposed life cycle approach process to sustainable (eco) urban settlements in tropical context. Life Cycle Analysis (LCA) within product life cycle and Life Cycle Approach in Sustainable Architecture (LISA) within design or building life cycle has responsibility in achieving the sustainability. Whilst in comparable way the development could either be a new installation or an addition to an existing system, need a kind of life cycle process and best option for each case would be quite different [6]. For instance the true cost of water supply systems in her study is assessed using a life cycle approach, which incorporates not only the initial construction but also maintenance, replacement and final demolition of systems over the useful life.

In favor of cradle to grave paradigm as sustainability base, the integration of construction, maintenance, replacement, and final demolition of systems over the useful life could be performed as well to other infrastructures embraced by urban settlements. I.e. Highway, streets, and walks; Public utilities such as water supply, sanitary sewer, storm water sewer; Private utilities such as Gas, Electricity, Telephone; Public facilities and services such as Administrative and service offices, Fire and police stations, Libraries, Schools, Park and playgrounds, Solid waste collection.

As mentioned before life cycle analyses could be performed individually to respective sub systems and achieve cumulative outcomes, but breeches caused by the interdependencies between sub systems or infrastructures and facilities should be matters to be considered and analyzed as cost and energy consumers. Several principles and guidelines for sub systems embraced by urban settlements among others Principles of Built Environment in Context of Sustainable Development [1] and Guidelines of Eco-Housing in Tropical Regions [9] that consist of matters should be analyzed and applied, shows comprehensiveness and the depth of cradle to grave paradigm.

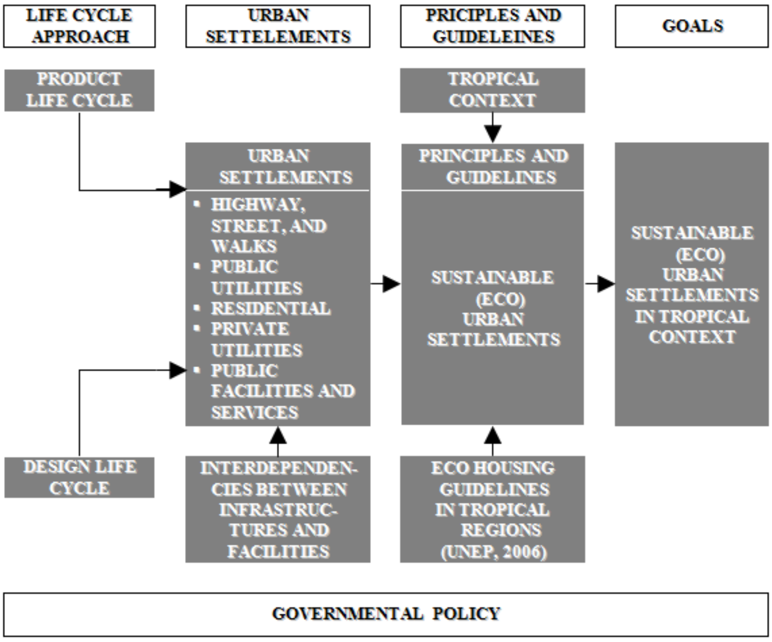

Figure 5. Life Cycle Approach to Sustainable (Eco) Urban Settlements in Tropical Context

Tropical context in general will mainly influence the principles in regard with climate i.e. thermal comfort, wind velocity, humidity; besides culture and society. Finally, Governmental Policy has important role and responsibility besides has to have commitment concerning the realization of overall concepts, since without a kind law inforcement the concepts will remain yet piece of papers.

3.4 PRINCIPLES OF SUSTAINABLE (ECO) BUILT ENVIRONMENT AND ECO-HOUSING GUIDELINES

Principles of built environment, architecture in smaller scale, in sustainable development context [1], embraces the consecutive matters to be considered in achieving natural sustainability as follows: Architecture and Construction: Site: General, Pedestrians Concept, Outdoor Air Conditioning, Landscape; Buildings: General, Solar Orientation, Form and Space Configuration, Façade, Structural System, Construction and Materials, Mechanical and Electrical/ Utilities, Building Automation System, Landscape.; Procurement Strategy; Policy; Designers and Architects' Role, managing resources, materials, users, and development; Energy Consumption; Resources**,** consists of Natural and Man made resources.

In comparable way Eco-Housing Guidelines in Tropical Regions [9] embraces guidelines for the consecutive matters to be considered in achieving natural sustainability as follows: Pre-design guidelines; Site planning; Material and product selection; Sustainable use of energy; Water and sanitation; Solid waste management; Indoor environment quality; Construction administration; Building commissioning, operation and maintenance. Life cycle approach is one of several methods mentioned in guidelines that could be performed to establish Eco-Housing design.

4. LCA IN ACTION

Following section will portray the LCA in action. As mention before, sustainability of Urban Settlements is too huge to be analyzed as a system. With the intention that each sub system embraced should be analyzed separately i.e. (eco) housing/ residential, common buildings, infrastructure that consist of highway, street, and walks, public facilities and services such as water supply and waste water systems. The concern of tropical context will mostly influence the design, method of construction, and materials. Due to limitation, LCA in action will not describe all of sub systems of the settlements embraced, but sub systems which are considered can represent another buildings and infrastructures with similar issues.

4.1 BUILDINGS

Following analysis should be applied on building design processes in common, and take in to consideration particularly at construction process stage. Design process will produce Specification i.e. Building Breadth which will affect Construction choices and Fit Out process. Concurrently design process should take Operational Process which consists of Utilization and Repair/ Maintenance, in to concern in matters of cost and energy that will be spent and environmental impact that will occur by making choices of design, construction and materials, and fitting out. Furthermore overall process will be affected by Decommissioning and Material Transport as well. Overall steps below should take in to consideration along the process of design, and decisively should be taken care at the Construction Process stage [2].

Figure 6. Life Cycle Analysis of Building

LIFE CYCLE PROCESS	SUB SYSTEMS	DECOMMIS SIONING	MATERIAL TRANSPORT
DESIGN PROCESS			
Specification	▪ Building Breadth ▪ Building Life ▪ Door Area ▪ Floor to Ceiling Height ▪ Length ▪ Number of Floor ▪ Number of Lift ▪ Window Height	–	–
CONSTRUCTION PROCESS			
Construction	▪ Structure ▪ Walls ▪ Windows	NO	YES
Fit Out	▪ Air Conditioning ▪ Finishing ▪ Installation ▪ Stair	NO	YES
OPERATIONAL PROCESS			
Utilization	▪ Heating ▪ Lighting ▪ Office Equipment ▪ Other Electrical Appliances ▪ Water Heater	–	–
Repair/ Maintenance	▪ Air Conditioning ▪ Finishing ▪ Installation ▪ Structure ▪ Walls ▪ Doors	–	YES

Figure 7. Construction (Process) Stage

CONSTRUCTION		SPECIFICATION	DECOMIS SIONING	MATERIAL TRANSPORT	
STRUCTURE	Roof Structure	Pitched Roof, Concrete Slab	No	Railway Highway Sea	No Yes No
	Sub structure	Foundations, slab, and groundbeam.	No	Train Highway Sea	No Yes No
	Upper Floors/ Frame	Celullar beams and composite slabs. Composite beams and composite slabs. Precast hollow concrete core units. Reinforced concrete slabs. Precast beam and floor slab.	No	Train Highway Sea	No Yes No
WALLS	External Wall	Concrete blocks with brick face.	No	Train Highway Sea	No Yes No
	Internal Wall	Concrete blocks, timber studs, plasterboard lining.	No	Train Highway Sea	No Yes No
WINDOWS	Windows	UPVC frame, doubled glazed.	No	Train Highway Sea	No Yes No

Construction Process shows details of specification of consecutive structural items, Upper Floors/ Frame, Substructure, Roof Structure that consists of respective specifications that followed by decomissioning and material transport remarks. Each item of specifications has respective LCI (Life Cycle Inventory) data.

LCI data will shows material consumptions and attributes of Upper Floors/ Frame: Number of floors – 1. Each used material has respective equation. GGE = Greenhouse Gass Emissions stated in t equiv CO_2, Mass stated in kg, t. Resource Energy stated in TJ. GGE calculation including IPCC weighting factors (global warming potensials) such as CH_4 dan N_2O.

Impact Chart will show total investigated environmental impacts that will occur along the process, for instance energy consumption that will be used by the building, GGE (Greenhouse Gas Emissions), NO_x, SO_x, NMVOC (Non Methane Volatile Organic Compounds), SPM (Suspended Particular Matter), and Water consumption.

Bill of Materials will show the amount of each material needed. For instance, Upper Floor/ Frame item of Construction Stage that consists of following components, Concrete Block, Timber, and Material Transport, and respective component consists of various materials. The amount of materials including material transport will be calculated for each component.

Base Materials Data will provide data base information of base materials, such as Aluminium and Asphalt, concerning environmental impacts attribute for instance GGE (Greenhouse Gas Emissions), NMVOC (Non Methane Volatile Organic Compounds), NO_x, Resource Energy, SO_x, and Water, that followed by their respective value and recycling credit.

4.2 INFRASTRUCTURES

LCA of Water Supply in Auckland, New Zealand-Based on similar paradigm, the true cost of water supply systems is assessed using a life cycle approach, which incorporates not only the initial construction but also maintenance, replacement and final demolition of systems over the useful life. Residential density/ settlement patterns with the least environmental impact for mains water supply are identified in terms of life cycle energy and carbon dioxide emissions by detailed analysis of various land use patterns and the existing mains water supply system in Auckland, New Zealand [6].

Environmental Credential of Road in Australia-Life Cycle Environmental Impacts of construction, maintenance, and utilisation of asphalt and concrete roads in Australia. The roads construction systems investigated include urban highways and residential streets. Various types of subgrade also considered. The investigation includes the use of recycled reinforced steel and the use of blast furnace slag, as a cement and aggregate replacement. The system analyzed included manufacture of all materials from resources in the ground, construction site activities, construction equipment, repairs/ maintenance, and finally, decommissioning. The entire life cycle is considered, from resources in ground to demolition, and recycling/ landfill of the structure. Transportation mode and distance are included for each material [2].

5. CONCLUSIONS

a. Life Cycle Approaches could be performed to Urban Settlements on purpose to achieve the sustainability as Eco Settlements, although it has to be performed seperately to each systems embraced by settlements. Nevertheless there are breeches that will occur caused by interdependencies between sub systems. Problems could be solved as long as the influence of interdependency includes into substance to be analyzed instead of disregard them on purpose simplification.
b. Residential facilities or housing as immense parts of Urban Seettlements will importantly determine the scale of other systems embraced by settelements, such as support and services system. Eco-Housing Guidelines in Tropical Regions [9] which contend with i.e. Sustainable use of energy; Water and sanitation; Solid waste management; Indoor environment quality, has effectively confirmed the matters.
c. Automation of LCA tools, by means of information and communication technology or computers potencies such as LISA, established by BHP Australia, besides will streamline the designs the tools will shorten the elapsed process time additionally.
d. Governmental Policy along with their law enforcement has important role concerning the realization of overall concepts, without that matters the concepts will remain piece of papers.

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