ACHIEVING THE BEST VALUE THROUGH ENVIRONMENTAL SUSTAINABLE CONSTRUCTION

INTEGRATED PROCESS MODEL

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Dedication

To my parents,

For their Wisdom and Guidance

Declaration

I hearby declare that this submission of thesis is my own work and that, to the best my knowledge and belief, it contain neither materials or facts previously published or written by another person nor materials or facts which to a substantial extent has been accepted for the award of any degree or diploma of a University or other Institute of higher studies, except where an acknowledgement is made in the text.

UOM Verified Signature

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R.M.A.S. Manewa

July 2007.

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Abstract

Value Management (VM) and Environmental Sustainability (ES) are increasingly becoming important tools to be considered in construction. VM is one of the recognized techniques that made substantial cost savings on construction projects and sustainability is about delivering better long term value for the built environment and its inhabitants. The attention on ES issues in VM remains untapped area due to scarcity of information. Theoretically, the intrinsic capabilities and the positive relationships between these two heighten VM position as an effective means for sustainability improvements. The purpose of this research study is to identify how the ES criteria could be incorporated into the VM process and it's acceptability by the construction clients. The research is focused on a development of a process model by combining both ES and the best value criteria to select construction materials.

The research was placed in qualitative research philosophies as the aim was to generate rich data from the experiences of VM team to find the means of ES delivery in VM. This research begins from the data gathered through a comprehensive literature review and unstructured interviews. Based on the literature review the Integrated Process Model (IPM) was developed. The developed model was tested through multiple case studies to find the client's acceptance towards the environment favourable material selection.

It was found 47% of materials derived from the IPM are purely matching with the client's choice. By adopting this process model at the very early stages of material selection the acceptance can be improved further.

The research can concluded that the VM and ES can be incorporated through the Integrated Process Model to select construction materials. Further the model has the high level of acceptance among the construction clients and the early application of the model provides multiple benefits to the project stakeholders.

Key Words: Best Value, Value Management, Environment Sustainability, Construction Materials, Integrated Process Model

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Abbreviations

BV	-	Best Value
CS	-	Combined Scoring
ES	-	Environment Sustainability
ESI	-	Environment Sustainable Index
FAST	-	Functional Analysis System Technique
GS	-	Green Scoring
IPM	-	Integrated Process Model
LCA	-	Life Cycle Assessment
MCS	-	Multi Criteria Scoring
UN	-	United Nations
VI	-	Value Index
VM	-	Value Management

Chapter One

Introduction

Chapter One

Introduction

The purpose of this research study is to introduce an Integrated Process Model (IPM) to select construction materials which provides a balance between Best Value (BV) and Environment Sustainability (ES). At present ES is considered as one of the BV criteria in Value Management (VM) process, but it has not addressed its' multifaceted nature properly. To minimize those limitations in the current practice it was hoped to develop the IPM by combining both BV and ES criteria. The model is hoped to test the client's acceptance towards the material selection process.

1.1 Background

Clients are seeking the best return to their investments and their objective is to have a project that perfectly balances the competing criteria of time, cost and quality (Best and Valence, 1999). The 'Environment' is recently added as one of the significant constraint to the existence and that ought to be considered in construction process. On the global scale, construction products and processes consume a critical amount of material and energy sources, and are responsible for a very significant portion of pollution by harmful and damaging emissions and wastes (Hajek, 2001). To minimize those burdens, it was recognized to direct the projects towards sustainability.

Sustainability concerns protecting environmental quality, enhancing social prosperity and improving economic performance (Addis and Talbot, 2001). With reference to the

Brutland Report released by the World Commission on Environment and Development (1987), it is meeting the needs of the present without compromising the ability of future generations to meet their own needs. It promotes a balanced approach by taking account of the need to continue in business, but does not seek profitability at the expense of the environment or society's needs (MaSC, 2002). Therefore it is recognised to develop a proper tool to measure the sustainability levels of any product or a process.

There are literally hundreds of indicators and assessment methods for evaluating sustainability, but these often conflict, badly structured and do not have a common vocabulary (Brandon and Lumbardi, 2005). The United Nations (2006) has introduced 50 core indicators of sustainability which are part of a larger set of 98 indicators. Among them most of the indicators are concerning the environment issues. The relationship between construction activities and the environment is well recognized (Ofori, 1997), because most of the construction activities are directly open to the natural environment and most of the construction products are based on natural resources.

When directing any product towards environment sustainable goals, materials, air quality, energy, water, environmental health and biodiversity are the key indicators that need to be monitored properly (ESI, 2005). Among them construction materials play a significant role. Therefore it is highlighted to find a means to minimize the environmental hazardous through construction material while balancing the other BV criteria. Selecting environment preferably building material is one way to improve environmental performance of buildings (Sturges, 2004). Through the application of green materials and processes ES can be achieved. The reusability, recyclability, renewability, embodied energy content and other destructive emissions are the identical key variables for material green labeling (Hajek, 2001).

The considerable demand for Best Value (BV) applications in construction was identified. There are variety of BV processes are increasingly being introduced and it is essential to identify the most effective process depending on the level of suitability (Cha and O'Connor, 2005). Borrowing from the best of many different disciplines and management processes, VM is probably the most complete process available to deliver the BV (Martin, 1997). It is a structured approach to establishing what value means to a client in meeting a perceived need by clearly defining and agreeing the project objectives and establishing how they can best be achieved (Construction Industry Board, 1997).

The varying expectations of building owners mean that value has different meanings for different people (Best and Valence, 1999). VM is one of the decision support tools that focus on maximising the functional value of a product and service. It always focuses to achieve sprit of every activity and attempt to eliminate unnecessary burdens. Therefore VM is selected as the value optimisation technique which will be best fitted to the BV criteria. At present there is an identical demand for BV applications in Sri Lankan construction industry. As a result the VM process is incorporated in the Standard Bidding Document for construction works which was published in the beginning of 2007.

The application of VM throughout a project life cycle derives multiple benefits (Kelly and Browen, 1995) to client as well as the society. The tool frequently uses to choose the construction materials in terms of the BV. Therefore incorporating the ES criteria to VM process will provide better solutions to the client and the society.

At present, the ES and VM are being practiced as independent decision support tools (Manewa etal, 2005). The ES is already identified as one of a value optimisation criterion in multi criteria scoring process without considering its multi faceted nature. The value assign for the ES criterion is just a figure given by the VM team without compromising the integrated indicators that reflects the reliable ES. It has recently been suggested that the future of the construction industry lies in adopting a new business model based on the concept of integrated solutions (Brady etal, 2005).

This research is primarily focusing to originate stability between these two concepts by introducing an Integrated Process Model to select construction materials. Further it is an attempt to guide the construction project participants to select eco friendly materials which adds the BV for their ultimate selection. The eco friendliness of a material is based on the life cycle assessment which addresses recycle content, reusability, recyclability, renewability, embedded energy and other emissions.

This would ensure the VM practices remain competitive. At the same time, ES issues and eco thinking would be absorbed in the project process. By realizing the potential of VM as a means to improve ES, it is hoped that this research would instigate further research in this area, which would benefit both VM and sustainability consideration.

1.2 Research Problem

The construction clients are claiming the best value (BV) for their money. In their value driven journey they are paying poor attention to protect the environment. At present environment sustainability (ES) is becoming as one of the global issue and it is considered as one of the criterion when delivering the BV. But ES is a multidimensional concept and it's hard to address as a single criterion in any process. Therefore the research focused to analyse how the environment sustainable criteria can be incorporated into the value management process and it's acceptability by the construction clients when choosing the materials.

1.3 Research Objectives

The objectives of this research study are;

- To develop an Integrated Process Model (IPM) by combining both ES and VM criteria.
- To check the validity of the proposed model

Making the better balance between best value and environment is significant. At present these concepts are practicing as independent decision support tools in construction industry. Therefore it was hoped this model will addresses both concepts together and delivers better solution than their independent practices when choosing construction materials.

1.4 Scope of Research

The research focuses on environment sustainable improvements in construction material selection and it may not address the economic and social grounds of sustainability in detailed. The integrated process model was adapted to the material selection process of selected building elements to check its validity.

1.5 Research Findings

The developed model was tested through multiple case studies to find the client's acceptance towards the environment favourable material selection. It was found 47% of materials derived from the IPM are purely matching with the client's choice. By adopting this process model at the very early stages of material selection the acceptance can be improved further. It was difficult to generalize the findings obtained through case studies.

1.6 Thesis Structure

Chapter one introduces the research.

Chapter two focuses on a three phases of literature review. The first part reviews the Environment Sustainability and its applications in construction process and the second part focuses on Best Value through Value Management. The last part aimed to integrate the both concepts together and the chapter will conclude with a research hypothesis.

Chapter three describes the research methodology. The research was placed in qualitative research philosophies as the aim was to generate rich data from the experiences of VM team to find the means of ES delivery in VM. An Integrated Process Model (IPM) was developed and it was tested its acceptance among the construction clients in Sri Lanka.

The data is analysed in Chapter Four. The multiple case studies were used to analyse the derived data through client's choice and the IPM.

Chapter Five concludes the work and presents the contributions. Further it is highlights some recommendations for the industry at last.

Chapter Two

Literature Review

Chapter Two

Literature Review

The Chapter reviews the necessity of establishing an Integrated Process Model (IPM) to select construction materials in terms of Best Value (BV) and the Environment Sustainability (ES). It was hoped the model will bring satisfactory solution to both the client and the society when selecting a construction material. The model was tested in its validity and concludes with a research hypothesis.

2.1 Sustainability

Defining what 'Sustainability' means in the construction industry, its issues and purposes have been discussed by many authors (Addis and Talbot, 2001; WS Atkins Consultants, 2001; Baldock, 2000; Department of the Environment, Transport and the Regions, 2000; Raynsford, 2000; Bogenstatter, 2000; Parkin, 2000; Edwards, 1999; Hill and Bowen, 1997; Miyatake, 1996). According to Gibbere (2003) sustainability is the simple idea of ensuring a better quality of life for everyone now and for generations to come.

In its widest sense sustainability is about delivering better long term value for the built environment and its inhabitants (Hayles, 2003) and it's an achievement of a better quality of life through the efficient use of resources, which realise continued social progress while maintaining stable economic growth and caring for the environment (Sustainable Development Toolkit, 2005). Kibert etal (2000) have identified that the application of principles of sustainability to human activities ultimately must result in the scrutiny of all sectors of economic activity to assess the changes required to provide for a high quality of life for future generations. The concept 'sustainability' is amalgamating with economic, social and environmental issues (Lombardi and Brandon, 2002) which are further known as 'the three pillars of sustainability'. Achieving the best balance between these three pillars is significant when any project is driven through sustainability.

In the context of construction, social sustainability is often the least considered area but it has the potential to bring the most benefits (SD Toolkit, 2005). Economic sustainability focuses on the importance of stable economic growth and environment sustainability is the most significant concept that ought to be addressed in construction (Lippiatt, 2002). It basically concerned with protecting and conserving both biodiversity and the environment, by reducing waste, preventing pollution using water and other natural resources as efficiently as possible (SD Toolkit, 2005). The construction has significant impact to the environment (RICS, 2005). Therefore addressing the ES issues in construction is vital.

2.1.1 Environment Sustainability

Environment Sustainability (ES) is a context driven concept and different societies tend to define it based on their own values, needs and expectations. The philosophy of ES is to leave the earth in as good or better shape for future generations than we found it for ourselves (Veleva etal, 2003). By a definition, human activity is only environmentally sustainable when it can be performed or maintained indefinitely without depleting natural resources or degrading the natural environment (Khalfan, 2002).

It is one of the significant sustainable parameter which is incorporating with multiple variables. Natural Resources, air quality, water resources, bio diversity and habitat, environmental health, energy are the key performance indicators of the ES (ESI, 2005). Most of the indicators are depending on multiple variables. When concerning the natural resources the building materials have great impact on ES. Sustainable building materials have environmental and health merits which traditional materials have typically not considered. The production and use of these materials means less energy consumption, less natural resource depletion and pollution, and are generally less toxic for both the planet and its occupants. Through a greening process the environmental favourable results can be obtained.

ES is not well addressed in construction and at present it makes number of repercussions in global arena. As a result, the sustainable concerns are added to the construction recently through the 'Sustainable Construction'. The consideration on nature should be given when the people are carrying the development activities. The current interest in sustainable development has come from pressure groups and particularly those associated with the green movement who saw the depletion of non renewable resources, the pollution of the air, water and the breakdown of social conscience through globalization, as leading to the demise of mankind and the balance of nature which presently sustains living creatures (Brandon and Lombardi, 2005). Buildings also account for 40 % of the energy and 16 % of the water used annually worldwide and one-sixth of the world's fresh water withdrawals, one quarter of it's wood harvest and two fifth of its material and energy flows (Augenbroe and Pearce, 2000).

It's comprehensive and long-term focus requires that attention be paid to natural resource endowments, past environmental performance, and the ability to change future pollution and resource use trajectories as well as present environmental results (EPI, 2006). If any product is labeled as environment favourable that should be well balanced with low embodied and maintenance energy, high content of reusability, compatibility with environmental policies and the design incorporate materials with a long life and low maintenance requirements. With reference to SD Toolkit (2005) the design should use materials, which have a low environmental impact. That is examining the processes around how the material is obtained or manufactured and whether it can be re-used or even recycled at the end of its useful life. Through a proper handling of materials ES can be achieved in satisfactory level.

When the construction industry is considered globally, it is by far the largest consumer of materials on planet earth (Sturges, 2004). They have throughout the century been the most dominant of all types of materials used, representing as much as three quarters (by weight) of consumed renewable and nonrenewable resources annually (Matos and Wagner, 2005). Roodman and Lenssen (1995) have cited that the building construction consumes 40 % of the raw stone, gravel, and sand used globally each year, and 25 % of the virgin wood. It is clear that the environment protection from construction activities is vital.

2.1.2 Sustainable Construction

The concept of sustainable construction emerged simultaneously the evolution of the concept of sustainable development. It is generally used to describe the application of sustainable development to the construction industry.

One tenth of the global economy is dedicated to constructing, operating and equipping buildings and infrastructure facilities. Buildings and structures use raw materials, some of which are non renewable. They use energy to extract these materials and to manufacture components (Brandon and Lombardi, 2005). Those activities solely account for approximately 40% of the material entering the world economy (Chen and Chamber, 1999). Over 80% of construction materials come from natural resources (Ganesan, 2000). And all of these resources are consumed in the construction operation of built environment.

Environmental stress has often been seen as the result of the growing demand on scarce resources and the pollution generated by the rising living standard of the relatively affluent (Brutland Report, 1987). Since the construction industry is directly influenced to the economic growth and that can be seen as one of the environment burdensome industry. The fundamental purpose of sustainable construction is to reduce or even reverse the harmful impact of buildings on the natural environment (Malin, 2004). Further the value of an end product can be increased through ecological sustainable principles (Durham, 1999).

It is a critical issue for the systems and techniques that employ to measure progress (Brandon and Lombardi, 2005). The initial focus was on how to deal with the issues of limited resources, especially energy and on how to reduce impacts on the natural environment. As well emphasis was placed on technical issues such as materials, building and infrastructure components, construction methods and technologies and energy related concepts as and when the concept is being developed.

The concept was originally proposed to discuss the responsibility of construction industry in attaining the suitability and adherence the principles of sustainable development. The international concern on the concept was firstly appreciated in the 'first international conference on sustainable construction', held in Tampa, Florida in 1994. The main objective of the conference was 'to assess progress in the new discipline that might be called sustainable construction or green construction' (Kibert, 1994, cited Hill and Bowen 1996).

Kibert etal (2000) cited that 'sustainable construction is creating a healthy built environment using recourses efficient, ecologically based principles'. Environmental burdens caused by construction can be mitigated and also the construction technology has potential to be used as remedial for the environment. So the sustainable construction can also be perceived as response of the construction sector to the challenge of sustainable development. The scope of the construction is widening the new arena for minimize of resource depletion, environmental degradation and creating a healthy built environment into the panorama besides the traditional tripartite criteria which is time, cost and quality. This shift of sustainability can be seen as a new paradigm.

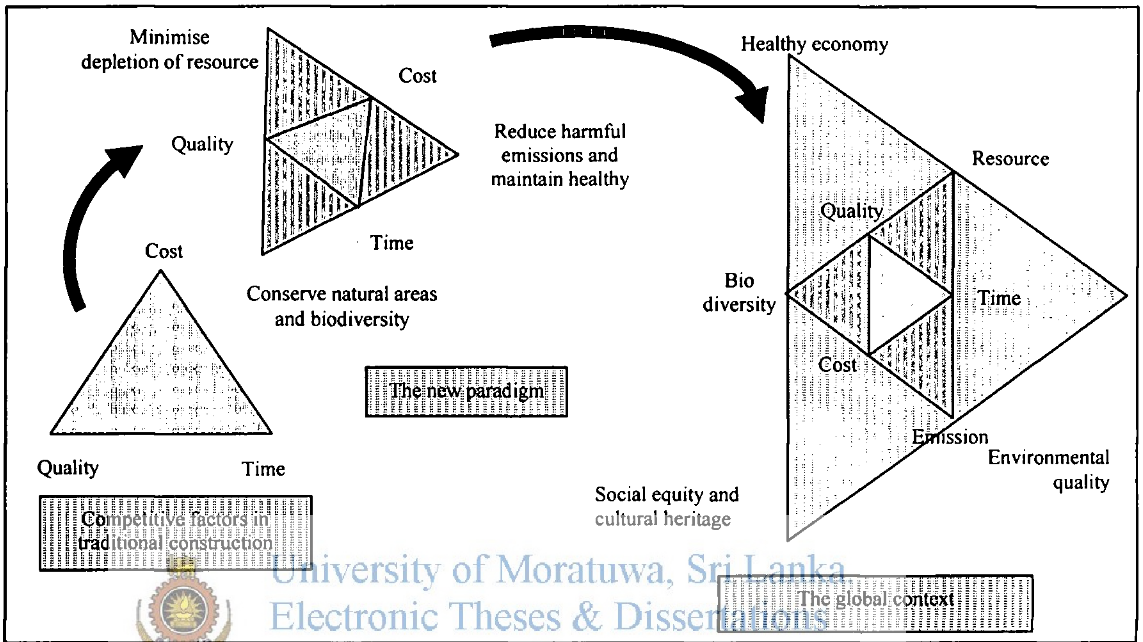

Figure 1 : The Challenges of Environment Sustainability

(Source: Houvilla and Koskela, 1998)

Sustainable issues in construction should be addressed in advance and need to continue up to the completion of any product. Therefore the process can be called as cradle to grave appraisal, which includes managing the serviceability of a building during its life span and ultimate deconstruction, sustainable disposal of debris and recycling of resources (Kibert, 1994, cited Hill and Bowen 1996).

To achieve sustainability within the construction industry needs to adhere with number of principles. It is important to point out that optimization of all the principles with regard to a particular project might not always possible. The principles need to be implemented by the interested and affected parties. Hajek, (2001), developed a model for environmentally based optimisation which ultimately directs the product towards sustainable construction. The model gives the idea that how the sustainable construction can be achieved through selection of materials at the design stage.

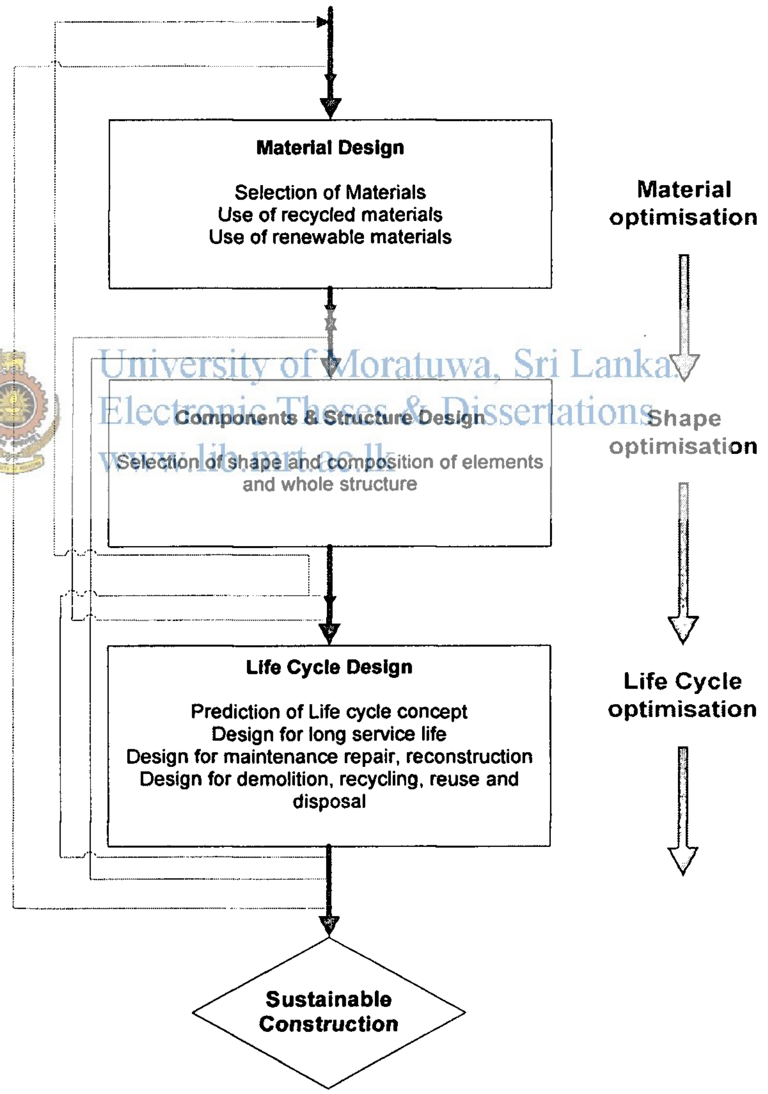

Figure 2 : Concepts of Environmentally Based Optimisation

Source: Hajek, (2001)

Through the literature review it was found there are few models available for achieve environment sustainability as well as the best value in construction processes. But any model may not combine both concepts together in construction.

2.1.3 Environment Sustainable Material Selection

Construction industry consumes large amount of natural resources annually, by the material itself or converting them to a composite materials. On the other hand none of the conventional raw materials used in the construction industry are available without same degree of environmental impact (Mudannayake, 2004). The construction materials and products directly and indirectly affect many impact areas (Malin, 2004). Therefore it is very much important to select an eco friendly material that minimizes such effects.

The increased consumption of materials and the associated negative impacts on the environment make ground for the construction industry to developed environmentally sustainable / green materials selection process. As far as the environmental point of view is concerned, not all the construction materials comply with the desired environmental specifications and standards. Consequently, it becomes necessary to select the applicable alternatives which can fulfill the environmental criteria as well as mitigate or avoid the environmental impacts as far as possible. Further the cumulative effect of seemingly small, local impacts over the life cycle of a material can have substantial or even catastrophic consequences on a global scale. The Impact of a given material can occur at all stages of the material's life cycle, from extraction and processing through the useful operating life to end use (disposal or recycling). Careful analysis and selection of the materials used and the way they are combined can yield significant improvements in the comfort, cost effectiveness and energy efficiency.

Life Cycle Assessment (LCA) is available to systematically consider the environmental impacts of the whole construction process and has already produced some important results within the material industry (Khalfan, 2002). It is the method used to measure these environmental impacts over the total life span of the materials. This includes extraction, manufacture, transportation, use or operation and eventual disposal or reuse (Jonsson etal, 1997). LCA can be applied to a whole product or to an individual element or process included in that product. The methodologies and other concepts such as clean technology reveal opportunities for improved performance of existing products and processes also encourage developing innovative new opportunities (Parkin, 2000). The environment needs to be protected and natural resources have to be saved for future generations while at the same time the economic interests of the companies have to be secured and employment has to be created (Eyerer etal, 2005). However, there is no tool for measuring the social sustainability (Graubner and Reiche, 2001).

Therefore many different steps towards the goal of sustainability need to be suggested. A method for evaluating these steps is needed. There are number of methods available to assess the environment sustainability. Each evaluation method has considerable limitations (Bentivegna, 1997). Therefore finding a suitable tool to assess the environment impacts from the construction materials is critical. To date, efforts to reduce the environmental impacts of buildings and construction have focused primarily on making them more energy efficient. A valid priority is given the huge potential for improving a building's total life cycle environmental impacts through design initiatives targeting the usage phase (Trusty and Meil, 2005). As with every economic sector, the construction industry's purchases of materials and services sets into motion a chain of processes from raw material acquisition through manufacturing, transport, and retailing. All of these activities, in turn, have significant upstream (off-site) environmental implications, whether in terms of energy and raw resource use or emissions to air, land or water. Understanding both the usage phase and upstream impacts is essential. But, most potential upstream environmental costs and benefits have been unknown, invisible, and ignored. Therefore it is significant to minimize the impacts through construction processes by utilising green materials as much as possible. Green building materials are composed of renewable, rather than nonrenewable resources (Dorsthorst, 2004). Those are environmentally responsible because impacts are considered over the life of the product. Depending upon project specific goals, an assessment of green materials may involve an evaluation of one or more of the criteria (Froeschle, 1999).

2.2 Best Value

Best Value, in its broadest sense, is ensuring that the right choices are made about obtaining the optimum balance of benefit in relation to cost and risk (SD toolkit, 2005). Larry Miles (1961,cited Michel, 2001) defined best Value as: 'a product or service that has appropriate performance and cost and as a problem solving system aimed at reducing expenditure of time and money whilst maintaining or increasing performance'. Typically value is a coupling of utility value and esteem value (Porter, 1998).

There are large numbers of concepts to improve value of a product or a process. Such as, Total Quality Management (TQM), lean thinking, decision trapping philosophies and reinvention/reengineering process. TQM focuses on quality management, while reengineering focus principally in management or business philosophies. Decision trapping is broad and complete technique to cover all areas of the job plan but decision making steps tend to be broader and lack incremental guide steps (Russo and Schoemaker, 1989). Lean thinking is also value based method, which is broader than value management applying for high level of development especially for manufacturing (James and Daniel, 1996). Among all those techniques value management was chose as one of the best tool. It is a complete process that works for all situations.

2.2.1 Value Management

Value Management was used principally to identify and eliminate unnecessary costs. However it is equally effective in increasing performance and addressing resources other than cost. Various gurus have attempted at definition of VM in different ways (Austin and Thomson 2001; Corne and Leeuw 2001; Albert et al 1996; Fong 1998; Green and Popper 1990; Kelly & Male 1992:1987, Kelly et al 2002; McElligott and Norton 1995).

VM is a structured, analytical process which seeks to satisfy 'customer' needs by ensuring that all necessary functions are provided at the lowest total cost, while maintaining the required levels of quality and performance (Institute of Value Managers Australia, 2005). It is an approach that brings added value to any type of project that has a degree of complexity or involves different professional disciplines (Atkinson, 1999).

With reference to Shillito (1999) it is an analysis of the functional value of a product, process or service. This led to a search for alternative product component but for a means of fulfilling the function of the component (McGeorge and Palmer, 2002). It uses to increase the value of a product where value is defined as the ratio of performance to cost, and product is defined as the result of someone's effort. It can be undertaken at any stage of the project design (Seeley, 1996). McElligott and Norton (1995) have identified VM as a systematic, multidisciplinary effort directed toward analysing the functions of projects for the purpose of achieving the best value at the lowest overall life cycle cost.

Martin (1997) further suggested VM started as a great concept, and has grown from both within it and from others. The process brings right people together at the right time regardless of where they are located in the supply chain, is an integrating function within the project value chain (Kelly etal, 2004). Ferry and Brandon (1984) illustrated the search for value in building design by considering a theoretical expenditure.

Therefore VM is identified as one of the recognised techniques that made substantial cost savings on construction projects. Further in its broader sense, it can be defined as an organized effort directed at analyzing designed building features, systems, equipment, and material selections for the purpose of achieving essential functions at the lowest life cycle cost consistent with required performance, quality, reliability, and safety (GSA, 2005). It is 'a service which maximize the functional value of a project by managing its evolution and development from conception to completion, through the comparison and audit of all decisions against a value system which, determined by the client or customer' (Kelly and Male, 1992). Since the tool has high competitive advantage than other management tools most of the industries compelled to deem VM as the best technique that provides best value for investment. With reference to the Institute of Value Managers United Kingdom (2003) VM is a style of management particularly dedicated to motivating people, developing skills and promoting synergies and innovation, with the aim of maximizing the overall performance of an organization. Hayles (2003), identified VM as a methodology is proposed as a means to achieve sustainable decision making. It provides a structured approach to the assessment and development of a project to increase the likelihood of achieving these requirements at optimum whole life value for money (SD Toolkit, 2005).

At present there is no alternative management tool or technique available that can be used for the purpose of VM (Neasbey etal, 1999). It is a novel concept that was introduced recently for the construction products and processes. Further it's a function oriented methodology, which focuses on best value by minimizing the sources of waste. Environment sustainability is one of a most significant best value criterion and the link between these two concepts is vital in local and global contexts. When integrating both concepts in construction processes the stakeholders can be benefited rather than their independent practices.

The competition between uses of VM versus other techniques is very intense (Karunasena, 2005). It began as a functional procedure to secure products, become a procurement and product improvement tool, and eventually graduated to its present multi-faceted form (Martin, 2004). Further it is a process that is accepted in worldwide. It use, basic components, and structure are not governed by a small group but by governmental and professional association standards of practice (BRE Scotland, 2001). VM contains safeguards for avoiding failure. The technique works for clients, providing a much lower risk of failure. It basically follows a job plan which is a unique key component of VM. This is the glue hat bind all the crucial good decision making elements into a reliable step by step process (Karunasena, 2005). Although the VM has several job plans available all contain the basic elements that meet the steps of good decision making. In general VM uses procedure that stresses the positive aspects such as: high performing team concepts, creativity capacity, matching activity to disciplines, and focusing on the cooperative human sprits.

Moving forwards, the characteristics, purposes and functions of VM were re-examined to interpret the principles of sustainability within the scope of VM practices. Literature was critically reviewed for hints or information that connects VM with sustainability. Sustainability issues are part of the project functions or included in the many differing needs of a project. The term sustainability may not be used frequently in VM. Value experts are regularly appear in VM studies as criteria or components of a FAST diagram or value tree search for basic function (Hamilton, 2002; Woodhead and Downs, 2001; Schneider, 1999; Connaughton and Green, 1996; McElligott and Norton 1995). Addis and Talbot (2001) stated that in achieving best value rather than lowest cost, VM will take account of many factors, which cover environmental protection and social interest. Phillips (1999) argued that the incorporation of sustainability objectives within VM produces an agreed, long term, sustainable solution. VM provides the map and compass for environmental enhancement (Yeomans, 1999). Schneider (1999) recommended the incorporation of sustainability into VM as an effort to move into more resource efficient construction. The attributes of VM give better business decision, increased effectiveness, improved products and services, enhanced competitiveness, improved internal communication, teamwork and decisions which can be supported by all stakeholders (British Standard EN 12973, 2000).

By linking value and sustainability the concept allows for the consideration of 'price-less' evaluations within a construction process. As the industry exposed perhaps more than any other to issues of public space and environmental impact, construction is being driven towards the use of complex, multi issue consultations with stakeholders within which whole life value can operate as a contextual limit (Holt, 2001).

2.2.1.1 Value Management Approach

The success of VM lies in its methodical approach. It is an ongoing process and should be used to continuously review all aspects of a project against customer needs (Karunasena, 2005). The job plan is widely accepted value enhancement process that frequently applies in construction projects. It's systematic and follows a few steps towards the value enhancement of a product. Those steps are;

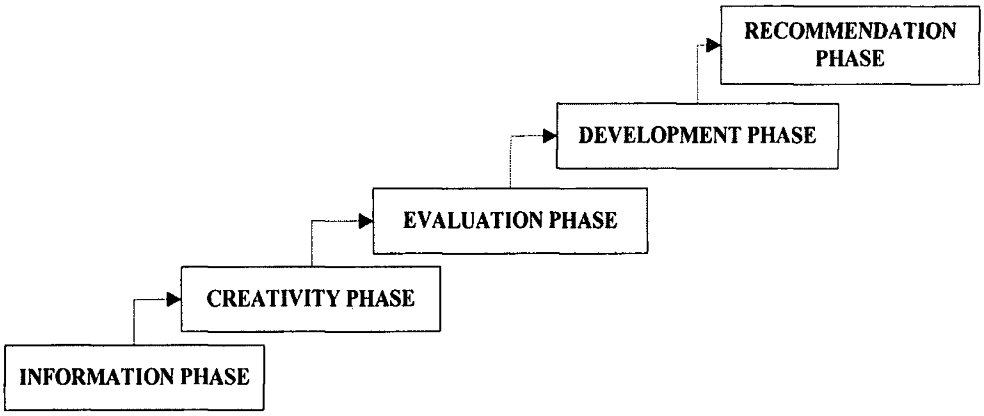

Figure 3 : Value Management Job Plan

Source: McElligott and Norton, 1995.

Information Phase

Identify candidate projects for VM study, and select specific projects to achieve maximum value, energy savings and other benefits, such as a shorter construction schedule. Further it concerned with the sharing, disseminating and clarification of information relating to the project and includes identifying the problem situation, identifying the project function (Neasbey etal, 1999). The establishment of VM team is significant in this stage.

Creativity Phase

Brainstorm functions of design element are isolated in the information phase, and develop a number of alternatives for each function. Group synergy is utilized to create more numerous and more creative options than is possible with the members working individually (Neasbey etal, 1999).

Evaluation Phase

This phase analyzes the results of Creativity Phase. By a detailed review of various alternatives, select the best ideas for further expansion. Experience shows that the alternatives must be carefully evaluated to assess whether they fulfill the functional requirements of the project (Atkinson, 1999). The evaluating team must use the full project cycle costs to determine the potential cost savings and not simply construction costs.

Development Phase

At this stage the collection of additional data to analyze the alternatives which were derived during the evaluation phase and prepare cost.

Implementation Phase

At the beginning of the implementation stage the recommended alternatives are present to decision makers clearly and in sufficient detail for their consideration and potential approval. During this phase it ensures approved recommendations are rapidly and properly translated into action in order to achieve the savings of project improvements.

The job plan provides a platform to maximize best value criteria of selected alternatives. VM effort in the early stages of project design affords greater savings and allows a change of direction, if appropriate, without affecting project delivery schedules (Value Engineering Annual Report, 1999). Emphasis is on obtaining maximum life cycle value for 'first-cost' rupees budgeted for the project. If savings are identified, the project budget may be reduced, or the money may be reallocated, if justifiable, for features that would lend greater life cycle value to the project.

2.2.2 Managing Value in Construction

The Value Management (VM) approach requires understanding and experience not only of the technical design and construction process, but also of the legal, cultural and management environment. It is one of the significant tool that emphasis on defining the purpose or function of the project as a whole. Each element of the project is identified and ranked using its cost/worth ratio and so areas of potential improvement are highlighted. It is not a matter of reducing the quality of the product or the standard of the design or investigation. It is instead finding solutions that match the functional requirements of the project as closely as possible. This is essentially a process of optimizing resources in the widest sense.

In construction projects this focused approach can create savings in the direct cost of materials, the time of construction. VM can be applied to the whole project cycle. It is at the project concept stage that the professional team can most readily achieve the major savings. The VM team can identify the overall functional requirements at this stage and this approach can usefully be part of the overall risk management approach to the project. In construction projects the professional team can decide matters of procurement and particularly when to involve contractors in value engineering examining the buildability of the project.

The most critical phase in construction projects is at the 35% design stage (Atkinson, 1999). The participants can more clearly define the detailed functional requirements. At this stage the material specifications, design parameters, construction, environment restrictions and assumptions are needed to reassess.

This process of VM, in construction is appropriate to complex projects involving several disciplines and experts. Brainstorming sessions allow a facilitator to ensure that each expert or discipline participates in the free ranging examination of options. The team should not place too much reliance on past successes. Extrapolation of experience from one project to another does not necessarily provide the stimulus required for innovation. Instead, the team needs critically to examine experience in the light of the changed requirements of the new project. This ensures that in construction projects the engineering design and commercial arrangements, or in dispute resolution the presentation or analysis of evidence, matches the new functional requirements. The emphasis in VM is on specifying the functional requirements but this is difficult with little project definition. Redefining the functional requirements is necessary as the project definition develops, since the definition itself brings into focus, through the detail, the choices available.

Construction projects use a cost/worth model to analyze the functional value of the project elements (McElligott and Norton, 1995). Understanding the importance of the detailed functions of each element of the project is vital to constructing a cost/worth ratio model of the project design. This takes place at the later stages in the project cycle during detailed design and construction and requires an accurate cost model. Those functions of the element design that are necessary have a value that the professional team can evaluate based on the least cost to provide the function. Those functions that are not needed have no worth. By comparing the cost with its worth the team can work on the cost/worth model and identify those aspects of the design solution that will yield the greatest potential savings by redesign. This focused approach can be adopted in value engineering.

Considering the total project cycle costs is important including costs of maintenance, repair, replacement and removal at the end of the project life cycle. Consideration of buildability can introduce significant savings. The professional team needs to know the details of the economics of construction to decide the most cost effective solution. Significant savings can also be made during the bid and construction stages. This frequently occurs even without VM in traditional tendering processes. Contractors submit bids based on alternative designs to those issued for pricing by bidders. The evaluating team must use the full project cycle costs to determine the potential cost savings and not simply construction costs. Nonetheless contractors frequently satisfy the functional requirements of the project while reducing construction costs. They do so by adopting innovative construction techniques and/or by relying on their existing plant availability or particular construction expertise. In many projects savings are possible because the contractor considers the design and construction in more detail than the original designer. They evaluate material costs and complexity against large savings in production time. The application of this tool into a construction project the client is benefiting through the reduction of unnecessary cost as well as retrofitting the best alternatives to his project. It provides the opportunity to embed the sustainable criteria to the entire process. By integrating both sustainable criteria and value enhancement criteria the client as well as the society will receive the benefits.

2.3 Integration of ES and VM

VM practitioners have opportunities to minimise environmental and social damage through recommending suitable site location, selecting sustainable materials, determining elements or theme of design and choice of construction. Committing to sustainability during VM could lead to the vision of generating good economic return whilst delivering accountability and excellence in our social and environmental performance. The basic premise of this concept is to absorb sustainable elements, blending in the issues throughout the VM process to reduce the conflicting terms of cost and sustainability when designing. Solutions would be proposed to best match the client's economic needs without neglecting environmental and social needs. The idea behind integrating VM with sustainability is to put this concern at the forefront of VM thinking and along its activities. Sustainability should not be seen as an 'add on' to VM requirements but truly integrated into all facets of planning and design. The emphasis that participants in the workshop place on sustainability issues would determine the sustainability 'content' within the workshop.

Theoretically, integration of sustainability and VM should not change the generic process of VM as it only affects the scope and focus of the study. VM practitioners need to widen and apply their sustainability knowledge when defining functions, generating ideas and developing proposals.

It is important to acknowledge the existence of certain boundaries, which limit the influence that VM can have on the vision of sustainability such as time constraints and a preset scope and interest of study, which vary according to the project and the different timing of VM practices. The strategy and action taken to uphold this idea of integration must account for these boundaries. The perception that sustainability adds costs (Bartlett and Howard, 2000) and VM aims to reduce cost (Connaughton and Green, 1996) may lead to a seemingly conflicting interest. It is argued that their interest is not a dichotomy as presumed. Through the literature review it can be proposed that the outcome of sustainability consideration corresponds with VM purposes and functions.

2.4 Research Hypothesis

From the literature review, the importance of addressing the best value and environment sustainability criteria in construction material selection was identified. Therefore make a balance between both concepts it was proposed to develop a framework by integrating both processes. The model needs to test on its acceptance among the construction clients in local context.

Chapter Three

Research Methodology

Chapter Three

Research Methodology

This chapter elaborates the research methodology. The research design and the data collection methods are analysed. The research is focused on a development of a process model by combining environment sustainability and the best value criteria to select construction materials.

3.1 Research Design

The research was placed in qualitative research philosophies as the aim was to generate rich data from the experiences of Value Management (VM) team to find the means of Environment Sustainable (ES) delivery in VM. This research begins from the data gathered through a comprehensive literature review and unstructured interviews. Through a comprehensive literature review the concepts and the practices of VM and ES were studied in depth. The research study follows the following phases.

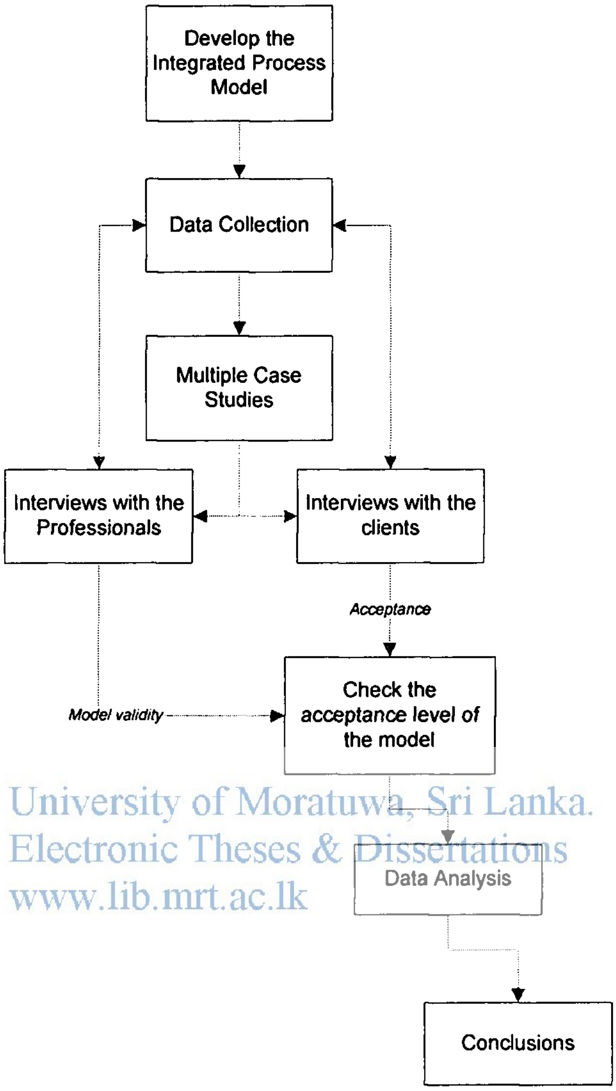

Figure 4 : Research Design

3.2 Integrated Process Model

The context changes when the consideration shifts from pure sustainability to value enhancement, because most of the dynamic developers expect the best value for their investment because of the greater competition in the global market. As far as the traditional material selection process is concerned, there is no any special attention was given to the sustainable issues. As well, the procedure followed was not so logical. Most of the design team members select the construction materials base on their intuition. Up to a greater extent the selected materials by the design team even by the developer might neither serve the purpose of the project nor ensure the value of an investment. However there can be seen some of the design team members and even some of the developers tend to do green designing rarely, but those designs addressed only the environmental sustainability. Those methods were not highly appreciated because some of the alternatives were expensive to use though they are environmentally sound. The necessity was to introduce a system which aims to select construction materials that have environmental and social soundness and at the same time fit with the economical agenda.

Based on the literature review the Integrated Process Model (IPM) was developed. The developed model is aimed to optimize the best value criteria and eco friendly attributes of building materials. The material derived through this model is concerned both the VM and ES criteria mutually.

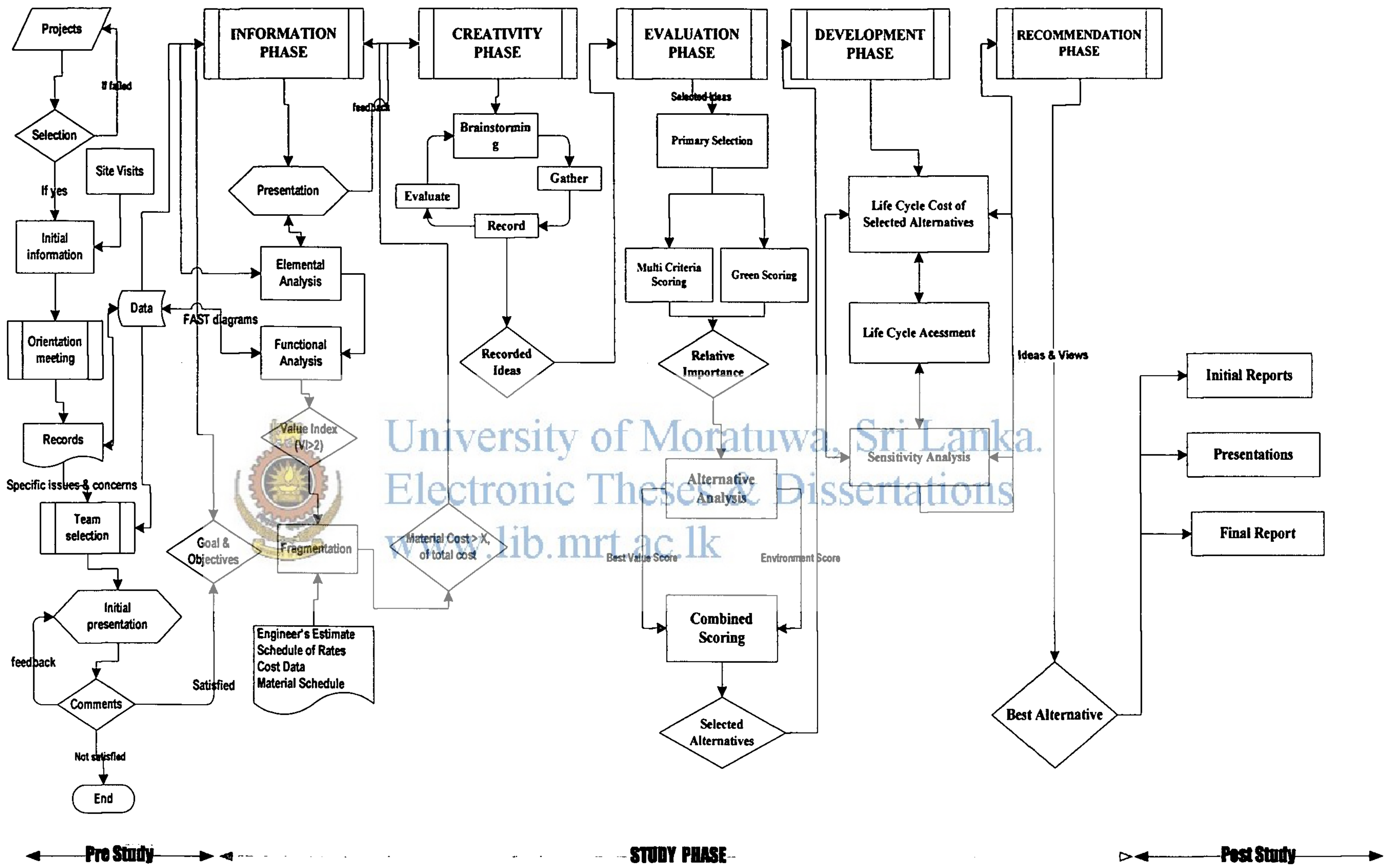

Figure 5 : The Integrated Process Model

3.2.1 The Model Development Phases

The rise of sustainability phenomenon and the best value criteria in this modern construction world initiated the search for opportune ways that will enable these concepts be infused into present working environments. Therefore this model will address the both concepts simultaneously and provides a reasonable answer when selecting construction materials. It follows pre- study, study and the post study phases consequently.

3.2.1.1 Pre Study Phase

At this stage, client's brief is inspecting in detail. After evaluating the brief the establishment of a VM team is important. The orientation meetings laid the proper base to carryon the entire process without any ambiguity.

The preliminary understanding of the project, client's objectives, expected constraints and boundaries are critically evaluated at this meeting. Finalizing the correct composition of a team is crucial to the success of the whole study. The Facilitator or team coordinator leads the team, but the leader shall essentially a person who has handful of experience in both VM and sustainable construction areas. The appointed professional team will examine the basic assumptions in the developed design. It is important to the success of this approach that the owner appoints a Value Manager who is independent of the project designers. The material specifications, the design parameters and the construction and environment restrictions and assumptions need to be reassessed in this stage to obtain best value for the investment. The appointed professional team needs to examine the basic assumptions in the developed design. The ideas born through them supposed to eliminate environment hurdles, which will derive from the project. The quality of the final results highly depends on the depth of information availability. Therefore it is important to obtain every possible information especially cost related once and distribute them among the group members. To obtain most reliable information it is very much important to arrange a site visit and prepare cost estimates for the selected project or an element.

3.2.1.2 Study Phase

Study Phase is the next stage of this model. At this stage further attention should be paid to obtain more reliable information of cost significant areas and to identify a comparative importance of each alternative. The VM job plan has incorporated to this stage.

Information Phase

At this stage the gathering of information based upon functions of elements and components of the final product is important. Following from the standard procedures of VM process the expression of the function is made by a noun plus a verb. It is important that the workshop should be presented with a detailed functional analysis of the client's requirements.

This can be simple brainstorming of the functions and possible alternatives, but the most common method is using a Functional Analysis Systems Technique (FAST). FAST is an important technique, which is frequently utilized in VM. It is generally not undertaken on specific items or issues taken in isolation, but rather in the context of the whole scheme or system. The basic and secondary functions are evaluated during this process. The emphasis in VM is on specifying the functional requirements but this is difficult with little project definition. Redefining the functional requirements is necessary as the project definition develops, since the definition itself brings into focus, through the detail, the choices available.

VM places the emphasis on defining the purpose or function of the project as a whole. Each element of the project is identified and ranked using its cost/worth ratio (Value Index) and so areas of potential improvement are highlighted. The elements, which are having over '2' of value index (Cost/Worth), are subjected to further evaluation (McElligott and Norton, 1995). It is not a matter of reducing the quality of the product or the standard of the design or investigation. It is instead finding solutions that match the functional requirements of the project as closely as possible.

In construction projects this focused approach can create savings in the direct cost of materials and the time. When an element performs several functions the cost of that element or item may be prorated across the functions. The worth is considered to be the lowest cost at which only the basic and required secondary functions can be achieved. The secondary functions are allocated a worth of zero.

After identifying the allotted cost for a particular element they are then broken down in to components as material, labour and plant. This process is referred as fragmentation. The elements, which are having high material component, can be easily identified. In the case, if material component (X), is more than 1/2 of the total cost of that element it is included for further analysis.

Creativity Phase

This phase seeks to provide alternative solutions to the functions identified during the information stage. Organization of brainstorming sessions to achieve the best value criteria is significant. The team should not place too much reliance on past successes. Extrapolation of experience from one project to another does not necessarily provide the stimulus required for innovation. Instead, the team needs critically to examine experience in the light of the changed requirements of the new project. It should match with the new functional requirements.

The team leader is responsible to organize a brainstorming session and the team members are prompted to spontaneously produce ideas regarding the identified elements. The leader shall essentially a person who has handful of experience in both VM and ES. The ideas born through him supposed to eliminate environment hurdles, which will derive from the project. The identification of poorly valued areas, available alternatives, and material significance of elements is important.

All issues surrounding the client's requirements and the project were further identified and ranked. At this stage attention should be paid to obtain more reliable information of cost significant areas and to identify a comparative importance of each alternative.

Evaluation Phase

The model is based on the analysis of the VM proposals and ES of the selected alternatives. During this stage the advantages and disadvantages of generated ideas are need to be analyzed properly. The Combined Scoring Matrix (CSM), which is an amalgamation of Criteria Scoring Matrix and Material Green Scoring (MGS) processes, is used to select the best alternative. The significant best value criteria are listed in the CSM.

The next step is to assign a relative weight of importance to each and every criterion. This is an objective analysis by using Likert Scale and it commences with the comparison and rating of each criterion against all of the others. During comparison it is decided which of the two criteria is more important and the most important criterion is rated according to the key which is rating from one (1) to four (4). Weight of one belongs to the lowest preference and the four belongs to the highest preference of selected criteria.

When the comparison is over; the scores for each criterion must be totaled to provide a Relative Importance (RI) for each of the criteria. After completing the criteria scoring exercise, the next step would be the comparison of alternatives on the 'Alternative Analysis Matrix'. By evaluating each alternative against each of a criterion the scores are assigning from the range of one (1) to five (5). Poor, fair, good, very good and excellent keys are assigned the values of one to five respectively. The multiplication of the criterion weight by RI of all the alternatives will reflect the best score of each alternative.

The MGS process is one of the available tools to measure environment sustainability of materials. It is consisting with most significant environment sustainable criterion of materials. By considering these criteria the green points and RI of each ES criteria are calculated. Then the alternative analysis of materials will be carried out on the basis of ES criterion. The same scale was used to calculate the total green scores of selected alternatives. When constructing an element, most of the materials are composite based.

Therefore the composite material is taken as the simple arithmetic sum of the each individual material which builds up the element. But there are several environmental impacts to be considered, when the constituting materials are compiled together to form an element and these impacts are difficult to quantify. Finally Points are totaled for the alternatives as per the score they have obtained both in VM scheme and ES scheme. The alternatives that have scored fairly high can be selected to proceed to the development phase.

Development Phase

The objective of this phase is to develop the selected ideas as practicable proposals. The selected ideas present as proposals to the decision makers in Presentation phase. Generally those proposals will embedded with description of the original and proposed material composition of the element, advantages and disadvantages of each, life cycle cost implications and other supportive technical backups.

Recommendation Phase

The deep investigation of the expected performance of the selected alternative will be further taking into consideration during this phase. The external parties can involve and make their comments on selected alternatives to improve the identified performance further. The ultimate selection, which scored the highest in combined scoring matrix, can be recommended as the best alternative.

3.2.1.3 Post Study Phase

The post study phase is the last stage of the IPM. Most of the documentation activities such as preparation of initial report, presentations and final report of the study will be carried out in this stage. The VM team members should assist the investor's organization to overcome any hurdles of the implementation of good advantageous proposals.

Tools that help the selection of sustainable construction ingredients can advance the cause of sustainable development. Further the environment sustainability and economical viability of a project is primarily connected with the material selection. Therefore it is important to formulate a decision support tool, which facilitates the comparison between environmental and other desired aspects. Therefore a new way of thinking must be adopted to redirect the development towards sustainability in each activity of construction. The proposed model is a strategic process, which is primarily suggested to use as decision support tool. The process is aimed at the VM techniques, which will be adding value to the selected environmentally sound material. The case study showed that the process can be successfully implemented and it is possible to have the middle path, which will stand as value added sustainable selection.

3.2.2 Identified Barriers

Several barriers to integration have been identified from the interview surveys. These barriers can be divided into two categories as practical barriers and behavioural barriers (Abidin and Pasquire, 2004). Practical barriers relate to the technicality of VM practice while behavioural barriers relate to the misperception among VM practitioners about sustainability. This misperception is derived from the lack of understanding of the agenda and the lack of confidence in VM to deliver sustainability.

The time limitation and absence of guidance are identified as the most significant practical barriers. The period used for brainstorming sessions varies from half day to two days maximum. As time is limited, it is argued addressing the vast issues of sustainability is difficult. It is undeniable that there are various issues under the theme of sustainability and it is impractical to address them all in a workshop. Therefore the issues such are reusability, recyclability, embodied energy and other emissions were considered to measure the eco friendliness of a material. There was a flexibility to discuss the relevant sustainability issues that were identified as most critical, before bringing them into the workshop. Some respondents believed that integrating sustainability concerns into VM studies would slow down the progress of the study.

Absence of formal guidelines for sustainability posed another problem. Some respondents have their own internal guide for sustainability in their VM practices, which are confidential. These people rated their VM performance on sustainability as high while the rest rated as low or moderate. Without guidance, the integration of sustainability in VM may be difficult.

The behavioural barriers focused on the lack of awareness of sustainability, passive and negative perceptions about integration. The lack of knowledge and awareness of sustainability is related to the discussion on the level of sustainability knowledge being diffused in the VM studies. Sustainability knowledge would help the VM practitioners in understanding the importance of achieving sustainability in the projects and provide the basic need to broaden their scope to include issues related to environment and social.

Some respondents commented that the ES and VM as two separate issues. When this happened, ES easily becomes a burden and integrating sustainability was felt to mean adding more tasks to the participants. The perception that sustainability has a separate agenda, which may not go hand in hand with VM objectives, is misleading. Passive behaviours exist among VM practitioners regarding the inclusion of sustainability. VM practitioners argued that VM only responds to clients' demands and they do not always commit to sustainability. The notion that VM is bound to satisfy the client is understandable because they commission the services. However, clients may not have the adequate knowledge to drive them into demanding sustainability. VM practitioners should take this knowledge to them. If VM providers remain passive, the absorption of sustainability may not improve.

3.3 Case Studies

The selected cases were building projects and the sub unit of analysis was the elements of them. The selected projects are located at the Colombo Metropolitan Region.

3.3.1 Case Selection

Seven cases were selected for the analysis. Among them two were excluded from the detail analysis based on the non flexibility of the VM team building. Therefore the number of cases was limited to five. Those cases were further divided into fifteen sub unit of analysis base on their Value Index. The selected cases are;

Case I : Apartment complex located at No 08, Sripala Road, Mount Lavenia.

Case II : Semi Luxury apartment complex located at No 19, Arathusa Lane, Colombo 06.

Case III : Semi Luxury apartment complex located at No 97, Galle Road, Rathmalana.

Case IV : Residence, Wijerama Mawatha, Colombo 07

Case V : Condominium Apartment, Schoffield Avenue, Colombo 03.

Please refer the Annexure for the further details of the cases.

3.3.2 Case Design

The selected cases were designed in uniform way and obtained the required information to analyse. It was decided to meet the selected clients at the very early stage of this study and organise the team to start the value management workshops. After arranging a flexible day for the workshops it was decided to calculate the Value Index to find the poor valued elements of the selected cases through archiving the project information.

The next step towards the continuation of VM workshop was the identification of alternative materials for the selected elements. The analysis of best value and the ES criteria of those materials were carried out by the help of the VM team. The workshops were ended with a best material that derived through the VM team.

The derived material was tested against the client's choice and met the clients to check their acceptance towards the application of the proposed model in construction material selection.

3.4 Data Collection and Processing

The developed IPM is tested through a multiple case studies. The selected cases are the aforementioned building projects and the sub unit of analysis was the identical elements of each structure. All the proposed best value criteria were analysed through brainstorming processes and ES criteria that greening the material are incorporated at the same time to the process.

3.4.1 Project Information

Project information and elemental information were obtained through the archiving of project documents. Through detail analysis of the priced Bill of Quantities of the particular projects the elemental cost were identified and the Value Index (VI) was established. If the VI is more than 2 it was selected to have a VM application to identify the evolved unnecessary cost. The derived element cost is further separated to three major components of materials, labour and plant. To obtain a correct figure on those factors it was analysed the engineer's estimate, Standard building schedule of rates and Material schedules in depth.

Other than those, the general project information such as the name of the project, location, date of project start, names of clients, contractor, and consultants, and so on were obtained. The VM work shops were arranged by the support and assistance of the clients. The elements that brought the high VI are External Wall, Floor Slab, Internal Walls, Internal Floor Finishes, Partitions, Column, Beam, Air conditioner and Roof coverings. Therefore the model was used to find the best materials for above elements.

3.4.2 Brainstorming Sessions

The Best Value criteria of selected elements were obtained through the series of brainstorming processes conducted with the Value Management team. For a particular element it was found the following BV criteria. Further the most significant Environment Sustainable (ES) criteria for greening the materials were obtained through the literature review. Those criteria were incorporated to the model and considered at the VM work shops.

Table 1 : Integrated Criteria to the Model

BV Criteria	Case I				Case II				Case III		Case IV		Case V		
	Foun	Gflr	FlFin	Parti	Colmn	Beam	Slab	ExtWl	ExtWl	Wlfin	RrCv	IntWl	A/C	Ext Wl	FlrFn
Initial Cost	√	√	√	√	√	√	√	√	√	√			√	√	√
Maintenance Cost	√	√	√	√	√			√	√	√			√	√	√
Load bearability	√		√												
Durability	√	√	√	√	√	√	√		√	√			√	√	√
Const/Instal. Time	√	√	√	√	√	√	√	√	√	√			√	√	√
Aesthetic			√	√	√	√	√	√	√	√	√	√	√	√	√
Availability		√			√	√	√	√							
Slip Resistance			√												
Ability for Replace				√											
Insulation Properties				√				√	√	√				√	
Strength					√	√	√							√	
Service Integration					√		√					√			
Maximum Span						√									
Security								√			√	√		√	
Transfr/Transmit load											√	√			
Exclude climate											√				
Control Noise												√	√		
Spare requirement													√		
Heat Level													√		
Privacy											√			√	
Resist Corrosion											√				
Direct weather											√				
Create shading											√				
Resist Uplift											√				
Divide Space												√			
ES Criteria															
Reusability	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Recyclability	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Renewability	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Embodied energy	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Other emissions	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√

3.4.3 Interviews

Sixteen semi structured interviews were conducted among the experienced professionals who were proven in the area of the Construction Management in Sri Lanka. The applicability of Value Management techniques and improving the Environment Sustainable performance in construction projects were discussed. By analysisng their views as well as the knowledge dragged from the detail literature review the Integrated Process Model was developed and brought it back to the same interview panel to receive their further comments to its further improvement.

By applying the IPM to selected cases the suitable material in terms of Best Value and ES was obtained. The results obtained through the IPM were cross checked with the client's final choice and data was collected with relates to his acceptance towards the IPM.

3.4.4 Data Collection

Data were collected from May – November 2005 in the selected projects. All of the projects were located at the Colombo.

3.4.5 Data Processing

The materials derived through the Value Management, Environment Sustainability, Integrated Process Model and the Client's selection was tabulated as given in following Table.

Table 2 : Data Processing Table

Case	Element	Alternatives			Client's Choice [CC]
		Value Management	Environment Sustainability	IPM	
Case I	***Element I***	Material 1	Material 2	Material 3	Material 1
		Material 1	Material 2	Material 3	Material 2
		Material 1	Material 2	**Material 3**	**Material 3**
		Material 1	Material 2	Material 3	Material 4
		Material 1	Material 1	Material 2	Material 3
		Material 1	Material 2	Material 1	Material 3
		Material 1	Material 2	Material 2	Material 3

With reference to the above format all the collected data from the each element was tabulated. The similarities of material derived through each choice (VM, ES, IPM, and CC) were analysed in depth.

When it comes to an element the above matching patterns were identified and for a selected element either pattern was matched and found the frequency of them. The research is concluded by highlighting the client's acceptance through the frequency of those similarities derived through the Integrated Process Model and the Client's choice.

Chapter Four

Data Analysis

Chapter Four

Data Analysis

The data derived from the multiple case studies and the clients' acceptance towards the developed Integrated Process Model (IPM) was analysed in this chapter. Five main unit of analysis and the 15 sub unit of analysis were considered.

4.1 Descriptive Data Analysis

The descriptive data analysis began with the identification of elements in the selected case, which were having higher value Indexes. To choose the best material for those elements the analysis was done in four ways. First it was identified the best material in terms of Value Management and next in terms of the Environment Sustainability. After applying the Integrated Process Model again the most preferable material was found. At last the derived materials through VM, ES and the IPM were analysed with the client's selection.

4.1.1 Case Study I

The Case I is an apartment complex. It was found four elements which were having higher Value Indexes (VI). The selected elements were Foundation, Ground Floor Slab, Floor Finishes and Partitions. The VI belong to those elements are 2.78, 3.28, 4.3 and 2.38 consequently. The cost is more than the double of its worth implies the unnecessary burdens. Therefore it was interest to find those unnecessary cost avenues and propose a suitable material for the particular elements. The findings are as follows;

Table 3 : Findings from the Case I

Case I	Element	Alternatives			Client's Choice
		VM	ES	IPM	
Apartment Complex, No 08, Sripala Road, Mt. Lavenia	Foundation	Concrete	Timber	Concrete	Concrete
	Ground Floor Slab	Insitu Concrete	Timber	Insitu Concrete	Insitu Concrete
	Floor Finishes	Granite Tiles	Timber	Ceramic Tiles	Ceramic Tiles
	Partitions	Glazed	Timber	Timber	Brick

The dark coloured cells highlight the similarities of the materials in above four [VM, ES, IPM, CC] choices.

The most suitable foundation material derived through the VM study was Concrete. Timber was found as the best material in terms of the ES because of its green content is high. The IPM was furnished that the concrete is balancing the both VM and ES properly. When checking the client's selection behind this material selection it was found 'Concrete' yet again.

Same result was received from the material selection process for the Ground Floor Slab. In-situ concrete was originated through VM, IPM and the Client's choice as the best material.

Therefore it was brought bit repercussion to the VM team why the higher VI derived from that study even the VM alternative and the Client's choice is same for the foundation and the Ground Floor Slab. As a result they were able to identify where the unnecessary cost has hidden and the answer was the inefficiency of labour and plant handling in the foundation and ground floor slab construction.

When it comes to choose a suitable material for the Floor finishes the answers were Granite tiles from the VM, Timber from the ES, Ceramic Tiles form both the IPM and the Client's choice.

The slight difference was found from the next study with the client's choice and the IPM alternative. For a partition, timber was found through the IPM and client has gone for brick partitions. When analyzing why he has selected this the client is hoping to sell all the apartment units after finishing the complex. He doesn't have any idea to keep the ownership of the building and rented out all the apartment cells. Therefore he has preferred the rigid partition structure than the movable once.

Through this case study it can be concluded the alternatives generated through the IPM has 75% acceptance level of the client. If the above reason was not arrived he will be definitely going for a movable partition than the rigid structure. Then the client of the apartment complex which is located at No. 08, Sripala Road, Mount Lavenia will have 100% acceptance of the IPM.

4.1.2 Case Study II

The following case study is a semi luxury apartment complex located at No 19, Arathusa Lane, Colombo 06. It was found high VI in Columns, Beams, Floor Slab and the external walls. Those are respectively 3.78, 2.57, 4.33, and 3.45.

Table 4 : Findings from the Case Study II

Case II	Element	Alternatives			Client's Choice
		VM	ES	IPM	
Semi Luxury Apartment Complex, No 19, Arathusa Lane, Colombo 06	Column	Pre-cast Concrete	Pre-cast Concrete	Pre-cast Concrete	In-situ Concrete
	Beam	Pre-cast Concrete	Pre-cast Concrete	Pre-cast Concrete	In-situ Concrete
	Floor slab	Pre-cast Concrete	Timber	Pre-cast Concrete	In-situ Concrete
	External walls	Concrete	Block	**Brick**	**Brick**

The materials obtained from the VM, ES and the IPM processes for columns, beams and the floor slab was Pre-cast concrete. But the client has applied in-situ concrete for those elements. Even the materials are same but their way of application is differ in those elements. By improving best value criteria it was found the pre-cast applications are easy to handle, minimize wastage and easy to deliver and assemble. The time for complete the structure can reduce through the pre-cast units rather than the in-situ applications.

When analyzing the best material for external walls the IPM was proposed Brick as a good material which provides better balance between best value and the environment sustainable criteria. The client also selected the same material for his apartment complex.

From this case study it can be concluded the choices derived from the IPM is nearing to the client's choice. Through the study it was found 25% of similar result is given by the IPM and the client. But remaining elements such as columns, beams and the floor slab were constructed by using the concrete. But the IPM recommended the dry applications of concrete and client has high preference towards the wet application. Anyway the materials are same. Therefore it can be concluded again the IPM has 100% acceptance level from this client when selecting materials.

4.1.3 Case Study III

The following case study attempted to select suitable materials for external wall and internal wall finishes for a semi luxury apartment complex, which is located at Rathmalana. It was identified those two elements are not having high VI but the values are exceeded 2. Therefore those elements were selected to analyse further. The VI for external wall was 2.04 and internal wall finishes was 2.20.

Table 5 : Finding from the Case Study III

Case III	**Element**	**Alternatives**			**Client's Choice**
		VM	**ES**	**IPM**	
Semi Luxury Apartment No 97, Galle Road, Rathmalana	External Walls	Block	Timber	**Brick**	**Brick**
	Wall Finishes	Feb mix plus plaster	Lime Plaster	Feb mix plus plaster	Lime Plaster

The external wall material which can be accepted as the best in terms of both BV and ES is Brick. It was derived through the IPM. The client has chosen the same material for external walls.

When analyzing the best material for internal wall finishes, the IPM brought the Feb mix plus plaster as the best. But the client's choice was Lime plaster. When interviewing the client at the second time it was identified that he has not any experiences about the Feb mix plus application earlier and he has selected the Lime Plaster for internal wall finishes as usual. After identifying the benefits over the lime plaster he was pleased to use Feb mix plaster as internal wall finish.

Through this analysis it was found the client's acceptance towards the IPM was 50%. Both alternatives were purely matching in 50%. In this study also it can be concluded that the client has 100% acceptance of the materials originated through the IPM.

4.1.4 Case Study IV

Through the following case it was identified the high VI for roof coverings and the internal wall materials. The values were 3.65 and 3.21 respectively.

Table 6 : Findings from the Case IV

Case IV	**Element**	**Alternatives**			**Client's Choice**
		VM	**ES**	**IPM**	
Residence Wijerama Mw Colombo 07	Roof coverings	Zn Alum sheet	Half round tiles	Calicut tiles	Asbestos sheet
	Internal wall	1 B thk walls	Hollow block	**½ B thk Walls**	**½ B thk Walls**

The 50% acceptance level was obtained from the client towards the IPM findings. It was in a satisfactory level in this case study also. Therefore the developed IPM is highly appreciated for select materials which optimize both BV and the ES criteria.

4.1.5 Case Study V

This case was able to analyse suitable materials for external walls and the floor finishes. Other than those materials it was attempted to find the best type of air conditioner for a condominium apartment unit. The floor finishes are proposed for the living room by analyzing its functions. The derived VI was consequently 4.15 for air conditioner, 2.38 for external walls and 3.47 for floor finishes.

Table 7 : Findings from the Case V

Case V	Element	Alternatives			Client's Choice
		VM	ES	IPM	
Condominium Apartment Complex, Schoffield Avenue, Colombo 03	Air conditioner	Wall mount split type	Package Type	Wall mount split type	Package Type
	External Walls	Pre-cast concrete	Block walls	**Brick walls**	**Brick walls**
	Floor finishes (Living room)	Ceramic matt finish	Parquet	Homogenous matt finish	Ceramic matt finish

From the above analysis it was recognized that the client has 34% acceptance level towards the materials derived through the IPM. But the ultimate selection of the air conditioners and the floor finishes it was found that the very low difference between both choices. Therefore the client's acceptance level of the developed integrated process model can be further improved.

The obtained result from the five case studies was distributed among the experts for their final perusal. With reference to their comments it can be concluded that the model will be highly appreciated by the industry for select the construction materials. Most of the clients are flexible enough to accept the final outcome derived from the IPM.

The case studies demonstrated how VM techniques have been applied in different situations to come up a common aim, the integration of best value and environment sustainability in construction projects. The VM is one of the decision techniques, which is commonly used in construction industry to achieve the best value options. The case studies showed that the process can be successfully implemented and it is possible to have the middle path, which will stand as value added sustainable selection.

It is the customer that must decide value. The outcomes of the case studies show even for a same element at different projects the best value is drawn based on the client's needs and the choices made by the multi disciplinary team. It's not valid to propose a specific alternative material for any element because it will depend on the criteria proposed by the team. The concept of customer value is built on the idea that people make buying decisions based on the relationship between price and performance. Therefore it is very much difficult to propose a specific material for a particular element. Because the choices may vary from client to client, perceptions of multi disciplinary team, available materials and the scope of the project basically. The proposed model is supposed to be combined two concepts and optimizes the value in choices.

4.2 Advantages and Limitations of the Model

It is important to note that the new model has been equipped with several user-friendly features than the results obtain through the application of those concepts separately. In pure VM and ES material selection processes are aimed at one aspect only, either value maximization or the environmentally sustainability. But this model focused on both aspects simultaneously. As a result the value is added to the alternatives in addition to the environmental soundness.

Environmentally sustainable material selection individually will not amount to satisfy all the client's requirements. In some instances the adopting 'Green materials' may be contrary to the client's original requirements specially the financial restrictions and will become unsustainable in economic terms. The embedded VM techniques in this model will prevent aforesaid bottlenecks by retaining the client's requirements effectively. Other than those benefits the VM techniques suppose to ensure the functionality of the end product. The inclusion of creative brainstorming session is one of the very useful and effective techniques used in this model. This allows team members to input their inherent creativity to the process and decision makers to abstract the spirit of the whole effort. The model lined up to steps in an initial stage. Therefore the scope can be narrowed down up to a manageable context by means of selecting the cost significant materials. This contraction of scope will increase the efficiency of the study, because it will reduce the amount of items to be considered within the process. Most probably the majority of environmental friendly materials would not be the most economical alternative for an element. The inclusion of such an alternative in the design will result to have cost overruns in client's budget. If so the developer may not enjoy the real value of the investment. But the model has given flexibility to use any of the VM techniques available to reach the required results. This technical flexibility can be seen in many in the stages down the line in the process. The research is aimed at identifying the environmental impacts of constriction materials through green labeling. The collaborative or grouped behaviour has not been considered when deriving the green labels for the materials. However, in construction most of the materials are compiled together to form required elements or items of the built environment.

Chapter Five

Conclusions and Recommendations

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This research is an attempt to identify how the environment sustainable criteria could be incorporated into the value management process and it's acceptability by the construction clients in Sri Lankan context.

5.1 Conclusions

VM has been identified as having the potential to deliver sustainability for projects owing to its utilisation of diverse knowledge resources, professional disciplines and stakeholders, facilitated environment, strategic timing and effective processes. It ensures that sustainability is brought to the forefront before critical decisions are made. It could reduce the conflicting interest between cost, environmental and social issues. Commitment to sustainability can be secured through positive interaction between clients, Value Management (VM) facilitators as well as the team members. The goals and purposes of sustainability and VM are not in contrast as assumed by many VM practitioners. It is established that the sustainability vision corresponds with the direction of VM.

As expected, Environmental Sustainability (ES) issues have been incorporated within the VM workshops not as a single criterion but as multi criteria. However, as revealed from the field studies, there are gaps in practice that are believed to be caused by the barriers raised by the lack of understanding of and confidence about this agenda. The consideration on ES in construction is lower than expected. The attention given to these issues varies from one workshop to another. The importance depends on client needs and wants. This reliance on clients itself becomes a barrier to sustainability absorption as, although sustainability would improve the value and quality of the output, clients were perceived as less interested in sustainability during VM. This puts facilitators in a difficult position as VM responds to clients demand and not the other way around. Although they are in a strategic position to influence clients, the final words still rest with the clients.

Many of the VM practitioners claimed to have good knowledge on sustainability and aware of its importance, however, the lack of absorption of this knowledge into the VM process projected the need for aid in channelling their knowledge and addressing sustainability more effectively. Improvement in sustainability can be made possible if awareness and knowledge of it are injected before the workshop takes place.

ES issues are integrated to the project functions and objectives and should be dealt with accordingly during the process and not be treated as a separate agenda. The issues need to be raised early in the process and client commitment is vital. Formal guidance would be helpful as people do not seem to upload knowledge and information easily. Current VM performance needs to be assessed to indicate where improvement needs to be focused. From here, strategies for better integration in the future can be formulated.

Although VM is theoretically, a strategic vehicle to improve sustainability performance, the existence of gaps and barriers indicates the need of aid to firmly seize this opportunity. It is recommended that ways for alleviating these gaps and barriers should be sought such as producing tools, guidelines, improving knowledge etc. Promoting ES through VM will enhance the reputation of VM as a value enhancing technique and enable it to remain competitive in delivering its services, especially in terms of the quality of advice given and proposals produced.

Through the research findings it was identified the term 'sustainability' is very much important to achieve in construction. Through the concept of sustainable construction the industry was attempted to improve environmental sustainable goals in construction products and processes. There are multiple number of indicators were developed by the various institutions. To measure the sustainability in terms of eco friendliness is difficult even there are multiple methods available. The life cycle assessment is the most significant tool that is available at present to analyse the environmental impacts of construction materials.

When the material is being driven through the sustainability it should minimise the negative impacts to the environment. The renewability, recyclability, reusability, embodied energy contents and the other emissions were considered as to make the material green. Based on the expert opinions generated through the value management team, the green score could be measured through the selected indicators. Those indicators were able to quantify the level of environmental favourability of the selected materials. To what extent do the indicators need to select and do they actually measure the eco friendliness of a material.

The conclusions can be drawn through the findings of the research study. The study is focused on an integration of two discrete phenomena and developed a process model to select a construction material that permits both best value and environment sustainable criteria. The concept of sustainable construction is given predominant priority because of the inextricable linkage between the environment and the construction. The concept has evolved over many years. The initial focus was only on the environmental aspects.

However, in today's context the emphasis is placed on economical and social aspects. It is now recognized that sustainability is a tripartite paradigm which relies on its environmental, economical and social pillars. One of the key themes that should be adhered in striving to achieve sustainability in construction is to consider the ecological, economical and social context of the built facility for all project decision making at the very first possible stage. Hence intelligence decision making is required which includes full consideration and knowledge of the many tradeoffs and impacts associated with each alternative available to be chosen.

This research study on 'Integration of value management and environment sustainability to select construction materials' is one of the initials taken towards the sustainable decision making in construction industry. The final outcome of the study is basically permits a material that optimizes both concepts effectively. Further this process is capable of adhering the stated theme because, the process is about one of the very initial stage in construction process which is material selection and also the process prompts the decision makers to balance their decisions against the all sustainability aspects.

The financial benefits of sustainability are often being questioned by the construction stakeholders because, its marginality in giving returns and the inherent difficulties of quantifying the benefits. So, most the employers and contractors do not bother to comply with sustainability construction mechanisms. This was one of the key considerations which had to be deals with at the development of a process model. The whole process is structured in a strategic way by introducing one of the core VM techniques which is 'Function Analysis' as the thresh-hold for selecting the building component.

On the other hand, it is said that the traditional methods of material selection are ineffective in terms of functional and financial aspects. In the process the sustainable materials selection has been blended with the VM which is said to be effective than the traditional cost controlling systems. Therefore the engagement of VM techniques in new process provides total effective decision support tool. The effectiveness solely will not amount to success of any process. To stand as successful process the efficiency is important as same as the effectiveness in situation where the time is very crucial in any of the business activities.

The results of the case study raised the following results;

- The developed model can be applied for the selection of sustainable construction materials.
- In addition to the environmental sustainability, the process is being capable of adding more value to the selection
- The model facilitates the comparison of the sustainability aspects which are environmental, economical and social
- The model can be used as a decision support tool at the early stage of the project
- The model is appreciated because of its capability of being a tool to eliminate the unnecessary cost while on the way towards the sustainability

Sustainable concept is a new concept that required considering the sustainability objective for all decision making during the life cycle of the built facility. It is important to note that this concept is a relative and subjective phenomenon. The most suitable material among the available materials for a particular project may not necessarily be suitable for other instances even it seems that the scenario is same as previous. The selection will be varied according to the temporal and geographical factors as well as the perception of the professionals involved with the study. It is difficult to propose a specific material for a specific element. It depends on the client's needs, and the decisions derived through the brainstorming sessions. The selection is ultimately being the best because it's not a single person's decision and it has focused multidimensional criteria of the material.

The outcomes of the research found that the ES criteria can be incorporated into the VM process through the developed model and further it has overall 47% of acceptance among the construction clients in Sri Lanka. The acceptance can be further uplift by adopting it at the very early stage of any construction project. It was recognised from the result that the integration promotes the value enhanced product at the end and enable to remain competitive in delivering its functions.

5.2 Contributions and Implications

It can be identified the multiple applications of VM and ES in construction. But achieving the best value along with environment sustainability is lacking. Therefore it was hoped to develop a model by filing this gap by incorporating both best value and environment sustainable criteria in construction material selection. Construction industry is caused into the number of repercussions at present. Construction material has considerable effects to the environment. Therefore the research focused to achieve environment balance through the material selection process and meantime to deliver the best value to the project stakeholders.

The result makes an avenue to improve ES and VM concerns in construction material selection. Therefore it was hoped the research has added new knowledge to the existence through introducing this integrated process model to select construction materials. The model has considerable level of acceptance among the construction clients in Sri Lanka and hope it will bring the much more value for the international context too. The model can further sharpen through the innovative tools and techniques.

5.3 Recommendations

The case study conducted in this research demonstrate the important of structuring the decision making process to include 'Value' concept when working towards the final selection. As well the results of the case studies evident that the decision which was taking through this value oriented system synchronize the satisfaction of both aspects of sustainability and the financial viability.

This process model can be recommended to use at any stage of the construction process, but the application of the process at the early design stage will give more benefits than when it applies at the later stages because of the inborn cost reduction potentials at the initial stage.

Further, this process can be used as an analytical tool when the scenario is to select the most sustainable proposal from a set of proposals. It is possible to value the degree of sustainability that each proposal bas been achieved and then this will be the decision criteria for the selection of the proposals.

Based on the theoretical concept and potential of VM, the inclusion of sustainability within VM practices is realistic and practical. However, pilot studies revealed gaps in practice and barriers to integration, indicating room for improvement. It is proposed to introduce a way to alleviate the barriers to integration in order to reduce the gaps and promote better inclusion of sustainability in future VM practices. Improvement can be pursued from many angles. Among those are:

- search for ways to raise sustainability issues early in the VM practices
- seek ways to incorporate sustainability issues effectively within the defined time frame

- introduce a guide for sustainability in VM workshops
- prove VM capability as mechanism to deliver better sustainable value
- formulate strategies for effective sustainability inclusion within VM process
- Develop a complete set of environmental performance indicators with suitable metrics
- An analysis of present constraints posed by regulations is important to remove the barriers impeding new practices and products in the building industry.

By recommending the above improvements the research can further insight to the best outcomes rather than the independent practices of VM and the ES.

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Annexure

Annex - 1 : Case Study I - Foundation

CASE STUDY - I (i)

Project : Apartment Complex	***Element :*** Foundation
Location : No 08, Sripala Road, Mount Lavenia	***Value Index :*** 2.78
Estimated Project Cost : Rs. 49,337,456.00	***Basic Function:*** Sustain & Transfer the Load

Project Description :

A Four storied apartment, having 2600 m2 of Gross Floor Area. Lifting facility is included.

Value Criteria :	***Environment Sustainable Criteria :***
Initial Cost	Embodied Energy
Load bearing Capacity	Reusability
Durability	Recyclability
Time for construction	Other emissions
Maintenance Cost	

Generated Alternatives through Brainstorming :

1. Concrete (R/F)
2. Rubble
3. Bricks
4. Timber
5. Steel

Best Alternative, in terms of :

Value Management : **Concrete (R/F)**

Environment Sustainability : **Timber**

Client's Choice: **Concrete (R/F)**

Best material derived through the IPM : **Concrete (R/F)**

Annex - 2 : Case Study I - Ground Floor Slab

CASE STUDY - I (ii)

Project : Apartment Complex	***Element :*** Ground Floor Slab
Location : No 08, Sripala Road, Mount Lavenia	***Value Index :*** 3.28
Estimated Project Cost : Rs. 49,337,456.00	***Basic Function:*** Sustain and transfer load

Project Description :
A Four storied apartment, having 2600 m2 of Gross Floor Area. Lifting facility is included.

Value Criteria :	***Environment Sustainable Criteria :***
Initial Cost	Embodied Energy
Maintenance Cost	Reusability
Durability	Recyclability
Time for construction	Other emissions
Availability	

Generated Alternatives through Brainstorming :

1. Concrete (Mass)
2. Bricks
3. Timber
4. Steel

Best Alternative, in terms of :

Value Management :

Concrete (Mass)

Environment Sustainability :

Timber

Client's Choice: **Concrete (Mass)**

Best material derived through the IPM : **Concrete (Mass)**

Annex - 3 : Case Study I - Floor Finishes

CASE STUDY - I (iii)

Project : Apartment Complex	***Element :*** Floor Finishes
Location : No 08, Sripala Road, Mount Lavenia	***Value Index :*** 4.3
Estimated Project Cost : Rs. 49,337,456.00	***Basic Function:*** Enclosed floor

Project Description :
A Four storied apartment, having 2600 m2 of Gross Floor Area. Lifting facility is included.

Value Criteria :	***Environment Sustainable Criteria :***
Initial Cost	Embodied Energy
Aesthetic	Reusability
Durability	Recyclability
Maintenance Cost	Other emissions
Time for construction	
Slip Resistance	
Withstanding the Load (Live)	

Generated Alternatives through Brainstorming :

1. Cement Rendering
2. Ceramic Floor Tiling
3. Granite Tiling
4. Terrazo
5. Timber

Best Alternative, in terms of :

Value Management : **Granite Tiling**

Environment Sustainability : **Timber**

Client's Choice: **Ceramic Floor Tiling**

Best material derived through the IPM : **Ceramic Floor Tiling**

Annex - 4 : Case Study I - Partitions

CASE STUDY - I (iv)

Project : Apartment Complex	***Element :*** Partitions
Location : No 08, Sripala Road, Mount Lavenia	***Value Index :*** 2.38
Estimated Cost : Rs. 49,337,456.00	***Basic Function:*** Divide Space

Project Description :
A Four storied apartment, having 2600 m2 of Gross Floor Area. Lifting facility is included.

Value Criteria :	***Environment Sustainable Criteria :***
Initial Cost	Embodied Energy
Maintenance Cost	Reusability
Ability to replace	Recyclability
Durability	Other emissions
Aesthetic	
Insulation Properties	
Time for construction	

Generated Alternatives through Brainstorming :

1. Brick wall
2. Glazed wall
3. Metal Frame
4. Timber

Best Alternative, in terms of :

Value Management : **Glazed Walls**

Environment Sustainability : **Timber**

Client's Choice: **Brick**

Best material derived through the IPM : **Timber**

Annex - 5 : Case Study II - Columns

CASE STUDY - II (i)

Project : Semi Luxury Apartment Complex	***Element :*** Structure (Column)
Location : No 19, Arathusa Lane, Colombo 06	***Value Index :*** *3.78*
Estimated Project Cost : Rs. 61,500,298.00	***Basic Function:*** Transfer Load

Project Description :
Six storied apartment, 2100 m2 of Gross Floor Area. Lifting facility is included

Value Criteria : Initial Cost Maintenance Cost Strength Availability Time for construction Aesthetic Durability Integration of Finishes & Services	***Environment Sustainable Criteria :*** Embodied Energy Reusability Recyclability Other emissions

Generated Alternatives through Brainstorming : 1. In-situ Concrete 2. Pre-cast Concrete 3. Steel	***Best Alternative, in terms of :*** Value Management : **Pre-Cast Concrete** Environment Sustainability : **Pre-Cast Concrete**

Client's Choice:	**In situ Concrete**
Best material derived through the IPM :	**Pre-Cast Concrete**

Annex - 6 : Case Study II - Beams

CASE STUDY - II (ii)

Project : Semi Luxury Apartment Complex	***Element :*** Structure (Beam)
Location : No 19, Arathusa Lane, Colombo 06	***Value Index :*** *2.57*
Estimated Project Cost : Rs. 61,500,298.00	***Basic Function:*** Sustain and transfer loads

Project Description :
Six storied apartment, 2100 m^2 of Gross Floor Area. Lifting facility is included

Value Criteria : Initial Cost Strength Time for construction Durability Availability Aesthetic Maximum Span	***Environment Sustainable Criteria :*** Embodied Energy Reusability Recyclability Other emissions

Generated Alternatives through Brainstorming : 1. In-situ Concrete 2. Pre-cast Concrete 3. Steel	***Best Alternative, in terms of :*** Value Management : **Pre-Cast Concrete** Environment Sustainability : **Pre-Cast Concrete**

Client's Choice: **In-Situ Concrete**

Best material derived through the IPM : **Pre-Cast Concrete**

Annex - 7 : Case Study II - Upper floor slab

CASE STUDY - II (iii)

Project : Semi Luxury Apartment Complex	***Element :*** Structure (Upper Floor Slab)
Location : No 19, Arathusa Lane, Colombo 06	***Value Index :*** *4.33*
Estimated Project Cost : Rs. 61,500,298.00	***Basic Function:*** Sustain and transfer the loads

Project Description :
Six storied apartment, 2100 m^2 of Gross Floor Area. Lifting facility is included

Value Criteria :	***Environment Sustainable Criteria :***
Initial Cost	Embodied Energy
Strength	Reusability
Time for construction	Recyclability
Availability	Other emissions
Durability	
Integration of Finishes & Services	
Aesthetic	

Generated Alternatives through Brainstorming :

1. In-situ Concrete
2. Pre-cast Concrete
3. Timber

Best Alternative, in terms of :

Value Management : **Pre-Cast Concrete**

Environment Sustainability : **Timber**

Client's Choice: **In-Situ Concrete**

Best material derived through the IPM : **Pre-Cast Concrete**

Annex - 8 : Case Study II - External Walls

CASE STUDY - II (iv)

Project : Semi Luxury Apartment Complex	***Element :*** External Walls
Location : No 19, Arathusa Lane, Colombo 06	***Value Index :*** *3.45*
Estimated Project Cost : Rs. 61,500,298.00	***Basic Function:*** Enclosed the space

Project Description :
Six storied apartment, 2100 m^2 of Gross Floor Area. Lifting facility is included

Value Criteria :	***Environment Sustainable Criteria :***
Security	Embodied Energy
Initial Cost	Reusability
Aesthetic	Recyclability
Availability	Other emissions
Maintenance Cost	
Time for construction	
Insulation Properties	

Generated Alternatives through Brainstorming :

1. Brick Wall
2. Block Wall
3. Concrete Wall

Best Alternative, in terms of :

Value Management :

Concrete Walls

Environment Sustainability :

Block Walls

Client's Choice: **Brick Walls**

Best material derived through the IPM : **Brick Walls**

Annex - 9 : Case Study III - External Walls

CASE STUDY - III (i)

Project : Semi Luxury Apartment Complex	***Element :*** External Walls
Location : No 97, Galle Road, Rathmalana	***Value Index :*** *2.04*
Estimated Project Cost : Rs. 119,490,902.00	***Basic Function:*** Enclosed Space

Project Description :
Five storied apartment complex, 1550 m2 of Gross Floor Area. Ground floor is allocated for car parking facility. Lifting and CCTV systems are included.

Value Criteria : Initial Cost Maintenance Cost Aesthetic Time for construction Durability Insulation Properties	***Environment Sustainable Criteria :*** Embodied Energy Reusability Recyclability Other emissions
Generated Alternatives through Brainstorming : 1. Block Wall 2. Concrete Wall 3. Timber 4. Glazed Curtain Walls 5. Hollow Glass Blocks 6. Terra cotta Bricks 7. Lath Plaster walls 8. Metal Panels	***Best Alternative, in terms of :*** Value Management : **Block Wall** Environment Sustainability : **Timber Walls**

Client's Choice: **Brick Walls**

Best material derived through the IPM : **Brick Walls**

Annex - 10 : Case Study III - Wall Finishes

CASE STUDY - III (ii)

Project : Semi Luxury Apartment Complex	***Element :*** Wall Finishes
Location : No 97, Galle Road, Rathmalana	***Value Index :*** *2.20*
Estimated Project Cost : Rs. 119,490,902.00	***Basic Function:*** Protect the structure

Project Description :
Five storied apartment complex, 1550 m2 of Gross Floor Area. Ground floor is allocated for car parking facility. Lifting and CCTV systems are included.

Value Criteria :	***Environment Sustainable Criteria :***
Initial Cost	Embodied Energy
Maintenance Cost	Reusability
Aesthetic Properties	Recyclability
Insulation Properties	Other emissions
Time for construction	
Durability	

Generated Alternatives through Brainstorming :

1. Lime Plaster
2. Febmixplus plaster
3. Gypsum Board
4. Aluminium Cladding
5. Wall Papers

Best Alternative, in terms of :

Value Management :
Febmix plus plaster

Environment Sustainability :
Lime Plaster

Client's Choice: **Lime plaster**

Best material derived through the IPM : **Febmix plus plaster**

Annex - 11 : Case Study IV - Roof Coverings

CASE STUDY - IV (i)

Project : Residence	***Element :*** Roof Coverings
Location : Wijerama Mawatha, Colombo 07	***Value Index :*** *3.65*
Estimated Project Cost : Rs. 27,000,000.00	***Basic Function:*** Enclosed Surface

Project Description :
Seven numbers of two storey semi luxury housing scheme including sanitary facilities.

Value Criteria :	***Environment Sustainable Criteria :***
Transmit Load Exclude climate Resist decay/corrosion Directs rain water Aesthetic Creates shading Resist uplift Assure security	Embodied Energy Reusability Recyclability Other emissions

Generated Alternatives through Brainstorming :	***Best Alternative, in terms of :***
1. Half round tiles 2. Calicut tiles 3. Asbestos sheet 4. Zink Alum sheets	Value Management : **Zink Alum sheet** Environment Sustainability : **Half round tiles**

Client's Choice: **Asbestos sheet**

Best material derived through the IPM : **Calicut tile**

Annex - 12 : Case Study IV - Internal Walls

CASE STUDY - IV (ii)

Project : Residence	***Element :*** Internal walls
Location : Wijerama Mawatha, Colombo 07	***Value Index :*** *3.21*
Estimated Project Cost : Rs. 27,000,000.00	***Basic Function:*** Divide Space

Project Description :
Seven numbers of two storey semi luxury housing scheme including sanitary facilities.

Value Criteria : Divide space Attenuate noise Support services Transfer loads Maintain security Aesthetic	***Environment Sustainable Criteria :*** Embodied Energy Reusability Recyclability Other emissions
Generated Alternatives through Brainstorming : 1. One brick wall 2. Engineering bricks 3. Hollow block 4. Concrete block 5. Half brick wall	***Best Alternative, in terms of :*** Value Management : **One brick walls** Environment Sustainability : **Hollow block**

Client's Choice:	**Half Brick Wall**
Best material derived through the IPM :	**Half Brick Wall**

Annex - 13 : Case Study V - Air Conditioning System

CASE STUDY - V (i)

Project : Condominium Apartment	***Element :*** Air Conditioning System
Location : Schoffield Avenue, Colombo 03	***Value Index :*** *4.15*
Estimated Project Cost : Rs. 23,676,322.00	***Basic Function:*** Provides Comfort

Project Description :
Two storey apartments, approximate gross floor area is 450 m2. The estimated cost for Air conditioning system is 4.36% of total contract sum.

Value Criteria :

Initial cost
Maintenance cost
Required Space
Durability
Aesthetic
Control Noise
Time for install
Level of heat

Environment Sustainable Criteria :

Embodied Energy
Reusability
Noise Level
Electricity consumption
Heat level
Other emissions

Generated Alternatives through Brainstorming :

1. Window type
2. Ceiling mounted split type
3. Wall mounted split type
4. Floor mounted split type
5. Package type
6. Central A/C System

Best Alternative, in terms of :

Value Management :

Wall mounted split type

Environment Sustainability :

Package type

Client's Choice: **Package Type**

Best material derived through the IPM : **Wall mounted split type**

Annex - 14 : Case Study V - External Walls

CASE STUDY - V (ii)

Project : Condominium Apartment	***Element :*** External Wall
Location : Schoffield Avenue, Colombo 03	***Value Index :*** *2.38*
Estimated Project Cost : Rs. 23,676,322.00	***Basic Function:*** Enclosed Space

Project Description :
An Apartment with two storeys, approximate gross floor area is 450 m^2.

Value Criteria : Initial cost Maintenance cost Strength & Stability Security Resistance to weather Insulation properties Durability Aesthetic Privacy Time for construction	***Environment Sustainable Criteria :*** Embodied Energy Reusability Recyclability Other emissions
Generated Alternatives through Brainstorming : 1. Brick wall 2. Block wall 3. Concrete wall 4. Pre-cast concrete walls 5. Glazed curtain wall 6. Cladding 7. Steel panel 8. Timber wall	***Best Alternative, in terms of :*** Value Management : **Pre-cast Concrete wall** Environment Sustainability : **Block wall**

Client's Choice:	**Brick Wall**
Best material derived through the IPM :	**Brick Wall**

Annex - 15 : Case Study V - Floor Finishes

CASE STUDY - V (iii)

Project : Condominium Apartment	***Element :*** Floor Finishes
Location : Schoffield Avenue, Colombo 03	***Value Index :*** *3.47*
Estimated Project Cost : Rs. 23,676,322.00	***Basic Function:*** Enclosed Space

Project Description :
An Apartment with two storey, approximate gross floor area is 450 m^2.

Value Criteria : Initial cost Maintenance cost Aesthetic Durability Time for construction	***Environment Sustainable Criteria :*** Embodied Energy Reusability Recyclability Other emissions

Generated Alternatives through Brainstorming :

1. Cement Rendering
2. Gloss finish ceramic tile
3. Matt finish ceramic tile
4. Porcelain finish ceramic tile
5. Homogenous matt finish
6. Terrazzo
7. Terra cotta tile
8. Granite
9. Parquet – timber teak
10. Carpet

Best Alternative, in terms of :

Value Management :

Ceramic Matt Finish

Environment Sustainability :

Parquet – timber teak

Client's Choice: **Ceramic Gloss Finish**

Best material derived through the IPM : **Homogenous matt finish**