Construction Cost Management

in Resource Based Economy

Master thesis

International Master of Science in Construction and Real Estate Management

Joint Study Programme of Metropolia UAS and HTW Berlin

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To the late Jacque Fresco, your life work is inspiring.

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International Master of Science in Construction and Real Estate Management

Joint Study Programme of Helsinki Metropolia UAS and HTW Berlin 'UAS

Master Thesis for Mr Muhammad Faisal ElAzzazy

Student number: ***552947 (HTW) & 1505607 (Metropolia)***

Topic: CONSTRTUCTION COST MANAGEMENT IN RESOURCE BASED ECONOMY

Summary

The construction industry is one of the most consuming industries of natural resources, and it does that with a rate faster than their renewal. In Resource Based Economy, natural resources are quantified and consumed according to the renewal rate, while finding solution for using other resources instead, (not to decrease the demand, and to keep maintaining the supply).

The direct cost for road construction is estimated and priced in money values, with not-enough attention to the effect on the environment. Recent reports of sand being in shortage (due to the land reclamation, construction, etc.) are a wakeup call to construction industry. Sustainable development aspect "the environment" is being suppressed by the current economy and society.

The aim of this research is to develop a cost management model that considers the dry costs of road construction are the natural resources, and all other traditional costs are overhead, such as energy and manpower, because they are renewable or being laid off. The use of renewable energy is considered a sustainable step, and one possible next step should be using techniques to minimize construction usage of precious natural resources.

Objectives of the Study

1. To quantify the natural resources needed to the construction of a new road, and compare it against the rate of renewal.

2. To develop a cost management model with planning, estimation, budgeting, and control processes for resource based economy.

3. To explore the possible ways to decrease using natural resources, those are in shortage.

4. To identify the key benefits and barriers to the resource based economy construction.

The Master's Thesis project started on May. 20th, 2016 and will end August 25th, 2017. The Thesis will be presented in the colloquium in September, 2017.

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Abstract

Resource Based Economy tested according to criteria formulated from the construction cost management best practices. A cost management plan modeled to demonstrate the possibility of construction management under a new socio-economic system, which counts the consumed natural resources by construction as the dry cost to the environment.

Keywords: Constrcution cost management, Resource based economy, Road construction, Road rehabilitation.

Table of Contents

Table of Figures

List of Tabulations

1. Introduction

Construction accounts for one of the basic needs for all humanity throughout the history of the world. It consumes natural resources, both to form the physical part of the construction, and to assist in construction in the form of energy and scaffolding for examples. The natural resources that are parts of the physical matter of construction, which forms the main components, have changed through research and development, from natural stone bricks, to reinforced concrete and steel structures. They are mined and processed to satisfy the specified characteristics, as required by designers.

Cost management has been a very important part of all projects, because it provides the information required to evaluate the profits and losses, before, during, and after the projects. Resource management addresses the availability of all resources, which are c (Gasiorowski 1995)onsumed totally or partially by the projects, calculated as dry costs or overheads.

Technology is progressing exponentially and inventions in the robotics field are opening new potentials for Artificial Intelligence (AI) and Automation future, where human interaction in manufacturing and construction is being decreased and replaced by machines.

In order to investigate deeply in ideas related to the future of human kind, several aspects are researched to clarify the vision from several points of views. One of these ideas is The Venus Project (TVP) which considers a civilization that is based on three aspects, Society, Environment, and Technology. Progressing from the current technological and environmental status, society is expected to thrive to the level where humanity can survive without war, poverty and hunger.

This thesis discusses one possible construction model and its cost management that can be used during the automation of construction, but it is based on the current construction model, with redefining the word ‘cost’ to mean the dry cost of construction to the planet.

Free and clean energy is being researched for decades to reduce the usage of natural resources as a source of energy, especially the ones which are consumed or change their form as a physical composition to produce energy, resulting in decrease of the quantity of these natural resources that are available on the planet, such as coal and petroleum.

The current economic model has developed several solutions and problems. The ones that are considered in this thesis are mentioned hereunder.

1.1. General statement of the problem

The current civilization has had several problems which impact the construction industry and its sustainability.

1.1.1. The great depression in the United States in the 20th century and other economic crises are on repetitive cycles. It happened and it will keep on happening. Although the natural resources were available during those times, it was not used for development. The current economic system is not stable[1] and depressions affect construction industry greatly[2]. If money is excluded from construction costs, the natural resources availability is then the main focus[3], and that would increase the potential of construction in cases of economic crises.

1.1.2. Reports on the sand mafia[4] activities are an important indicator that the natural resources required for construction are not abundant everywhere, and additional measure should be considered to utilize what is available.

1.1.3. The existence of a large number of roads that need rehabilitation and construction across the world, but they remain unmaintained or unconstructed for years, while other roads with less importance or urgency are being rehabilitated and constructed. The criteria, on which the urgency and importance are based on, are not sustainable.

1.1.4. In order to avoid shortage of resources, unsustainable acts, and the impact of economic instability, Jacque Fresco suggested another economic model

[1] Gasiorowski, M. J. (1995). Economic Crisis and Political Regime Change: An Event History Analysis. American Political Science Review. Vol. 89, No. 4, pp. 882-897.

[2] Buckley, M. (2011). From Kerala to Dubai and back again: Construction migrants and the global (The Venus Project n.d.) (The Venus Project n.d.) (IPMA 2006) (A Guide To The Project Management Body of Knowledge 2013)economic crisis. Geoforum 43, pp. 250-259.

[3] Fresco, J. (2002). The Best That Money Can’t Buy. P 21

[4] Witsoe, J., 2012. Everyday corruption and the political mediation of the Indian state. Economic & Political Weekly, 47(6), p.47.

and called it “Resource Based Economy”. In addition to the previous concerns, Jacque Fresco addressed several concerns and found potential solutions for them, such as education, transportation, housing, city planning, etc.[5]

1.2. Significance of the Thesis

During this research, the construction costs shall be quantified in terms of natural resources, which are available on earth, and are not necessarily affected by the existence of the monetary system. It is a matter of motivation to get the human resources to do the required tasks, and that has been done several times along the history. From nationalism and religious beliefs to slavery, people would do anything to make sure the product/service is realized.

In addition to the benefits to the society, from continuing the construction works during economic crises, there are also the benefits to the research community. Applying the approach of development with total disregard to monetary values, can and will be a mean of sustainability among other industries, such as; agriculture, transportation, and mining.

The problems that emerge from the lack of confidence, during the breakdown of banks, for instance, can also be minimized, especially when people are informed that industries are not solely dependent on money, but mainly on available natural resources. These resources are to be identified, surveyed, and can still be used at a national/global scale.

Thus, the presented cost model is not only for Resource Based Economy, but also for the current construction model and economics.

1.3. Research Questions

1.3.1. How many materials are used in road construction and rehabilitation?

The input material shall be identified in the order of construction layers and order.

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[5] The Venus Project. www.thevenusproject.com/the-venus-project/aims-and-proposals [Accessed 15 Aug. 2017]

1.3.2. What are the natural resources that form those materials?

The materials used in road construction are broken down and traced back to their original natural resources.

1.3.3. How much is available? And where?

Those natural resources are quantified as available in Egypt according to the available statistics and data.

1.3.4. Which natural resources cannot be replaced, or are not renewable?

Those natural resources are categorized into renewable and non-renewable as a first degree, and replaceable and non-replaceable as the second degree.

1.3.5. What is the rate of usage?

Available information on the current road construction and rehabilitation projects shall be stated to demonstrate the required quantities of the natural resources.

1.3.6. Are there possible ways to avoid using them later?

Technological endeavours are changing the compositions of materials and constructions. The ones related to road construction and rehabilitation shall be presented.

1.3.7. What other trends or industries can apply the resource based economy?

The proposed cost model shall be discussed in different trends and industries to demonstrate the model effectiveness.

1.3.8. What are the strengths, weaknesses, opportunities and threats encountered during applying that technique?

A SWOT analysis is applied to the model.

1.4. Assumptions

For a progressive research such as this one, some assumptions are introduced, based on the Resource Based Economy model.

1.4.1. Construction is automated and machines are built to build other machines that are used in construction activities.

1.4.2. Natural resources are a common heritage of all humans, regardless of the location of these resources, and they are to be transported freely across the planet.

1.4.3. Data is available for scientific research and processed by advanced computers for decision making.

1.4.4. The characteristics of materials, although they differ from one design to the other, are assumed constant to facilitate the demonstration of the model.

1.4.5. The energy used during production, manufacturing, transportation and construction is disregarded during this research. The energy includes; human labour, electricity, fuel, etc.

1.4.6. The materials used for the manufacturing the machines are disregarded during this research. The materials include; steel, concrete for factories and other ancillary machines.

1.4.7. Data is stored in data centres, which are connected globally and updated as new sites are discovered and their quantities surveyed.

1.5. Definition of terms

1.5.1. Resource Based Economy

"The term and meaning was coined by Jacque Fresco, the founder of The Venus Project. The Venus Project proposes a holistic approach with a global socio-economic system that utilizes the most current technological and scientific advances to provide the highest possible living standard for all people on Earth.

In a Resource Based Economy, all goods and services are available to all people without the need for means of exchange such as money, credits, barter or any other means. For this to be achieved all resources must be declared as the common heritage of all Earth's inhabitants. Equipped with the latest scientific and technological marvels mankind could reach extremely high productivity levels and create abundance of resources.

Resource Based Economy concerns itself with three main factors, namely Environmental, Technological and Human."[6]

1.5.2. Natural Resources

These are the resources that are available in nature without any human intervention, before applying any processing to turn it into used materials.

1.5.3. Construction Costs

These are the natural resources that form the mass and volume of the construction, whether it is a road, a bridge, or a building.

1.5.4. Cost Management

'Project cost management estimates the cost of each work package, the sub-systems and the whole project and establishes the budget for the overall project. It also involves comparing planned versus actual costs incurred at various points in the project and estimating the remaining cost, as well as updating the final cost estimate. The cost of the deliverables should be measurable and calculable. The cost of any change should be calculated, agreed and documented."[7]

1.5.5. Resource Management

"Resource management consists of resource planning, with the identification and allocation of resources with the appropriate capability. It also includes optimising the way resources are utilised in the time schedule as well as the continuous monitoring and control of these resources. Resources embraces people, materials and the infrastructure (such as materials, equipment, facilities, services, information technology, information and documents, knowledge, funds) required to carry out project activities."[8]

1.5.6. Bottom-Up Estimating

"Bottom-up estimating is a method of estimating a component of work. The cost of individual work packages or activities is estimated to the greatest level of specified

[6] The Venus Project (2017) www.thevenusproject.com/resource-based-economy/ [Accessed 11 Aug. 2017]
[7] IPMA Competence Baseline, Version 3.0, 2006. P 64
[8] IPMA Competence Baseline, Version 3.0, 2006. P 62

detail. The detailed cost is then summarized or “rolled up” to higher levels for subsequent reporting and tracking purposes. The cost and accuracy of bottom-up cost estimating are typically influenced by the size and complexity of the individual activity or work package.”[9]

[9] Rose, K.H., 2013. A Guide to the Project Management Body of Knowledge (PMBOK® Guide)—Fifth Edition. Project management journal, 44(3). P 205

2. Literature Review

2.1. Resource Based Economy

“The term and meaning was coined by Jacque Fresco, the founder of The Venus Project. The Venus Project proposes a holistic approach with a global socio-economic system that utilizes the most current technological and scientific advances to provide the highest possible living standard for all people on Earth.

In a Resource Based Economy, all goods and services are available to all people without the need for means of exchange such as money, credits, barter or any other means. For this to be achieved all resources must be declared as the common heritage of all Earth’s inhabitants. Equipped with the latest scientific and technological marvels mankind could reach extremely high productivity levels and create abundance of resources.

Resource Based Economy concerns itself with three main factors, namely Environmental, Technological and Human.” [10]

2.1.1. National Mega-Projects

Resource Based Economy differs than Sustainable Development in that the Technology replaces the Economy, as one of the three aspects, and putting Economy under the Environmental aspect, from which comes the concept of a new cost management model.

This new cost management model can be explained in a chronological order, when a country decides to construct a Mega-Project, like the Suez Canal, the budget for the project is discussed and acquired, even if it has negative effects on other aspects. They are considered to have an open budget. Of course the amount of money required are calculated and managed, but mainly to assure the continuity of work. On the other hand, whatever resources that were required were acquired, no matter how dear they are. The tender process to choose the best offers are then made to decrease the amount of money, but the difference between the offers is not of an importance, and it is mostly an organizational issue.

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[10] The Venus Project (2017) www.thevenusproject.com/resource-based-economy/ [Accessed 11 Aug. 2017]

The real cost of construction then is the materials used, not the paid price. Throughout history, state-of-the-art mega-projects have been built. The following are some examples of projects that had monetary open budgets.

2.1.2. Projects examples:

The pyramids of Giza could be the oldest example for a construction built with a resource based mentality. The people who worked on that project were seen into having the required level of nutrition.[11]

The other important example is the manufacturing of aircrafts during the Second World War. A decision to prepare for war was the reason for manufacturing increase.[12]

And the last recent example is NASA, the National Aeronautics and Space Administration. NASA is exceeding their budget, and because it is a national interest, they are not to be stopped. The United States want to continue on their space research at any cost, and that leads to hiring the best scientists and acquiring the best material.[13]

2.1.3. Common heritage

Extinct natural resources, such as animals, are seen as statistics. Scarce natural resources, such as water and vegetables, in several locations of the world, are indicators that the nature capability is not well utilized. In-shortage natural resources, such as clean air represents a warning of dangerous measures.

Abundant natural resources, such as clean energy and sea water cost the environment nothing, unless no corrective measure is taken against climate change.

Red lists are being done to show the endangered natural resources that are in scarce, and the efforts of the scientific community to save these resources, in an

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[11] Harvard Magazine. harvardmagazine.com/2003/07/who-built-the-pyramids-html [Accessed 11 May 2017]

[12] Parker, Dana T. (2013). Building Victory: Aircraft Manufacturing in the Los Angeles Area in World War II

[13] Moonandback. http://moonandback.com/2011/09/15/impossibly-high-nasa-development-cost-are-heart-of-the-matter/) (Moonandback n.d.) [Accessed 11 May 2017]

attempt to keep them for the future generations and find alternatives to utilizing them.[14]

2.1.4. Money is actually limiting potential growth

The relation between natural resources availability and the economy is a phenomenon that describes the negative effect on economy when a country is having important natural resources. This phenomenon is called the Dutch disease.[15]

The profit and taxation systems and their impact on precious natural resources is an important indication of the scarcity of natural resources. When everything is translated in terms of money, everything gets mixed up and natural resources lose their real value, which reflects the need for it. Price increase of resources demonstrates the demand and supply situation, but for a certain limit, because the prices also includes the transportation, taxation and profit, which give a false indication of the value of the resources.

In addition to the above, in many instances, countries with great natural resources wealth grow less rapidly that the countries that are not rich in natural resources.[16]

2.1.5. Planned obsolescence

Examples of unsustainable measure and actions, and their relation to the current economic system, based on profit, are driving the environment to decline.[17] When a product is planned to malfunction after a certain period of time, in order to be disposed and another product to replace it, the old product is considered waste instead of raw material for the new product.

2.2. Road Construction and Rehabilitation

2.2.1. New construction

[14] International Union for Conservation of Nature and Natural Resources. Species Survival Commission, 1995. IUCN Red list categories. IUCN.
[15] Corden, W.M., 1984. (Corden 1984). oxford economic Papers, 36(3), pp.359-380.
[16] Sachs, J.D. and Warner, A.M., 2001. (Sachs and Warner 2001). European economic review, 45(4), pp.827-838.
[17] Bulow, J., 1986. (General Authority for Raods and Bridges & Land Transport n.d.). The Quarterly Journal of Economics, 101(4), pp.729-749.

In Egypt, the ministry of transportation delegates the General Authority for Roads and Bridges & Land Transport (GARBLT). GARBLT issued on their website more than 2500 km of road construction to be constructed between 2012 and 2017.[18]

2.2.2. Rehabilitation

GARBLT also issued the amount of road rehabilitation that is planned between 2012 and 2017, which exceeds 1600 km.

2.3. Availability of the components in nature

UN Environmental Programme (UNEP) reported that the sand and gravel are being mined at a faster rate than their renewal. In addition to that, the impact on rivers, deltas, and costal and marine ecosystems has been increasing negatively due to the land reclamation and excavation measures.[19]

2.3.1. Aggregates

Aggregates are the basic component of asphalt roads, which are categorized in to coarse and fine.

2.3.1.1. Coarse Aggregates

Course aggregates, such as crushed limestone, are sized between 4.75 mm till 150 mm.[20]

2.3.1.2. Fine Aggregates

Fine aggregates, or sand, are the particles that pass sieve no. 4 but do not pass sieve no. 200.[21]

2.3.2. Bitumen

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[18] GARBLT. http://www.garblt.gov.eg/index.php/component/content/article?id=133 [Accessed 14 Aug. 2017]

[19] UNEP. na.unep.net/geas/getUNEPPageWithArticleIDScript.php?article_id=110 [Accessed 14 Aug. 2017]

[20] Ingram, R.L., 1971. Sieve analysis. Procedures in sedimentary petrology, pp.49-67.

[21] Ingram, R.L., 1971. Sieve analysis. Procedures in sedimentary petrology, pp.49-67.

Bitumen is an extract from crude oil, along with several other materials that are used in all types of industries. That explains the extended usage of plastic, since it is a part of the extracted crude oil. Other extractions are Gasoline, Kerosene, and Diesel Oil. All these materials are used until now in a balanced way, but with the extended technology in clean energy, some of them will be produced along with others, although the demand will decrease.[22]

It is mandatory to the scientific community to prepare for the storage of the excess of these dangerous materials, in a manner to avoid additional pollution from disposal.

[22] Wess, J., 2004. Asphalt (bitumen) (No. 59). World Health Organization.

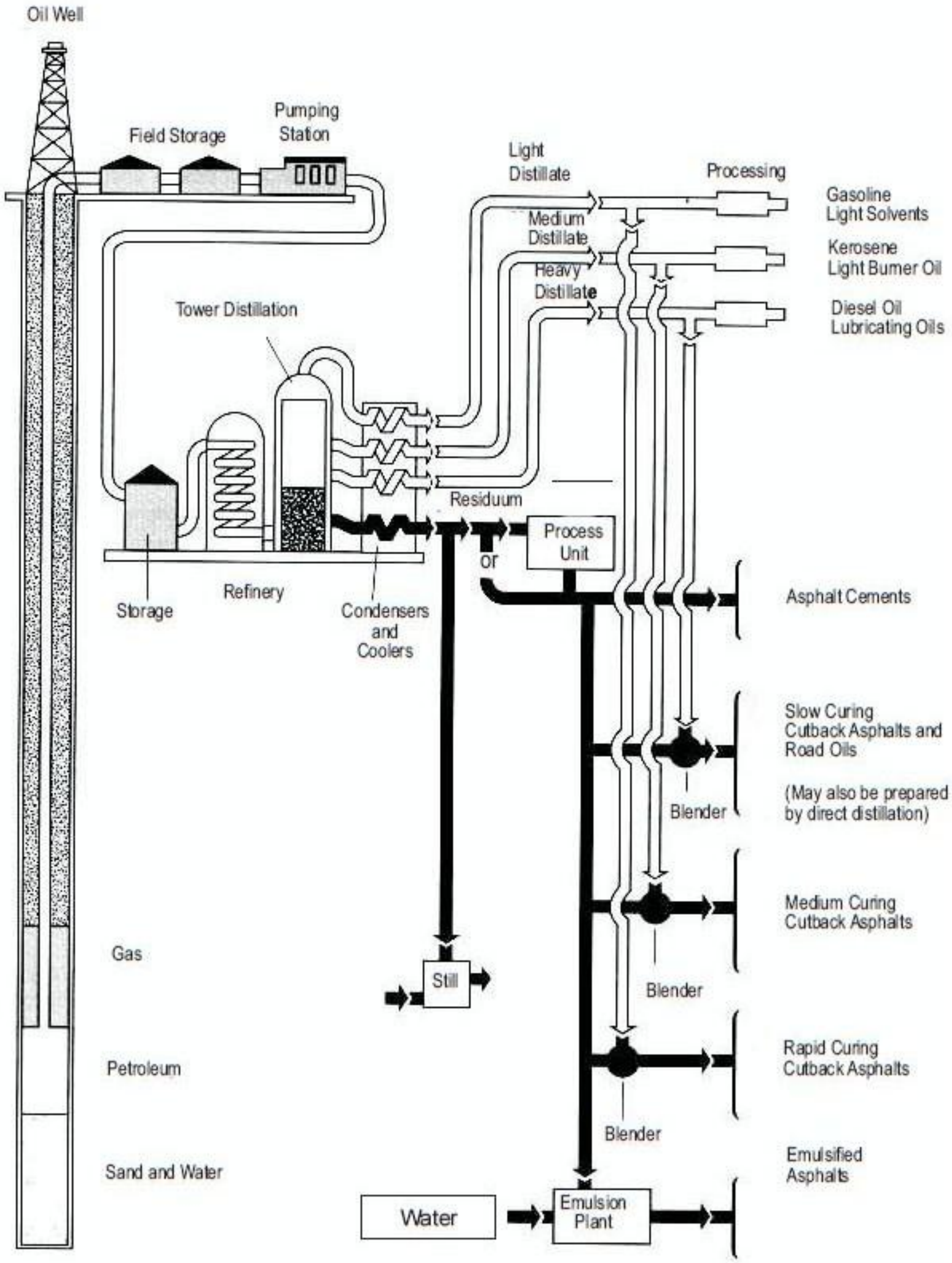

Figure 1 Petroleum Asphalt Flow Chart[23]

[23] http://www.virginiadot.org/business/resources/bu-mat-chapt1ap.pdf [Accessed 15 Aug. 2017]

The previous figure shows the extracted components of Petroleum, which are mainly five components, related to the Asphalt, namely: Emulsified Asphalts, Asphalt Cement, Diesel Oil, Kerosene, and Gasoline. For the purpose of this study, and since it is different from one well to the other, the required component is assumed 20% of the weight of the barrel.

2.3.3. Water

Water is simply one of the most important resources on earth, that it has been used by humanity and all living things, throughout history. Although the planet holds several resources of water, it is not accessible to all seven billion people on earth in 2017.

Additionally, it is highly used in all sorts of construction, manufacturing, agricultural, etc. but not all types of water can be used in construction. For example, the water that is used in concrete in superstructures has to be drinkable water.[24]

[24] Steinour, H.H., 1900. Concrete Mix Water--How Impure Can It Be? (No. 119).

3. Methodology

According to Project management Book of Knowledge (PMBoK 5.1) issued by Project Management Institute (PMI) there are four processes in project cost management knowledge area.[25]

Plan Cost Management: “The process that establishes the policies, procedures, and documentation for planning, managing, expending, and controlling project costs.”

Estimate Costs: “The process of developing an approximation of the monetary resources needed to complete project activities.”

Determine Budget: “The process of aggregating the estimated costs of individual activities or work packages to establish an authorized cost baseline.”

Control Costs: “The process of monitoring the status of the project to update the project costs and managing changes to the cost baseline.”

3.1. Introduction

Road pavement is an important part of transport system, which in most cases demonstrates the quality of life. It is done according to a set of procedures and is controlled by specifications, which differs from one issuing authority to the other. In this research, the rate of usage of the natural resources is investigated, according to the main areas of road construction; new construction, and roads rehabilitation.

The asphalt mix (or asphalt concrete) consists of graded aggregates, bind together with bitumen, in the matter of solid surface. Highways and runways are examples of utilities that require high quality. The design follows specific procedures to determine the types, ratios, and characteristics of the input materials, in order to assure the required benefit.

Road construction uses the adequate types of materials that can be used as a model, as they are divided into natural resources that are processed in different ways. Sand is used as a direct input to the road materials, while crushed stones have to be crushed into different sizes. On the other hand, bitumen is an extract from

[25] Rose, K.H., 2013. A Guide to the Project Management Body of Knowledge (PMBOK® Guide)—Fifth Edition. Project management journal, 44(3). P 193

crude oil, which is used for several other materials production, such as gasoline, the minimum required amount of bitumen for asphalt shall be estimated, with the awareness of the excess, and its fate.

Highways England, a governmental body in UK, has eight research sectors; one of them is the impact of road construction and rehabilitation on environment and how to minimize it, with the aim of making the use of main resources sustainable, and also to increase the requirements.[26]

The case study method is most suitable for this research, due to its suitability in sampling processes and models. Projects are the basic focus of project management, and construction is mainly performed on project organisational level. In addition to that, the case study will facilitate the repetition of the structure among other construction and rehabilitation projects, adding and changing the inputs according to the materials used and their natural resources.

The questionnaire method is not suitable for this research, due to the diverse of opinions related to the future of construction.

The end product of the methodology is a cost management model that accounts for the natural resources that forms the volume of the construction as the main dry cost. Energy is not introduced as dry cost, but as a free resource, since technology is getting towards free energy. Also with the automation of construction being under research and development, it is expected to have minimum human interaction within construction processes.

For simplicity, the layers and the design mix are presented on a general scale, and the quantities of materials and natural resources are estimated roughly.

3.2. Case study 1 (New Construction)

3.2.1. Cross Section

Case study 1 investigates the construction of a new rural road, single carriage way, starting with the excavation and earth work, until the final layer of asphalt. The road is

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[26] Highways England, www.gov.uk/government/organisations/highways-england/about/research [Accessed on 11 May 2017]

60 km long with width of 10.5 meters for the two asphalt layers, and 11 meters for the sub-base.

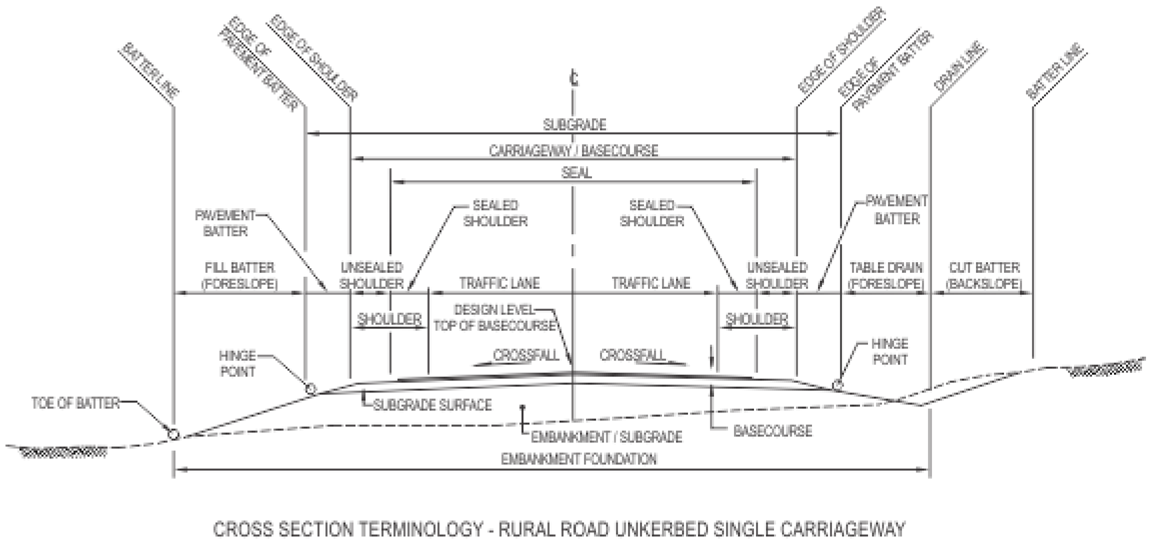

Figure 2 Cross Section of Case 1[27]

3.2.2. Layers

Layers are the items described in the Bill of Quantity (BOQ) and are coded accordingly. Layers are typically detailed into:

3.2.2.1. Subgrade Fill

Cut and fill activities are designed to minimise the amount of waste, but in most cases it is not exactly equal. That means there is always some more or some less of the material used, even when no additives are used.

In the first case study, the procured quantity of this layer is in cubic meter 175’000, with item number 1.

It is formed of granular sand and gravel put on the ground and levelled using a grader according to the design levels. For the purpose of compaction, water is used with a quantity of one cubic meter for every cubic meter of sand. Water sources can be rivers, seas, wells, or sewage water.

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27 https://www.mainroads.wa.gov.au/Documents/cross%20section%20terminology%20-%20rural%20road%20unkerbed%20single%20carriageway.GIF [Accessed 14 Aug. 2017]

3.2.2.2. Subgrade Cut

Subgrade Cut is the item that covers all ground waste that shall be removed from site. The item number is 2 and the quantity is 15’000 m^3.

3.2.2.3. Rock Demolition

It is expected to find some volumes of rocks that cannot be used in the construction of this project, and thus they shall be disposed. The item number is 3 and the quantity is also 15’000 m^3.

3.2.2.4. Base Course

Base course forms the basic layer of the road, because all layers that come next copy its geometry. The unit for this item is in square meter, and an average thickness is proposed to level the road.

The base course is a compacted mixture of crushed limestone and sand. Water is also used for the purpose of compaction, with the amount 0.8 cubic meters of water to one cubic meter of base course.

The item code for this layer is number 4, with the quantity of 660’000 m^2.

3.2.2.5. MCO

Extracted from crude oil and sprayed over the base course, before applying the first layer. It works as an adhesive between asphalt layer and base coarse layer. The rate of spraying is 1.5 kg/m^2.

The thickness of this layer is excluded when the volume of the road is calculated, because it is very small compared to the thickness of other layer, thus is can be neglected.

The unit of this layer is in square meter although it is formed of a material that is measured in kg during transportation. The item code is 5 and the quantity in square meters is 630’000.

3.2.2.6. Asphalt layer 1

The binder course is compacted asphalt mix of 6 cm thickness. It consists of aggregates, and bitumen. The bitumen is the binding material that holds the aggregates together.

The quantity is 630’000 m^2 and the item code is 6.

3.2.2.7. RC 3000

Extracted from crude oil and sprayed over the first asphalt layer, before applying the second layer. It works as adhesive between the two asphalt layers. The rate of spraying is 0.5 kg/m^2.

The quantity is 630’000 m^2 and the item code is 7.

3.2.2.8. Asphalt layer 2

It is the surface layer that wears out from contact and friction with vehicles tyres. In addition to the materials used for the first layer, industrial powder is used to fill the void between the particles, which accounts for 5% of the volume of the mix.

The quantity is 630’000 m^2 and the item code is 8

3.2.3. Bill of Quantity

The following table shows the total quantities of the items used for the first case study.

S	Description	Unit	Quantity	Notes
1	Subgrade Fill	m3	175,000	Procured
2	Subgrade Cut	m3	15,000	Disposed
3	Rock Demolition	m3	15,000	Disposed
4	Base Coarse	m2	660,000	25 cm thick
5	MCO - Medium Curing Cutback Asp	m2	630,000	1.5 kg/m2
6	Asphalt Layer 1	m2	630,000	6 cm thick
7	RC3000 - Rapid Curing Cutback As	m2	630,000	0.5 kg/m2
8	Asphalt Layer 2	m2	630,000	5 cm thick

Table 1 Bill of Quantities of Case 1

3.2.4. Items Breakdown

In page 1 of appendix A, the items breakdown is tabulated. The positive quantities are the amounts that shall be procured to the site, while the negative quantities indicate to the amounts that shall be disposed outside of the site.

The units in the BOQ are converted to the transportation units, and thus all units are either cubic meters or tons. The transported materials are quantified according to the best practices and experience.

The total quantity of procured materials in cubic meters is 853,458, which is the water and aggregates, while the disposed materials are 30,000 m^3. The quantity of petroleum products procurement is 8,152 tons.

Procure Pertoleum Products	ton	8,152
Dispose Rocks and ground	m3	- 30,000
Procure Aggregates and Water	m3	853,458

Table 2 Procured and Disposed quantities for case study 1

3.2.4.1. Subgrade Fill

The two components of this item are water and graded crushed limestone. The quantity as indicated above is 175,000 m^3. The amount of water used for compaction is equal to the volume of the layer, thus it is estimated to 175,000 m^3.

Water is given the code ‘W001’ and description ‘Water for compaction’. It can be fresh or salt water. ‘S002’ is the code of the procured graded crushed limestone, and the description is ‘Sand procurement for ground leveling’.

3.2.4.2. Subgrade Cut

The ‘sand disposal for site clearing’ is the only material in this item. It has the code ‘S001’ and cubic meters unit. The quantity is 15,000 m^3.

3.2.4.3. Rock Demolition

The ‘Rock disposal for site clearing’ is the only material in this item. It has the code ‘R001’ and cubic meter unit. The quantity is 15,000 m^3.

3.2.4.4. Base Course

There are three materials that are used in this item, graded crushed stones, sand, and water, with the codes ‘CS001’, ‘S003’, and ‘W001’, respectively. The quantities as presented in page 1 of appendix 1 for the three materials are 165,000, 49,500, and 165,000 m^3, respectively.

The water used in item 1 'Subgrade Fill' is also used for this item, thus given the same material code 'W001'.

3.2.4.5. MCO

The 'MCO - Medium Curing Cutback Asphalt' is the only material in this item. It has the code 'MCO001' and the unit is ton. The quantity is 945 tons, which is the conversion of 1.5 kg/m^2 when multiplied by the total area of application.

3.2.4.6. Asphalt Layer 1

This item uses three different sizes of crushed stones, sand, water, and bitumen. The latter is measured in ton, while the rest are measured in cubic meters.

It is noted that the summation of the aggregates volume exceeds the volume of the layer by 29%, and that is due to the smaller aggregates filling the spaces between the bigger aggregates.

The density of this item is 3.19 ton/m^3, and the bitumen per cent of the total weight of this item is 4%. The breakdown of this layer is tabulated in page 2 of appendix 1, and the process of estimating the materials quantities is shown in the following two figures.

Area (m^2) x Thickness (m) → Volume (m^3) x Density (ton/m^3) → Weight (ton) → Bitumen and Aggregates Weight

Figure 3 Asphalt Layers estimation process

Aggregates Weight (ton) x Materials Relative Weight → Materials Weight (ton) ÷ Density (ton/m^3) → Materials Volume

Figure 4 Asphalt aggregates estimation process

3.2.4.7. RC3000

The 'RC3000 - Rapid Curing Cutback Asphalt' is the only material in this item. It has the code 'RC3000' and the unit is ton. The quantity is 315 tons, which is the conversion of 0.5 kg/m^2 when multiplied by the total area of application.

3.2.4.8. Asphalt Layer 2

Appendix 1 page 4 tabulates the quantity estimation for this item. It follows the same estimation process as shown in Figure **3** Asphalt Layers estimation process and **Error! Reference source not found.**.

It is noted that the summation of the aggregates volume exceeds the volume of the layer by 34%, and that is due to the smaller aggregates filling the spaces between the bigger aggregates.

3.2.5. Materials Quantities

3.2.5.1. Aggregates

Aggregates are the sand and crushed stones used in the base and asphalt.

3.2.5.1.1. Fine Aggregates

Fine Aggregates (or sand) are the particles that passes sieve #4, but do not pass sieve #200. For this case study; they are given the codes "S002", and "S003", with quantities in m^3 175,000, and 72,800, respectively.

They are the result from the items "Subgrade Fill", "Base Coarse", "Asphalt Layer 1", and "Asphalt Layer 2" as shown in the appendix A.

3.2.5.1.2. Coarse Aggregates

Coarse aggregates (or crushed stones) vary in size and for this case study; they are given the codes "CS001", "CS002", "CS003", and "CS004", with quantities in m^3 29,771, 22,674, 15,138, and 165,000, respectively.

They are the result from the items "Base Coarse", "Asphalt Layer 1", and "Asphalt Layer 2" as shown in appendix A.

3.2.5.2. Bitumen

It is extracted from crude oil through refineries, and transported in tanks. It is given the code “Bitu001”, with quantity in ton 6892.

It is the result from the items “Asphalt Layer 1” and “Asphalt Layer 2” as shown in appendix A.

3.2.5.3. Water

Water that is used in road pavements is used in compaction, and cleaning the compactors rollers. It is given the codes “W001” and “W002”, with quantities in m^3 340000 and 31500, respectively.

They are the result from the items “Subgrade Fill”, “Base course”, “Asphalt Layer 1”, and “Asphalt Layer 2” as shown in appendix A.

3.2.5.4. Disposal

The disposed materials are resulting from the cutting of the subgrade, and the mixing processes. They are given the codes ‘S001’ and ‘R001’ with quantities in m^3 15000.

They are the result from the items ‘Subgrade Cut’ and ‘Rock disposal for site clearing’ as shown in appendix A.

3.2.5.5. MCO

Medium curing cutback asphalt is the sprayed layer on the Sub-base to avoid the transmission of moisture, and also works as an adhesive between the Sub-base layer and the first asphalt layer. It is given the code “MCO001” with a quantity in ton 945.

It is the result of the standalone item “MCO” as shown in appendix A.

3.2.5.6. RC3000

Rapid curing cutback asphalt is sprayed on the first layer of asphalt and before the second layer, and works as an adhesive between both layers. It is given the code “RC3000” with a quantity in ton 315.

It is the result of the standalone item “RC3000” as shown in appendix A.

3.2.5.7. Industrial Dust/Powder

The quantity of the Dust/Powder in cubic meters is 1,575, and the code is ‘Dust002’.

3.2.6. Natural Resources Quantities

The quantities of natural resources used in the first case studies are tabulated in Appendix A page 5, showing the summation of the materials extracted from the same natural resources.

Note that the Bitumen, MCO, and RC3000 are added together, and are assumed to form 20% of the total weight of the used crude oil. The unit used to demonstrate the quantities for the mined crude oil is the barrel, which is approximately 7.15 barrels per metric ton.

The waste during extraction is assumed 5% for the aggregates and 7% for the water. No waste is considered for the petroleum products and the disposed materials.

The simple coding that has been used so far can be progressed to indicate more information. New codes are introduced at this stage, which indicate the natural resources that are processed to form the materials used. The total quarried quantity of limestone ‘LS001’ is 245,866 m^3, and of crude oil ‘CO001’ is 291,345 barrels.

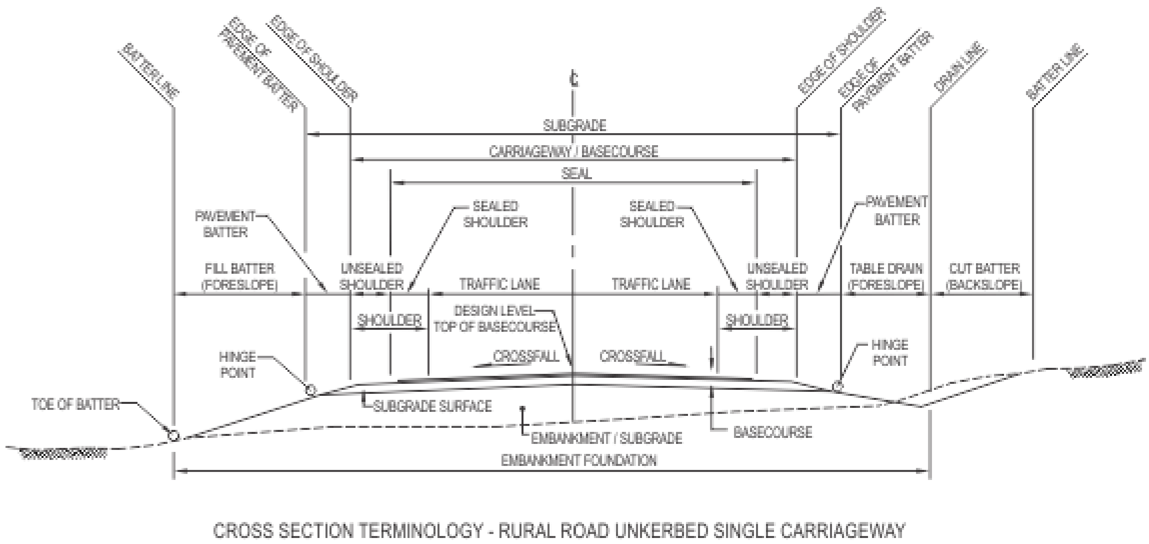
Code	Description	Unit	Quarry Qty
LS001	Limestone 001	m3	245,866
S001	Sand disposal for site clearing	m3	- 15,000
S002	Sand procurement for ground levelling	m3	183,750
S003	Sand mixed with crushed stones - 003	m3	76,440
R001	Rock disposal for site clearing	m3	- 15,000
W001	Water for compaction	m3	363,800
W002	Water for cleaning the compactors rollers	m3	33,705
CO001	Crude Oil	barrels	291,345

Table 3 Quantities of Natural Resources for case study 1

3.3. Case study 2 (Road Rehabilitation)

3.3.1. Cross Section

Case study 2 investigates the rehabilitation of a road, where the final layer is to be removed and another layer with the same thickness is added instead.



<u>Figure 5 Cross section of case study 2[28]</u>

3.3.2. Layers

3.3.2.1. Asphalt Layer removal

The case study is the typical surface layer removal, and the thickness is assumed 5 cm, which also covers the disposal of that old material. The code of this item is 1 with a quantity in cubic meter equals 630,000.

3.3.2.2. RC3000

This item is same as 3.2.2.7, with the difference in quantity and code. In case study 2 the layer is coded number 2, and the quantity is 630,000 m^3.

3.3.2.3. Surface Asphalt Layer

This item is same as 3.2.2.8, with the difference in quantity, description, and code. In case study 2 the layer is coded number 3, the description is 'Surface Asphalt Layer', and the quantity is 630,000 m^3.

3.3.3. Bill of Quantity

The following table shows the total quantities of the items used for the first case study.

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28 https://www.mainroads.wa.gov.au/Documents/cross%20section%20terminology%20-%20rural%20road%20unkerbed%20single%20carriageway.GIF [Accessed 14 Aug. 2017]

S	Description	Unit	Quantity	Notes
1	Asphalt Layer removal	m2	630,000	5 cm thick
2	RC3000 - Rapid Curing Cutback Asphalt	m2	630,000	0.5 kg/m2
3	Surface Asphalt Layer	m2	630,000	5 cm thick

Table 4 Case study 2 Bill of Quantity

3.3.4. Items Breakdown

In page 1 of appendix B, the items breakdown is tabulated. The positive quantities are the amounts that shall be procured to the site, while the negative quantities indicate to the amounts that shall be disposed outside of the site.

The total quantity of procured materials in cubic meters is 853,458, which is the water and aggregates, while the disposed materials are 30,000 m3. The quantity of petroleum products procurement is 8,152 tons.

Procure Pertoleum Products	ton	4,023
Dispose Rocks and ground	m3	- 52,500
Procure Aggregates and Water	m3	59,381

Table 5 Procured and Disposed quantities for case study 2

3.3.4.1. Asphalt Layer Removal

This item has one material to be disposed out of the site. The material is coded ‘Asph001’ and has the volume of 52,500 m^3.

3.3.4.2. RC3000

The ‘RC3000 - Rapid Curing Cutback Asphalt’ is the only material in this item. It has the code ‘RC3000’ and the unit is ton. The quantity is 315 tons, which is the conversion of 0.5 kg/m2 when multiplied by the total area of application.

3.3.4.3. Surface Asphalt Layer

Appendix B page 2 tabulates the quantity estimation for this item.

3.3.5. Natural Resources Quantities

The quantities of natural resources used in the second case study are tabulated in Appendix B page 5, showing the summation of the materials extracted from the same natural resources.

3.4. Origins

The locations of quarries and petroleum well, etc. are surveyed and added to the data centers that is connected and updated once they are discovered. Using the laser scanning technology, the quantities are estimated to the closest detail.

The data required to be added to the list are the location coordinates using Global Positioning System (GPS). Also the physical characteristics are tested to be categorized and summed to their likes. The estimated quantities are planned according to the nearby projects, or according to the required special specifications.

3.5. Plants

The fixed plants and semi-movable plants are determined automatically with the rate of processing using automatic sensors. They are coded to distinguish between the different activities, and the products are coded in batches to be used in the required projects. Big data statistics are used to process the huge amount of data and information.

Plants are to be coded by industrial system designers but generally here are the lists of machines required for the construction process. Oil distillation plants, Limestone crushing plants, including bulldozers, loaders, crushers, and storage. The rates of usage and live recording of processed materials are stored on the database. In addition to that, the materials are divided into batches and these batches are utilized to the project while they are recorded.

3.6. Machines

The Venus Project (TVP) have several designs of machines, some of them are for road construction, which are fully automated. The ‘Construction’ page on TVP website addresses the automated construction systems, automated cranes, laser excavators, industrial robots, and nanotechnology. Scientists and engineer can build these machines, it is a matter of dedicated efforts.

Machines are to be coded by industrial system designers but generally here are the lists of machines required for the construction process. Tracks, Loaders, Graders, Finishers, several types of Compactors, Water tanks, and Asphalt mixers.

The machines are connected through satellites and GPS, in order to track the movement and locations of batches.

3.7. Cost management model

The model is divided into four processes, same as in PMBoK , planning, estimation, budgeting, and control. The cost management plan has the procedures and processes that shall be followed to manage construction costs.

The level of accuracy in such a model depends on the sensitivity of the sensors installed for measurements. For example, the weight of aggregates that are divided into three different sizes indicates the mix weight, and thus the whole asphalt mix can be measured or calculated more accurately.

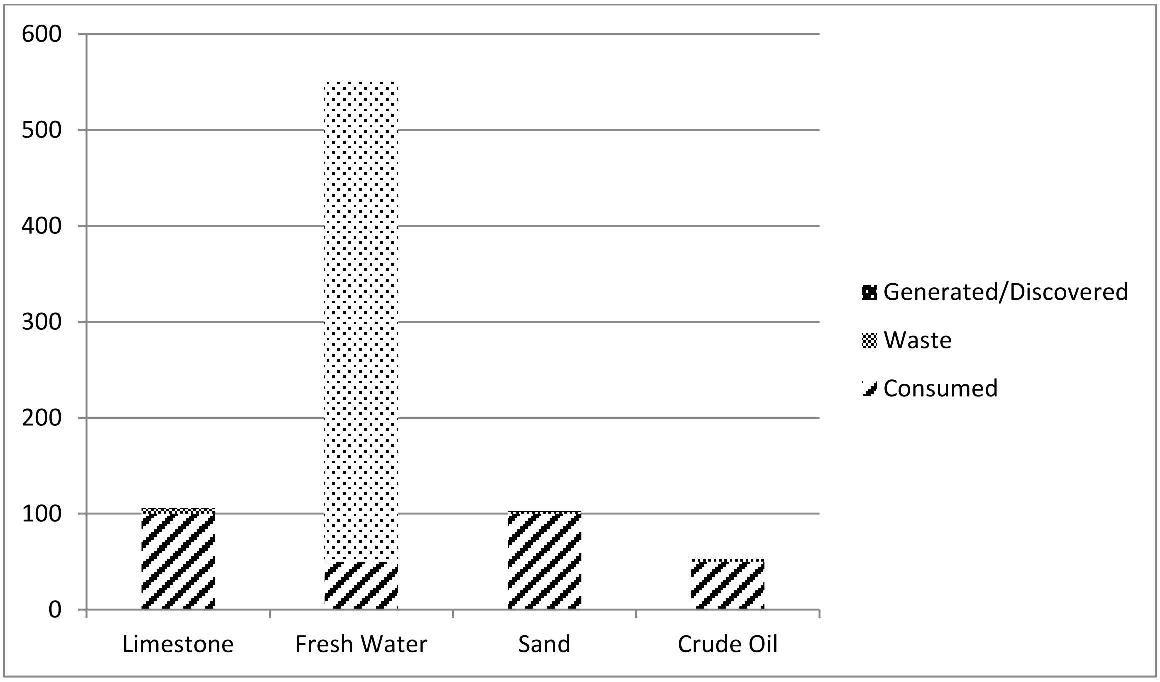
The reporting format is the database platform using big data technology to store, analyse and retrieve live data. The recording is done with the precision mentioned above. The work breakdown structure (WBS) points where the costs shall be measured is established according to the available sensors technology to the date. The best is to measure all the WBS, such as, the exact quantities of bitumen, sand, water, etc. used during the construction process.

The units of measure are metric. Common units are meter, square meter, cubic meter, litre, ton, etc. The level of precision shall be four decimals for recording and processing, and two decimals for reporting.

Using the Building Information Modelling (BIM), quantities are surveyed and coded to direct and navigate the following tasks done by machines. The Management Information System (MIS) details the processes and their mapping, going through the analysis of the design, and evaluating the required natural resources, to the execution and recording of the utilized quantities.

Tracking is stored on a cloud database, ready to add to it data from all other sources of information. Then the control process can accurately be performed, using the Reserve Analysis method for example.

The database is global and located on the internet. From this model, the amount of natural resources consumed by road construction projects can be calculated, and traced back their origins.



The database has the following lists:

1. Natural resources list
2. Origins of natural resources
3. Products decomposition
4. Bill of Quantities
5. Machines list

4. Findings

4.1. Future of the current road construction method

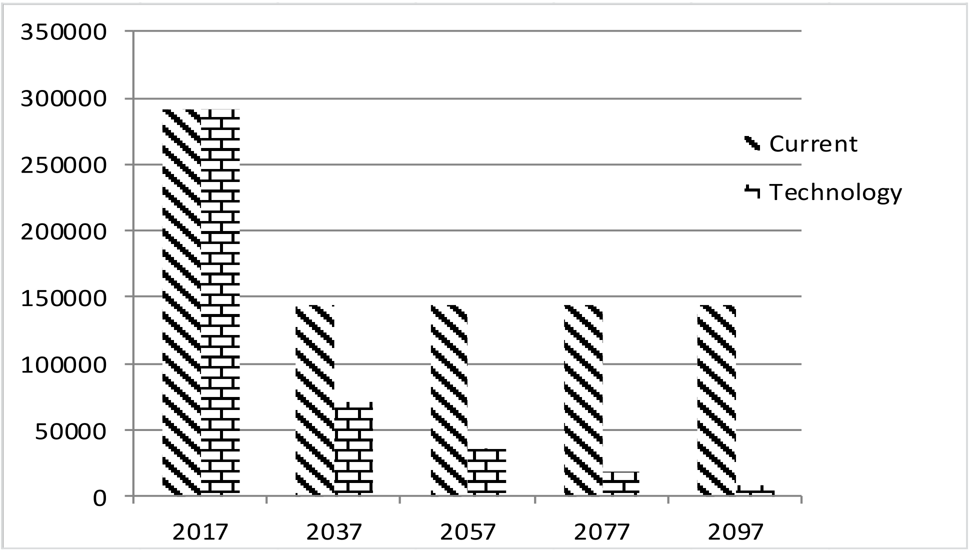
4.1.1. Different Materials

There are several products in use that has been made to decrease the use of precious natural resources, and there are others under trial and in laboratories. The technology of construction materials employs thousands of experts, and companies around the world are racing to provide effective solutions for their clients.

Some examples include a Netherlands Company Introducing Plastic Roads That Are More Durable, Climate Friendly than Asphalt[29]. Other companies are introducing a composite material to increase the sand characteristics for road constructions[30]

4.1.2. Investment Planning

Figure 6 demonstrates the difference between the amounts of barrels as natural resources using the current road technology, against the future technology which suggests the usage of fewer resources.



[29] ThinkProgress, thinkprogress.org/netherlands-company-introduces-plastic-roads-that-are-more-durable-climate-friendly-than-asphalt-ecb7c2a11a50 [Accessed 17 May 2017]

[30] PRS, www.prs-med.com/daz/b/roadways/?kw1=Roadway%20Design&kw2=Roadway%20Construction&kw3=Roadway%20Contractors&utm_source=google&utm_medium=cpc&gclid=COzwhsuHytQCFaW17QodoCkM0g [Accessed 17 May 2017]

Figure 6 Current Technology VS Required Technology

In addition, when considering the rate of renewal of natural resources, it is the opposite of the inflation in the monetary system, as the value of natural resources increases when used later than now. In the monetary system, and due to inflation, money loses its value, that is one reason, it is better to use the money now than later, which in return means using more resources now than later.

While in resource based economy, when the resources are left for the next generations, they increase, either by the rate of renewal, or the discovery of new resources.

4.2. SWOT analysis

Strengths

1. Control the natural resources
2. Forecast the where shortages come next, in order to find an early solution or replacement
3. Increase in natural resources globally
4. Fair distribution of materials

Weaknesses

1. Long time to implement.
2. Lack of researches regarding RBE.

Opportunities

1. Increasing number of volunteers.
2. UN support to establish the first city.

Threats

1. Current economic system domination, which makes the awareness process of this model more difficult.

5. Conclusion and Recommendations

5.1. Conclusion

From the above findings, and comparisons, it is concluded that Resource Based Economy can be applied to the cost management model. If it is treated as a national project, The Venus Project can be the starting point to a new socio-economical system that is suitable to all people, where the natural resources are maintained, and the supply exceeds the demand.

The United Nations (UN) have several Programmes that can work together to apply and develop this socio-economic system, among them are the United Nations Environmental Programme (UNEP) and the United Nations Development Programme (UNDP).

5.2. Recommendations

This research focused on the cost management of construction. Other research areas are suggested, such as; time management, quality management, and scope management.

The construction industry is only one industry that can apply resource based economy. Other industries are agriculture food, automotive industry, and even the hospitality industry.

The integration between models is a target to develop accuracy, since there are common natural resources consumed by several industries, such as clean water.

The two case studies investigate road construction. Other case studies can be; The Venus Project research centre, hotel, factory, etc.

Declaration of Authorship

I hereby declare that the attached Master’s thesis was completed independently and without the prohibited assistance of third parties, and that no sources or assistance were used other than those listed. All passages whose content or wording originates from another publication have been marked as such. Neither this thesis nor any variant of it has previously been submitted to an examining authority or published.

Date	Signature of the student

Appendix

Appendix A (Case Study 1)

Code	Description	Unit	Quantity
	Subgrade Fill		
S002	Sand procurement for ground levelling	m3	175,000
W001	Water for compaction	m3	175,000
	Subgrade Cut		
S001	Sand disposal for site clearing	m3	- 15,000
	Rock Demolition		
R001	Rock disposal for site clearing	m3	- 15,000
	Base Course		
CS004	Crushed Stones - several sizes	m3	165,000
S003	Sand mixed with crushed stones - 003	m3	49,500
W001	Water for compaction	m3	165,000
	MCO - Medium Curing Cutback Asphalt		
MCO001	MCO - Medium Curing Cutback Asphalt	ton	945
	Asphalt Layer 1 (2.19 ton/m3 & 4%)		
CS003	Crushed Stones - Size 3	m3	15,138
CS002	Crushed Stones - size 2	m3	13,927
CS001	Crushed Stones - Size 1	m3	10,092
S003	Sand mixed with crushed stones - 003	m3	9,669
Bitu001	Bitumen 001	ton	3,184
W002	Water for cleaning the compactors rollers	m3	15,750
	RC3000 - Rapid Curing Cutback Asphalt		
RC3000	RC3000 - Rapid Curing Cutback Asphalt	ton	315
	Asphalt Layer 2 (2.339 ton/m3 & 5.3%)		
CS002	Crushed Stones - size 2	m3	8,746
CS001	Crushed Stones - Size 1	m3	19,679
S003	Sand mixed with crushed stones - 003	m3	13,631
Dust002	Industrial Dust 002	m3	1,575
Bitu001	Bitumen 001	ton	3,708
W002	Water for cleaning the compactors rollers	m3	15,750

Items Breakdown

Description	Unit	Quantity
Layer quantitiy	m2	630000
Layer thickness	m	0.06
Layer Volume	m3	37800
Asphalt 1 density	ton/m3	2.19
Asphalt 1 Weight	ton	82782
Bitumen Weight		4.00%
Bitumen Weight	ton	3184
Aggregates weight	ton	79598
Size 3 weight		31%
Size 2 weight		29%
Size 1 weight		21%
Sand weight		19%
Size 3 weight	ton	24978
Size 2 weight	ton	22980
Size 1 weight	ton	16652
Sand weight	ton	14987
Size 3	m3	15138
Size 2	m3	13927
Size 1	m3	10092
Sand	m3	9669

Asphalt Layer 1 Breakdown

Description	Unit	Quantity
Layer quantitiy	m2	630,000
Layer thickness	m	0.05
Layer Volume	m3	31500
Asphalt 2 density	ton/m3	2.339
Asphalt 2 Weight	ton	73678.50
Bitumen Weight		5.3%
Bitumen Weight	ton	3708.41
Aggregates weight	ton	69970.09
Size 2 weight		20%
Size 1 weight		45%
Sand weight		30%
Powder weight		5%
Size 2 weight	ton	13994
Size 1 weight	ton	31487
Sand weight	ton	20991
Powder weight	ton	3499
Size 2	m3	8746
Size 1	m3	19679
Sand	m3	13631

<u>Asphalt Layer 2 Breakdown</u>

Code	Description	Unit	Quantity
CS004	Crushed Stones - several sizes - 001	m3	165,000
CS003	Crushed Stones - Size 3	m3	15,138
CS002	Crushed Stones - size 2	m3	22,674
CS001	Crushed Stones - Size 1	m3	29,771
Dust002	Industrial Dust 002	m3	1,575
S001	Sand disposal for site clearing	m3	- 15,000
S002	Sand procurement for ground levelling	m3	175,000
S003	Sand mixed with crushed stones - 003	m3	72,800
R001	Rock disposal for site clearing	m3	- 15,000
Bitu001	Bitumen 001	ton	6,892
MCO001	MCO - Medium Curing Cutback Asphalt	ton	945
RC3000	RC3000 - Rapid Curing Cutback Asphalt	ton	315
W001	Water for compaction	m3	340,000
W002	Water for cleaning the compactors rollers	m3	31,500

<u>Materials Quantities</u>

Code	Description	Unit	Quarry Qty
LS001	Limestone 001	m3	245,866
S001	Sand disposal for site clearing	m3	- 15,000
S002	Sand procurement for ground levelling	m3	183,750
S003	Sand mixed with crushed stones - 003	m3	76,440
R001	Rock disposal for site clearing	m3	- 15,000
W001	Water for compaction	m3	363,800
W002	Water for cleaning the compactors rollers	m3	33,705
CO001	Crude Oil (Details below)	barrels	291,345
Bitu001	Bitumen 001	ton	6,892
MCO001	MCO - Medium Curing Cutback Asphalt	ton	945
RC3000	RC3000 - Rapid Curing Cutback Asphalt	ton	315

Natural Resources Quantities

Appendix B (Case Study 2)

Code	Description	Unit	Quantity
	Asphalt Layer Removal		
Asph001	Old Asphalt quantity	m3	- 52,500
	RC3000 - Rapid Curing Cutback Asphalt		
RC3000	RC3000 - Rapid Curing Cutback Asphalt	ton	315
	Surface Asphalt Layer (2.339 ton/m3 & 5.3%)		
CS002	Crushed Stones - Size 2	m3	10,933
CS001	Crushed Stones - Size 1	m3	17,493
S003	Sand mixed with crushed stones - 003	m3	13,631
Dust002	Industrial Dust 002	m3	1,575
Bitu001	Bitumen 001	ton	3,708
W002	Water for cleaning the compactors rollers	m3	15,750

<u>Items Breakdown</u>

Description	Unit	Quantity
Layer quantitiy	m2	630,000
Layer thickness	m	0.05
Layer Volume	m3	31500
Asphalt 2 density	ton/m3	2.339
Asphalt 2 Weight	ton	73678.50
Bitumen Weight		5.3%
Bitumen Weight	ton	3708.41
Aggregates weight	ton	69970.09
Size 2 weight		25%
Size 1 weight		40%
Sand weight		30%
Powder weight		5%
Size 2 weight	ton	17493
Size 1 weight	ton	27988
Sand weight	ton	20991
Powder weight	ton	3499
Size 2	m3	10933
Size 1	m3	17493
Sand	m3	13631

Surface Asphalt Layer Breakdown

Code	Description	Unit	Quantity
Asph001	Old Asphalt quantity	m3	- 52,500
CS002	Crushed Stones - size 2	m3	10,933
CS001	Crushed Stones - Size 1	m3	17,493
Dust002	Industrial Dust 002	m3	1,575
S003	Sand mixed with crushed stones - 003	m3	13,631
Bitu001	Bitumen 001	ton	3,708
RC3000	RC3000 - Rapid Curing Cutback Asphalt	ton	315
W002	Water for cleaning the compactors rollers	m3	15,750

Materials Quantities

Code	Description	Unit	Quarry Qty
LS001	Limestone 001	m3	- 23,625
S003	Sand mixed with crushed stones - 003	m3	14,312
W002	Water for cleaning the compactors rollers	m3	16,853
CO001	Crude Oil (Details below)	barrels	143,787
Bitu001	Bitumen 001	ton	3,708
RC3000	RC3000 - Rapid Curing Cutback Asphalt	ton	315

Natural Resources Quantities

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