The International Network on Appropriate Technology

Proceedings of the

6th International Conference on Appropriate Technology

"Appropriate Technology for the 21st Century: Technological Innovation to Empower Africa"

Hosted at the

Kenyatta University Conference Center

Nairobi, Kenya, November 25 – 29, 2014

SECTION V: CONSTRUCTION AND INFRASTRUCTURE

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EFFICIENT CEMENT PRODUCTION BY DESIGN MODIFICATION OF GRINDING CIRCUITS: CASE STUDY OF EAPCC KUNKUR QUARRY, ATHI RIVER, KENYA

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Abstract

The main objective of any cement manufacturing company is to maximize profits through efficient cement production. Effectiveness of production also helps a cement manufacturing company remain in the growing competitive market in the cement industry. To meet this objective, production costs must be minimized while maximizing the mill throughput and without compromising the cement quality. Production costs are minimized by ensuring power consumption is at the minimum while good cement quality is ensured by achieving the required particle size distribution (PSD) as well as avoiding overgrinding. Retention time in cement grinding which is the time taken by material to attain the required particle size before it reaches the mill outlet, can be reduced by the use of a closed mill grinding circuit arrangement, where cement raw materials undergo a two-stage processing; grinding and classification/ separation. This ensures that power consumption is reduced; mill throughput is increased as well as improving cement quality in terms of PSD and controlling the temperature effect on gypsum. This research is aimed at modifying an existing mill system from open to a closed circuit in the aim of achieving efficient production of cement. Analysis of both circuits is done by use of mathematical techniques relating various mill parameters to show the viability of the design modification..

Key words: grinding circuit, Power consumption, Retention time, Mill throughput, Particle size distribution, Overgrinding

INTRODUCTION

Cement grinding is the process by which cement raw materials are reduced in size inside a mill. The various types of mills used in grinding (particle size reduction) include the roller mill, rod mill and the ball mill. Ball mills are most commonly used in cement milling. A ball mill can operate either on open circuit or closed circuit. In a closed circuit, an air classifier (separator) receives ground material from the mill, separates the fines and the coarse particles and recirculates the coarse materials back to the mill for further grinding while the fines are the final product and are taken to cement silos for storage .An open grinding circuit lacks an air classifier (separator). That is, the material coming out of the end trunions of the mill is the final product (Cement & Concrete Association of New Zealand 1989).

Efficient cement production can be defined as one in which the specific power consumption is low, the rate of production (tonnes per hour, tph) is high and quality of cement is optimized while minimizing the production cost. Previous research has shown that an open circuit grinding system is associated with little or no control of fineness, possibility of overgrinding and higher temperature of products. The characteristics of open grinding circuit translate to high specific power consumption, low production rate and poor quality of cement. A closed circuit has a high production rate, low specific power consumption and produces high quality cement as compared to an open circuit. Thus it can be used in place of an open circuit.

Design modification can be defined as structural changes made on a pre-existing system. For grinding circuits, an open grinding circuit can be modified to a closed circuit by installation of an air classifier (separator).

East African Portland Cement Company (EAPCC) has four mills (mill nos. 1, 3, 4 and 5). Three of these mills (mill nos. 1, 3 and 4) operate as open circuit mills while mill no. 5 operate as a closed circuit mill. The production for each of the mills 1, 3 and 4 is low as compared to mill no. 5 which operates in a closed circuit.

The increasing competition in the cement industry hence the need for efficiency improvement, reinforces the need for grinding optimization. This paper seeks to address the challenges associated with an open circuit by modifying the design in EAPCC Ltd and installing separators to change the open grinding circuit to a closed one.

Figure I: Arrangement of an open circuit system

The challenges associated with an open circuit grinding circuit are;

- Little or no control of fineness
- Not adapted to high fineness
- Possibility of overgrinding
- Higher temperature of products
- Broad particles size distribution

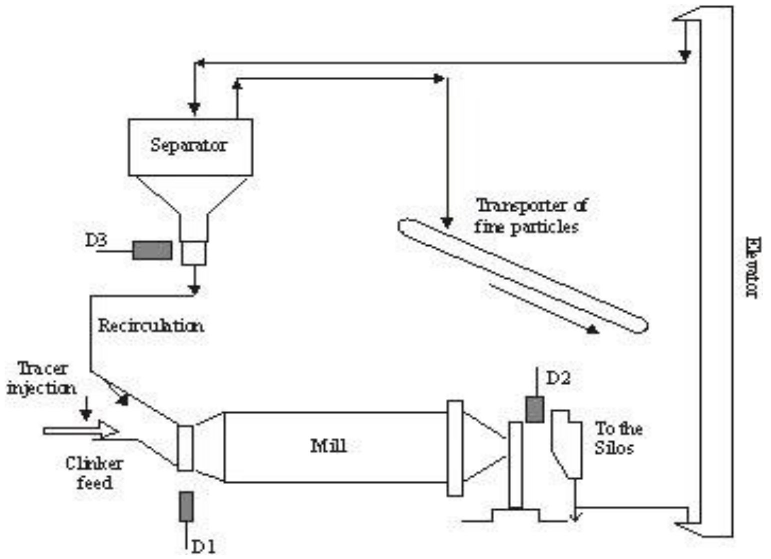

Figure II: Arrangement of a closed circuit grinding system.

Gypsum which is responsible for setting of cement has water of hydration. Stability of gypsum dehydration is very dependent on the stability of the grinding temperature. However, the problems of temperature instability and gypsum dehydration can be solved effectively by the use of a closed circuit milling system since retention time is minimized and mill temperatures are controlled.

Project Objectives

The main objectives in this case study are:

- To reduce the specific power consumption
- To control particle size distribution (PSD)
- To increase mill throughput

METHODOLOGY

The study involves collection of relevant data such as: Mill throughputs, Mill capacities, Mill dimensions, Mill operational parameters; Mill temperatures, Mill speed, Mill power consumption, Mill feed rates. Appropriate techniques/methods are used to analyze the data to determine the expected increase in production, size of the separator, determine the specific power consumption for the closed circuit cement mills and calculate payback time.

Data analysis

A comparison between the two mill systems is carried out by showing the percentage differences in power consumption and mill throughputs. Some assumptions are made during calculations to help arrive at a conclusion.

Power consumption

A feasibility study done by S.S. Krishnan showed that cement grinding as a sub-process consumes the highest amount of time in cement manufacturing and thus it is the most power consuming stage. This is shown in the graph below.

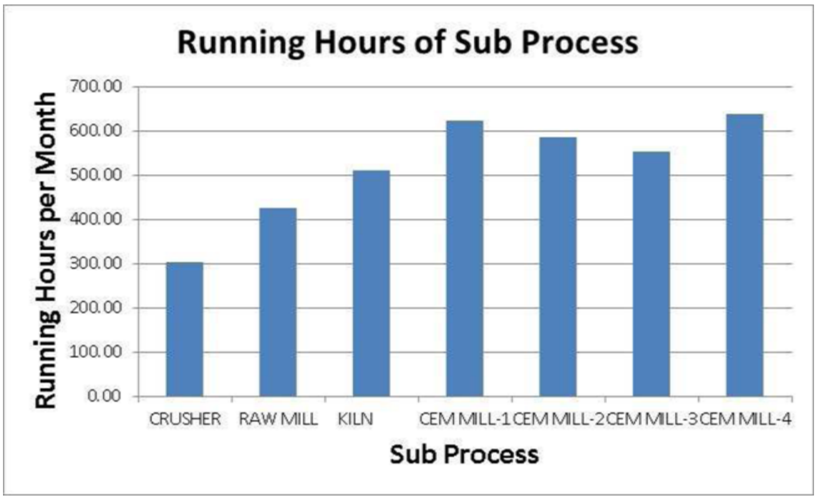

Figure III: Running Hours of Major Sub process in a Cement Plant (Source: S.S. Krishnan)

Production costs is a factor emphasizing the need to use less energy and therefore the development of more energy efficient grinding circuits (Jankovic, et al. 2004). The consumption of electrical energy depends on the grindability of the cement constituents and the type of grinding system.

Bond's equation describes the specific power required to reduce a feed from a specified feed F_{80} to a product with a specified P_{80}:

$$W_m = W_i\left(\frac{10}{\sqrt{P_{80}}} - \frac{10}{\sqrt{F_{80}}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:
W_m is mill specific motor output power (kWh/t),
W_i - is the Bond ball mill work index (kWh/t),
P_{80} - is sieve size passing 80% of the mill product (μm),
F_{80} - is the sieve size passing 80% of the mill feed (μm).

Theoretical case study in this paper will consider the following data:

Table I: Theoretical data used in the case study

	Open-mill circuit	*Closed-mill circuit*
P_{80}	90μm	150 μm
F_{80}	30000μm	30000 μm

Specific power calculations for;

i. Open mill circuit

$$W_m = W_i\left(\frac{10}{\sqrt{P_{80}}} - \frac{10}{\sqrt{F_{80}}}\right)$$

$$W_m = 10.18\left(\frac{10}{\sqrt{90}} - \frac{10}{\sqrt{30000}}\right)$$

= 10.1429 Kwh/t

ii. Proposed Closed circuit

$$W_m = W_i\left(\frac{10}{\sqrt{P_{80}}} - \frac{10}{\sqrt{F_{80}}}\right)$$

$$W_m = 10.18\left(\frac{10}{\sqrt{150}} - \frac{10}{\sqrt{30000}}\right)$$

= 7.7242 Kwh/t

Mill throughput (Production vs. Blaine)

To calculate the target production, the following formula is adapted.

$$P_2 = \frac{P_1}{e^{\frac{(B_2 - B_1)\times 0,49}{1000}}}$$

Where;

P1= current output

P2= new (target) output

B1 = current blaine

B2 = new blaine

Calculation of mill throughput for mill 4, given the following data; the target output

(production, P_2):

$$P_2 = \frac{P_1}{e^{\frac{(B_2 - B_1)\times 0,49}{1000}}}$$ = 56.37 t/hr

Table II: Data used for mill 4 throughput computations

Data	*Value*
Current output (P1):	40 tph
Current Blaine (B1):	3800 cm^2/g
New Blaine (B2):	3100 cm^2/g

The above calculations show that decreasing the specific surface area (Blaine) of cement without compromising the cement quality increases production by 40.9%.

Table III: Data used for mill 1 & 3 throughput computation

Data	*Value*
Current output (P1):	30 tph
Current Blaine (B1):	3800 cm^2/g
New Blaine (B2):	3100 cm^2/g

Given the above data for mill 1 & 3, the target output (production, P_2) can be calculated as follows:

$$P_2 = \frac{P_1}{e^{\frac{(B_2 - B_1)\times 0{,}49}{1000}}}$$

= 42.28 t/hr

A production of 42.28t/h for each of mills 1& 3 is expected. The above calculations show that decreasing the specific surface area (blaine) of cement without compromising the cement quality increases production by 40.9%.

Total production for mill 1 & 3:

= mill 1 production+ mill 3 production

= 42.28 tons/hr + 42.28tons/hr

= 84.56 tons/hr

Closed circuit mill systems reduce the effect of cement overgrinding, hence reducing the blaine and thus increasing the mill production. The optimal production can be obtained with ease by varying the blaine within the required range.

Blaine control is achieved by varying separator motor speed (revolutions per minute). The higher the speed the higher the blaine and hence the higher the power consumption. It is seen from calculations above that a production of 56.37 tones per hour or even higher is possible by reducing blaine within the required range. This is only possible with a separator (closed circuit grinding system).

Mill feed rates for mill 4

For the closed circuit, the feed rates for mill four can be calculated as follows: with a target production of 56.37 tones per hour and assuming a condition where the mill feed per hour is equal to the mill output per hour and a separator course reject rate of 5 tones per hour.

Then the mill feed rate will be:

Fresh feed +separator feed = 56.37 ton/h +5ton/h = 61.37ton/h

Mill feed rates for each of mills 1 & 3

The current mill feed rate for each of the mills is 30 tons/hr. The mill feed rates for the raw materials are as follows:

Table IV: Mill feed rates

Data	*Value*
Clinker	16.5 tons/hr
Tuff:	12.0 tons/hr
Gypsum:	1.5 tons/hr

For the closed circuit, the feed rates can be calculated as follows: With a target production of 42.28 tons/hr and assuming a condition where the mill feed per hour is equal to the mill output per hour and assuming that the separator rejects are distributed equally to the two mills, separator coarse reject rate each mill will be 5 tons/hr;

Then the mill feed rate will be, (fresh feed +separator rejects).

84.56 ton/h +10 tons/h= 94.57tons/h

Fresh feed = 84.56 tons/hr

New feed rates = 55% of 42.28= 23.254tons/hr clinker

= 40% of 42.28= 16.912 tons/hr tuff

= 5% of 42.28= 2.114 tons/hr Gypsum

It is assumed that separator coarse rejects of 10 tons/hr is distributed equally to mills 1 and 3. Each has 5 tons/hr.

Separator sizing for Mill No.1 and No.3

The combined mill capacity for mills 1 and 3 is 100tph, but the current production for the two mills is 60tph. This production is 60% of the mill ratings. To improve the production to a target of 80% of the mill rating, an appropriate separator should be installed. The following calculations guide in the choosing of the appropriate separator.

Mill capacities (mill 1+mill 3) = 100tph

Current mills production = 60tph (mill fines)

Target mills production = 84.56 tph (separator fines)

Assumed Separator rejects is 10tph.

Circulation load, C.L. = R / F x 100

= 10 / 84.56 x 100

= 11.83%

$$Circulation\ factor = \left[1 + \frac{Circulating\ load\ , C.L\ \%}{100\%}\right] = \frac{Separator\ feed}{Production}$$

$$Circulation\ factor, C.F = \left[1 + \frac{11.83\ \%}{100\%}\right] = \frac{Separator\ feed}{84.56}$$

= 1.1183

The expected system production and feed rate to the separator was determined as follows:
Separator feed = C.F x Production = 1.1183 x 84.56 tph = 94.56tph
A separator with a minimum of feed rate 95tph is desirable for both mills 1 and 3 to achieve the target production. Similarly, Separator sizing for Mill No.4 is determined and a separator of a minimum feed rate of 62tph for mill 4 was found desirable to achieve the set target.

ECONOMIC ANALYSIS

Method of evaluation used in this project is; Payback time method. Pay-back time is the time required after the start of the project to pay off the initial investment from income. It is often used to judge small improvement projects on operating plant.
This involves calculation of the number of years required to return the original investment from the net cash flows. The decision rule is accepting the project with the shortest payback period. If the cash inflows are uniform the payback period can be calculated as: (= Initial investment/Annual cash inflows). The rule is, select the project if the payback time is reasonable.

Production Hours in a year = 8760 hours
Hours for maintenance per year = 8×52
= 416 hours
Available working hours = 8760 – 416 = 8344 hours
Target mills production/ yr = (56.37tonnes/hr+42.28tonnes/hr+42.28tonnes/hr.) × 8344 hrs./yr.
= 1,175, 919.92 tonnes/yr.
Selling price per tonnes of cement
= Ksh13,000
Assuming that all that is produced is sold, then
Annual cash inflows
=1,175,919.92 tonnes/yr. × Ksh13, 000 = Ksh15. 29 billion
Initial investment = Restructuring costs + purchase costs + Freight charges + taxes + Installation costs)
= Ksh200, 000,000
Payback time = Initial investment/Annual cash inflows
= 200, 000,000 ⁄15.29 billion = 5 days

CONCLUSION

The installation of a separator to the existing open mill circuits solves the challenges of the open circuit grinding system. The benefits achieved due to the design modification of cement grinding system are;

- Reduction in specific power consumption
- Possibility to vary the product blaine hence the production.
- Reduced retention time, improved control of PSD and mill temperature hence improved cement quality.

The adoption of closed circuit grinding system therefore addresses the key factors that define efficient cement production i.e. low power consumption, higher production rate (mill throughput) and improved cement quality. In conclusion this research paper illustrates the advantages of grinding circuit design modification as an optimization approach in obtaining efficient cement production.

RECOMMENDATIONS

Based on the analysis above, the following recommendations are made:

- The use of a closed milling circuit system should be adapted due to its advantages over the open milling circuit.
- Two separators to be installed, one for both mill 1 and mill 3 and the other separator for mill 4. Separators of feed rates of at least 95 tph for mills 1 and 3 and 62 tph for mill 4 should be installed so as to achieve the target mills production.
- A blaine of utmost 3100 cm^2/g should be targeted. Blaine is controlled in the separator by controlling the speed of the separator.

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CUT-OFF GRADE OPTIMIZATION TO MAXIMIZE THE NET PRESENT VALUE USING LANE'S APPROACH IN WHITTLE 4X

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Abstract
The maximization of NPV is primary objective in open pit mine planning processes. In an attempt to meet this objective, cut-off grade is considered in all the stages of mining. There are three stages involved in resource extraction which are; mining, processing and refining (marketing) which are all defined in Lane's approach. Using Lane's approach, the economics involved in each stage are identified independently and interacted to provide an optimum cut-off grade. A block model from a hypothetical gold mine is used to illustrate how Whittle is used in optimization of cut-off grade and showing the feasibility of the project with respect to the current market conditions. In this paper Whittle 4X applies Lane's approach to generate yearly profits and the NPV of the whole project in a production schedule. This paper analyses the application of Lane's approach for a single element in cut-off grade optimization through discussing economic and geological factors as applied in the calculation of the optimum cut-off grade. After optimizing the cut-off grade and generating a long term production schedule, an after cash analysis is carried out later in the project to validate its feasibility. Although the application of Lane's approach is not complex, it is not however widely appreciated in maximizing the net present value of mining operations.

Keywords: cut-off grade, net present value, grade-tonnage distribution curve, mining, processing, refining, Whittle 4X

INTRODUCTION

Cut-off grade is traditionally defined as the grade that is normally used to discriminate between ore and waste within a given ore body. It also differentiates between various ore types before processing takes place for different metallurgical processing options (Asad, 2002). The main objective of mining companies is to maximize the NPV throughout the mine life. The NPV expected throughout the mine life from an operation is dependent on interrelated variables such as mining and milling capacities, extraction sequence, and cut-off grade. These interdependent variables interact in a complex manner in defining the NPV of a project.

Using the cut-off grade, ore is sent to the treatment plant for further processing while waste is either left in place or sent to waste dumps. Sequence of extraction is dependent on the rates of production, the grade distribution of the deposit, and the cut-off grades. Cut-off grade directly affects profits therefore there is need for its optimization depending on the extraction sequences and capacities of the mining operation. The determination of capacities is directly related to the cut-off grades and extraction sequences. The choice of a cut-off grade used in mine operations is based on cut-off grade optimization by the use of cut-off grade policies that maximizes the NPV of the project (Asad and Erkan, 2011).

The cut-off grade policy used in this project is based on the Lane's approach. The approach uses cut-off grades higher than breakeven grades during early years of mining for faster recovery of the capital invested. This cut-off grade policy also satisfies the production constraints and accommodates the grade-tonnage distribution. Further the policy uses the dynamic cut-off grade whereby the NPV declines with depletion of the reserves. This outcome is because the policy tends to mine higher graded ore during the early years and lower graded ore in the later years (Lane, 1964, 1988).

The objective behind of maximizing NPV in the first years is to pay back the capital invested in the project as quickly as possible. This is referred to as the time value of money where the maximum economic return is achieved when the highest NPV of the future cash flows is generated (Dagdelen, 1992). Mine planning is the process that defines sets of values for each of these variables during life of the mine. This paper discusses the approach used to define the capacity of mining system that is in harmony with the grade distributions of the deposit through the planned extraction sequence and cut-off grade policy.

CUT-OFF GRADE OPTIMIZATION USING WHITTLE 4X

A block model of a hypothetical gold mine is imported into Whittle 4X prior to production scheduling being done. Production scheduling is done on the basis of real market conditions involving price, mining cost, milling cost, processing cost and other factors affecting the mine operation. In carrying out pit optimisation scenarios, many factors are considered in order to curb economical discrepancies due to changes in mining conditions. These factors include mining capacities, milling capacities, refining capacities and the costs associated with them.

A production plan with the largest NPV is selected whereby an optimal scenario is utilised to establish the production schedule that included ore and waste tonnage in each period. It is vital in mine planning to maximise NPV in all the stages of mine planning since it is directly related to the initial capital investment, discount rate and the life of the mine. Thus the mining and milling capacities are matched to maximise the NPV of the future discounted cash flows. The mining parameters used in this project are collected from other operational mines in the vicinity of the mine which formed the basis of the analysis.

In retrospect, the objective of this study is to get a unique cut-off grade policy that maximizes the NPV of the project. To do this a given set of capacities and the economic costs associated with each capacity, an extraction sequence and price are considered. The mining parameters in table 1 are based on a hypothetical gold mine which is the benchmark study of this paper.

Table V: Units of parameters used in Whittle

Parameters	***Value***
Slope angle	45˚
Mining cost	US$6 per tonne
Processing cost	US$20 per tonne
Refining/selling cost	US$2.4 per gram
Initial capital cost	US$300,000,000
Replacement capital cost (10%of the capital cost each year)	US$30,000,000
Gold price	US$48 per gram
Mining recovery	95%
Mining dilution	5%
Gold recovery	85%
Discount rate	10%
Mining capacity	45,000,000 tonnes
Milling capacity	Period 1(4,000,000) Period 2(9,000,000)
	Period 3(12,000,000)
Mining cost escalation (%/year)	2.50
Processing cost escalation (%/year)	2.50
Metal price escalation (%/year)	0.70

Table VI: Summary by rock type as shown in Whittle 4X

Rock type	*Total Tonnes*	*Minimum grade*	*Average grade*	*Maximum grade*
Ore	163,924,800	0.1049	2.228	6.5331
Waste	9,572,472,000			
Total tonnage of both ore and waste = 9,736,396,800				
Total Au= 365,226,487 grams				

PIT OPTIMISATION

The pit optimisation yielded a nest of pits by calculating the optimal outline for a range of economic scenarios (price and mining cost). This process ensured that the smallest pit generated by the lowest price or cost will be the best pit to start mining.

The mechanism used in pit and schedule optimisation improves the value of a project by mining high grade ore in the early years. In doing so NPV can be improved by bringing forward revenues and/or deferring costs, even if that means that total net cash flow generated over the life of the project is less.

When generating pit phases using Whittle Four-X (Lersch – Grossman algorithm), inner high value pit shells which are mined early, will have low stripping ratio, and/or higher grades than the average of the ultimate economic pit. When scheduling a pit with phases generated through pit optimisation, (if higher grade is a component driving the optimisation) then average grade of ore mined will be higher in the early years than later.

Therefore using pit phases based on pit optimisation it is likely to raise the early average grade processed by focussing on high grade areas for early mining. Higher early grades mean more early cash flow, at the expense of lower later cash flows, but with an increase in NPV.

PUSHBACK SELECTION

Whittle 4X creates a series of pit shells to make sequencing and scheduling easier by grouping all blocks on a bench. A series of pushbacks as indicated in the Pit by Pit graph are selected by analysis of discounted cash flows from the graph for each set of selected pushbacks. The criteria used involved identifying areas on the pit by pit graph where significant increases in material (ore and waste) are obvious as shown in figure 1 indicated by arrows. This indicated that for enough ore to be exposed, a pushback is required at a certain period prior to this increase. Each pushback is chosen by an iterative process that involved looking at how the output table (NPV in US$) behaved according to each pushback selected. The pushback that gave a higher net present value is chosen and in doing this process continually an optimal scenario is achieved.

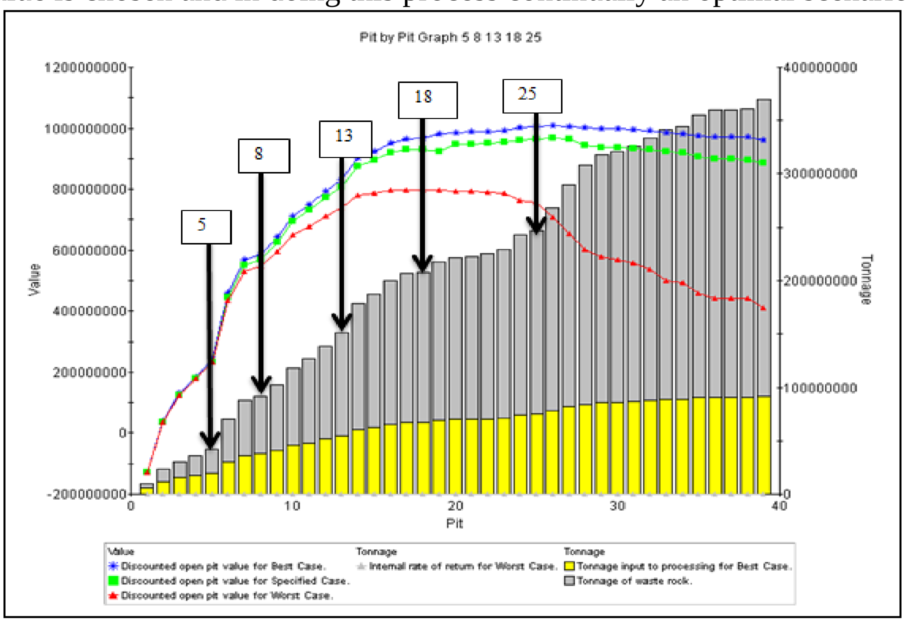

Figure IV: Pit by pit showing the pushback selection

PRODUCTION SCHEDULING

Production scheduling in this project is done using a suitable set of selected mining and milling capacities as specified in table 2. Using the same set of pushbacks as used in pit optimisation a balance of ore and waste tonnages is found by whittle 4X using Milawa NPV and Milawa balanced algorithms. The optimal scenario is then utilised to establish a production schedule that included ore and waste tonnage in each period.

To start with, it is vital to appreciate the core factors that influence the NPV. In general, the present value of future discounted cash flow is considered Net Present Value (NPV) that is directly related to the initial capital investment, discount rate and the Life of mine (LOM). Among these factors, the initial capital investment has an influence on the truck fleet capacity, the larger the capacity required, the more capital intensive the project becomes.

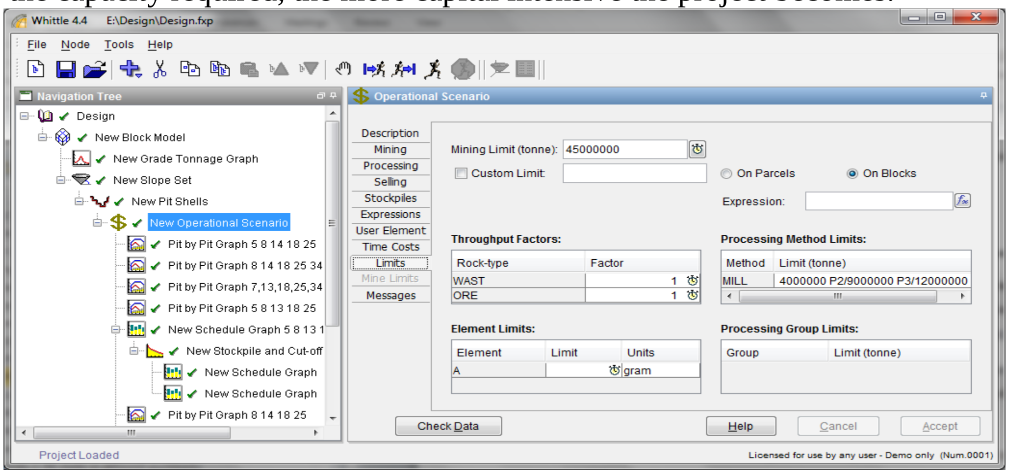

Figure V: Mining and milling capacities/limits used in Whittle in different periods

The mining and milling/processing capacities are matched to maximise the NPV. This is achieved by an iterative process that involved alternating economic variables, mining and milling capacities respectively until an optimal result is achieved.

In the case of pits, applying the Lerchs-Grossman (L-G) algorithm with varying revenue factors (say from 0.5 to 1.5) provided useful guidance for a value-based phasing strategy. The early mining pit shells are generated by high-grade and/or low stripping ratio. Once a set of optimal pit shapes have been generated the production schedule, subject to defined operational constraints, is optimized. The optimization analysis is performed properly resulting to a life-of-mine plan that maximized the net present value (NPV) of the project for specified set of assumptions (geological, geotechnical, metallurgical, market, environmental, etc.).

CUT-OFF GRADE POLICY AS REPORTED FROM WHITTLE 4X PER PERIOD

The cut-off grade policy used in Whittle 4X is based on the Lane's algorithm whereby the approach uses the concept of using cut-off grades higher than breakeven grades during early years for faster recovery of the capital invested.

The cut-off grade calculation satisfies the production constraints and accommodates the grade-tonnage distribution. The policy uses dynamic cut-off grade whereby the NPV declines with depletion of the reserves. This is because the policy tends to mine the higher cut-off grade during the early years and lower cut-off grade in the later years. Using the original data in the optimal scenario, optimization of the cut-off grade is done by adding a "New Stockpile and Cut-off Optimization (Type 2)" node to the optimized schedule graph node.

After running the software, the cut-off grade policy generated is tabulated as shown in table 3. The cut-off grade changes along the mine life such that the higher grade ore is mined in the early years while the lower grade ore is mined later. This is done in the aim of maximizing the NPV of future cash flows.

The cut-off grade optimization maximizes undiscounted profit for a given mining operation thus increasing the return of investment. The discounted cash-flows increased in the early years significantly and then decreased later as the ore deposit got depleted.

Table VII: Cut-off grade policy as reported from Whittle 4X per period

Period	*Cut-off Grade*	*Quantity of ore mined(tonnes)*	*Quantity of ore processed(tonnes)*	*Quantity of gold produced(tonnes)*	*Open-pit cash-flow (US$)*	*Open pit disc. cash-flow (US$)*
1	1.519	6120977	5809534	4938104	22738110	20671009
2	1.804	16274288	15460573	13141487	312783982	258499159
3	1.762	21303702	20212259	17180420	308012976	231414708
4	1.858	22394827	21265616	18075774	374274193	255634310
5	1.689	20411775	19363974	16459378	245563846	152475828
6	1.791	21530732	20454195	17386066	288211499	162687878
7	1.786	21244060	20171329	17145630	280084774	143727775
8	1.654	8933988	8487289	7214195	86117105	42101738
					1,917,786,485	**1,267,212,405**

AFTER-TAX CASH ANALYSIS

Financial technical models (in Microsoft Excel) are used to calculate after tax cash flows, NPV, and IRR for the mine project. Net present value (NPV) and internal rate of return (IRR) in the summary below is used in checking the feasibility of the project.

Table VIII: Summary of the after-tax cash analysis (US$)

Year	***Taxable Income***	***Net Income***	***Cash-flow***
0	-1000000	-1000000	-301000000
1	-2000000	-2000000	-1000000
2	188904063	122787641	141454307.6
3	536508109	348730270.8	365396937.5
4	703575122	457323829.2	473990495.9
5	735295680	477942191.9	494608858.5
6	663578993	431326345.4	447993012
7	695622646	452154720	468821386.7
8	680749807	442487374.2	459154040.9
9	105885371	68825491.08	252158824.4
		NPV @15% (US$)	**1,153,962,866**
		IRR (%)	**62.68**

Conclusions

In this paper a block model of a hypothetical gold deposit is used as input to Whittle 4X to generate a grade-tonnage distribution of the deposit. The grade tonnage distribution and current economic parameters are then used to create an optimum cut-off grade policy using Whittle 4X. Cut-off grade optimization is done to generate a production schedule which is used further for after-cash analysis.

Whittle 4X is used in optimization of cut-off grade for the open pit (disregarding the underground mine). Open pit mine has 138,214,349 tonnes of ore that is mineable over a period of 8 years. The underground mine has 21,499,245 tonnes of ore that is mineable over a period of 8 years. These tonnages and life of mine were derived from Vulcan software that can be used to design the underground pit to have an annually ore production of 2,500,000 tonnes.

Whittle 4X is concerned with designing open pits and had no direct relevance to underground mining. It was found that if both open pit and underground methods are to be used, this can affect the design of the open pit, and Whittle 4X can take account of this. Although Whittle 4X takes account for the presence of the underground mine, it does not schedule underground material or include underground material in any limits. This limits the usage of the software in mine planning of the entire project.

Further study is required to find how Whittle 4X applies all other complex mining situations into the cut-off grade optimization algorithm. For instance, an investigation into how Whittle 4X applies situations such as stockpiling, blending, and ore body with multiple minerals is necessary. In conclusion, this research paper provides an insight into Whittle 4X's application in optimizing cut-off grade. The research identified how Whittle software can optimize cut-off grade and its applicability in daily mine planning of any given mine project.

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FORECASTING MINERAL EXPORTS QUANTITIES IN SUDAN USING MOVING AVERAGES AND WINTER'S THREE-PARAMETER EXPONENTIAL SMOOTHED METHOD

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Abstract
The country of Sudan started to actively explore mineral deposits in the past century. However, the contribution of mineral industry to the national income still does not exceed 3% due to the limitation of the resource availability. This paper aims to find a mathematical model that is able to forecast mineral exports quantities since this is an essential component of industrial development. The key seasonal variables likely to affect the mineral export quantities at particular time scales were assessed and later analyzed to determine the most appropriate forecast model. Time series data collected in a sequential manner was employed to achieve this using two forecasting methods namely, the moving averages method and Winter's three-parameter exponential smoothed method.

Keywords: Mineral forecasting, Time series analysis, Moving averages method, Exponential smoothed method.

INTRODUCTION

Archaeologist discoveries indicate that old Nubian land is rich with gold and gemstone and they exported different mineral to all world. The paper aims to find a mathematical model to forecast mineral exports quantities in Sudan since is an essential activity contributing to the industrial development. (Sudanese Ministry of Minerals, 2013). This is the first paper that attempts to forecast a quantity is mineral in Sudan.
Thus the objectives of this paper are:

(1) Find a mathematical model to forecast mineral exports quantities in Sudan.
(2) Determine the most important variables that affect mineral exports quantities.

We have two hypotheses to test:

(1) Exponential smoothed method is able to produce better forecast than moving averages method.
(2) Minerals exports are affected by seasonal variations.

The authors used two forecasting methods: traditional moving averages method and three-parameter exponential smoothed method as a modern one.
The data has been used in the period from Jan 2009 to Dec 2012.

RESEARCH METHODOLOGY

Two approaches have been used:

1. Descriptive approach: here we displayed the data by graphs and obtaining basic measures.
2. Analytical approach: here statistical analytical methods have been used.

TIME SERIES METHODS

Time series analysis has been described as one of the most important methods that have been used for forecasting (Brui, 2002).

There are two types of time series:

- Continuous: if measurements are taken at every time slot for example: ECG , in medicine
- Discrete: if measurements are taken at specified periods for example: monthly rain rates (Bashir, 2013)

Time series has two domains: time domain and frequency domain (Khawaja, 2009).
It consists of: Secular Trend (T), Cyclical Variations (C), Seasonal Variations (S) and Irregular Variations (I) (Ibrahim, 2010).

Decomposition methods are used to analyze time series to determine its nature and aims to:

1. Isolate and measure the different variations that affect time series. (Mustafa, 1999).
2. Adjust time series by removing seasonal and irregular variations to enable analyzing of the series behavior in the future without being obscured by random and seasonal variations. (Mustafa, 1999).
3. Improve forecasting by considering seasonal variations. (Mustafa, 1999).

As mentioned in the introduction there are two types:

a) Moving Average method: This method is a standard traditional known as technique.
b) Winter's three parameter exponential smoothed method: This method is used when there is seasonal variation. Also it addresses Secular Trend problem. This method depends on three constants α,**β** and **γ**. ($0 \le \alpha, \beta, \gamma \le 1$)(Bashir, 2013).

$S_t = \alpha\left(y_t / I_{t-1}\right) + \left(1-\alpha\right)\left(S_{t-1} + b_{t-1}\right)$ $S_t \equiv$ The equation of general smoothing

$b_t = \gamma\left(S_t - S_{t-1}\right) + \left(1-\gamma\right)b_{t-1}$ $b_t \equiv$The equation of general trend

$I_t = \beta\left(y_t / S_t\right) + \left(1-\beta\right)I_{t-1}$ $I_t \equiv$ The equation of seasonal smoothing

$F_{t+m} = \left(S_t + b_{tm}\right) + I_{t-l+m}$ $F_{t+m} \equiv$ The equation of forecasting (Bashir, 2013)

Forecasting the phenomena include a small percentage of error. Forecasting errors are Mean Absolute Deviation, Mean Absolute Percentage Error and Mean Squared Error. (Mustafa, 1999). Least Squares Method aims at reducing Mean Squared Error in the slope of the time series. Mean Absolute Percentage Error is a relative measure used in descriptive studies which doesn't require statistical inferences, but it is rarely used due to the difficulties in its statistical features (Mustafa, 1999).

Analysis of Mineral Exports Quantities

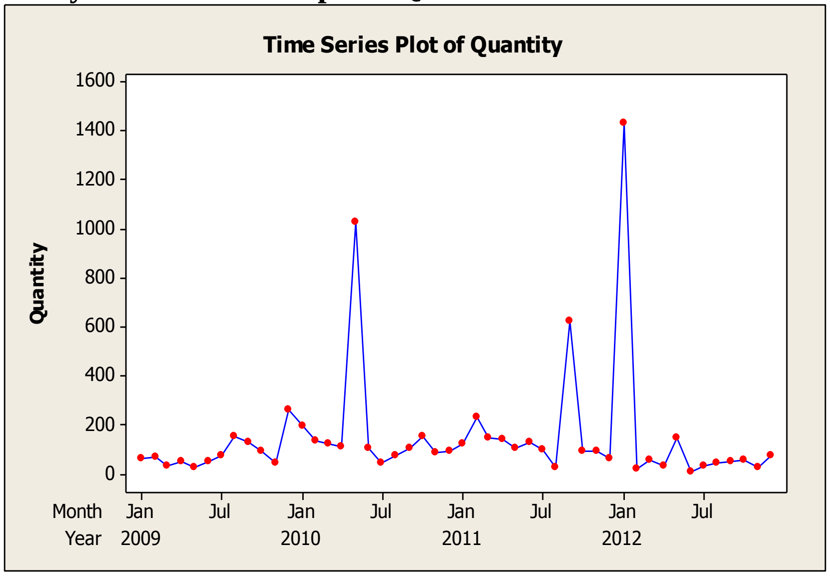

Figure 3.1 Test time series changes of monthly mineral exports quantities.

In the above figure 3.1 we note that the result of test time series changes that illustrate the effect of seasonal variations, then these variations should be analyzed through isolation and measurements to get rid of the effect of seasonal variations so be able to forecast about future values of mineral exports quantities independently from seasonal variations effects.

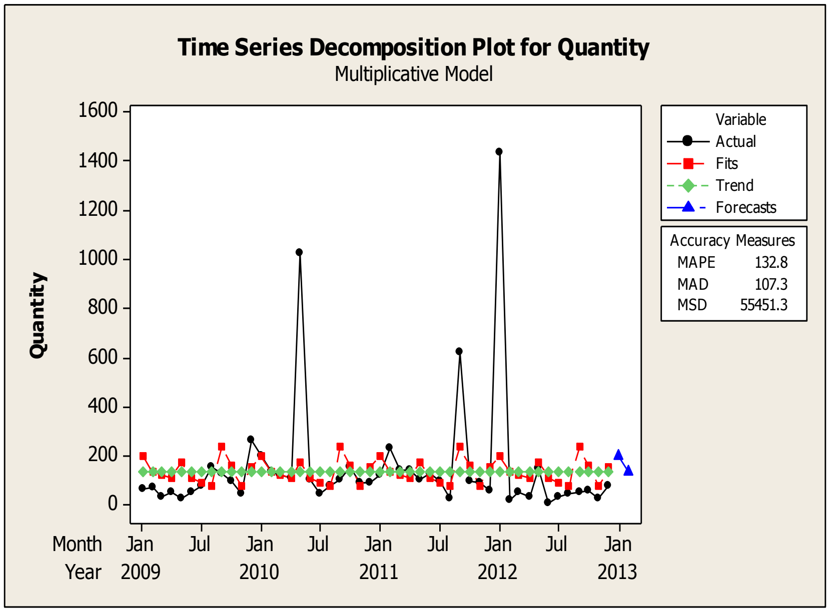

Figure 3.2 decomposition methods which used to isolate measurements of seasonal variations existing in time series and to determine seasonal Indices

In Figure 3.2, we note the trend, which has a constant value equal to 135.70, Mean Absolute Percentage Error (MAPE) = 132.8,Mean Absolute Deviation (MAD) =107.3 and Mean Squared Error (MSD) = 55451.3.

Table 3.1 periods from Jan (2009, 2010, 2011, 2012) to Dec (2009, 2010, 2011, 2012), seasonal Indices and fits.

Period	**Seasonal Indices**	**Fits**
Jan (2009,2010,2011,2012)	1.45640	197.646
Feb (2009,2010,2011,2012)	0.984218	133.566
Mar(2009,2010,2011,2012)	0.906306	122.933
Apr (2009,2010,2011,2012)	0.796562	108.100
May(2009,2010,2011,2012)	1.27315	172.77
Jun (2009,2010,2011,2012)	0.781175	106.012
Jul (2009,2010,2011,2012)	0.669183	90.813
Aug (2009,2010,2011,2012)	0.580808	78.820
Sep (2009,2010,2011,2012)	1.73067	234.865
Oct (2009,2010,2011,2012)	1.15815	157.170
Nov (2009,2010,2011,2012)	0.558116	75.741
Dec (2009,2010,2011,2012)	1.10526	149.993

According to the Table 3.1, we notice that Seasonal Indices and fits are constant in the periods from Jan (2009, 2010, 2011, and 2012) to Dec (2009, 2010, 2011, and 2012).

Furthermore, we observe that seasonal indicator affects minerals export quantities to increase if the seasonal indicator is greater than integer 1 in periods :(Jan, May, Sep, Oct and Dec) while it affects it negatively if seasonal indicator is less than integer 1 in periods: (Feb, Mar, Apr, Jun, Jul, Aug and Nov) and when the seasonal indicator is equal to integer 1 it doesn't affect the minerals export quantities. Fits are increased or decreased according to seasonal effects.

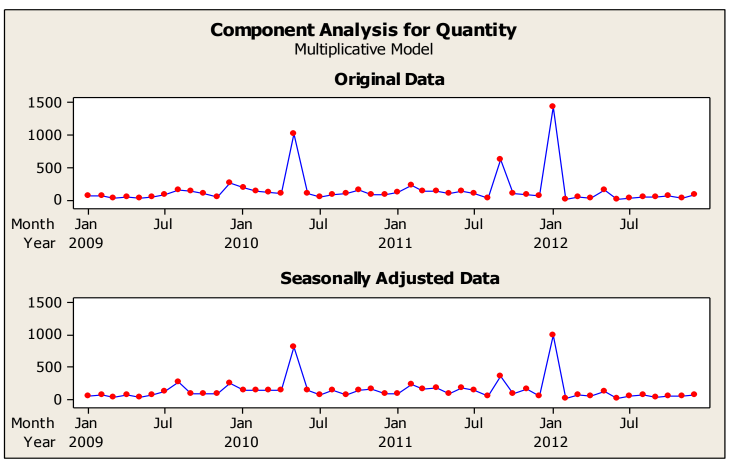

Figure 3.3 comparisons between time series for original data and seasonally adjusted series.
According to the above Figure 3.3 shows original data series that contains seasonal variations, and isolate seasonal variations of seasonally adjusted data.

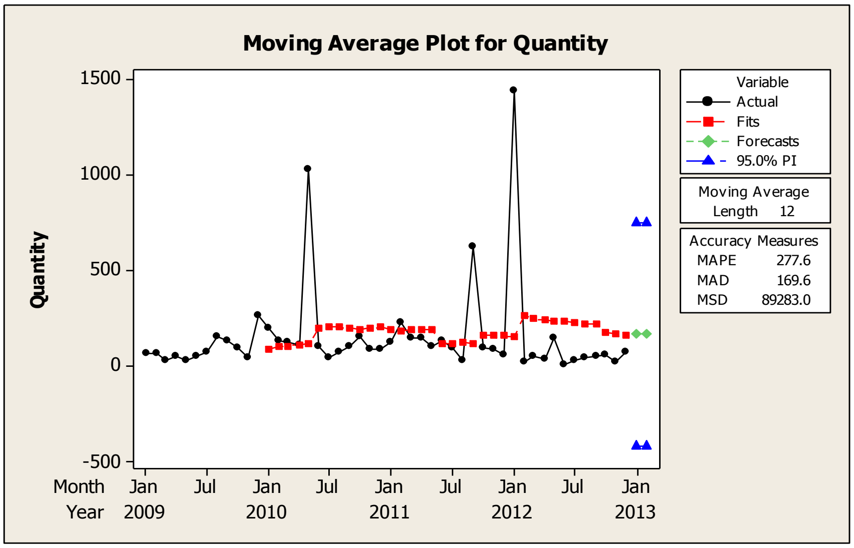

Figure 3.4 Moving Averages models results.

From the above Figure 3.4, we found that Mean Absolute Percentage Error (MAPE) = 277.6, Mean Absolute Deviation (MAD) = 169.6 and Mean Squared Error (MSD) = 89283.0.

Tables 3.2 represent the upper and lower limits and values of confidence with 95% level of significance for forecasting in moving average.

Period	**Forecast**	**Upper**	**Lower**
Jan 2013	164.03	749.672	-421.612
Feb 2013	164.03	749.672	-421.612

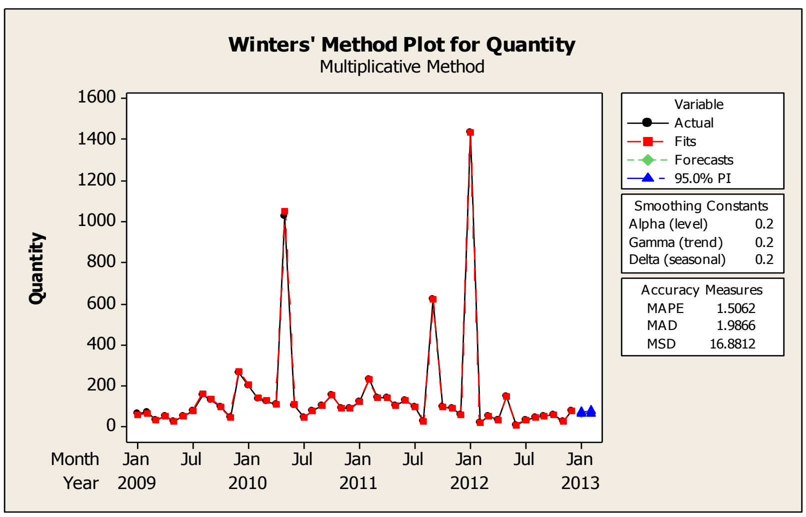

Figure 3.5 shows Winter's Exponential smoothing:

From the above Figure 3.5, we found that Mean Absolute Percentage Error (MAPE) =1.5062, Mean Absolute Deviation (MAD) = 1.9866 and Mean Squared Error (MSD) = 16.8812. Table 3.3 shows smoothing constants between (0-1) for Winter's Method.

Smoothing Constants	
Alpha(α)	0.2
Gamma(γ)	0.2

Delta(δ)	0.2

Table 3.4 shows upper and lower limits and values of confidence with 95% level of significance for forecasting using Winter's Exponential smoothing.

Period	Forecast	Upper	Lower
Jan 2013	65.2131	70.0803	60.3460
Feb 2013	68.4691	73.4126	63.5257

Results and Conclusion

The main results and conclusion of this paper can be summarized as:

- Moving averages method and winter's Exponential smoothing models are influenced by the pattern of input data.
- Winter's exponential smoothing models that depend on kicked weights of time series values provide more accurate and realistic forecasts than moving averages which depend on equal weights of time series values.
- The degrees of seasonal variations affect a direct impact on the obtained result.
- Winter's Exponential smoothing model provides results that are better than the moving averages model.

Recommendations

According to our results the most important recommendations are:

- Setting a clear strategies and plans for mineral exploration stages in Sudan.
- Address the problem of random mining in Sudan by arranging it and benefits from the previous experiences.
- Stability in conflict zones that rich with mineral enables to going on exploration attempts in these areas.
- Fluctuation of companies' production leads to instability in the average of mineral wealth production during months of this study.
- Using of modern technology to create database that stores mineral wealth production areas and produced quantity from every mineral then use these data to perform an economic analysis.
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IMPACT OF TECHNOLOGY TRANSFER ON ENERGY CONSUMPTION IN INDUSTRIAL SECTOR

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Abstract

The twin concepts of knowledge and technology transfer are not new to the third world nations. The role of technology in development has attracted increased attention in recent years, particularly around the question of how to bridge the technological gap between countries with different levels of industrial capacity. The industrial sector involves a range of activities, which is significant to energy consumption and a considerable source of both conventional pollutants and greenhouse gas emissions.

This paper focuses on technology transfer, how advantageous it is to enhance and promote a green economy with more emphasis on the industrial sector. Technology transfer definition, the need for transfer, methods of transfer and the barriers to overcome, which constitute an overview of technology transfer are addressed. This study shows the various areas in which most of the energy consumed in the industry could be saved through improved technology and technology transfer.

Keywords: energy consumption, technology transfer, industrial sector, emissions.

Introduction

Knowledge and technology transfer play a major role in international assistance to developing nations (UNCTAD, 2010). These twin concepts are nothing new to many third world nations. Since the middle of the twentieth century, these nations have been engaged in intense efforts to import the developed technologies of the northern industrialized countries and bridge the economic gap between the North and the South (David M. Haug, 1992).
Industry is the part of the economy that transforms raw materials into manufactured goods. This sector uses a large amount of energy to power a diverse range of manufacturing and resource extraction processes. Many industrial processes require large amounts of heat and mechanical power, most of which is delivered as natural gas, petroleum fuels and as electricity (Lawrence B. Evans, 2003).

To cut down on energy consumption, solutions have been implemented. Among them, technology transfer has been introduced. Advanced technologies have the potential to dramatically reduce industrial energy consumption and improve the energy economics for the major industries. International technology transfer has been the focus of attention in the effort to mitigate and adapt to the global climate change. By exploiting existing resources, foreign and domestic technology transfer may directly affect the economic development of the recipient country in many ways. Strategies and improved energy technologies can dramatically reduce industrial energy consumption.

The next section will provide a general overview of the technology transfer process, including technology transfer definition, the need for technology transfer, forms and methods of transferring technology and the barriers to technology transfer. The section after that focuses on energy consumption in the industrial sector. Finally, the last section deals with the measures implemented to reduce industrial energy consumption in relation to technology transfer.

OVERVIEW OF THE TECHNOLOGY TRANSFER PROCESS

The definitions and concepts of technology transfer have been discussed in many different ways based on the disciplines of research and according to the purpose of the research (Bozeman, 2000). All the definitions concur that the term technology transfer encompasses all the activities related to flows of applicable knowledge, skill, capability, expertise, equipment or facilities from one location to another within a specific time frame (Ramanathan, 2001). The transfer of technology requires a sustained relationship between two entities over a period of time to enable the receiving entity to produce the product with the desired level of quality standards and cost efficiency (Reddy and Zhoa, 1990).

Hoffman and Girvan (1990) argue that technology transfer needs to be perceived in terms of achieving three core objectives: The generation of new knowledge, the introduction of new techniques by means of investment of new plants, and the improvement of existing techniques.

There are many factors to be considered in transferring a technology and different theories and models have been addressing some of these factors. The failure to take these factors into account resulted in many unsatisfactory outcomes of technology transfer.

We develop a model below (Figure 1), which considers the technology transfer process as a sequence of steps. These steps are discussed further below.

Needs assessment: This is the first and the most crucial step. This involves identifying the needs of the recipient society.

Technology assessment: The aim of technology assessment is to inform decision makers, to provide an early warning signal for unintended consequences, to prepare stakeholders for possible technological changes, or to facilitate the participation of stakeholders in decision making (Smits/Leyten, 1988).

Decision on a technology: After assessing the possible alternative technologies, the most appropriate technology is selected.

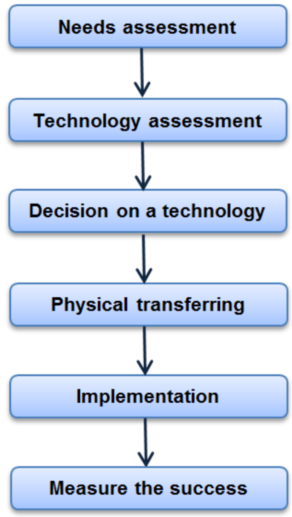

Figure 1. Technology transfer steps

Physical transfer: This includes all the procurement and transportation processes of the technology.

Implementation: The final process of technology transfer is implementing the technology. Absorption and further modification of the technology should be taken into account for developing countries as stated by Awny (2005).

Measure the success: Measuring the success or failure of the transfer process helps to learn from mistakes and leads to improving the next transfer processes.

Technological knowledge, experience and equipment can be transferred through various channels such as export, foreign direct investments (FDI), joint ventures, licensing and imitation.

Foreign direct investments: Foreign direct investment (FDI) is a direct investment into production or business in a country by an individual or company of another country (OECD Factbook 2013). Foreign direct investment (FDI) is a key element in international economic integration. FDI creates direct, stable and long-lasting links between economies. It encourages the transfer of technology and know-how between countries, and allows the host economy to promote its products more widely in international markets. FDI is also an additional source of funding for investment and, under the right policy environment, can be an important vehicle for development.

Joint ventures: Joint ventures are long-term relationships involving the pooling of assets, joint management, profit and risk sharing, joint marketing, servicing, and production. In a typical agreement, technology is transferred primarily through technical liaisons, training, and continuing operational support. Foreign investors have become increasingly willing to participate in joint ventures and partnerships with firms in developing countries.

Licensing: Since every patented technology is unique, every license agreement reflects the particular needs and expectations of the licensor and licensee. Technology licensing and transfer of technology are important factors in strategic alliances and international joint ventures in order to maintain a competitive edge in a market economy.

Imitation: As Jovanovic (1997) estimates, the learning cost of new knowledge is huge. Imitative activity has long been identified as a learning activity. Many firms start up by imitating, and they often develop new technology based on the knowledge they learnt from others.

Technology transfer implies the movement of physical structure, knowledge, skills, organization, values, and capital from the site of generation to the receiving site (Mittelman & Pasha, 1997). Although technology transfer is often seen as a private interaction between two companies or trade partners, institutional barriers and policies influence the transaction process, as well as the efficiency of the transfer process.

Market and financial barriers: Market and financial barriers are frequently present due to a shortage of financial resources and a lack of developed markets for the technology. Shortage of financing is very common in developing countries and caused by poor macroeconomic conditions, which can include underdeveloped financial sectors, high import duties, high or uncertain inflation or interest rates, uncertain stability of tax and tariff policies and investment risks. Difficulties in accessing capital due to inadequate financial strength usually pose serious obstacles to the private sector, mainly to small and medium enterprises.

Institutional and informational barriers: These include: lack of supporting policies and frameworks, including codes and standards for the evaluation and implementation of environmentally sound technologies; lack of support for an open and transparent international banking and trading system; low, often subsidized conventional energy prices resulting in negative incentives to adopt energy-saving measures and renewable energy technologies; inadequate vision about and understanding of local need and demands; shortage of information that can be caused by limited access to media resulting in lack of data, knowledge and awareness, especially about emerging technologies; and lack of access to relevant and credible information on potential partners to allow for the timely formation of effective relationships, which can enhance the penetration of environmentally sound technologies.

Other barriers: Other important barriers are: lack of understanding the role of developed and developing countries and international institutions in the failures and successes of past technology cooperation arrangements; insufficient human and institutional capabilities; inability to access, select, import, develop and adapt appropriate technologies; lack of science, engineering and technical knowledge available to private industry; insufficient R&D because of lack of relevant investments and inadequate science and educational infrastructure (IPCC 2000).

Technology is a passive resource whose effectiveness depends on humans. Consequently, one of the most critical components for effective technology transfer is a person's ability to learn new technology, which can be gained through extended education.

ENERGY CONSUMPTION IN THE INDUSTRIAL SECTOR

The industrial sector is extremely diverse and involves a range of activities. Aggregate energy use and emissions depend on the structure on industry and the energy and carbon intensity of each of the activities. According to EIA Data, industry is the major user of energy in modern society, accounting for roughly 51.7% of final energy use. Coal and oil are heavily used, especially by primary industry and manufacturing and refining. Gas is being used increasingly to replace coal because it is a cleaner fuel producing less impact on the environment. Electricity is only a minor component of industrial energy use, especially in its application in driving electric motors.

In the industrial sector, energy is used primarily to produce heat, to generate steam or as a source of motive power. For example, coal is one of the types of energy used by the cement industry to heat cement ovens. Many other industries use natural gas to fuel boilers for steam generation and electricity to power motors for pumps and fans.

The mix and the intensity of fuels consumed in the industrial sector vary across regions and countries, depending on the level and mix of economic activity and technological development. Although electricity is used in virtually the entire sector, it is the pulp and paper and the smelting and refining industries that require the most electricity.

The International Energy Outlook 2013 projected that industrial world energy consumption will grow between 2010 and 2040. Much of the long-term growth in industrial sector delivered energy consumption takes place in countries outside the Organization for Economic Cooperation and Development (OECD).

In fact, it can be seen on the diagram below that the non-OECD countries, which accounted for 64% of world total delivered energy in the industrial sector in 2010, will grow to account for 72% of world total delivered energy consumption in the industrial sector in 2040.

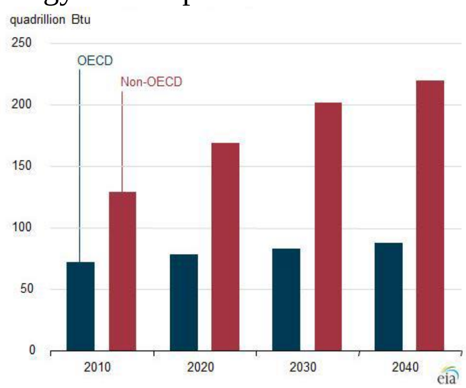

Figure 2. OECD and non-OECD industrial sector delivered energy consumption
Source: *IEO 2013*

Industrial production is an important engine to increase the economic activity, generate employment, and build up the infrastructure in developing countries. Investment in industry seems to have a stronger relation with economic growth than investments in other sectors (UNIDO, 1997). Since the beginning of the industrial age, the growth in the world economy has been driven by the increased use of energy. Technologies developed for a special industrial infrastructure may not always be the right choice for another. Adaptation and development of technology to suit the needs is an essential step in successful transfer of technology. Technology transfer is a process involving the trade and investment in technology. The globalization of industries will impact technology transfer in such a way that transfer of technology within and between countries will meet similar barriers and challenges.

Technology transfer involves more than hardware supply, it can involve the complex processes of sharing knowledge and adapting technology to meeting local conditions. Domestic technical and managerial capacities, institutions and investments in technological learning all influence the effectiveness with which technology can be absorbed and adapted. These considerations complicate the measurement problem. Human resource and institutional development are crucial to facilitating technology utilization. Institutional development includes capacities for technology and business assessment, incubation, and technology testing and demonstration.

MEASURES TO REDUCE ENERGY CONSUMPTION IN THE INDUSTRIAL SECTOR

Industrial motor systems such as pumping systems, fan systems, compressed air systems, and materials processing systems account for 63% of the electricity consumed in the industrial sector. For example, electric motor-driven systems used for production processes consumed 679 billion kWh in 2010 (McKane et al., 2010). As shown on the chart in Fig. 3, pumping, fan, and compressed air systems represent over a half of the motor-driven system electricity consumption.

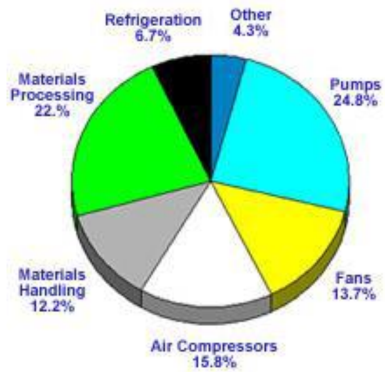

Figure 3. Motor system energy consumption by application. ***Source*****:** A. McKane et al., 2010.

These systems, along with steam systems and process heating equipment, have been a particular focus on strategies to save energy.

Steam: Steam is used for a multitude of purposes in industrial plants. It can provide heat for chemical processing, hot water for cleaning purposes, steam for input to turbines for producing power and so on. Steam is generally produced by boilers.

In addition, a simple maintenance program to ensure that all components of the boiler are operating at peak performance can result in substantial savings. In the absence of a good maintenance system, the burners and condensate return systems can wear or get out of adjustment. These factors can end up costing a steam system up to 20-30% of initial efficiency over 2-3 years. An estimated 10% possible energy savings on average can be achieved through improved maintenance (DOE, 2001a), which may also reduce the emissions of critical air pollutants.

Compressed air systems: Compressed air systems can consume a large component of energy, and offer the potential for large financial savings from reduced energy consumption. The biggest component of a compressed air system is the compressor unit. Compressors can utilise a variety of fuel sources, including diesel, petrol and electricity. According to the US Department of Energy, optimizing compressed air systems by installing variable speed drives, along with preventive maintenance to detect and fix air leaks, can improve energy efficiency 20-50%.

Furnaces: Furnaces are widely used in the manufacturing and mining industries. Although similar to boilers, they are usually used to melt metals for casting. Many of the potential areas for energy savings are the result of high capital cost, or require detailed changes in the current operation of the factory. These include rescheduling to reduce the occurrence of a furnace being heated with less than an optimum load, automatic control of furnaces, insulation of the furnace as well as modifications to the furnace. Although these items require large amounts of capital, consideration should be given to these issues, especially where the furnace is due to be replaced, or where a new furnace is to be purchased. Furnace systems often offer good potential for heat recovery systems where the very high temperatures in the exhaust air can be used to preheat the combustion air entering the system (DOE).

Heat Recovery: In many cases, a heat recovery unit can recover 50-90% of the available thermal energy for space heating, industrial process heating, water heating, makeup air heating, boiler makeup water preheating, industrial drying, industrial cleaning processes, heat pumps, laundries or preheating aspirated air for oil burners. Implementing this measure recovers up to 20% of the energy used in compressed air systems annually for space heating (Price, A. and M.H. Ross, 1989).

CONCLUSION

This study looked at technology transfer in relation to reducing energy use in the industrial sector. The various ways of transferring various technologies without leaving out the barriers to be dealt with in seeing to the successful transfer were investigated. Maintenance was identified as a key factor in improving the ways technology can assist in the reduction of industrial energy use. The areas with big industrial energy saving potential were identified, together with the corresponding reduction means.

It is very important for governments, stakeholders and concerned industry managers and operatives to recognise the importance of technology transfer in improving the use of energy. Industrial energy reduction will constitute greener environment and the long-term benefits that come with it. It is advised that breaking the barriers to technology transfer will go a long way in achieving a present and future green environment.

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WEALTH: A community based platform for integrated basic rural infrastructure

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Keywords: WEALTH; service learning; appropriate technology; community informatics; humanitarian engineering

Abstract: Sudan as developing country is far from achieving coherently the Millennium Development Goals (MDG). Targets regarding: poverty eradication, education, health and environment sustainability are usually addressed by different development agencies, government and NGOs in separate, while the problems are interrelated. The integration between fields requires multidisciplinary community based approach and engineering capacity building to develop solutions with high harmony, autonomy, community participation and engagement. We proposed the WEALTH initiative as a pilot project to build a platform that utilizes Appropriate Technology (AT), Service Learning (SL) and Product Development to develop, design and deploy an integrated basic rural infrastructure around (Water, Energy, Agriculture, Learning, Training and Health).The framework challenges the integration and collaboration of academia, rural communities, engineering practitioners, economist, development agencies and NGOs to design a robust knowledge and capacity platform that develops community based participation model to capture the rural community needs and requirements about infrastructures problems, and to build capacity through service learning that is capable to design and deploy the sustainable and appropriate technology's solution which maximizes the community participation. This paper reflects how this platform is developed, the potentials of this integration and collaboration on stakeholders, and the potential of the integration of the infrastructure.

INTRODUCTION

The Millennium Development Goals (MDG) set by the UN play an important role to reveal the problem status that faces countries, especially the developing countries since these goals cover the most essential and critical survival problems. Measuring goals will reflect the development status quo in addition to ease the decision making. MDG covers eight areas mainly; eradication of extreme poverty, primary education, maternity health, reduce mortality from HIV and malaria, sustainable development, gender equality and international collaboration on development. While measuring the achievement in MDG helps policy makers to address the problems that were faced, but the main obstacle is there is no well organized data repository with integrity to reflect these efforts; a clear example, during the period between 2005-2014 Sudan issued only one report about MDG in 2010 (UNDP,2014), with low level of data integrity, never the less there are many developing countries that faced severe problems regarding their basic service infrastructure specially in the rural areas, the lack of these infrastructure leads to interrelated problems of health , poverty, desertification and low production. Interrelation of the problems and their causes act just as a syndrome causes hindrance for sustainable development, there was an estimated of 800 million people in the world who have no access to clean water, 2.5 billions live without adequate sanitation, over that, diseases associated with water, sanitation and hygiene (WASH) conditions comprised 6 to 7% of mortality in less developed countries (WHO and UNICEF , 2014). There are an estimation of 18% of world population without access to grid electricity services while many people specially in Africa (~ 700 millions) used forest resources as main energy source for cooking which lead to continuous degradation of land resources hence desertification. Poverty eradication must be addressed as a high priority since the majority of people of the Sudan are farmers or who are working in the value chain of agriculture's economics, so recovery of land fertility can help to overcome desertification and enhance the production. The problems regarding Water, Sanitation, Energy, Education, Health and Agriculture, although it are highly interrelated, it usually addressed by loosely integrated policy and with sparse efforts of NGOs and government. The methods for addressing the problem lack integrity and robust development of appropriate technology characterized by sustainability, harmony and autonomy which need multidisciplinary approaches while the capacity building not acquires this view yet.

Engineering Service Learning (SL) was spread for the last decades as learning and pedagogy approach that brings engineers close to the real community problems beside provide a solution with moderate community participation. Many SL approaches benefits and characteristics were reported in comprehensive report (Eyler, 2001). Such new learning capabilities and experience are built in environment where high complicated real problems addressed by multidisciplinary approach, sustainability of solution and exposed to real experience of multidisciplinary problem.

Many development solutions lacks the sustainability and large spread of uses, projects like the biogas and enhanced stove, remain in its pilot model without further development to ease the uses and commercial spread. Product lifecycle is not completed as it happens in its industrial peers while several other solutions especially in energy, electricity and water were implemented by donation from rich countries still left people with an economic burden to adopt large implementations.

We propose an initiative called WEALTH that provides (through service learning , appropriate technology and product development) a rural basic infrastructure’s knowledge platform enriches capacity building around these problems, the platform energize the collaboration between academics, universities, education institutes , NGOs, research centres, engineering practitioners and societies for the implementation of the framework. This paper will examine the potentiality of integration, appropriate technology and service learning through study of similar experience, focus study and develop a model that can work in the Sudan which capturing the requirement of the stakeholders.

In the rest of this paper, section II provides literature review while section III will examine knowledge map and appropriate technology research foci, the potentiality of integration and how these problems were addressed before; section IV will discuss the proposed model and community informatics to support the initiative, the result given in section V

LITERATURE REVIEW

In the Human Development Report HDR 1990 directed by the economist Mahboob Alhaq, UN coined a new definition to Human Development escaping from relying only on GDP measures, they defined it as “*Human development is a process of enlarging people's choices. The most critical ones are to lead a long and healthy life, to be educated and to enjoy a decent standard of living; additional choices include political freedom, guaranteed human rights and selfrespec*t” (UNDP, 2014b). The definition identifies the health, education and standard living as enablers of enlarging people's choices. Measuring Standard Living was conducted by the World Bank through its unified Living Standards Measurement Study (LSMS) (World Bank, 2014), besides measuring the household's income there is a part that is concerns with the access of infrastructure, mainly Piped Water, Electricity, Sewer Service, and Telephone Service. Kristin Komives and et al. studied globally the links between infrastructure coverage and income groups (Komives, 2001).

Marc A. Jeuland and et al. examined the association between inadequate access of WASH infrastructure (Water, Sanitation, and Hygiene) and WASH-related mortality rates(Jeuland, 2013), they present country-level projections for WASH coverage and for WASH-related mortality in developing regions over a long time horizon (1975–2050) and provide dynamic estimates of the economic value of potential reductions in this WASH-related mortality, although many regions shows huge future improvement but health losses will likely remain high in Sub- Saharan African over the medium term , which suggests that accelerated efforts are needed to improve access to water and sanitation. The interrelations between development, infrastructure service, economics and health suggest the integration in strategic policy and multidisciplinary approach in capacity building.

There are no large number of university programs that had one program to study these interrelation fields, or co-operation between different programs to approach developmental problems in coherent multidisciplinary way, in recent years there an emerging fields of Humanitarian Engineering (HE), in USA many universities established a program for HE such as university of Pennsylvania, in addition IEEE had a conference in Humanitarian Engineering. On the other hand; for more than two decades SL was introduced in the engineering field as learning and pedagogy method that brings the student close to community and exposed the student to real experience of problems in their context. An annotated bibliography and findings of SL provide by Eyler J and et al (Eyler, 2001).

John Tharakan reflects the experience of Engineers Without Borders USA(EWB-USA) and Howard University in SL and how they addressed problems in a community in western Kenya by appropriate technology to provide clean water, he also search for the institutionalization of SL to meet quality assurance guidelines for outcome-based engineering education(Tharakan, 2011). Kurtis G. Paterson and et al. utilize Business Canvas in the planning and design of the Learning through Service (LTS) in order to fully realize potential of SL (Kurtis, 2014). These efforts of enhancing community based curriculums are very important although it needs to take a rigorous process of Product Development that is mature in industrial manufacturing in order to design products that can work. The UN high commissioner of refugee in The Guardian article argued about many products that have a lack of context and culture consideration then failed to provide what designed for (the Guardian, 2014). Securing human development need a good quality and integrity of information to aid strategic policy planning and better assessment of the development program. World Bank in SLMS (Komives, 2001) unified the survey and methodology of collecting data,

UNICEF and WHO introduced Joint Monitoring Programme (JMP) to reflect coherent high quality data about their mutual areas (WHO and UNICEF , 2014). These effort recalls fostering the field of Community Informatics where the Information about, for, and by community seek more harmony and autonomy in community context, references (Romm, 2001; Pitkin, 2001), [11-12] give good background about the topics in terms of CIs , rural and development.

METHODOLOGY

In order to study the potentiality of proposed infrastructure we utilize Knowledge Map of all projects and cases that found in Engineering for change (E4C) solutions library (Engineering for Change, 2014). A simple classification is used to give a semantic based Knowledge Map that looks to the dimensions of problems addressed by the case, mainly: the community based elements, the economic elements, integration between infrastructure and the types of organizations that involved in the case. We defined problem, community, economic, integration depths as the measure of how many elements that discussed in the single case, if the problem depth of the case is 2 that means two individual problems were addressed by the case(although the categorization is subjective, but it give a good analysis), the library cases had an average of 1.7, 1.4, 0.6 and 0.88 for Problem depth,

Community elements , Economic elements and Integration of infrastructure depths respectively, this show that most study were not pay high attention of economic and infrastructure integration aspects, there was almost absence of rigours economic analysis of all cases, all the mentioned was a little bit about the cost or in better case how to build business around the solution , Figure 1. Give detailed measure per infrastructure

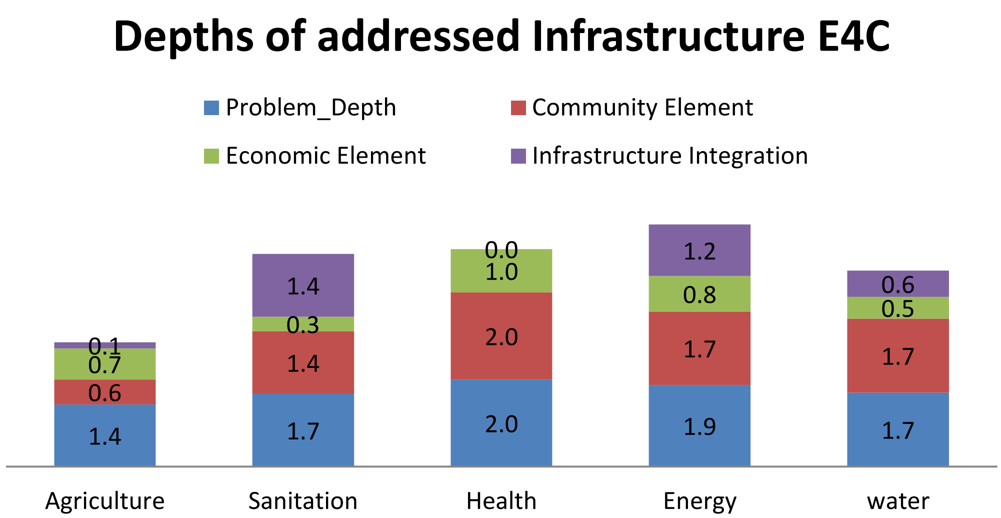

Figure1. Depths of addressed Infrastructures (E4C data, number of the cases=44).

While Energy, Health and Water showed high problem and community depths, the high infrastructures integration reported by Sanitation and Energy respectively, the economic addressing in general was weak. In order to reveal which infrastructure can be potentially integrated with the other, joint correlation matrix was constructed. We defined correlation index as

$$I = \{1,2,3,\ldots,n\} where\ I\ is\ infrastructure\ enumaration$$

$$A = \left\{ a_{ij} / a_{ii} \ , \forall\ i,j = 1,2,3,\ldots,n\ \in I \right\} \qquad Eq.1$$

Where a_{ij} represent the number of integration between infrastructure services i and j here i represents the base service of the case, a_{ij} represent all cases of the service i in the sample. From the sample of cases in case library, illustrated in the Table1, Energy infrastructure showed potentiality to be integrated with Health (0.5), Agriculture (0.3) where Sanitation has high integration potentiality with Health (0.89) and Agriculture (0.56).

	Water	Energy	Health	Sanitation	Agriculture
Water	1.00	0.00	0.30	0.10	0.20
Energy	0.06	1.00	0.56	0.19	0.31
Health	0.00	0.00	1.00	0.00	0.00
Sanitation	0.00	0.00	0.89	1.00	0.56
Agriculture	0.14	0.00	0.00	0.00	1.00

Table1. Correlation Matrix E4C data

Similar to E4C solutions library, we look carefully on two conferences of ICAT (Appropriate Technology, 2014), mainly the 4th and 3rd ICAT. ICAT conferences for decade remain the most influential AT conferences in Africa, it conducted by International Network for Appropriate Technology (INAT) in collaboration with African universities and held in Africa the land of less developed countries, the analysis of ICAT show general low depth in problem, community and economic depths (except for water 2.1 and 2.2) with low infrastructure integration (except in health 2.0) Figure.2 give a good picture. One last valuable notice, ICAT are dominant by universities researches while E4C dominant by NGOs initiatives this suggest that if these two entities work together they boost integration and provide a continuous framework that looking to the rural area with real evolved R&D.

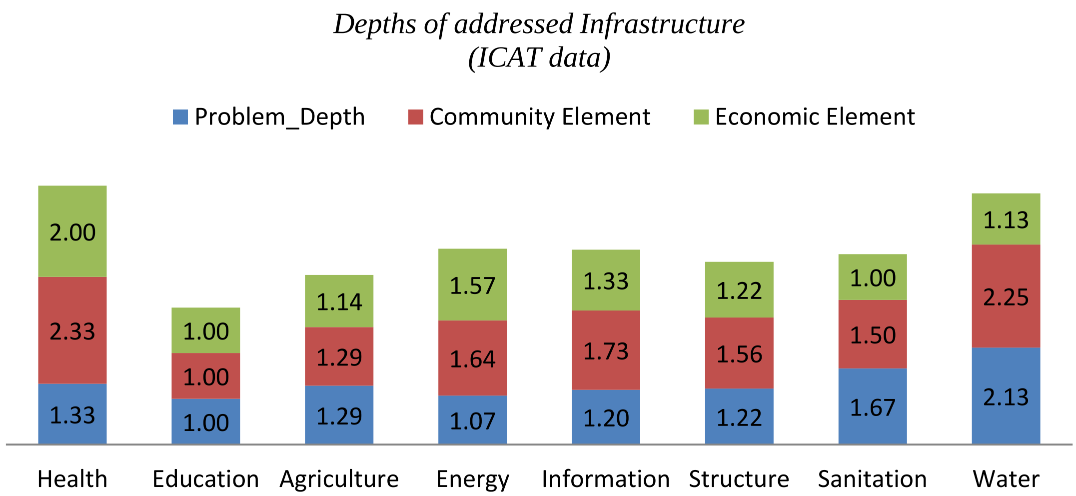

Figure2. Depths of addressed Infrastructure (ICAT data, number of the cases=63)

The Model

Analysis of E4C case library and two ICAT conferences urge the need for a model that has high multidisciplinary integration, community centric driven projects , rigorous economic analysis and social economy transformation, rich CIs to aid the decision and community self transcendence, and deep understanding of community culture and capabilities to absorb and embody its indigenous knowledge in the solution. A new approach is needed in order to raise capacity for product development, transforming pedagogy for both community and professionals (Engineers and Students) capacity building. When we look at the current working models of AT that target humanitarian needs we found many simple and practical solutions that were developed by NGOs that work close to the community, although some aspects of economy were touched but it lacks solid rigorous economic studies that will cover large projects benefits and impact.

On the other hand, University and Research Centres usually tackle the problem with a very narrow scope since most studies do not belong to a large research umbrella program, the deficiency of integration lowers the benefits of such researches, and many promising research ideas were not developed further since most of the researchers did not possess the industrial capacity of developing an idea into product, and if they have ,the nature of research centres itself did not support further development, many engineering organizations expand the dimension of handling community problems further, EWB in USA, India and Australia set a good practises to step further in community based HE. The works of EWB-USA featured by community-driven development, sustainable engineering, and long participatory project implementation while creating transformative experiences which enriches global perspectives and create responsible leaders. The nature of organization itself is non profit humanitarian organization driven by engineer practitioners, educators and students chapters. The Indian version is a non profit society with focus on sustainable development by engineers and other professionals and also adopts the student and practitioner chapter structure. EWB Australia had an interested model; it is registered as non profit company with focus on capacity building and long-term development around HE and local communities' partnership.

There were many attempts to addresses the problem of designing a framework that maximizes the collaboration between stakeholders and their return benefits in the area of HE development. Kurtis G Paterson and et al developed a non-profit business model canvas to serve as a tool that would help design effective LTS programs. The resulting blueprint contained nine important elements to consider for SL program (Kurtis, 2014). They indentified potentially the risks of unequal relationships between the communities and "academy" since community expressed a desire for "jointly creating knowledge with the university". Verharen C, Tharakan J, and et al, developed a model that focus on survivals ethics, and reflected the experience of EWB, universities and community, they emphasized a lot on integration, integrating science, engineering and ethics in the efforts of multidisciplinary teams dedicated to this task. They argue that integration is important aspect of the model hence the problem of basic infrastructure causal factors that affect the success of projects (Verharen, 2014).

We will adopt their models since they put the problem of sustainable development as an urgent survival ethics and we added three critical issues to the model: shifting the model to be more transformative participatory approach where community in its core rather than intervention approach and embodied social sciences and pedagogy that support this transcend, secondly develop extensively community informatics that play a major role of a conciseness and community cognitive about their status quo and aid smartly any development decisions, and at last the insight economic analysis which raise the community capabilities to get out from the economic trap, this economic aspect supported by Frugal Engineering and social based product development, the proposed model will further improve by collecting stakeholderS feedback and requirements and study of possible interactions dynamics.

COMMUNITY INFORMATICS

WEALTH is based upon Community Informatics CIs, which is the information about, by and for the community. CIs is the participatory approach data collection, models, maps and indicators to raise the awareness and participation of community in revealing their status quo, benchmark their state with peer communities and appreciate their own effort on development progress and sustain the achievements. The problems of data integrity, coarse data samples that cannot depict the details, updated information; these entire problems can be solved if we approach a community based crowd Information System where simple and affordable technologies such as SMS and web based applications are utilized to establish a new participatory interactive CIs system. The design will seeks content rich, flexible interface, harmony and autonomy with community, in (Romm, 2001) the concept was examined carefully, while at same time put all potential benefits of ICT on the use of the community based on real value chain analysis. The ICs system will be developed by the crowds of ICT's students and academies that have a high commitment to the movement of ICT4DEV.

B. PRODUCT DEVELOPMENT

As reported by the Guardian, the words of refugee high commissioner depict why we need to carefully consider Product Development "*I've been in refugee camps where large, beautiful solar cook stoves were used as storage places because they didn't cook the food fast enough, …, designers mistakenly think they can come up with a one-size-fits-all approach, failing to understand the cultural complexity of cooking or the conditions in which the stoves are used*."(the Guardian, 2014). The idea usually remains in its pilot phase failing to capture the community needs. What complicates the situation is that, the developer may design a product to a community at poverty using a concept of a wealthy community; a new approach to product development that targets the majority of population is required. Frugal Engineering is a concept that has emerged in the last few years to describe how the product/service, development process must be completely rethought and rebuilt in order to design, develop and deliver innovative solutions to customers at the Base-of-the- Pyramid (BOP) (Colledge, 2014). Engineers must design and build high quality, feature-appropriate technologies and products that are affordable, require low maintenance, reduce waste and inefficiency, products were designed with the socio-ecological context of the customer in mind, and can be purchased by the customer within the context of their income and cash flow situation.

RESULTS AND CONCLUSION

To achieve Human Development targets, communities in developing country must get out from inter-causal problems; these are mainly present due to the acute deficiency of survival infrastructure in addition to poverty and very low income economics. Fragmented address of the problem will not overcome such situation. Study of initiatives on Humanitarian Engineering and Appropriate Technology, mainly the cases from E4C and Researches in ICAT conferences, depict a weak multidisciplinary integration, lack of deep economic analysis, incomplete solution development cycle and a need to build capacity around community based approach. A multidisciplinary framework was proposed, guided by humanitarian engineering, appropriate technology, service learning, and product development. In such framework community centric approach in its core where we shifted to more transformative approach for both community and Engineers to get out of the trap, this means that recall transformative pedagogy, social science, and economic approach. The framework will be supported by appropriate Community

Informatics in such ways that examine every detailed dynamic decision and support participation and social transformation. The proposed framework will be refined further using stakeholder feedback, requirements and their recommendation about operation and governance process design.

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