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Case study

Feasibility of producing nano cement in a traditional cement factory in Iraq

Sada Abdul Abdalkhaliq Hasan Alyasiry[a], Iyad Salim Alkroosh[a,*], Prabir Kumar Sarker[b]

[a] Department of Civil Engineering, College of Engineering, University of Al-Qadisiyah, Iraq
[b] Department of Civil Engineering, School of Civil and Mechanical Engineering, Curtin University, WA, Australia

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ABSTRACT

This study investigates the economic feasibility of producing nano cement through the establishment of a production line within an existing cement factory. Creating a nano cement production line within the Alkufa Cement factory in Iraq is selected as a case study. Evaluation measures including internal rate of return (IRR), net present value (NPV) and breakeven point (BEP) are used to evaluate the possible gain that can be achieved from this option. The results demonstrated a positive NPV. The IRR is found to be 26.8% and BEP is reached within 3 years after the establishment of the line. This indicates that producing nano cement in the existing cement factory is economically feasible and can be more advantageous than the ordinary cement.

1. Introduction

It is estimated that a total of 4.3 billion tonnes of cement is produced worldwide annually with a rapid increase in demand [1]. The production of such a huge quantity of cement is associated with enormous energy consumption, significant cost and greenhouse gas emissions to the environment. It is therefore necessary to develop alternative binders which are cost effective and more environment friendly. Introducing a new technology to cement manufacturing methods that are consistent with the principles of sustainability can be a proper response to this necessity. Using nanotechnology for producing nano cement may be considered as a potential approach in this regard.

This technology of manufacturing can be achieved by increasing the specific surface area of cement by producing cement particles of nano scale i.e. the particle of size less than 100 nano meter. Increasing the surface area increases the chemical reactivity and nucleation effect, thus improving strength and durability of concrete with less quantity of cement [2–7].

The grains of nano cement are covered by solid shells in the process of grinding (mechanical activation). The shell is a capsule with thickness of several tens of nanometers of modified polymer compound, which imparts a radically new quality to Portland cement and concretes [8,9].

Nanotechnology can help to overcome major environmental challenges by reducing CO_2 emissions and produce cement of better quality. With the use of this technology, the amount of carbon dioxide emitted from cement factories is reduced significantly through reduction of the quantities of produced cement [10–15]. The technology has also been used for producing cement of better properties as a result of incorporating various nanomaterials such as Silicon Dioxide nanoparticles (SiO_2), nano-$CaCO_3$, Carbon nanotubes composite fibers, and Aluminum Oxide nanoparticles (Al_2O_3). The nanomaterials are mainly used to enhance various mechanical properties of the cementations materials: crack resistance, corrosion resistance, tensile strength and compressive strength [16–24].

* Corresponding author.
E-mail addresses: iyad.alkroosh@curtin.edu.au, iyad.alkroosh@qu.edu.iq (I.S. Alkroosh).

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Since 2001, an increased number of researches have been conducted indicating that nanotechnology is a potential alternative to the traditional cement production methods [25–29]. Thus, there is a technical possibility of adopting nanotechnology in cement production. However, in addition to the ongoing scientific research, it is also necessary to study the economic aspects of this alternative in order to evaluate its cost effectiveness. This paper presents a study evaluating the suitability of introducing nanotechnology through the establishment of nano cement production line within a traditional cement factory. The economic feasibility of establishing a production line of nano cement within the Alkufa cement factory of Iraq, using the silica sand, has been studied.

2. Background

In 2012, certification of six types of nano cements was made by Rusnano Ltd verified a full compliance of produced nano cements with general purpose nano cement technical conditions (TU – 5733-067-66331738-2012). At the end of 2014, the national prestandard 19-2014 (Nanomodified Portland Cement Technical Conditions) was approved by the Russian Federation, and the international nano cements patenting was begun [28]. Sabdonoa et al. [23] found that the nano cement content has significant effect on the compressive strength of mortar. Mistry [30] studied the effect of nano materials on various properties of concrete in comparison with conventional cementations materials. It was shown that the increased surface area of nano materials improved compressive and flexural strengths at early ages, reduced porosity and reduced water absorption.

Bickbau and Shykun [31] showed that the characteristics of ultra-high strength concrete using nano cement was significantly improved. The use of nano cement reduced shrinkage, increased strength, reduced permeability and thus increased the long term durability of concrete.

Bickbau [32] discussed the implementation of the low-clinker nano cements technology and showed that there is a real opportunity to reduce cost per tonne of cement by 40–60 kg unit fuel, improve the cement quality and increase the production in any cement plant without constructing clinker burning steps. This will decrease emissions of the operating cement plants per tonne of nanocement by 30 to 40%. Ikhlef [33,36] provided results of different tests investigated mechanical and physical characteristics of mortars and concretes consisting nano cements. The results showed improvement in water absorption of mortar and concrete. The 28-day compressive strength of concrete increased by 10–65%.

Selvaraj et al. [34] have recently carried out a study of reactivity of nano cement in concrete. They found that 30% replacement of OPC by nano cement led to excellent strength characteristic. Thus, nano cement proved to be an outstanding construction material for many applications in the building industry. Sarsam et al. [35] concluded that the addition of nano coal fly ash or limestone dust in the range of 2–6% as partial replacement of cement shows significant reduction in the water absorption properties of concrete.

The above research works in literature shows the benefits of nano cement in terms of strength and durability of concrete. Thus, a case study has been conducted to investigate the feasibility of the addition of a nano cement product line in an existing conventional cement factory.

2.1. Nano cement manufacturing process

The production of nano cement from sand & clinker is performed by mixing mineral supplement additions such as fly ash and slag or silica sand with crushed and grinded clinker or cement [33,36]. Before processing into the mill which is shown in Fig. 1, the moisture content of the mixture must not exceed 3%. This is achieved by making the mixture passing through a drying unit attached to the production unit. The mixture is grinded for 30 to 40 min in the mill [9]. Finally, nano cement is produced as the output of chemical reaction of clinker particles with a modifier.

As shown in Fig. 2, the production process of nano cement begins with adding a tonne of grinded Portland cement or clinker to a tonne of materials comprising sand or silica sand and polymeric modifier such as sodium naphthalene (FDN – 05) in dry form (polymeric modifier of 0.6%–2.0% and silica sand additive). Then, mineral supplements are added in a form of nuggets (300 mm in diameter) and gypsum of 5% to 6% moisture content (0.3%–6.0% gypsum rock). The output of the process is two tonnes of nano

Fig. 1. Turbine ball mill; (Source: http://www.hxjq-crusher.com/products/chinaware-ball-mill.html).

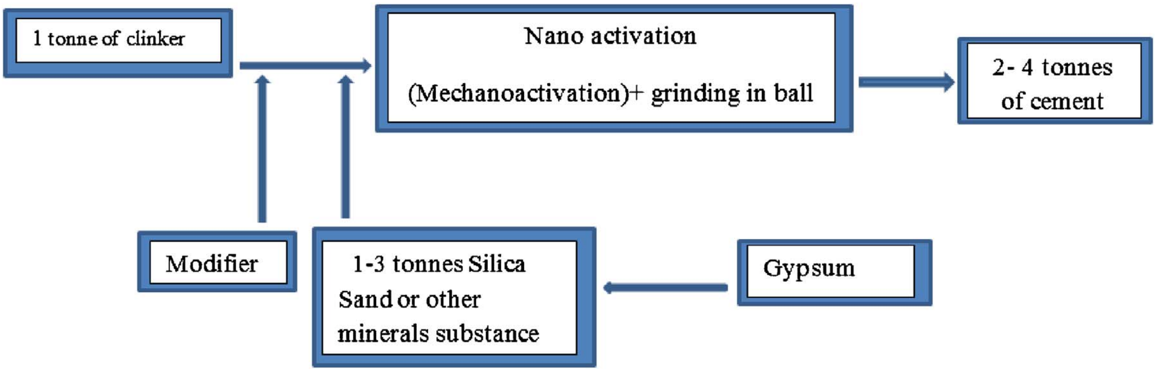

Fig. 2. Nano-cement production flow chart.

cement. Consequently, the cost of consumed fuel per a tonne of cement is reduced considering the required cost for the additional grinding and energy [9].

Details of processing line to produce nano cement on the base of cement clinker processing are shown in Fig. 3. Raw materials except the modifier are weighted and mixed and processed to the Bin feeder. Then homogenizing and modifier addition take place before feeding the mixture into the Ball mill where grinding is performed to produce nano cement. The dust generated due to the process is cached and controlled by the fabric filter.

2.2. Advantages of producing nano cement

The following advantages can be achieved by producing and using nano cement [9]:

- Increase of cement production without building a new plant.
- Utilization of local raw materials such as silica sand, damped wastes slag or fly ash in new production and usage of semi-finished clinker as raw material.
- Because of increased fineness of cement, concretes develop super high strength, high resistance to water, sulfate, chloride and acids. This enables construction of complexes civil engineering and architectural members such as thin membranes, supporting columns, beams, large-span structures, tubing, concrete frames and bridge structures. The effect of nano cement improves the impermeability of concrete that will eventually increase of service life of structures.
- Possible reduction in the ratio of reinforcement by 30–50% due to the use of strong and super strong concretes.
- Achieving compressive strength of 60–70 MPa within 24 h and 70% of 28-day strength of concrete within 72 h. Thus, the economic benefit can be achieved through reduction of form release time and significant reduction of overall construction time of the project.

3. The proposed project

In this project, the use of nanotechnology is proposed to produce nano cement through establishing a new line of production

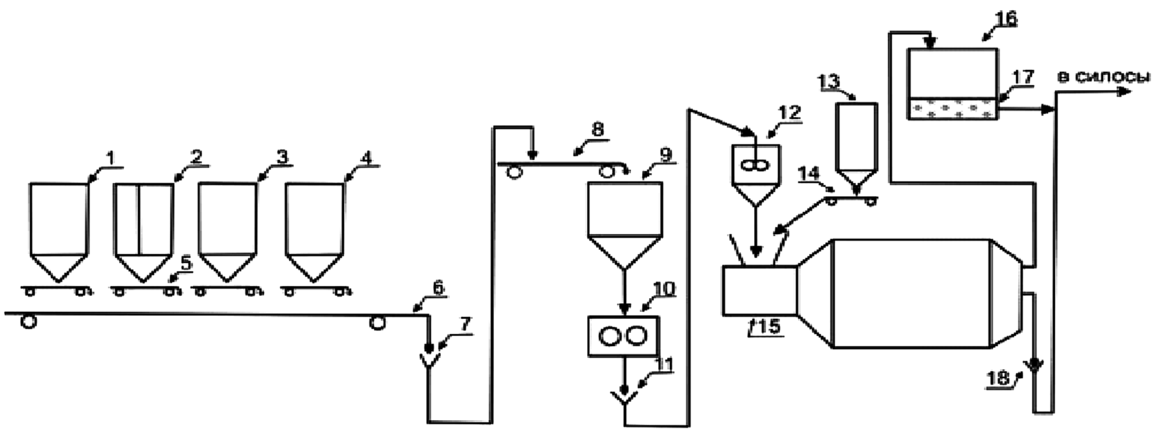

Fig. 3. Processing line for the production nano-cement (Source: [31]). *1: Coal slag storage; 2: Bunker of gypsum; 3: Bin for sand; 4: Bin for clinker; 5,6,8: Weight – measuring; 7,11,18: Band type conveyors; 9: Bin feeder; 10: Press-rolling rock; 12: Bin feeder for mix homogenizing; 13: Modifier bin feeder; 14: Proportioning belt; 15: Ball mill; 16, 17: Fabric filter.*

Table 1
Chemical analysis of Aridma sand.

Chemical components	Percentage by weight%
SiO_2	99.2
Fe_2O_3	0.092
Al_2O_3	0.66
CaO	< 1
MgO	0.04
Na_2O	0.04
K_2O	0.03
L.O.I	0.4

within Alkufa Cement factory in Iraq. This choice was made because the raw materials for manufacturing nano cement are available in the vicinity of the factory. The other necessary resources such as land, water, electricity etc. are also available for the establishment of the extended production line.

Alkufa Cement factory is a part of the Southern Cement State Company which was established in 1977. The head office of the company laid in Al-Najaf Governorate, about 7 km from the city of Kufa. The company owns several plants in the Southern region of Iraq. Each plant has four production lines with annual capacity of 1781000 t of cement. The factory produces ordinary Portland cement which conforms with the Iraqi Specifications No. 5/1984 as well as the requirements of the Ministry of Industry and Minerals. In August 2010, the factory was awarded Certificate of Quality by the Ministry of Planning and Development cooperation central agency for standardization and quality control.

3.1. Raw materials and cost

Different Supplementary materials can be used to produce nano cement depending on what is available in the region of production. For instance, sand is used in deserted countries while fly ash and furnace slag are used in industrial areas where industrial salvage is available. Iraq is a country which is rich in silica sand that usually exists in a form of white rock containing a high ratio of silica (up to 99% SiO_2). In this study, therefore, silica sand is used as a Supplementary material. Ardima sand quarry is selected as a site to supply the raw material because it has sand of a high level of silica and it is the nearest location to Alkufa Cement factory (about 100 km). The clinker will be supplied from Alkufa Cement factory. Tables 1 and 2 present the properties of Ardima province sand and Alkufa's cement. They conform with specified properties of nano cement raw materials as described by Ikhlef [33,36]. The modifier, sodium naphthalene sulfonate (FDN–05) with density varying from 0.78 to 0.88 gm/cm^3 will be imported from Russia. This type of modifier has been used for producing nano cement e.g. Abu Dhabi National Cement Factory. The gypsum with minerals will be brought from the markets of Najaf. Table 3 shows the quantities and costs of raw materials used to produce a tonne of nano cement including transportation cost. Based on cost of materials in Iraqi market at the time of this study, the total cost of raw materials will be US$ 58.75 per tonne.

3.2. Equipment and machinery

Our investigation found that China has the fastest developing cement industry in the world. The cement production in China increased from 0.20 billion tonnes to 2.50 billion tonnes between 1990 and 2014 [28]. This indicates that China would be the best place for acquiring equipment of good quality at attractive prices. Therefore, the equipment will be imported from China.

A ball mill of dimensions 4.2 m × 11.0 m with operational power and feeding devices was selected for the project. The total

Table 2
Properties of Alkufa Portland cement.

Parameters		Range
Lime saturation coefficient		0.9–1.0
Magnesium oxide (MgO)%		1.5–2.5
SO3 Content%		2.2–2.6
Loss on ignition%		2.5–3.5
Insoluble residue%		0.5–1.2
Fineness (m^2/kg)		325–340
Initial setting time (min)		125–180
Final setting time (hr)		3–3.7
(mm) Le-Chatelier soundness		0–2
Specific gravity (kg/litter)		3.10–3.18
Bulk density (kg/m^3)		1.404 ± 0.1
Compressive strength as per Iraqi Standard (MPa)	3d	34–39
	7d	42–49
	28d	59–65

Table 3
Cost of raw materials for 1 t of nano-cement.

No	Type	Quantity (kg)	Cost US$/unit	Total cost (US$)
1	Clinker	750	0.065	48.75
2	sand Silica	250	0.04	10
3	Gypsum and modifier	16.5	0.0003	0.00495
Cost/t Total				58.75

weight of the mill is 137 t and has a motor of 800 kW power. The maximum size of feeding materials into the mill is 25 mm. The mill discharges the materials of 0.075 mm size, at rate of 25–130 t per hour. The photo of the mill is shown in Fig. 1.

Silo bunkers are used to store the materials including sand, clinker, gypsum and coal ash. There are also three feeder bins as shown in Fig. 2. The storage capacities of the bunkers are 50 t to 200 t. A Bag filter will be used for cement dust. It is made of polyester fiber: weave type of plain and satin.

3.3. Product quality and demand

As described earlier, concrete containing nano cement has higher strength and is more durable than that made of ordinary Portland cement. Therefore, nano cement concrete will be more suitable for construction of structures, especially those exposed to aggressive environment [12,38]. To ensure quality of the produced nano cement in terms of ingredients, fineness, setting times, soundness and strength, a comprehensive quality control (QC) plan will be followed. The plan specifies that only quality product will be sent out of the factory and asserts the compulsory implementation of: (i) from each lot number of samples will be taken for physical and chemical tests; (ii) all kinds of tests required for the production and inspection of inward materials continue to be performed by the executives of the Production Department; (iii) each batch of nano cement shall be packed in a plastic or waterproof bag; (iv) usual inspection of bags at the time of packing and conducting random sampling tests to ensure that the bags are at good quality and the weight of the loaded bags are correct; (v) the short bags are not allowed to move out of the factory; (vi) the produced nano cement will be saved for a long time in the bunkers; and (vii) monitoring of quality of materials shall be ongoing, and plant maintenance and calibration of equipment will be carried out by qualified personnel. The executive of quality assurance (QA) shall check the details of branding on the bags before packing the cement and he/she will be responsible to monitor adherence to all provisions made by the United Arab Emirates Bureau of Standards for various tests. The executive shall also monitor the conditions of various equipment and other provisions. Additionally, he/she shall monitor the mode of sampling by Production Department for testing of various input materials at different stages and make comprehensive report to the General Manager. A continuous communication and feedback from consumers will be maintained to improve the product for future development. A contact channel with experts shall also be established.

The proposed nano cement will be produced to have specific gravity (GS) and specific surface area (SSA) of 2.11 and 3,582,400 cm^2/g, respectively [37]. These properties surpass those of ordinary Portland cement, i.e. GS = 3.15 and SSA = 3112 cm^2/g.

The rate of demand on the product of the project under investigation is based on the product superiority, newness and quality. The rate also depends on the reduction of the imported cement quantities. This can be achieved by working with government bodies to market the cement at a lower price than that of the imported Portland cement. The Planned productivity will be 300,000 t/year (1000 t/day).

4. The costs of the proposed project and revenue

4.1. Capital and annual fixed costs

The capital cost is the sum of the costs of the items which are required for establishment of the new production line. Land, equipment, building and services installation, and furniture represent the main items needed for the proposed project. This cost is payed off during the initial phase of the project and because of its scale, it is considered as a major challenge to deciding the approval

Table 4
Summary of capital costs of the proposed project.

No	Item	Cost (million US$)
1	Land	Available
2	Buildings, water and electrical installations	Available
3	Cost of equipment (ball mill, bunkers, bag filter, laboratory)	9.48
4	Transport, installation and delivery expenses	0.1
5	Furniture	Available
6	Air conditioning	Available
	Total of capital fixed cost	9.58

Table 5
The estimated annual fixed cost.

No	Item	Cost (US$) × 1000	Rate of depreciation	Depreciation cost (US $) × 1000	Annual percentage of maintenance	Maintenance cost (US$) × 1000
1	Land	Available	–	–	–	–
2	Buildings, electrical and water installations	16	5%	0.8	3%	0.480
3	Imported factory (machines and equipment) including setting cost	9580	5%	479	100% of depreciation cost	479
5	Furniture and other inventories	2.5	5%	0.125	5%	0.125
6	Air-conditioning	1.5	10%	0.150	10%	0.150
7	Sum of annual cost			480.07		479.7
8	Annual insurance cost					39.4
9	Total sum of annual cost					999.230

of the project. The cost of tools and equipment is estimated based on the study of Shykun [39]. The estimated total cost of tools and equipment, including setting cost of the new line of production is US$9.58 million as detailed in row 3 of Table 4. The availability of land and building in the existing factory have reduced the estimated capital cost of planned new production line and played as an encouraging factor for establishment of the new line. Building and its services installations, equipment and furniture are the items that will annually depreciate and require maintenance. The rate of depreciation is expected to be 5%–10% as provided by Nasr [40] and the maintenance in the range of 3%-10%. The machine is the main item that governs the cost of depreciation, maintenance and insurance, as can be seen in Table 5. The total annual cost is expected to be 1 million US Dollar as shown in row 9 of the table.

4.2. Variable costs

The total annual variable costs are the sum of administrative, materials and operational costs. The variable cost might vary annually in a range between US$ (41–75) per tonne or remain constant at US$60/t. Details of estimating the components of variable cost are described in the following sub-sections.

4.2.1. Administrative services

The staff who will manage and operate the new production line is composed of three teams: management, engineering and technicians. There will also be a security unit which guards the whole factory. The number of required personnel is given in column 3 of Table 6. The salaries of top management staff and security personnel are paid by the main factory, so the increase in their payments due to additional work is considered in this study. The monthly range of increase in their salaries will be US$100-US$350 depending on the position. The monthly payments of engineers and other employees are listed in column 4 of Table 6. The sum of the annual salaries will be US$ 81,480 as shown in row 6 of Table 6.

4.2.2. Annual costs of materials

The annual volume of production depends on the daily production of the mill. The mill can produce 25–130 t of cement per hour. According to the production plan, the mill will produce 100 t/h. Therefore, the daily production will reach 1,000 t, on assumption that the mill will run 10 h a day (based on the Alkufa factory work condition). Hence, the expected annual production of nano cement will be 300,000 t. The estimated cost of 1 t of nano cement from raw materials is US$58.75, as detailed in Table 3. Thus, the annual cost of raw materials will be US$17625,000/year (1000 T/day × 300 day/year × US$58.75) as provided in row 3 of Table 7.

Table 6
Salaries of the staff.

Staff	Description	No	Monthly salary (US$)	Total salary (US$)
Management unit	General manager	1	350	1200
	Board of directors	3	200	
	Accounts manager	1	150	
	Accountant	1	100	
Engineering unit	Mechanical Engineer	1	770	770
	Civil Engineer	1	770	770
Technical unit	Technician	1	580	580
	Technician assistant	1	385	385
	Skilled workers	2	580	1160
	Workers	5	385	1925
Security	Guards	Available	Available	Available
Total monthly salaries				6790
Total annual salaries				81480

Table 7
Annual variable cost.

Item	Cost (US$)
Administrative services (total annual salaries)	81480
Raw materials	17625000
Operational services	552573
Total annual variable cost	18259053

4.2.3. *Operational services*

The operational services include cost of gas, power and others. The approximate sum of annual operational cost will be US $552,573 as given in row 4 of Table 7.

4.3. *Revenue*

As the product will be new to the market, the suggested price is fixed at US$75 per tonne (less than the current price of cement in the market) or depending on the demand the price would vary from US$90 to US$60. This to make the product competitive with the ordinary Portland cement which is available at a price of $90- $100 per tonne. At the ultimate production rate of 300 thousand tonnes per year, the expected annual revenue will be US$22.5 millions. In the first year, 50% − 75% of production is assumed to be sold, as the product will be new to the market. The whole production is expected to be sold in the subsequent years.

5. Economic feasibility study

Taking into account the time value of money, the following indicators are adopted in the financial and economic feasibility study.

5.1. *Net present value (NPV)*

The net present value (NPV) is defined as the sum of the present value (PV) of incoming and outgoing cash flows over a period of time [41–43]. Based on the current interest rate adopted by the Iraqi banks, and on assumption that the annual cost will remain constant during the period of study, the present value of the costs will inversely vary with time, as shown in Table 8. It will reach its least value at year nine to be US$8167391954 at a discount rate of 10% and US$50095214 at a discount rate of 50%. On the other hand, the annual revenue is expected to be US$11250000 in year 1 and then doubled in year two and stay stable until the end of year 9. At the two selected discount rates, 10% and 50%, the annual revenue will steadily decrease as can be seen in columns 4 and 5 from left in Table 9. It can also be seen that at a discount rate 10%, the difference between total revenues and total cost is positive (US $1009579), whereas at a discount rate 50% the difference is negative (−1390214), as shown in Table 10. This indicates that the project is economically feasible and can make profit.

5.2. *Internal rate of return (IRR)*

One important method of economic analysis is estimating IRR of the investment. It is a discount rate that makes the net present value of cash flows equal to zero [41,44]. Assuming any two values of interest rate, IRR can be calculated by interpolation when net present value equal to zero. On the assumption that the construction period is not more than a year and based on the interest rate of 10% and interest rate of 50%, IRR can be calculated from the data given in Tables 8 and 9. The obtained IRR is found to be 26.8%. This value is considered higher than the discounted rate adopted by Iraqi banks and giving indication that the project profitable.

Table 8
The present value of the cash flow of fixed and variable costs.

Time (year)	Year	Annual cost (US$)	Discounted present value of costs (US$)	
			R 10%	R 50%
0	2016	9580000	9580000	9580000
1	2017	19258283	17507530	12838855
2	2018	19258283	15915936.36	8559236.9
3	2019	19258283	14469033.06	5706157.9
4	2020	19258283	13153666.42	3804105.3
5	2021	19258283	11957878.56	2536070.2
6	2022	19258283	10870798.69	1690713.5
7	2023	19258283	9882544.265	1127142.3
8	2024	19258283	8984131.15	751428.2
9	2025	19258283	8167391.954	500952.14
Total			120488910.5	47094661.73

Table 9
Present value of revenues and savings.

Time	Year	Annual returns (US$)	R 10%	R 50%
0	2016	0	0	0
1	2017	11250000	12375000	16875000
2	2018	22500000	18595041.32	10000000
3	2019	22500000	16904583.02	6666667
4	2020	22500000	15367802.75	4444444
5	2021	22500000	13970729.77	2962963
6	2022	22500000	12700663.43	1975309
7	2023	22500000	11546057.66	1316872
8	2024	22500000	10496416.05	877915
9	2025	22500000	9542196.413	585276.6
Total			121498490.4	45704447

Table 10
Comparison of discounted costs and revenues.

NPV	Discounted cost (US$)	Discounted returns (US$)	Discount rate
1009579.954	120758910.5	121498490.4	10%
−1390214.997	47364662	45704447	50%

5.3. Break − even point (BEP)

It is the point where total cost of a project becomes equal to its revenue; at this point a project neither earns any profit nor it suffers any loss (zero profit point). The point tells how much sales should be made to cover all expenses of the project and at what sale volume the project will start generating profit [41,45,46]. Two scenarios are expected for the form of the relationship between the revenue and the accumulative number units. In the first scenario, a linear relationship of revenue versus accumulative number of units is predicted. Thus, the zero-profit point would be reached in 3 years and the BEP is determined using Equation 1.

$$BEP = FC/(S\text{-}V) \quad (1)$$

Where;

BEP: break – even point; *FC*: total fixed expenses; *S*: selling price of a single unit of product; *V*: variable expenses a single unit of product.

In this project,

FC = US$ 9850000, S = US$ 75/tonne, V = US$ 64.19/tonne

This relationship is constructed on assumption that sale price will remain fixed during the period of study and the production rate at 300000 t/year. So, the *BEP* = 911193 t. This indicates that to make profit, the factory must produce more than 911193 t of nano cement at least for the first three years. Fig. 4 shows the anticipated *BEP* and when the project will start making profit. It appears that at a production rate of 300,000 t/year, the *BEP* will be reached in 3 years.

In the second scenario, the variable cost and sale price of produced tonnes of nano cement would vary annually. The sale price of a tonne of nano cement will inversely vary with demand which will force the price to drop from US$90, the price at which no sale, to

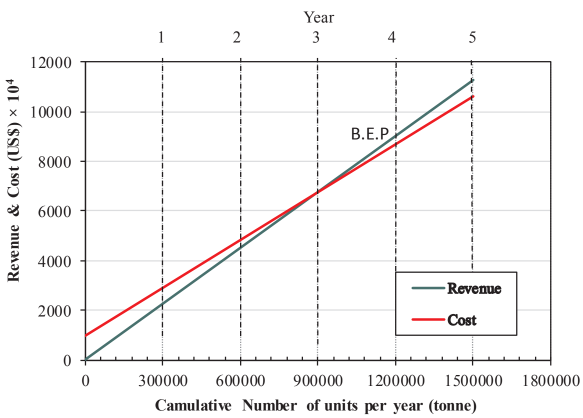

Fig. 4. Relationship of cumulative cost and revenue versus the cumulative annual number of units based on linear analysis.

Table 11
Predicted annual variations of sale price, cost and demand.

Year	Price per tonne (US $)	Cost per tonne (US$)	Demand (tonne)	Cumulative number of units (tonne)	Revenue (US$) × 10^5	Total Cost (US$) × 10^5
0	90	0	0	0	0	98.50[a]
1	80	41.25	220000	220000	176.00	189.25
2	77	42.75	235000	455000	350.35	293.01
3	69	48.75	250000	705000	486.45	442.18
4	65	57.75	270000	975000	633.75	661.56
5	63	67.50	295000	1270000	800.10	955.75
6	60	75.00	300000	1570000	942.00	1276.00

[a] Fixed cost.

$60 where full production capacity of the plant is sold. On the other hand, the variable cost of the tonne will rise from $41 to $75. The variable cost may ascent up due to increase in operation cost, wages of employees and the rising cost of raw materials. The anticipated variations of sale price with production rate are presented in Table 11.

When annual variable cost and sale price vary nonuniformly, relationships are expected to be nonlinear between revenue and total cost with accumulative number of tonnes sold. At the beginning of the production, even the demand rate might start low, the revenue will rise rapidly because of the high price per tonne; however, the corresponding cost will rise steadily. Fig. 5 shows that after a year of production, the cost and revenue curves intersect, i.e. the first BEP is reached. The functions that draw cost and revenue curves can be derived from the data presented in Table 11. The cost function may be expressed by Eq. (2).

$$Q = 3 \times 10^{-10} X^2 + 3 \times 10^{-4} X + 102.20 \tag{2}$$

while the revenue function is given by Eq. (3).

$$R = -10^{-10}X^2 + 8 \times 10^{-4}X + 9.51 \tag{3}$$

Where; Q: total cost; R: revenue; X: cumulative number of units (tonnes)

From Eqs. (2) and (3), the first $BEP = 800000$ t

The increase in profit will continue and may reach its peak after two and a half years. However, the profitability may continue to increase in a decreasing rate because of the drop in sale price. Factors such as low demand, down turn in construction industry, involvement of other competitors in the market and discount offered to clients may force the sale price to drop and hence change the trend of the profit curve. Inversely, the annual variable cost may rise progressively due to increase in operation cost, wages of employees and rising the cost of raw materials. Thus, another BEP is reached beyond which the factory will not make profit anymore. Recalling Eqs. (2) and (3), the 2nd BEP is determined to be 900000 t.

Comparing the two scenarios, the proposed production line can be feasible if the factory maintains its sale at rates above 250000 t annually providing the sale price will not drop below $65 per tonne and the variable cost will not rise above $55.

6. SWOT analysis

The analysis technique that a business organization can perform for each of its products and markets when deciding on the best way to achieve future growth involves strength weakness, opportunity and threats (SWOT) analysis [47]. The strength in this project is that there is ongoing increase in demand for cement due to continuous increase in number of residential units built all over the country and the number of construction projects in most of Iraqi provinces. Statistics of last five years have shown an annual increase

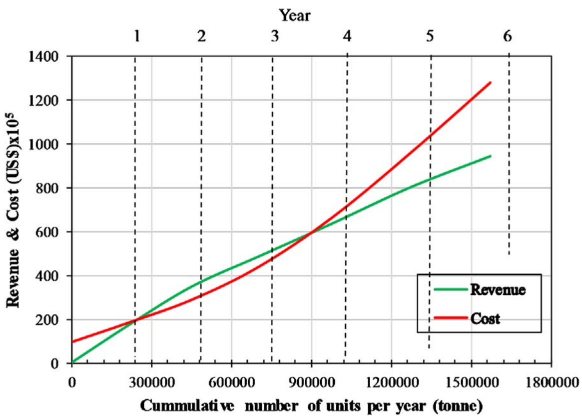

Fig. 5. Relationship of cumulative cost and revenue versus the cumulative annual number of units based on nonlinear analysis.

in demand for cement due to rapid expansion in construction industry [48]. The other strength is that workforce and raw materials are available in the existing factory or nearby. Moreover, there is no such plant producing nano cement in Iraq. Thus, this can also be considered as a strength of this project. However, the difficulty is that since the product is new to the market, consumers would be conservative to buy the forecasted amount of production at the beginning. Therefore, sale rate can be expected to be within 50% of the planned production in the first year. This point has been accounted for in calculations of profitability measurements.

There would also be some risks threating the success of the project. Other competitors may enter the market particularly if the product gained the confident of consumers and became recognised worldwide. Decline in building and construction projects is another threat to the success of the project, as this will be associated with a decline in demand for cement. Other form of risk is seen as the instability of the political situation in Iraq which may lead to fluctuation in dollar exchange rate and hence affecting the sell price. The involvement of another competitor in the business would be advantageous. For instance, the construction of a new plant in United Arab Emirates at the end of 2016 will likely increase demand for the product through the promotion of the new product in the market. In addition, the market is growing fast, so the existence of other competitor would have insignificant effect on the sale rate of the proposed product. In the foreseen future, construction industry is expected to keep growing in Iraq because of the desperate need for reconstruction and renovation of what have been destroyed by war. The planned production can be increased by introducing new technology as a result increasing sale and profitability.

7. Conclusion

The results of this study confirms that the establishment of nano cement production line within existing cement factory is feasible. The new product can reduce the unit price of cement by US$25 and improve the quality of the cement.

The calculated NPV, IRR and BEP indicate that the proposed project is feasible with the advantage of low risk. Considering the project is sensitive to the inflation rate, increasing the cash flow by 1% will lead to rise in IRR to reach 28.5% or more. Hence, the project is economically feasible. As the expected IRR is 26.8%, there will be encouragement for the establishment of the project. It was also determined that from calculation of the breakeven point, the factory can make a profit if the sale rate is at least 250,000 t per year. The payback period is between 1 and 3 years. In addition, the current demand for cement gives a strong indication that all of the produced quantity will be sold.

In order for the project to be profitable, the proposed production line should sell an amount of nano cement larger than 800000–900000 t. This means that the production line starts to make profit, approximately, when its production reaches 17.3% of the planned productivity within 1–3 years. The use of nanotechnology can increase the annual volume of cement production without construction of new cement plants.

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