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Integrated performance enhancement in the cement industry

Given the disparate nature of the emerging cement scenarios in the MENA region, success and even survival depends on the ability to adapt. Most companies have consequently initiated focused efforts covering various aspects of their cement operations. While conventional focus may yield marginal to moderate results, incremental benefits can be reaped by harnessing the multi-functional dimensions of all internally controllable variables through an integrative approach. From ingeniously exploiting the hidden potential of the raw material portfolio to uncovering untapped value in the geographic market mix, innovative initiatives in the entire value chain of operations results in far higher success.

The key features of such initiatives include ensuring comprehensive coverage of the entire value chain, a focus on bottom-line results, exploration of the potential of non-conventional areas, adding value to on-going initiatives in terms of time and cost savings, use of optimisation tools to achieve superior solutions and employing a three-phased approach consisting of assessment, action and monitoring.

The MENA region as a whole is characterised by high per capita consumption of cement, over 700kg/capita/yr in 2010. With its 327 million inhabitants this dwarfs the world's average consumption of 400kg/capita/yr.

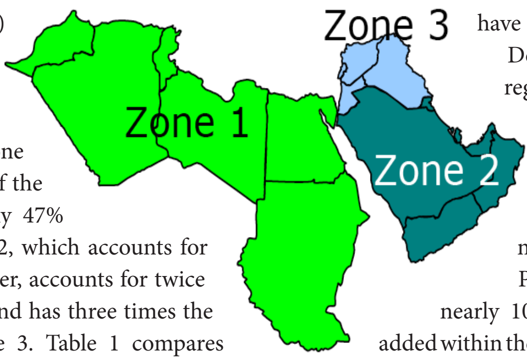
The MENA region can be considered to consist of three zones as depicted in Figure 1. Zone 1 consists of the countries of North Africa and Sudan, Zone 2 consists of the Gulf Cooperation Council (GCC) and Yemen and Zone 3 consists of Lebanon, Jordan, Syria and Iraq.

Zone 1 is the largest zone with 62% of the population of the region, but accounts for only 47% of the cement market. Zone 2, which accounts for 18% of the population however, accounts for twice the consumption of Zone 3 and has three times the production capacity of Zone 3. Table 1 compares the population, market size, supply capacity of the three zones.

The region (especially the GCC) has seen unprecedented growth in the last five years. About 108Mt/yr of production capacity has been added in the region. Table 2 compares the capacity additions in the three zones in the last five years.

Zone 2 accounted for the lion's share of this capacity increase, with over 60% of the increase happening in this region. Zone 1 and Zone 3 share the balance almost equally. Though the demand growth also kept up with most of this increase, the events of the recent past have led to some distinct demand supply imbalances.

Zone 2 is clearly in surplus while Zone 1 is mostly in deficit. In Zone 3, Iraq is deficient in terms of cement while other countries have a surplus of cement.



Left - Figure 1: The MENA region can be considered to be split into three zones.

Despite the setbacks to the region's economies in the recent past, the growth outlook for the future is positive and most producers are gearing up to meet the growth challenge.

Production capacity of nearly 100Mt/yr is expected to be added within the next five years. Most of this addition is expected to be in Zone 1, with over half the new projects being planned there. Zone 2 and Zone 3 are expected to have equal shares in the new capacity addition. Table 3 shows the expected capacity increases to 2015.

Looking at the envisaged capacity additions with the expected growth in demand in this way reveals that the demand supply imbalances may well be carried over into the future, though the intensity of the

	Population		Market		Capacity	
Zone	Millions	%	Mt	%	Mt/yr	%
1	201	62	109	47	102	42
2	64	19	84	36	108	44
3	62	19	38	17	36	15
Total	**327**	**100**	**231**	**100**	**246**	**100**

Below left - Table 1: Comparison of population, cement market size and installed capacity of the three zones within the MENA region.

Zone	Capacity (2005)	Increase	Capacity (2010)	Share of increase (%)
1	83Mt/yr	19Mt/yr	102Mt/yr	18
2	40Mt/yr	68Mt/yr	108Mt/yr	63
3	14Mt/yr	21Mt/yr	36Mt/yr	20
Total	**327Mt/yr**	**108Mt/yr**	**246Mt/yr**	**100**

Left - Table 2: Comparison of capacity additions for the three zones of the MENA region between 2005 and 2010.

challenges faced may differ between countries.

To complicate matters, other issues like the removal of subsidies on fuel and power, stricter environmental requirements and pollution controls and government control over exports or prices may make it even more difficult for the industry in some parts of the region. This implies that piecemeal approaches to solve problems as and when they occur is unlikely to solve the larger issues facing the industry.

Thus, an enhanced, continuing focus on controllable variables becomes absolutely imperative to remain competitive and profitable. The actions that must be taken by producers operating in markets with cement deficits may vary from the actions of producers in surplus markets, but an integrated approach to enhancing performance is imperative for the best results for those in either situation.

Zone	Capacity (2010)	Likely increase	Capacity (2015)	Demand forecast for 2015
1	102Mt/yr	52Mt/yr	154Mt/yr	159Mt/yr
2	108Mt/yr	24Mt/yr	131Mt/yr	118Mt/yr
3	36Mt/yr	24Mt/yr	59Mt/yr	65Mt/yr
Total	**246Mt/yr**	**100Mt/yr**	**346Mt/yr**	**342Mt/yr**

Above - Table 3: Comparison of likely capacity additions for the three zones within the MENA region in the period to 2015.

Integrated approach

Realising the need for continuous improvement as a means of retaining a competitive edge, most cement companies have initiated on-going programs covering various aspects of cement operations. This focus on continuous improvement has yielded fairly good results, with a number of key performance indicators showing improvement. However, a structured approach that addresses the issues previously mentioned, will significantly complement these continuous improvement initiatives.

Integration can only be ensured if the entire supply chain is included in the scope of coverage. The term 'supply chain' here refers to the entire process by which inputs are converted into outputs and supplied to the final customer. It also includes auxiliary input flows into the system and auxiliary output flows out of the system. The following issues are important to note:

- The supply chain consists not only of plant operations but encompasses suppliers on one end and the customer at the other.

- The supply chain consists not only of the physical process of production but also includes the other practices such as procurement and inventory policies that go with the manufacturing process.

Improvement initiatives also need to be holistically integrated in terms of the different functional skills that are required to obtain optimal improvements. For example, a change in the raw mix can influence things such as the cost of raw materials, the cost of the fuel required to calcine the new raw materials, the cost of the power used for grinding due to different raw materials and clinker characteristics, the cost of consumables such as refractories, grinding media and lining plates, equipment output rates, ease of operation and the life-span of the relevant raw material deposits.

Some of these factors may have a positive effect on cost reduction and some negative. The choice would therefore be to select the most optimal from a host of distinct options.

Focus on the bottom-line

Not only is it important to improve the physical parameters with regard to mechanical performance, it is equally important to seek reduction in costs and an increase in revenue. The use of less expensive substitutes such as pozzolana, slag and RDF and technological improvements such as power factor reduction and material handling improvements can also be appropriately investigated to help with cost reduction.

Other than just 'de-bottlenecking,' areas such as enhancement of workforce productivity and realisation of latent equipment capacity can benefit from innovative intervention policies.

In the case of revenue, the use of an optimal market access strategy as well as a well-formulated product mix can be extremely effective in order to realise a higher return for every unit shipped. Even in the case of the cement industry in the MENA region, significant gains from optimising distribution and product mix strategy have been demonstrated.

Non-conventional areas

The improvement initiatives in the MENA region's cement industry have largely been restricted to conventional areas for cost reduction. Areas that have so far not been fully optimised include:

- **Outsourcing** - Apart from allowing management to concentrate efforts in more important areas, outsourcing of non-core activities has significant cost-reduction implications. While some traditionally outsourced areas include security, catering, packing and transportation, there are further areas such as maintenance, workshop facilities and quarrying (other than blasting) where outsourcing is possible.

- **Overhead reduction** - On average, in Saudi Arabia overheads contribute nearly 20% of the total cost of cement production. To date not enough attention has

Below: New constructions such as the Atbara Cement Plant in Sudan were the exception rather than the rule between 2005 and 2010. Only 18% of cement capacity addition in the MENA region was in Zone 1 countries during this period.

been paid towards arresting costs in this area. Data shows that roughly 40% of these are administrative overheads whereas 60% are factory overheads. Even a 5% reduction could yield an annualised average saving of over US$0.9m for a 1Mt/yr cement plant. Rental values, insurance rates, working capital interest, waste elimination and streamlining of administrative processes are all areas that need to be closely studied to help unleash savings.

Value additions in on-going initiatives

Experience shows that to preclude 'in-box' thinking, external assistance in even on-going bottom-line improvement schemes has tremendous potential for value-addition. In-company personnel often get acclimatised to a constraint-based approach, rather than an opportunity-based one. Value additions can be effected in any or more of the following three areas:

• **Costs of implementation** - Given external experience in diverse environments, savings can be made in terms of both capital as well as revenue expenditure associated with improvement projects. Numerous examples are available how fine-tuning of existing equipment can eliminate the need for capital-intensive capacity augmentation.

• **Time of implementation** - Implementation times for improvement projects have also been dramatically cut down through external intervention. This has helped not only in realising benefits faster but also in reducing extremely expensive downtime.

• **Bold targets** - Indicators set for improvement targets have also been seen to suffer on account of both 'in-box' thinking and conservative tendencies. External intervention often helps in establishing and achieving bolder targets.

Use of optimisation tools

The use of optimisation tools in the MENA cement industry has been negligible to date. Experience has shown that the usage of allocation models, replacement and maintenance models, inventory models, queuing models, sequencing and co-ordination models, network models, (non-)linear programming models and search models for decision making have significantly facilitated initiatives such as those discussed here.

The usage of these models in various application areas generally consist of six interdependent steps, namely problem formulation, model construction, data assimilation, solution derivation, model testing and solution implementation. Several companies in the developed world now also include operational research practitioners in their continuous improvement project teams.

Structuring the system

In terms of setting up a system to make improvement initiatives a perpetual way of life, two issues need to be addressed in parallel:

1. Organisational structure

Those with analytical and knowledge-related strengths should constitute the core organisational structure for ensuring continuous improvement. This team itself can be segregated according to an Ishikawa-like fish-bone structure. It has been seen that such a structure is most amenable for problem analysis as well as knowledge management.

The full-time responsibility of the core team would be to shortlist improvement projects in consultation with senior management, harness external expertise where required, subject each identified improvement project to rigorous analysis and postulate problem-solving recommendations. It would also be responsible for managing knowledge by storing information and making this available to the rest of the company. Members from the operations framework of the company would jointly participate with select members of the core team in the action phase in which improvement projects are actually implemented.

2. Initiative planning

Structured planning is vital to preclude the possibility of errors in area choice and effort repetition. Experience shows that the initiatives most likely to produce expected results are those that have been meticulously and holistically planned. Companies that have a good track record of implementing improvement initiatives follow three distinct phases:

1 - Assessment phase - This is the starting phase in which short-listing of initiatives is first done using pre-set criteria. Relevant data is collected, analyses are completed and improvement potential identified both in terms of physical and cost parameters. Implementation plans are constructed and resource requirements are specified. Depending on the size of the company or plant as well as its current status in terms of implementing improvement initiatives, the assessment phase can extend over a period of two to four months.

2 - Action phase - This is the phase in which, as the name itself signifies, implementation is actually done. As has been already mentioned in the previous sub-section on an organisation's structure, personnel from plant operations as well as external experts assist the core team as part of improvement projects in executing the action phase.

Since the realisation of benefits may require a change in operating practices, the implementation phase may also include training when required. The output of this phase is the actual improvements effected along with the management system to measure and ensure the longevity of the improved performance. Depending on the number of sub-projects taken up in the first portfolio, the action phase can extend over a period of nine to 24 months.

3 - Monitoring Phase - This phase refers to the tracking of the actual improvement caused by the action phase through the management system. Statistical analysis as an interpretative tool is rigorously employed to preclude the possibility that the improvement occurred due to chance. Modification and mid-course corrections are also considered during this phase to ensure that the improved performance stays on track. It is observed that this phase normally runs over a period of three to six months for each sub-project group.

Case study

The structured approach proposed in this article has been applied in various cement plants in the international environment. In one such comprehensive application, Holtec Consulting Pvt. Ltd (Holtec) carried out a performance enhancement study in a cement plant in the MENA region.

Above: Construction of a cement plant in Tahama in Saudi Arabia (2009). Zone 3 countries (which include Saudi Arabia) will see combined cement capacity additions of around 24Mt/yr in the period to 2015.

At the time of study, the plant was operating at a clinker production level of about 6100t/day. The average specific fuel consumption and specific power consumption at the time of study were about 790–800kcal/kg clinker and about 107kWh/t cement respectively.

Plant details

The plant's main machinery included an impact crusher for limestone, a corrective crusher for red clay, sand stone and iron ore, an additive crusher for gypsum, a vertical roller mill for raw material grinding, a dry process kiln with twin string preheater, an inline calciner consisting of smoke chamber with burner and mixing chamber, a grate cooler and a two chamber closed-circuit ball mill for cement grinding.

Findings and recommendations

A diagnostic approach in the study was supported by online process measurement. Comprehensive discussion with plant executives helped in understanding the operational constraints. After a detailed study, several improvement measures were recommended for performance enhancement. The potential capacity of the plant was assessed to be 6750t/day clinker with some investment. Some of the recommendations given to achieve this capacity improvement and also reduce costs are given below:

Mining - The quarry was found to have high magnesium (MgO) limestone below the cement-grade limestone. This could be mixed with cement-grade limestone. Two benches at two different locations were developed, one each for limestone and MgO limestone. A raw mix was designed considering the use of blended limestone and use of clay, iron ore and sand stone as correctives. A limestone reserve of 176Mt was available, but the reserves could be enhanced to 224Mt with judicial blending of high MgO limestone. With the use of blended limestone, the life of mine was increased from the estimated 39 years to over 50 years.

The drill rate and powder factor were improved and fuel consumption in excavator and dumper was reduced by rationalising mine operations.

Raw material grinding - Raw material grinding was optimised by properly balancing the hot-gas flow through the mill, improving the functioning of the mechanical flaps and air lock system, removing the damper at the raw mill/kiln bag house fan inlet to reduce pressure drop and optimising the particle size of the raw mill feed by modifying the crusher.

Pyroprocessing - All the weighing equipment including kiln feed flow meters, oil flow meters and cooler fan piezo rings were calibrated for improving accuracy.

The frequency of 'snowman' formation in the clinker cooler was reduced by raw mix optimisation. The operating volumes of the cooler fans installed in the static grate and first chamber were increased and the cooler grate speed was optimised to improve cooler recuperation efficiency. The cooler recuperation efficiency was improved from about 60% to about 70%. The kiln hood draft was maintained between -5mmWG and -8mmWG by the cooler ESP fan.

Dust extraction apparatus was installed in the preheater exhaust gas bypass duct to the raw mill bag house. To ensure the desired temperature at higher kiln capacities, a damaged dilution air fan in the raw mill bag house inlet was repaired.

Cement grinding - Cleaning of the mill diaphragm and central screen at regular intervals during scheduled maintenance and improving the functioning of mechanical flaps at mill discharge was recommended for efficient operation. To increase the mill capacity, the following recommended actions were implemented. The classifier speed and fresh air damper position were optimised to reduce dynamic classifier rejects. A separate mill discharge air slide venting line was installed to reduce air-slide air quantity to the mill outlet. The grinding media charge was optimised by analysing the grinding path. A proper venting system was installed for mill feed belt conveyor discharge hood and mill discharge air-slide.

A water spray system was installed to control the mill's internal temperature and the high-pressure oil pump for a slide shoe bearing was replaced. A duct connecting the cement mill classifier to the bag filters was modified to improve gas distribution.

The improvement measures that did not need any investment were implemented immediately in a planned manner in Phase I. Subsequently, the recommendations with nominal investment were planned for execution in Phase II. The following achievements were possible in unit operations:

• The raw mill capacity was increased from about 450t/hr to about 480t/hr. Additional capacity increase to about 530t/hr was possible after Phase II.

• Kiln capacity increased from 6100t/day to 6300t/day. This could be further increased to 6750t/day.

• Specific fuel consumption decreased from 795kcal/kg of clinker to 770 kcal/kg of clinker. After phase II this could be further reduced to 729 kcal/kg of clinker.

• The cement mill capacity was increased from 135t/hr to 145t/hr. This could be increased to as much as 160t/hr. With the above recommendations, the reported power consumption of 107kWh/t of cement could have been reduced by 5–10kWh/t of cement. However, no special efforts were made to reduce the specific power consumption as the cost of power was very low in the country where the plant is located. Moreover, the plant operational consistency improved substantially and as a result annual production increased significantly. Savings in terms of thermal energy were possible with only minor investment.

Market

The performance enhancement in the plant resulted in a higher volume of cement that needed to be sold. This necessitated improvements in the plant's marketing process. The current market of this cement producer consisted of three geographic regions, Region 1 which was the core market in which it was located, Region 2 which was an adjacent cement-deficient region and Region 3, exports. Exports were recently subject to a conditional ban, which stipulated domestic prices if exports were to be continued. The ex-factory realisation would fall by 20% if exports were continued, so the company had to divert its export volumes (in addition to the extra production) to the domestic market, if possible without lowering realisation.

To offset the adverse effects of halting exports, a new region was targeted in the domestic market. Region 4, though distant, had higher prices and was likely to remain as a cement deficient region in the long run. The distribution mix in the regions was optimised for maximising returns using measures of competitive advantage and market attractiveness.

Product mix optimisation

Product mix optimisation was conducted to determine how much of each of the plant's products should be made. The product mix in Region 2 included blended cement but a full cost-benefit analysis revealed that the costs of its production did not warrant the additional revenue it brought the company. The product mix was limited to OPC and sulphate-resistant cement only.

Bagged cement was considered as a distinct product from bulk cement in the product mix optimisation exercise. Thus, the exercise also derived the bag : bulk ratio. The distribution mix had yielded the market-imposed constraints for the exercise.

Product mix optimisation helped achieve a saving of US$1.13m without any additional investment. A forward integration strategy into the ready-mix concrete (RMC) business was recommended as it would give a closer reach to the end customers and improve sales volumes and overall realisations even when there is a surplus situation in the plant's core market.

Other cost-reduction measures

Overheads - The inventory carrying costs for 'fast-moving items' were reduced by modification of re-order cycle and order size. Analysis and simulation of the demand of operating and breakdown spares over a 10-year period helped to rationalise inventories of spares and consumables. The stock of in-process material and finished goods could be optimised using statistical techniques. This has lowered the working capital requirements and hence financial costs have dropped.

Transportation and logistical costs - These costs were influenced by the redistribution as well as by the changes in bag : bulk ratio. They could also be renegotiated lower by reducing the truck waiting time at the dispatch department by simulating the queuing process and vary the queuing discipline and service factor.

Conclusion

While there are considerable savings achievable through using a focused approached towards plant operations, the minor investments required appear to be unviable at first glance, especially when it implies increased output in a surplus market. However, when the integrated approach looks at the broader picture, the investments are not only viable, but necessary. By using an integrated approach the potential average savings are US$12.32m/yr.

The plant being referred to in this case is located in a country where power and fuel costs are fairly low and hence there is little justification in an investment to further reduce heat consumption to 729kcal/kg. Similarly, producing blended cement which reduces specific fuel consumption by reducing the clinker ratio is not justified.

Perhaps in another country, in which power and fuel costs are much higher, the investments to further reduce heat consumption and production of blended cement could be justified.