Lean Six Sigma for Cement Processes - CemLean6S

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Abstract

Improvement philosophies like Total Quality Management, Six Sigma, Lean Production, Lean Management and Lean Six Sigma are frequently used in many businesses. The reported use of these philosophies within cement manufacturing is still scarce. This is somewhat surprising since cement manufacturing as a process industry operates with large numbers of data and handles large value streams where waste could occur. This should make cement manufacturing a suitable area for a number of improvement methodologies. This paper uses a model for describing quality philosophies consisting of the elements of purpose, principles, methodologies, tools, roll-out and improvement management processes. This model is then used for a proposed interpretation of Lean Six Sigma. The generic model is then further developed to a proposed model for Lean Six Sigma for cement manufacturing – CemLean6S

Keywords
Lean Six Sigma; Cement manufacturing; Customised improvement; Shared value; Environment; Carbon emissions

1. Introduction

Pressure on improvement is high in most businesses. Different improvement philosophies have been tested and analysed during the last 30 years. With the entry of the Japanese industry on the world market in the 1970s focus was on what has been called Total Quality Management (TQM). Other similar quality and improvement philosophies include Six Sigma, Lean Production, Lean Management and Lean Six Sigma. The ISO 9000 family of standards could also be seen as a strategy for quality improvement. World wide there are more than 1.1 million certified quality management systems based on ISO 9001 (ISO, 2012). Apart from the use of ISO standards the reported use of different quality and improvement philosophies within cement manufacturing still appears scarce. Globally cement manufacturing is an important business with considerable production value and huge numbers of data, which should make it well suited for a philosophy such as Lean Six Sigma. Cement manufacturing also has a significant carbon footprint. General estimates are that some 5% of man made carbon emissions originate from cement production (WBCSD, 2002). These emissions are likely to put focus on value creation in order to improve the ratio of building value per carbon footprint. Creating conditions for affordable housing represents a social value that to some extent could balance the high carbon footprint. This could be seen as an example of what is called shared value (Porter and Kramer, 2006; Porter and Kramer, 2011). The idea is that profits can be maximised by focusing on shared value creation. For the cement industry there should be good opportunities for this since there is a great need of providing better housing conditions, especially in the developing world where cement building value per price paid could be considerably improved (Isaksson, 2005). This paper presents a literature review on the reported use of different improvement philosophies in cement manufacturing.

Even if improvement philosophies are often claimed to be generic there could be an advantage in customisation. Improvement philosophies such as TQM, ISO 9000, Six Sigma, Lean and Lean Six Sigma have important similarities. Dahlgaard and Dahlgaard (2006) claim that: “It is shown that the lean production philosophy and the Six Sigma steps are essentially the same and both have developed from the same root – the Japanese TQM practices”. Lean Six Sigma claims to have combined the best parts of variability reduction in Six Sigma and the reduction of waste and increased speed in Lean (Atmaca and Girenes, 2011; George, 2002). There are also many common elements in the mentioned quality philosophies (Fredriksson and Isaksson, 2014). It seems that when focus changes from one philosophy to another the better functioning elements from the previously used philosophies are retained. Lean Six Sigma supposedly combines the best of Six Sigma and Lean. Generally it should be of value to customise improvement philosophies for the business in question. One area of interest is Lean Six Sigma and the customisation of it for the cement industry and cement processes. In order to do this we first need to describe our starting point with a proposed generic Six Sigma philosophy. This could be done also considering the inclusion of the most important elements from TQM, ISO 9000 and ideas from the shared value approach. This paper proposes a model for generic Lean Six Sigma and a model customised for cement manufacturing - CemLean6S.

2. Methodology

To establish the current level of research on quality and improvement philosophies and cement manufacturing, searches have been carried out in the databases Scopus, Web of Science and Google Scholar. We have used the search term “Cement manufacturing” in all fields (Scopus) and topic (Web of Science). Within these findings we have then searched for

“TQM”, “ISO 9000 OR ISO 9001”, “Lean” and “Six Sigma” to assess the number of hits and to find relevant articles. In Scopus we have also searched for “Lean Production” and “cement” and on Google Scholar for “Lean Six Sigma” and “Cement production”.

Based on a literature review we describe important elements in Lean Six Sigma. This retrieved information is fitted into a model describing quality philosophies with the elements purpose, principles, methodologies, tools, roll-out process and steady state management process (Fredriksson and Isaksson, 2014). The roll-out process for the generic Lean Six Sigma philosophy and the management process are not studied in this paper, but are discussed for CemLean6S. The model is used to identify key elements of general Lean Six Sigma, see Figure 1. When defining the Lean Six Sigma for cement processes – CemLean6S – we start from the practice. We start by defining the overarching y-value of cement manufacturing in terms of value creation and resource use. For doing this we use the process approach and a chosen process notation based on Isaksson (2006) and Isaksson et al. (2010). With a defined y-value we are able in the cement manufacturing context to identify methodologies that can be used to control the y-value. We also discuss the roll-out and management processes. This is done using the cement technology expertise and change management expertise of the authors and by applying some reverse engineering by externalisation of tacit knowledge into the Lean Six Sigma format. In order to exemplify the work we focus on the process of cement milling. This is an important sub-process in the integrated cement factory that converts limestone and other raw materials into cement for dispatch, see Figure 2. Based on typical methodologies for improvement work in cement milling we identify important principles and tools. We discuss the stages of the Six Sigma DMAIC process to describe how y-values and x-values are defined and how they could be worked with.

3. Lean, Six Sigma, ISO 9000 and TQM in the cement industry

Search on “cement manufacturing” in Scopus and Web of Sciences resulted respectively in 1456 and 197 hits, see Table 1.

Table 1. Search results for cement manufacturing and quality philosophies.

Database	Search word	All fields	AND ISO 9001 or ISO 9000	AND TQM	AND LEAN	AND Six Sigma	AND "Lean Six Sigma"
Scopus (all fields)	"Cement manufacturing"	1456	2	2	4	0	0
Web of Science (in topic)	"Cement manufacturing"	197	0	0	0	0	0

Source: Literature search by authors

Only a few articles were found. None of the hits in Table 1 were found relevant in describing how to work with Lean or Six Sigma in cement manufacturing. Since there were more hits in Scopus and as we are concerned with production we used the search term “Lean production” for Scopus and received 5822 hits but only 32 when combined with the search world “cement”. Of these 32 articles only two actually dealt with cement manufacturing, but not in a relevant way for our study. In Google Scholar we got 8 hits for “Lean Six Sigma” and “Cement Manufacturing”. Again only two were relevant to the cement industry. One deals with Six Sigma in supplier selection (ul Haque, et al. 2010) and the other with energy management across different industries (Espindle, 2011). The conclusion is that there is little written in academic texts about how quality philosophies could be applied in cement manufacturing and nothing that we have found which would describe Lean Six Sigma in the cement industry. This indicates that in order to develop Lean Six Sigma for cement manufacturing we could base it on general Lean Six Sigma and then customise it.

4. Describing Lean Six Sigma

Lean Production and Lean Management are based on the Toyota Production Systems (TPS). Liker (2004) has made an interpretation of the TPS and describes "The Toyota Way" with 14 principles. These 14 principles are divided into four groups with "Right process will produce right results" including seven principles. These seven principles deal with the elimination of waste (muda). Elimination of waste forms an essential part of the Lean philosophy. From now on we use the word Lean to describe Lean Production, Lean Management and the Toyota Way. Atmaca and Girenes (2011) state that: "Lean Management focuses on eliminating loss in process and reducing the complexity". Lean could be seen to work for speed and waste elimination. The Six Sigma philosophy launched by Motorola in 1987 has a clear focus on reducing variability (Magnusson et al., 2003). Fredriksson and Isaksson (2014) interpret the purpose of Six Sigma as variability reduction, see Table 2.

Table 2. Purposes of different quality philosophies.

TQM	**Six Sigma**	**Lean**	**ISO 9000 standards**
Increasing customer satisfaction with the same or reduced amount of resources	Reducing variation	Reducing waste	Enhancing customer satisfaction

Source: Fredriksson and Isaksson (2014)

ISO 9000 has a leadership principle called "System approach to management", which could be related to focus on all stakeholders in the studied system. This again links to the shared value concept where focus is on creating stakeholder value while maximising shareholder value (Porter and Kramer, 2006; Porter and Kramer 2011).

We propose the following purpose for our interpretation of Lean Six Sigma as: "Maximising stakeholder value creation by minimising waste and variation, while respecting minimum requirements for all stakeholders". The principles that support this could be extracted from Lean and Six Sigma with some additions from other quality and improvement philosophies. Fredriksson and Isaksson (2014) have identified core principles for some quality philosophies, see Table 3. They interpret a number of Lean principles as methodologies, or how things are done. The list for Lean principles is therefore somewhat shortened. We use Table 3 as a starting point to identify our proposed principles for Lean Six Sigma.

Without top management commitment it is hard to envisage organisational success. The principle proposed is: "Top management commitment to the philosophy, purpose and principles". In a resource-constrained economy not everybody can get all of the things they want. Customer focus could be seen as the wants and needs of customers (Garvin, 1984). Priority should be on needs, but without ignoring wants. Customers could be considered as one of many stakeholders, even if with certain priorities. We propose here the principle of: "Focus on stakeholder needs". The focus on particular stakeholders, like customers is handled with the different methodologies employed, where companies can decide the priorities.

Table 3. Identified principles for TQM, ISO 9000, Lean Management and Six Sigma.

TQM	ISO 9000 standards	Lean Management	Six Sigma
Committed leadership	Leadership	Grow leaders who thoroughly understand the work, live the philosophy and teach it to others	Top management commitment
Focus on customers	Customer focus		Stakeholder involvement
Focus on processes	Process approach	Working with processes	Focus on processes
Base decisions on facts	Factual approach to decision making	Make decisions slowly by consensus, thoroughly considering all options	Base decisions on facts
Improve continuously	Continual improvement	Continuous improvement (kaizen)	Continuous improvement
Let everyone be committed	Involvement of people	Respect your extended network of partners and suppliers by challenging them and helping them improve	
	System approach to management		
	Mutually beneficial supplier relationships		
		Base your management decisions on a long-term philosophy	
		Implement decisions rapidly	
		Become a learning organisation	

Source: Fredriksson and Isaksson (2014)

The process, or in other words the network of activities, is the one that delivers value to customers. All quality philosophies in Table 3 identify focus on processes. We choose the principle of: “Work with processes”. In Table 3, “basing decisions on facts” is also mentioned by all studied philosophies. Our interpretation of this is: “Factual approach to decisions making”. Decisions occasionally need to be done quickly while relying mostly on gut feeling. However, this should be the exception, not the rule. Systems should be in place which assure the availability of all relevant factual information. This information, which should be as factual as possible, should be used. Lean Kaizen is mentioned as an example of continuous improvement. Kaizen is often seen as continuous incremental improvement. The Six Sigma philosophy with project-based improvement is more like the stepwise improvement called kaikaku in Japanese. Joseph Juran called this breakthrough improvement. Both of these are needed in continuous improvement. Our proposal becomes: “Continuous incremental and breakthrough improvement”. As soon as an improvement activity is considered to be a project we label it as breakthrough improvement. Continuous improvement is handled as part of ordinary work. We believe that quality and improvement work should be part of everybody’s work to make it effective. The proposed principle is: “Work for making everybody committed in the system”. This reflects a belief that everybody should be committed. Letting everybody be committed implies that this is optional. We believe that systems focus is important and therefore propose: “Systems approach to management”. Our proposed purpose is about stakeholder value creation. This obviously should be in the long term avoiding shortsighted sub-optimisation. We therefore propose to include the Lean principle: "Base your management decisions on a long-term philosophy".

Table 4. Proposed principles, methodologies and tools for Lean Six Sigma

Principles	**Methodologies**	**Tools**
Top management commitment to the philosophy purpose and principles	Demonstrating commitment to all principles in decision making;	Routines for Genchi Genbutsu (go and see for yourself and Management By Walking Around (MBWA)
Focus on stakeholder needs	Carrying out stakeholder communication Working with stakeholder surveys Working with adapted Quality Function Deployment (QFD) Reducing waste in the system	Different matrices supporting QFD. Question checklist Modified house of quality Checklist for waste
Work with processes	Value flow analysis (this links to all of the seven types of waste: overproduction; waiting, time on hand; unnecessary overprocessing; incorrect processing; excess inventory; motion; and defects (Liker, 2004) Process Management Reducing process variation Benchmarking Process analysis Working with process capability Working with Statistical Process Control (SPC)	Tools could be such as rules for JIT (Just in time), Heijunka (evening out production), Jidoka and Poka Yoke (foolproofing), Process maps Capability indices SPC-graphs; SPC software
Factual approach to decisions making	Collecting facts Analysing and organising numeric data Analysing and organising verbal data Risk management	System for organising reports and data; 7QC tools (most of them, Bergman and Klefsjö, 2010); 7 Management and planning tools (Bergman and Klefsjö, 2010) FMEA models
Continuous incremental and breakthrough improvement	Working with Kaizen Working with DMAIC	DMAIC checklist and breakdown
Work for making everybody committed in the system	Employee training; Employee participation in improvement work; Involve key players	Training schedule List of key players
Systems approach to management	Working with process based system modes	System models; System KPI
Base your management decisions on a long-term philosophy	Working with long range plans	

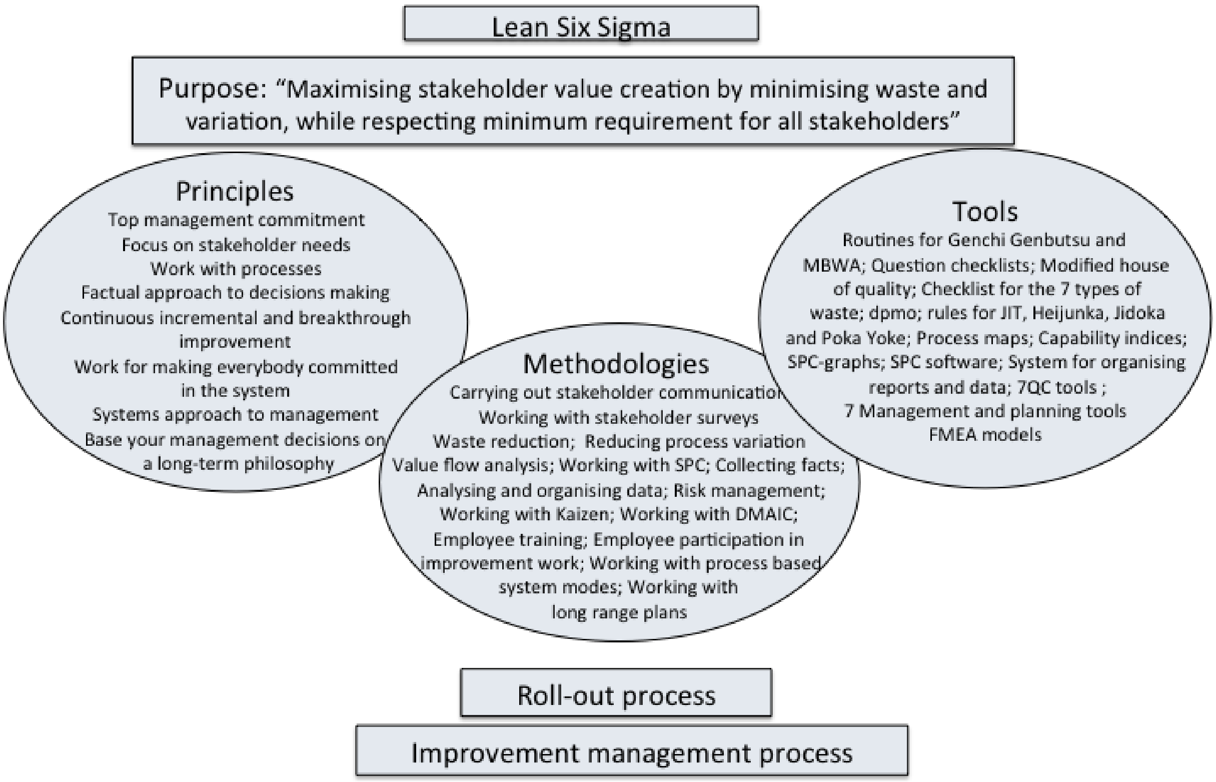
Source: Proposal of principles, methodologies and tools by authors

We have excluded three principles that are included in Table 3. We believe that the principle: "Mutually beneficial supplier relationships" could be included in "Focus on stakeholder needs". The principle: "Implement decisions rapidly" could be seen as part of the general continuous improvement. The principle: "Become a learning organisation" is excluded for the moment, since the meaning of it depends on how a learning organisation is defined, which is a complex issue requiring further research. We believe that for a start the chosen eight principles will enable us to define Lean Six Sigma, see Table 4. Based on the principles identified and input from quality philosophies we identify typical methodologies and tools. Focus here is on identifying methodologies. The methodologies and tools proposed should primarily be seen as examples.

5. Modelling Lean Six Sigma

The working definition for Lean Six Sigma is interpreted based on a model that describes the main elements of a quality philosophy (Fredrikssona and Isaksson, 2014). This model originates from others describing a quality management system as consisting of a purpose, values, methodologies and tools (Hellsten and Klefsjö, 2000), see Figure 1.

Figure 1. Model for describing elements in an improvement philosophy applied for Lean Six Sigma. Note that the number of methodologies and tools, due to presentation practicality, has been slightly reduced compared to Table 4.



Source: Proposal based on Fredriksson and Isaksson (2014).

Values in the model proposed by Hellsten and Klefsjö (2000) could be seen as agreed principles in the organisation, which could be such as customer focus and focus on processes. We have retained the expression principles also used by Dean and Bowen (1994). Methodologies are ways of working and could be such as carrying out risk analyses, working with process management and organising quality circles. We describe a tool as a noun. Tools which could be used include checklists, process map templates and computer programs. Elements that have been added to the model by Hellsten and Klefsjö (2000) are the roll-out process that is used for introducing the philosophy and the management process of the philosophy in the steady state. The logic for this is that with clear roll-out and management processes the risk for changing the original philosophy increases. As an example the Six

Sigma philosophy has more details on roll-out and management than for example TQM (Fredriksson and Isaksson, 2014).

Based on the principle of process approach we need a way to describe the organisational system or parts of it with a process. For this we use a basic division of processes in management, main and support processes and a notation for resources. An example of the approach used is shown in Figure 2.

6. Defining CemLean6S

We start by discussing how the proposed purpose of Lean Six Sigma - “Maximising stakeholder value creation by minimising waste and variation, while respecting minimum requirements for all stakeholders” – could be translated to cement manufacturing. The main value creation could be seen as building potential. Cement acts as the glue in concrete. This implies that the higher the cement strength then the higher the concrete strength will be, or alternatively that more concrete of the same original strength can be produced. Also, the more cement a plant can produce, the higher the building potential will be. This indicates that overall value creation could be seen as a combination of cement strength*tonnes. This can be expressed as the compressive strength of cement in MegaPascal (MPa) times the tonnes produced, which could be expressed as MPa*tonnes. Maximising stakeholder value creation would therefore be maximising MPa*tonnes. Variation plays an important role in cement quality. Since final compressive strength is measured at 28 days this means that in most cases cement has already been converted into concrete in a building before test values confirming compliance are available. The customer must be able to trust that the cement delivers the value promised and the lower the strength variation, the higher the customer value will be. The strength level and maximal plant capacity achieved is a function of the design of the plant and how this design is used to maximise the potential of the raw materials and the process. A quick review of the seven types of waste indicates that overproduction, waiting, incorrect processing, excess inventory, and defects could be relevant to the cement industry. The main form of waste in cement manufacturing could occur in the form of incorrect processing, which either does not capture the full strength potential of the material or causes deterioration of the product in the process. Cement and clinker, the main constituent in cement, react readily with humidity, which reduces the cement strength and increases variability. Another form of waste that could be important is waiting, which could be interpreted as stoppages in the process, normally measured with the Run Factor. Formal defects in strength are rare given wide range of strength allowed in most cement standards. However, if defects are defined based on more narrow customer specifications, then strength variation could be an important form of waste. The cement manufacturing process includes considerable storing of materials and therefore has high costs of inventory. However, some of these inventories also act as active processes in form of mixing, where smaller storage might mean increased variation. Cement plants are capital-intensive investments and the degrees of freedom in making changes to storage arrangements, such as silo sizes, are often limited.

To produce building value drives costs. At plant level we could follow the total cost for production in, for example, US$. In this scenario costs together with the profit margin become the price. Both shareholders and customers have an interest in low costs for production. With low costs the options for shared value increase. From a customer perspective the price is important. Customers want maximal building value for minimal costs. Cement manufacturing is highly energy dependent, resulting in considerable carbon emissions. Additionally the main raw material, limestone generates high carbon losses when processed. Depending on the process and the cement raw materials used the carbon footprint of a tonne of cement could be some 600-1000kgs of carbon dioxide emissions. Carbon emissions from the cement industry, account for some 5% of total manmade carbon emissions (WBCSD, 2002). This puts the harm in the form of carbon emissions into a special position among emissions and makes it suitable to use as an example. The price of the cement could also be seen as a social indicator (Isaksson et al. 2010; Isaksson et al. 2014). Most new building is taking place in developing countries where needs for better housing are often urgent and where monetary resources are limited.

At this stage we only identify what we believe are the three main stakeholders in our system: Customers, shareholders and environment. For each of these we have identified the main concern in order to help us establish a purpose for CemLean6S. The proposed purpose is: "Maximising cement building potential, while making best use of resources, by reducing waste and variation". This relatively narrow definition enables us to identify the overall y-values of the Define step in the DMAIC-process of Six Sigma based on Isaksson et al. (2010) as:

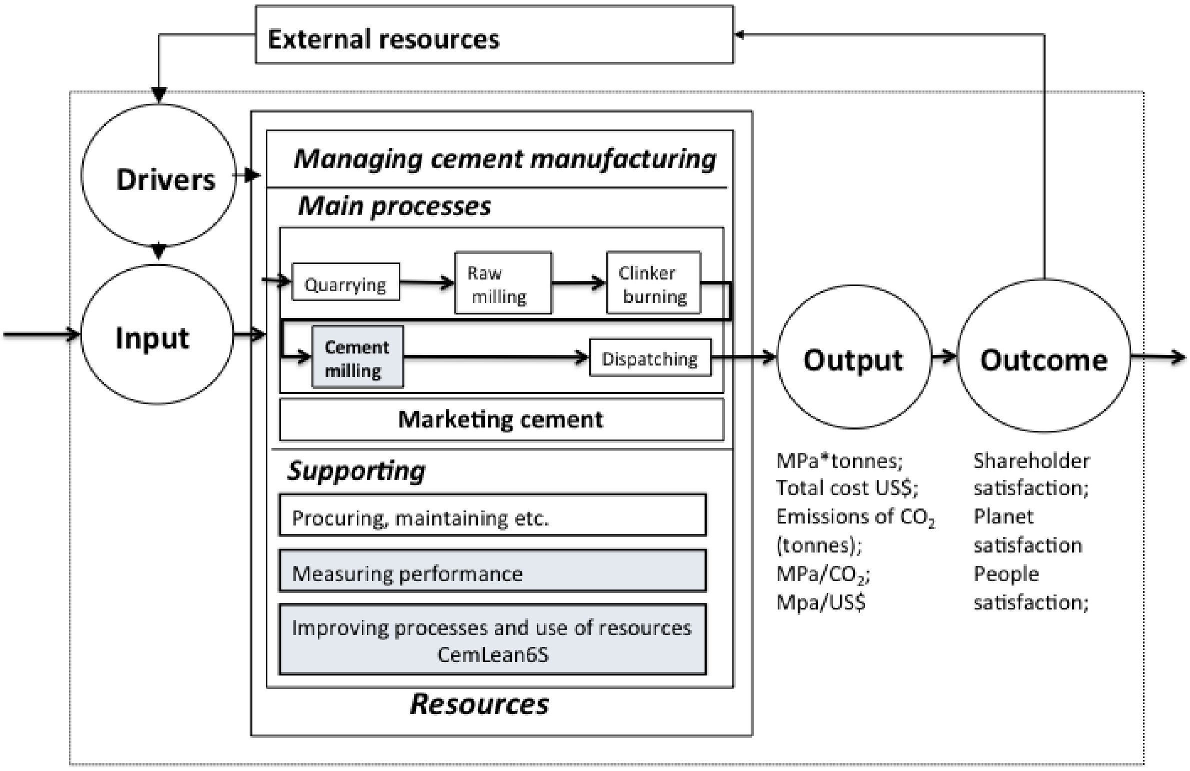
Value creation: MPa*tonnes (shareholder and customer)
Cost: Total cost of production (shareholder)
Environment: Total tonnes of CO_2-emissions (environment)

Based on the above we can envisage two important relative indicators relating to what could be seen as the two main global stakeholders – Planet and People (Isaksson et al. 2014):

Planet: MPa/CO_2-emissions
People: MPa/US$

To simplify the review we focus on the sub-process of cement milling, see Figure 2. The overall y-value still is the same. The value adding in the dispatching process is packaging, where as the main value of the product is the cement itself. To make better sense out of this a process-based system model can be used (Isaksson, 2006; Isaksson et al., 2010). The purpose of the model is to highlight the important system elements requiring focus in the work to maximise value production and to minimise costs. In Figure 2, external resources are such as the local level of development with respect to education, competition, technology and corruption. Challenges for running an identical cement mill installation in a developed country could vary considerably to those in a developing country. Therefore a system model should be able to describe differences in this context. The output is described with the main y-values describing value produced and use of resources. The output, such as level of profit and building value per price will lead to an outcome, which is defined as the stakeholder interpretation of output. The outcome in the form of for example customer satisfaction will become a feedback forming a driver for change. The external resources filter the signal. If for example the company has a monopoly the impact of the customer feedback might be dampened as compared to a situation with fierce competition. Similarly environmental performance feedback depends on the external resource of legislation and the will to enforce it, as well as the level of societal corruption. Input is in addition to raw materials defined as the market demand converted into a production plan. Resources in the model are such as the equipment, personnel, management and organisational competence. The measurement system could also be seen as an important resource. The measurement system resource consists of the IT-resources and routines for follow up and control. The support process of measuring performance has been highlighted in Figure 2 to indicate the importance of this as part of the improvement philosophy. Without reliable measurements the principle of basing decisions on facts cannot be respected. The support process of improving processes and resources is proposed in CemLean6S.

Figure 2. Process based system model for cement milling.



Source: Adapted from Isaksson (2006) and Isaksson et al. (2010).

The process based system model is used as part of the initial diagnosis to check the current performance of the y value looking at output and outcome. The diagnosis is similar to the "Define" stage of Six Sigma. However, the explicit purpose of the diagnosis is to define the improvement potential defined as the difference between the theoretical best value of being on target and the actual performance. The logic of defects per million operations (dpmo) could be used. The purpose of the diagnosis is to assess if there is enough value that can be realised meriting an analysis of the main causes of this potential. Already at the level of diagnosis some analysis of data is needed. This consists of looking at how the chosen y-performances are in terms of average, variation and trends. The performance for a period of some two years is compared to target and to benchmark performance. In the Define of DMAIC, focus is often on solving known problems. However, in the cement manufacturing context, experience shows that this risks of excluding substantial opportunities in increasing value. Identified problems are in some cases only the tip of the iceberg when it comes to identifying improvement opportunities.

The next stage, when it has been confirmed that there is enough identified improvement potential to proceed, is to identify the main x's affecting the y parameter, based on the Six Sigma approach of $y = f(x_1, x_2, \ldots x_n)$, see for example Magnusson et al (2003). Identification of the main x's affecting y at the purely technical level can be done using different predictive models. With cement manufacturing this can help identify the main x's that affect the strength value creation. Compared to only using number crunching on existing databases for y and x, prior understanding can be used to speed up the improvement process. Examples of this in cement milling are predictive models for cement strength, gypsum optimisation where cement strength is related to the percentage of gypsum added and functions for cement strength dependence on level and type of grinding aid addition. Fineness and particle size distribution (psd) also affect cement strength. The psd is affected by equipment type and process settings. Examples of this are the separator type and its performance, separator airflows, grinding media load and grinding media distribution. For all these relationships relating the y of strength performance to x's of control there are theories and best practises to be found that could form the basis of CemLean6S methodologies. In Table 5 some results based on identified relevant methodologies in cement milling, which have been linked to principles and tools. The work is done on the basis of Table 4. In Table 4 we have also included a proposed model for breakthrough improvement - DASIAS. This forms part of the improvement management process. This process consists of six steps and is based on a proposal on a generic improvement process (Isaksson, 2006), to form the DASIAS improvement management process (operational part):

Diagnosing **–** finding the improvement potential (value creating, cost reduction, reduction of the carbon footprint)
Analysing **–** finding the causes for the existing potential $y = f(x_1, x_2, \ldots x_n)$.
Solving **–** proposing solutions and choosing improvement strategy
Improving **–** project management
Anchoring **–** changes into KPI, management system documents and culture
Studying **–** double loop learning and improvements to approach

There are many similarities to DMAIC. Working with Six Sigma could be one option when solutions are proposed. But, it could also be that the solution is to introduce a quality management system. The roll-out process is linked to the DASIAS process in such a way that the first step in improvement is creating interest and particularly, creating management interest. There are several ways to convince management that improvements are possible and are needed. A typical way is to help management to solve a problem and thereby create credibility. This requires a good understanding of cement technology and improvement skills. Another way of creating trust is to train personnel. The third way, which is proposed for the roll-out process start of creating interest, is to carry out an Opportunity Study. An Opportunity Study demonstrates to management that there is unrealised improvement potential. In practical terms this means carrying out a "quick and dirty" assessment using the Diagnosing-Analysing-Solving (DAS) steps and presenting the findings to plant management. The requirements for further work are that management is convinced that the improvement potential is real and that the identified causes and proposed solutions make sense. In addition, management needs to buy into the purpose and principles of the CemLean6S. A confirmation of the commitment is when management agrees to participate in a training session explaining the improvement philosophy logic. This is similar to the introduction of Six Sigma where the start of the improvement process is often marked by management training.

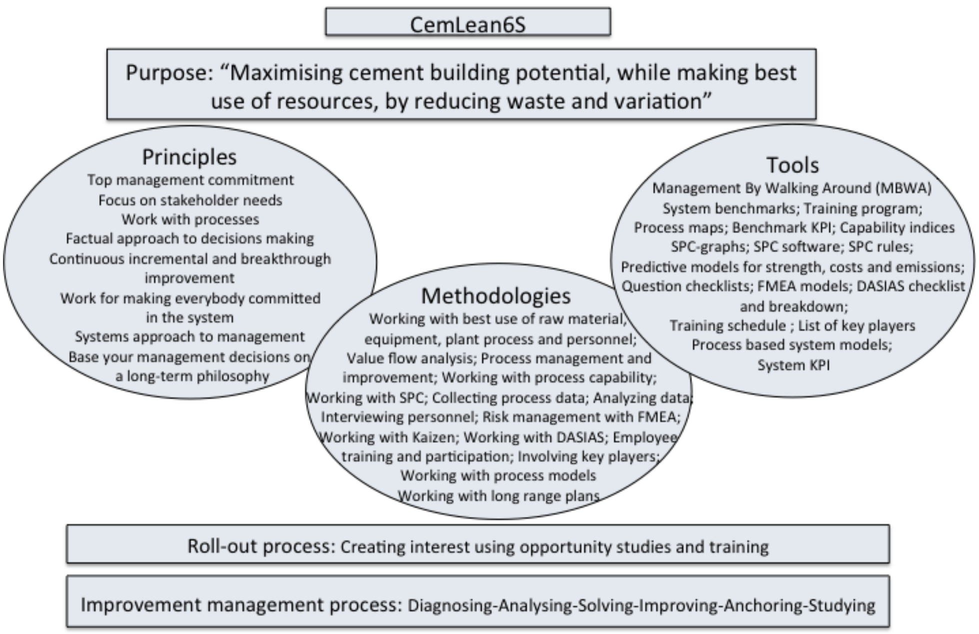
In Figure 3 the generic Lean Six Sigma from Figure 1 has been transformed to CemLean6S. The purpose and principles should be relatively well anchored. All the principles proposed from the generic Lean Six Sigma have been retained. The methodologies and tools should mainly be seen as examples. The roll-out process is only indicative. The improvement management process based on DASIAS only covers the operational part. The management of change and the linking of this to general management have not been described.

Table 5. Principles, methodologies and tools for CemLean6S

Principles	**Methodologies**	**Tools**
Top management commitment to the philosophy purpose and principles	*Demonstrating commitment to all principles in decision making;*	*Management By Walking Around (MBWA)*
Focus on stakeholder needs	Working with best use of raw material, equipment, plant process, personnel and management	System benchmarks Training programs
Work with processes	*Value flow analysis* (incorrect processing, waiting, defects) *Process management* and improvement *Reducing process variation* *Benchmarking* *Process analysis* *Working with process capability* *Working with Statistical Process Control (SPC)*	 *Process maps* Benchmark KPI *Capability indices* *SPC-graphs; SPC software* SPC rules
Factual approach to decisions making	Collecting process data Analysing data using multiple regression analyses Interviewing personnel Risk management with FMEA	Predictive models for strength, costs and emissions Question checklists *FMEA models*
Continuous incremental and breakthrough improvement	*Working with Kaizen* Working with DASIAS	 DASIAS checklist and breakdown
Work for making everybody committed in the system	*Employee training;* *Employee participation in improvement work;* Involving key players	*Training schedule* *List of key players*
Systems approach to management	*Working with process based system modes*	*System models;* *System KPI*
Base your management decisions on a long-term philosophy	*Working with long range plans*	

Source: Input from Table 4 and proposed analysis. Text that has not been changed from Table 4 is marked in italic

Figure 3. Description of CemLean6S. Methodologies and tools should be seen as examples and the roll-out and improvement management processes as the first iteration



Source: Proposal based on Figure 1 and Table 5

7. Conclusions

A model for generic Lean Six Sigma has been proposed and described in Figure 1. Most of the proposed principles are similar to those in TQM, ISO 9000, Lean and Six Sigma. The model has been customised for cement manufacturing and cement manufacturing processes by identifying the main value created and by demonstrating how this could be practically implemented. The main y-values identified are building value in strength*tonnes, total cost and total CO_2-emissions. This work results in two relative indicators that can be used for optimising shared value. These are building value compared to price and building value compared to CO_2-emissions (Isaksson et al. 2010). By identifying a clear purpose for the improvement philosophy it becomes possible to identify the main y-values. This then leads to the possibility to use cement technology knowledge to speed up the process of identifying predictive formulas for y. A preliminary improvement management process is also identified as Diagnosing-Analysing-Solving-Improving-Anchoring-Studying (DASIAS). Only a few important parts of the roll-out process are identified. These are creating management interest, management and employee training and pilot improvement work using opportunity studies. The resulting CemLean6S model is presented in Figure 3.

8. Discussion

This paper covers many areas superficially. Future research is therefore needed in several areas. Defining Lean Six Sigma merits a deeper study. The proposed model for describing a philosophy with the elements of purpose, principles, methodologies, tools, roll-out and improvement management processes need to be validated. On a practical level the proposed CemLean6S should be tested to get feedback for improvement and to validate the model. The indication is that there could be substantial benefits in the customisation of an improvement methodology. Also, there is a value in using a model to describe the content of the chosen improvement methodology. This makes it easier to see what is used and could act as a way of standardisation.

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