

Modelling and Measuring Excellence for Sustainability – Examples from building in Tanzania

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Abstract

Purpose. In a resource-limited world it is logical that business excellence should focus on sustainability. The purpose of this paper is to exemplify areas of synergy between Quality and Sustainability.

Methodology. The starting point has been in identified vital few stakeholders and their needs on the global level. These needs have then been exemplified in building processes in Dar es Salaam Tanzania using quality principles, practices and tools.

Findings. By transforming the quality principle of customer focus into stakeholder needs focus and by redefining main stakeholders as Planet and People, conditions are created to operationalize sustainable development. Sustainability in the studied system has been defined as affordable building materials with a low carbon footprint. Cement drives both building costs and the carbon footprint. This means that cement productivity compared to price and to the carbon footprint can be used as indicators for sustainability excellence. Cement productivity in concrete is defined as compressive strength divided by cement percentage and expressed as Mega Pascal*tons. Based on a defined benchmark, cement productivity can be expressed relatively. The cement productivity in the studied system is only at 20%. Using well grounded vital few performance indicators in absolute and relative terms enables using principles, practices and tools from quality management to support sustainable development.

Practical implications. Focus on needs satisfaction compared to only footprints could in the cement industry reduce the need for Carbon Capture and Storage

Originality/value. The results present a radically different view of sustainability based on focus on critical stakeholder needs.

Keywords

Sustainability; quality; stakeholder; process; model; building

1. Introduction

The 17 UN Sustainable Development Goals (SDGs) from 2015 oblige countries and companies to work with sustainability issues (UNSDG, 2015). For any company this work is complex. It could be argued that principles, practices and tools for quality management should support work for increased sustainability (Isaksson 2006; Fredriksson and Isaksson, 2016). The Pareto principle, with focus on the vital few sustainability issues could be of help. On the global level there are many threats. Steffen et al. (2015) single out climate change and loss of biodiversity as the two main ones, which each on their own could destabilise life on global level. Impacts on biodiversity are hard to measure, in comparison the effects on climate are easy to assess and causes for problems are well known. This makes work with efforts on climate change a good starting point. If what is easy to measure and important is not done properly all the rest can be cast in doubt. This means that company climate management is a good indicator for overall sustainability management. Work with company climate management could be chosen as an important indicator for the level of Planet focus.

All people are stakeholders, but needs of those living in poverty should be given priority. The no 1 goal in the UN SDGs is: “No Poverty”. It could be argued that with global value chains all organisations have some relation to poverty and that this therefore should be a priority area with a special focus on those living in absolute poverty (Isaksson, 2018a), as stated in the SDG 1.1 target: “By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than \$1.25 a day”. Work for reducing poverty could be chosen as an important indicator for People focus (Isaksson, 2018a).

Carbon emissions, from a consumer point of view are driven by food, buildings, transport and shopping (Isaksson et al. 2015). Possibly the most important of these is the building value chain accounting for some 40% of all energy consumed globally and for 20-40% of carbon emissions depending on the type of energy consumed. Poor countries normally lack infrastructure and housing is mostly a problem. Such countries will require important building activities. It is estimated that most new buildings will be built in developing countries.

The youngest continent is Africa with f 1.2 billion people in 2015 and where the population is expected to rise to 1.7 billion in 2030 (PopulationPyramid, 2018a). One of the big challenges will be to satisfy the housing needs providing both quality and sustainability.

The background of this work is in a longitudinal project for improving quality and sustainability in the building supply chain with focus on the production of sand and cement – sandcrete - blocks in Dar es Salaam, Tanzania. The working hypothesis has been that applying quality and sustainability principles should lead to improved performance benefiting Profit, People and Planet by increasing performance and by reducing costs of poor quality. In the work done several aspects of block production have been studied. These are such as defining quality and sustainability, studying how quality and sustainability performance could be assessed, analysing causes for the current situation and finding ways of improvement. The work has resulted in several publications dealing with different aspects of the sandcrete production. The work done, and results obtained have been used to highlight quality and sustainability synergies.

The following areas of quality and sustainability synergies have been highlighted:

1. Visualising the studied system
2. Identifying who the main stakeholders are in the studied system for sandcrete production and which their needs are
3. Indicators and targets for stakeholder value in the sandcrete value chain
4. Improvement potential for stakeholder value improvement

5. Analysing causes for the detected improvement potential
6. Improvement opportunities for stakeholder value

2. Theory background

2.1. Description of the system studied

Tanzania is a typical poor African country with a population of 53 million (2015), which is rapidly growing. The prediction for 2030 is a population of 83 million (PopulationPyramid, 2018b). Building activities are expanding, which can be seen in the rapid increase of cement manufacturing capacity. Dar es Salaam is the largest city and the economic hub of the country. The population is growing rapidly which puts pressure on building houses.

Sandcrete or sand cement blocks are the most common cement application for houses in Dar es Salaam (Isaksson and Babatunde, 2017). Cement, water and sand are mixed and compressed to blocks that are cured and sold. Sandcrete blocks only use sand and cement whereas concrete blocks have substantial additions of aggregates. There is no clear difference. Often small amounts of aggregates – “chippings” – are added to the sandcrete mixes. These blocks are used both in private houses and in apartment blocks as well as for building walls. Blocks are normally solid and weigh about 20-30 kg, which means that they can be handled manually. Estimated from 2018 indicate that about 1 million tons of cement is used for producing sandcrete and concrete blocks in Dar es Salaam. The production is done by a large number of small producers in very simple conditions. The total number of building blocks produced yearly is, based on the amount of cement used, estimated to about 600-800 millions. The total number of block producers in Dar es Salaam is difficult to assess but has been reported to be at least 500 (Sabai et al. 2016) but could be much higher. The most common type of producer uses locally manufactured equipment with typically one to four production lines consisting of a pan mixer followed by an electrical vibrating machine. Sand, cement, aggregates and water are used as raw materials. The produced blocks are often sold directly from the small factory. The most common block is a “6 inch” solid block weighing about 30 kg (Sabai et al. 2016). There are some plants that produce hollow blocks. These are normally delivered to larger projects and produced by more advanced producers. Globally, when cement-based blocks are used in building they are often hollow, but due to difference reasons these are not widely used in Tanzania (Isaksson et al. 2012). Hollow blocks have advantages such as being lighter and easier to work with, having better insulation and also providing better use of cement (Isaksson and Babatunde, 2017).

2.2. Quality principles and sustainability

Customer focus is a core principle in Quality Management (QM). Deming defines quality as: “Quality should be aimed at the needs of the customer, present and future” (Bergman & Klefsjö, 2010: p22). Isaksson (2018a) suggests a sustainability definition based on Deming as: “Sustainability should be aimed at the needs of the stakeholder, present and future”. The quality focus from QM is enlarged to sustainability focus. This supposes the identification of the main stakeholders. There are many definitions of stakeholders. One frequently used is that of Freeman and Reed (1983), being: “Any identifiable group or individual who can affect the achievement of an organisation’s objectives or who is affected by the achievement of an organisation’s objectives”. Isaksson (2006) uses this definition with the clarification of that customers, future generations and nature, amongst others, are seen as stakeholders. In Isaksson et al. (2015) the global main stakeholders are identified as People and Planet with

Profit been seen as a means to an end. Isaksson (2018a) suggests that declining resources will increase focus on company business ideas and what value they are producing. Companies providing the best value compared to harm done should be those retaining their license to operate.

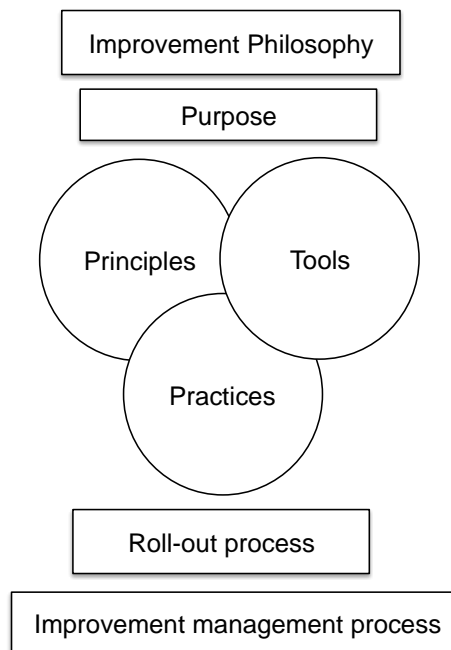
Based on Steffen et al. (2015) and the UN SDGs the global key stakeholders are defined as climate, biodiversity and people living in extreme poverty (Isaksson 2018a; 2018c). It is suggested that these stakeholders and their needs should always be considered in addition to other specific stakeholder needs that the studied system is affecting. Stakeholders should be identified in the entire value chain (GRI 101, 2016; Isaksson and Cöster, 2018).

The process approach is another core principle of QM and can be used to visualise, analyse and manage processes both on a detailed and on a system level (Bergman and Klefsjö, 2010).

2.3. Practices and tools for quality and sustainability

Process performance could be expressed in terms of quality and sustainability. Isaksson (2018b) proposes using two system models to describe organisations and systems. The first model based on Isaksson and Taylor (2014) describes the elements in the improvement philosophy. The main elements in the model are Principles, Practises and Tools (PPT), see Figure 1.

Figure 1. The Principles, Practices and Tools (PPT) system model used to identify important elements for an improvement strategy.

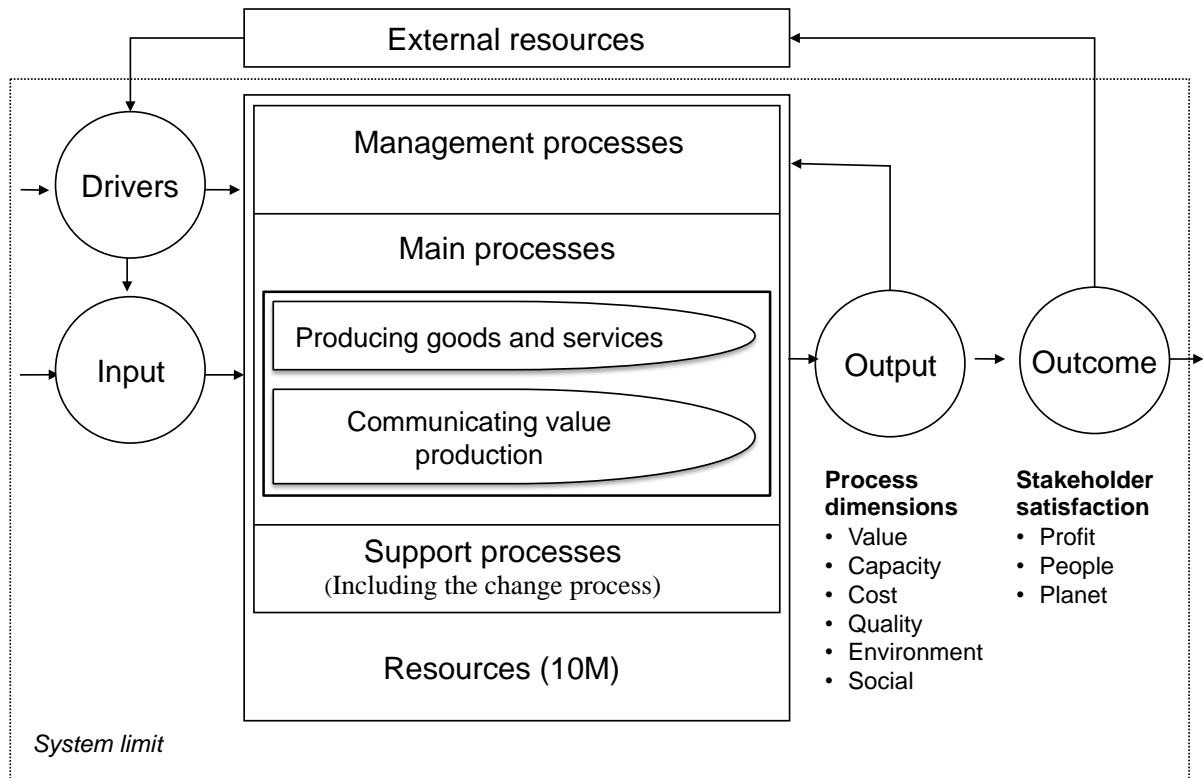


Source: Based on Isaksson and Taylor (2014) and Fredriksson and Isaksson (2016).

The PPT model in Figure 1 is static and the elements need to be related to current processes in the studied system as well as to change in the studied system. Therefore, the second model needed is a Process Based System Model (Isaksson 2018b). In Figure 2 the PBSM is presented (Isaksson, 2016). This model describes the steady state. In order to

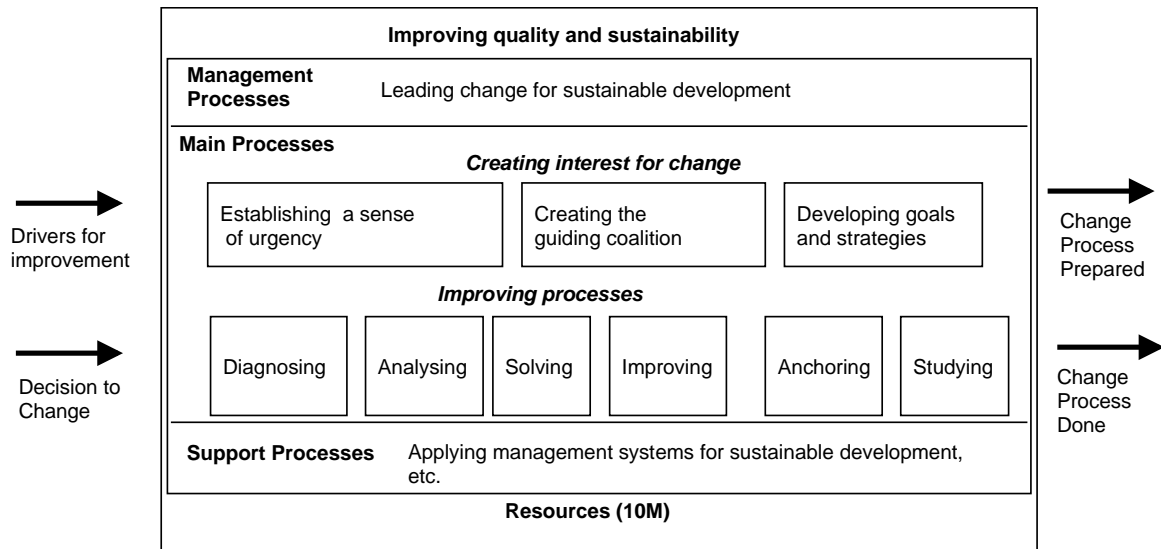
visualise the situation properly it is important to differentiate between the process in the steady state and a change process (Isaksson 2006; 2016). The suggestion here is to combine the PPT-model and two versions of the PBSM-model when describing and improving systems Isaksson (2018b). The PBSM in Figure 2 has two default main processes, producing goods and services and communicating value produces or in other words value adding and marketing. In the model there are five types of indicators described as drivers, input, output, outcome and resources.

Figure 2. The Process Based System Model (PBSM).



Source: Isaksson (2016).

Figure 3. The PBSM-model applied on the change process in Figure 2.



Source: Based on Isaksson (2006).

Focus in this paper is on output and outcome. Output is what the process delivers and outcome is the level of stakeholder satisfaction. One default support process is exemplified. This, is a change process that can be described using the same PBSM model, see Figure 3. Figure 3 describes an improvement process in two stages. The first one describes how to create interest for change and the second one describes the improvement itself. The studied project has worked with diagnosing, analysing and solving at the level of trying to establish a sense of urgency for change (Isaksson, 2015).

2.4. Quality in Africa

The level of use of basic quality management practices could be seen to relate to the use of ISO 9000. The latest version of the Quality Management Standard ISO 9001:2015 is based on management principles that are similar to the content of TQM.

Globally there are about 1.1 million ISO 9001 certificates divided into different parts of the world, see Table 1.

Africa is far behind with QM compared with other regions such as for example Europe. In Europe there were 2016 some 450 000 certificates to be compared with only 13 000 in Africa (ISOTC, 2016). The number of ISO 9001 certificates has some flaws as indicator as can be seen from the low number of certificates in North America. A low figure, which, based on Table 1, is further declining. The number is increasing in both Africa and East Asia and Pacific, in the latter from an already high level. The conclusion from this is that introducing basic QM in Africa could pose some challenges while also having a great potential for significant effects (Isaksson et al. 2016).

Table I. Number of ISO 9001 certificates globally (ISOTC, 2016)

Year 2016 - ISO 9001	Total	Share	Growth
TOTAL	1105937	%	%
Africa	13378	1%	10%
Central and South America	52094	5%	5%
North America	44252	4%	-6%
Europe	451415	41%	3%
East Asia and Pacific	480445	43%	14%
Central and South Asia	41370	4%	1%
Middle East	22983	2%	1%

3. Method

The results from the “Block Excellency Project” consisting of on-going work started in Dar es Salaam in 2009, have been studied. In the project an approach of Innovation Action Research (Kaplan 1998) has been applied. This means that in addition to active work for the benefit of the studied organisations new approaches have been developed in the process, which then have been tested and improved. Results from the research and development have led to new models, methods and indicators for visualising, measuring and assessing performance. The research has so far generated some 10-15 conference presentations and some 3-5 journal articles relating partly or fully to the project, with further work in progress. These results have been studied and analysed in the context of quality for sustainability or Excellence for Sustainability. Input from Isaksson et al. (2015) consists of value per harm indicators and together with input from Isaksson (2018 c) that focus in the Triple Bottom Line should be on People and Planet needs. Isaksson (2018a) specifies critical Planet and People stakeholders as climate, biodiversity and those living in poverty and suggests including the atmosphere, biosphere and lithosphere as stakeholders. For those living in poverty the most important indicator is the price of products (Isaksson et al. 2010). Stakeholder needs are viewed in the entire value chain (Isaksson and Cöster, 2018). The value chain is described using Process Based System Models and the elements in the improvement strategy are defined using the PPT-model (Isaksson 2018b; Isaksson and Kinabo, 2018). The overall maturity of work with sustainability is reviewed based on Isaksson and Hallencreutz (2008) that propose a maturity scale for sustainable development.

4. Results

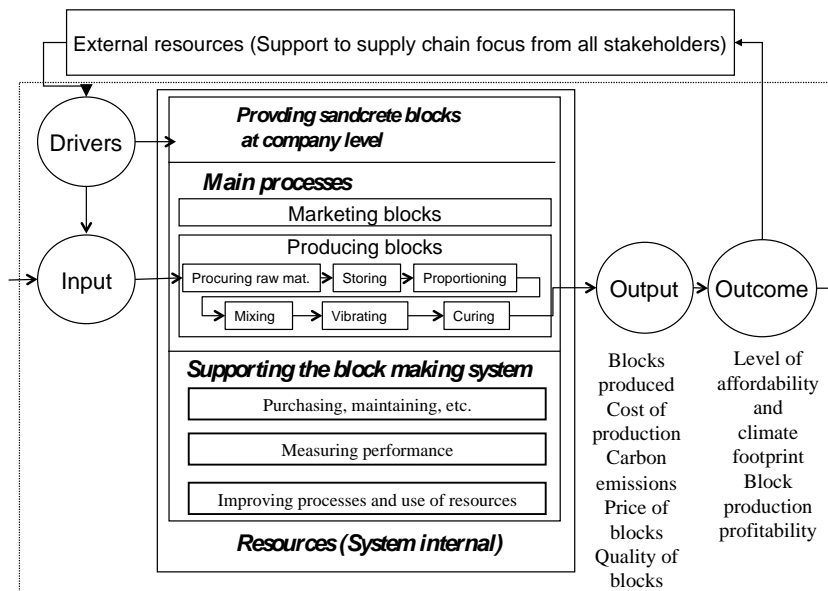
Results are presented below for the six topics of synergies highlighted in the introduction.

4.1 Visualising the studied system and how quality and sustainability could be described

To visualise the system or the value chain studied, the Process Based System Model (PBSM) from Figure 2 can be used, see Figure 4. The purpose is to identify potential stakeholders by studying all the processes and resources needed for the system. In order to identify stakeholders the entire value chain should be studied (Isaksson and Cöster, 2018). In Figure 4 the first part of the value chain, notably the production of cement and the last part of using the blocks have been omitted. Focus here is on the block producers that are important stakeholders, since their productivity and carbon footprint strongly influences block performance and price. The production sub-processes are important to understand when

working with improvement. For doing this, impacts on outcomes need to be identified. This is discussed in section 4.2. Based on important impacts, output performance indicators can be chosen. The choice of these is discussed in section 4.3.

Figure 4. Sandcrete block production at company level



Source: Based on Isaksson (2014).

Important internal resources are such as Management competence, Measurement System, Methods of work Machine resources, Market and Manpower. These are not further dealt with in this paper.

Generally, resources could be described using a 10 M checklist (Isaksson, 2016). Improvement could be focused on processes - the network of activities - or on the resources that support it or both. External resources in Figure 4 are such as general competence, how the authorities understand the system and the situation of block makers, but also level of competitiveness and availability of financing. One specific issue of importance is the level of corruption, which has a strong effect on the business climate. The system described in Figure 4 is for any block producer working in the Dar es Salaam area.

4.2 Identifying who the main stakeholders are in the studied system for sandcrete production and which their needs are

Focus here is on the two stakeholders, climate and poor people. Biodiversity could be important in the value chain, but there is no information on this. Also, for Planet, the main effect from buildings and especially cement production is the carbon footprint. According to the “Technology Roadmap Low-Carbon Transition in the Cement Industry” emissions from cement manufacturing account for 7% of global carbon emissions (WBCSD 2018). This puts focus on climate management. The interpretation for people needs is that these could mainly be seen as affordable housing. In practice this means sufficient living space in m² for as low price as possible. The total cost includes the plot, the housing material and the building of the house.

In Dar es Salaam it is estimated that about 70% of all buildings are unofficial, they are technically speaking squatters, even if the houses could be big and expensive. Only a small minority can afford officially built buildings. Customers as important stakeholders could therefore be divided into two categories, the official and unofficial ones. Since the poor people are found in the unofficial building sector these people are chosen as important stakeholders. Most of the studied block producers deliver mainly to the unofficial sector and this is where the focus in the Block Excellency project is.

Buying a house in the unofficial sector means buying a plot directly with a traditional landowner without including authorities. There will be no water, no sewage and no electricity in the house. The cement bought will come from a process controlled by standards whereas blocks bought will be produced without any formal quality control. Normally a technician – fundi – is involved who will choose the blocks used. He will check the blocks manually to see if they are strong enough. Some blocks will be dropped to check how they break. Most fundi, block producers and customers have no notion of what compressive strength in Mega Pascal (MPa) is. Some producers know that there is a standard but only a few, especially government and big contractor go further into ascertaining that the required strength is met. The needs for the house builder and the fundi are that the blocks appear good enough to serve for house building. For the reputation of the fundi it is important that houses do not break down. The quality control is based on trust and reputation. This supports the expected low level of Quality Management and signals problems with improvement, since little or no data are available. The laboratory test results from the study of sandcrete blocks also indicates low performance, see section Figure 5.

Main People stakeholders are poor people using sandcrete blocks for individual houses and the fundi working with them. Their requirements are blocks, which are strong enough for a one-storey building and that are as cheap as possible. Block producers are also important stakeholders. They are trying to maximise earnings while delivering blocks that people want to buy. Cement producers are also stakeholders. They control the type, strength, price and carbon emissions of the cement produced.

The Planet stakeholder “Climate”, with the need to stop carbon emissions is currently weak in the studied system. The cement manufacturers have some pressure on them to manage their climate footprint. Cement drives both price and the carbon footprint in blocks (Isaksson and Babatunde 2017). The cement manufacturers are also the most competent organisations in the value chain from raw materials to blocks used in house building. Many of the cement producers are part of international organisations and have access to latest technology and knowledge. Authorities are stakeholders in the form of defining standards and setting requirements such as the block standard TZS 283: 2002 that defines block strength requirements. In Figure 4 these could be seen as external resources.

In Figure 4 the main stakeholder needs, affordability, climate footprint and business profitability have been presented. The outcome measures the level of satisfaction. The quantity and quality of production output with price and carbon emissions leads to the outcome.

The R&D in the Block Excellency project has focused on the perspective of the block maker and the possibilities there are to improve performance that can benefit customers, the environment and the block production business.

The cost and quality of blocks influence house performance and house affordability. Costs for walls constitute an important part of the building material costs. Therefore, a m^2 of wall could be used as unit of study. Important issues are cost and carbon footprint per m^2 . The quality requirement is that the wall strength is within safety margins. The cost of a m^2 of wall,

its strength and carbon emissions can be determined by the performance of the individual blocks. The conclusion is that an important part of the performance in the process for providing poor people with affordable houses with a low climate footprint can be described with block performance in terms of right strength to lowest cost and right strength to lowest carbon footprint. The right strength is what is needed for the block when either in a carrying or non-carrying wall. The challenge is to define correct targets for strength and then to achieve these targets with the lowest cement content possible. This could be further elaborated by studying the cement type and the carbon footprint of the cement. At this stage it is sufficient to base assessments on quantity of cement used only.

4.3 Indicators and targets in the sandcrete value chain

The starting point for any improvement is the ability to measure current performance. With relevant indicators and targets for best performance it is possible to highlight improvement potential. There needs to be opportunities for improvement to create any interest for change, see Figure 3.

Block customers assess blocks by face value and few block producers can tell what the strengths of their blocks are. The common way of measuring both productivity and quality is to indicate the number of blocks produced per bag. E.g. six-inch solid blocks are often produced with a recipe of 30 blocks per 50 kg bag of cement. This could be a barrier to improvement, since cement productivity improvement could lead to more blocks being produced per bag. The strength could be the same but since it is not measured customers could be sceptical. In order to be able to compare block producers, blocks need to be taken for testing with the corresponding recipe. In order to be able to assess how different block producers were using the cement the indicator strength*blocks per bag was first introduced (Isaksson et al. 2012) to be followed by MPa*tons (Isaksson 2015; Mrema and Isaksson, 2015; Isaksson and Babatunde, 2017). The MPa*ton can be used both for cement and cement applications such as sandcrete and concrete. In cement it is the product of measured compressive strength in MPa times the tons produced, which could be equated with building value produced. The MPa*tons in cement applications is a measure of how the utilisation of the inherent cement strength has been realised in the application. The MPa*tons or the cement productivity in the application is calculated in the sandcrete blocks as the measured compressive strength in MPa divided by the percentage of cement. The relative cement productivity can be estimated using ordinary concrete as reference. For ordinary concrete the reference has been set at 270 MPa*tons and the performance in blocks can then be calculated as percentage of this (Babatunde and Isaksson, 2017).

The MPa*ton for cement is a good proxy for user value. The skilled customer can adjust cement addition to the required concrete strength when cement performance is constant. For block customers the situation is more complicated. They need to get blocks that are strong enough for the intended wall, but they will not profit from supplementary strength. That is, blocks could have a high MPa*ton value indicating good use of cement in the block production but blocks could have excessive strength values which would not constitute supplementary value for the customers, which means waste of cement leading to higher prices and higher carbon emissions.

There is a mandatory block standard that stipulates an average strength of 4 MPa and with an absolute minimum value of 3.0 MPa for all types of blocks (TZS 283:2002(E)). However, many producers are not producing according to the standard and it could be questioned if what is required in the standard is needed (Sabai et al. 2016). Isaksson et al. (2012) suggest a target value of 2.2 MPa and a standard deviation of <0.3 MPa. This would with a block at

minus four standard deviations lead to a compressive strength of 1 MPa, which for a six inch block would correspond to a load bearing capacity of 7 tons, which would be 18 times the static weight of the building (Sabai et al. 2016). Blocks of 1 MPa seem to be sold and used without problems, which supports the view that requiring 4 MPa is excessive. Here, it seems, that following the standard, which normally is applied for official buildings would increase costs and the carbon footprint. There probably is a misinterpretation of the standard, which should be seen as a requirement of durability and not of the compressive strength in buildings. The carrying load of walls is calculated based on the strength and size of blocks used. Larger blocks can carry more and therefore there should not be too strict requirements on the blocks. This presents an example of how the external resource that the Tanzania Bureau of Standards is, does not support customer needs. This could also be the case with other parts of the official building system where bureaucracy and corruption could lead to increased costs for customers. This means that the external resources described in Figure 4 might not fully be supporting the building needs of poor people.

The main performance indicators identified can be expressed as relative value per harm indicators (Isaksson et al. 2015). These are MPa*tons/price and MPa*tons/ton CO₂ (Isaksson and Babatunde, 2017). At the same time the compressive strength for solid blocks should be at least 2.2 MPa and the carrying load of walls should be at about 5-7 tons for a one-storey house. These are preliminary indications to enable an assessment of the improvement potential.

Earlier performance as reported by testing institutes only provides the compressive strength but not the cement productivity as MPa*tons. The GRI standards suggest sales value and the distribution of it as indicators of performance (GRI 201; 2016). What is done here is an example of shifting assessment of product performance from a producer-based value indicator (price) to a customer-based indicator (user value).

Setting a benchmark for the prices of blocks is difficult. The competition between block makers is hard while costs for labour are low. Costs vary strongly with the input materials cement, sand and aggregates. Similarly, the target for carbon emissions could be discussed. Globally, net emissions should be zero in 2050. Since carbon emissions are mainly from cement manufacturing this is an issue that the cement industry needs to work with. Block producers have some possibilities to reduce cement consumption. Since improved cement productivity reduces costs as well as carbon emissions it is at this stage enough to focus on possibilities of reducing cement content. The indicator carbon productivity defined as % of benchmark MPa*tons (Isaksson and Babatunde) could be used as a proxy for quality and sustainability performance. In addition, the product must have a compressive strength at target.

4.4 Improvement potential for stakeholder value improvement

Results from the Dar es Salaam market indicate that strength performance in blocks is about 24% of benchmark performance (Isaksson and Babatunde, 2017). This is remarkably low use of the cement building potential. Theoretically if the entire potential could be realised four times more building value could be produced with the same amount of cement, which would mean cutting carbon emissions with 75%. Isaksson and Babatunde (2017) calculate the reduction as 460 000 tons of CO₂ per year for the assessed level of cement use of 800 000 tons per year. Cement consumption for blocks in Dar es Salaam as per 2018 is estimated to 1 000 000 tons per year. Also, the improvement potential does not include reducing variation and stabilizing average performance on 2.2 MPa. The current estimated average strength

based on Sabai et al. 2016 is 3.3 MPa. This means that the theoretical improvement potential in the entire system measured as value per cement used could be above 500%.

What most likely would happen in reality if cement performance went up and this reduced block prices significantly, is that consumption would increase. Carbon emissions would not be reduced as much as indicated but building value per carbon emissions would increase providing buildings for those needing them.

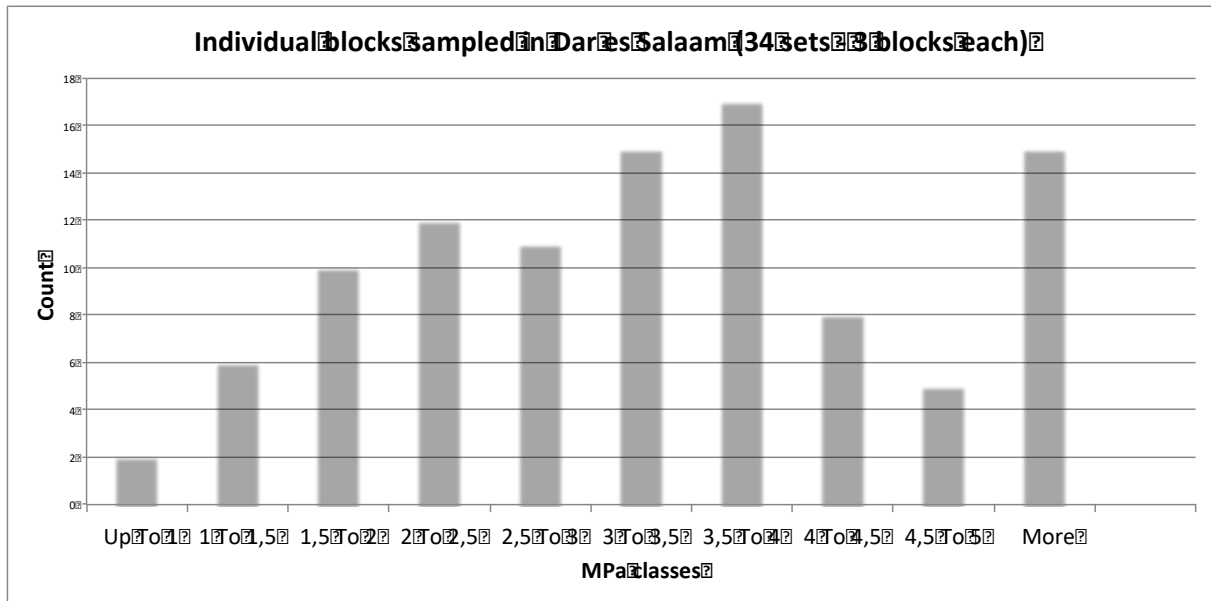
4.5 Analysing causes for the detected improvement potential

The main reason for the low cement productivity is a basic principle from concrete mixing, which is about the water to cement ratio in the mix. This ratio should be as low as possible since all surplus water will leave voids in the concrete when evaporating. However, water is needed to mix the materials. The problem with the sandcrete blocks is that the cement content is at about 5% while sand requires some 8-10% of water to be mixed properly (Mrema and Isaksson, 2016). This means that instead of a water cement ratio of about 0.5 the ratio can be 1.5-2. Based on standard concrete technology references the cement productivity when going from 0.5 to 1.5 as water to cement ratio is reduced to 20% (Isaksson and Babatunde, 2017). Increasing cement content would lead to non-required strength, higher prices and higher carbon emissions. The solid sandcrete blocks seem to be a dead end. However, even at the average low level of about 20% cement productivity there is considerable variation in the performance. Random sampling of 34 producers, carried out in 2015, indicated a large relative variation, see Figure 5 (Sabai et al. 2016). The mix ratios were not obtained during sampling. However, later data collection from plants shows that cement content mostly is around 5% without any substantial variation. This means that other factors than cement content affect the performance.

Results in Figure 5 indicate that the compressive strength still could vary between 1.5 MPa to 4.5 MPa even if the cement content is approximately the same. This is similar to what Isaksson et al. (2012) find, indicating that there could be at least a factor 4 in performance. Using 5% of cement for the range of 1.5 to 4.5 MPa results in a MPa*tons range from 30-90 which compared to the benchmark of 270 is 11-30%. This range is confirmed by several tests of blocks from different producers.

Considerable work has gone into trying to find explanations to the large variation. The logic has been that this knowledge would also support other block applications, such as hollow blocks.

Figure 5. Compressive strength results for sandcrete blocks.



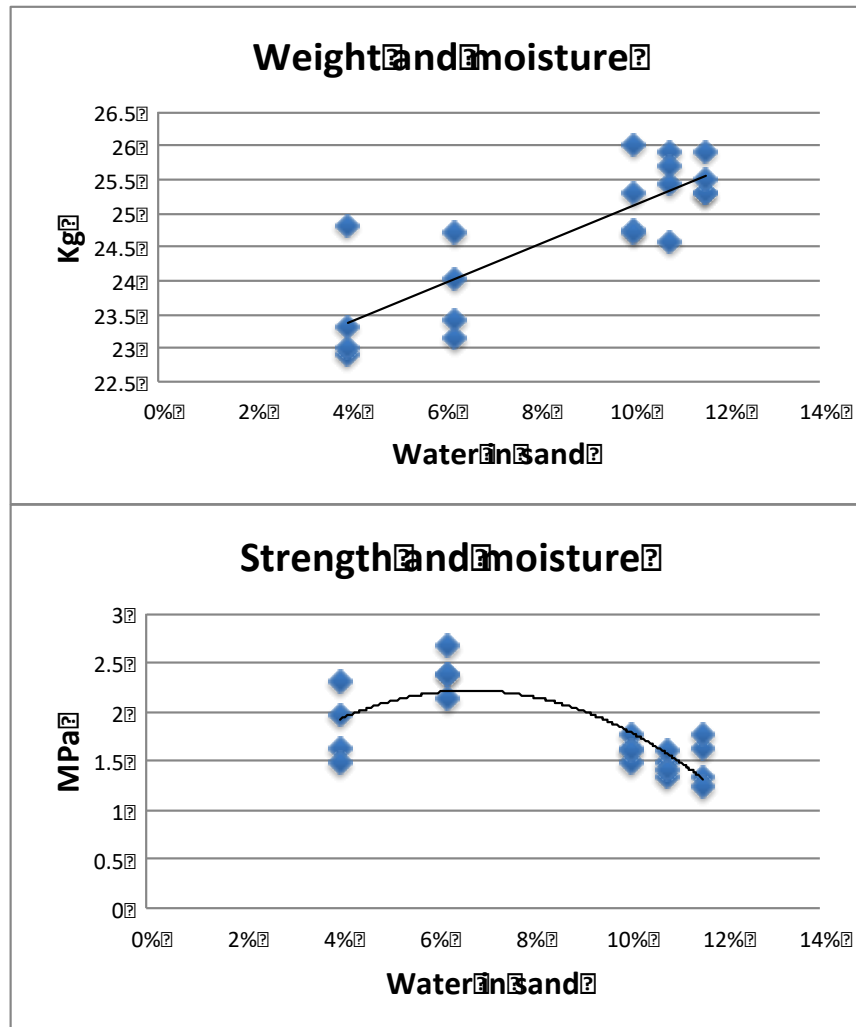
Source: Sabai et al. 2016.

The main things affecting sandcrete performance at the same water to cement ratio is compaction of the blocks, curing and the cement used. Mainly compaction has been studied. This depends on vibration and compressive force used, mix design and amount of water. The locally produced vibrating machines have only little of manual compression. Issues that have been looked into are time of vibration, sand quality and amount of water used. Out of these the amount of water used could be the largest source of variation. Theoretically dry sand should be used, which would enable exact dosing of water to provide a controlled mix. In practice sand is stored outside where it is subjected to sun and rain. The moisture content normally varies between 3-6% but could vary even more. The one in charge of mixing – the fundi – uses visual control to add a suitable amount of water. The problem is that this suitable amount of water is not calibrated with best strength performance, but with producing the blocks as quickly as possible. Normally personnel are paid per piece of block produced. Controlling moisture in the sand used is not easy in field conditions and none of the ordinary block producers do that. During the research it has been shown that moisture could be controlled indirectly by checking the weight of blocks. Provided the same recipe, the same time of vibration then the weight is a function of water added, see Figure 6. In repeated tests done it has been shown that blocks can be produced with a wide range of moisture content. There also seems to be an optimum value for water in sand, which is around 8-10%, but which could vary slightly with the amount of cement used (Mrema and Isaksson, 2016). The explanation is that with too little water there is poor compaction, which reduces strength. When amount of water increases the compaction improves but is finally outweighed by the increasing water to cement ratio.

Provided some basic quality control, plants could define a target strength, which could be controlled by weighing some blocks and informing the fundi who controls the water addition. This is not done in any of the plants, not even in the more sophisticated ones.

The varying sand moisture could explain a significant part of the strength variance. Several samplings of blocks at producers have shown strength performance factors of up to 2 related to block weight.

Figure 6. Sandcrete block weight and strength as function of water content in sand.



Source: Own presentation of non-published data

4.6 Improvement opportunities for stakeholder value

Isaksson (2016) states that there is an opportunity if the diagnosis shows that there is an improvement potential, if the analysis shows that this can be explained, if there are realisable solutions and if nobody is working with the issue. In the case of sandcrete production in Dar es Salaam there is an obvious opportunity for improvement since there is a considerable improvement potential in providing more value for poor customers with a lower carbon footprint. The causes for the opportunity can be explained and there are solutions. One first simple improvement could be optimising the water addition by introducing basic quality control in the form of weighing of the blocks. This could increase average performance and reduce variation providing considerably more user value for the same cost and for the same carbon footprint. During the nine years of the project the first author has not come in contact

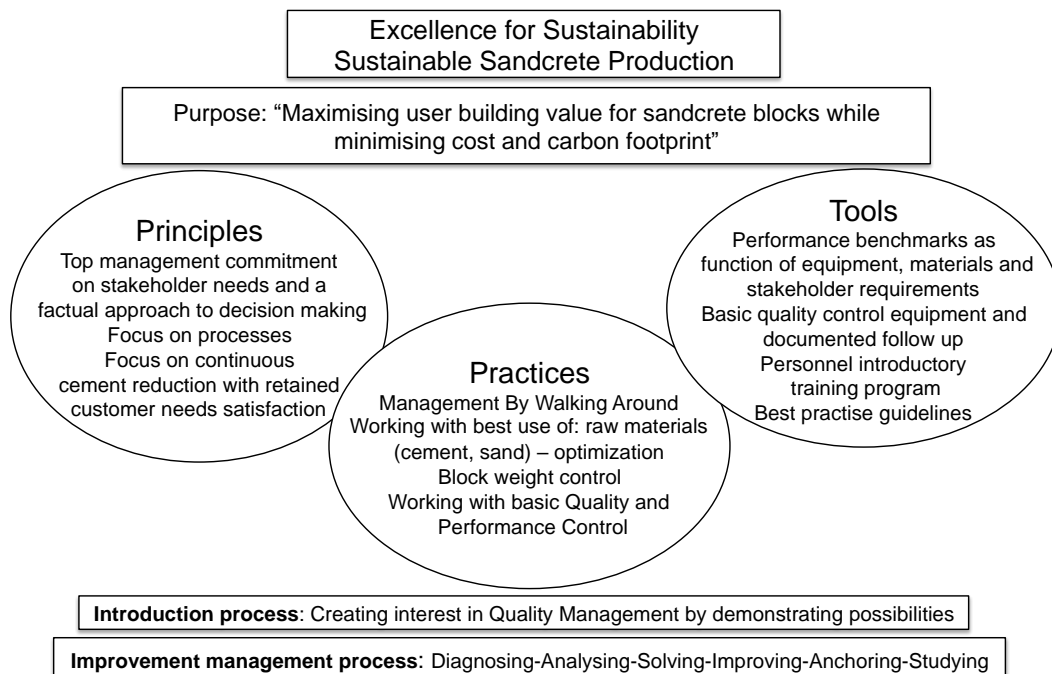
with any activities to systematically improve the block production system performance in Dar es Salaam. This indicates that there should be a good opportunity for improvement. However, generally it can be said that the greater the opportunity the lower the interest. Would there have been interest, then some part of the opportunity would have been realised.

Presenting the detected opportunity could be seen as part of “establishing a sense of urgency” in Figure 3 (Isaksson, 2016). So far, the published papers, the conference presentations, discussions with block producers and some cement manufacturers have not created any interest in change.

Another more substantial improvement could be change the block design from solid to hollow. The hollow blocks are frequently used in other countries. This should make it possible to increase the value of m² wall per price and carbon footprint. Another option is to use aggregates and thereby reduce the sand content. This will make compaction easier with less water and will improve the strength performance. There are advanced producers that instead of 95% sand only use about 35% sand and the rest being aggregates. There are some results indicating cement productivity of above 50% compared with the average of about 20-25%. The problem is that aggregates are four times as expensive as sand.

The improvement strategy elements could be modelled as in Figure 7. The model is a proposed strategy for improvement on the block producer level. In order to improve there must be some measurements. The suggestion is to start recording mixes used and the weight of blocks. This can be done to a low cost consisting of a balance and some reference measurements carried out at local testing laboratories.

Figure 7. The PPT-model for sustainable sandcrete production.



Source: Based on Figure 1

5. Discussion

The improvement potential could be over 500% in terms of MPa*tons per cement price and per carbon emissions. The studied case might not be representative for the level of existing improvement potential in a global context, but there are reasons to believe that substantial improvement potential exists in developing systems, where most of the new buildings are coming up. Isaksson (2007) indicates in a study of the global cement industry that the improvement potential in increased user value per carbon footprint is in the range of 15-30% but that it could be over 50% in developing plants. This would be in addition to the findings in the Block Excellence study that has not considered cement strength when studying the improvement potential. This strengthens the view that sustainability should be seen as the ratio of user value produced compared to price and footprints instead of focusing on the footprints.

The WBCSD Roadmap for sustainable cement focuses on how to reduce carbon emissions (Isaksson and Kinabo, 2018). Improvement of the user value is not included. Some new binders are discussed, but not how to improve cement productivity. It seems that cement productivity is something, which is rarely discussed as indicator. This indicates that the main contribution from quality to sustainability could be the focus on stakeholder value. There is also a need of looking at the tradition of doing like everybody else instead of focusing on value for harm and long-term sustainability. This requires government led initiatives.

The study of the system of providing affordable and low carbon footprint blocks in Dar es Salaam reveals a low level of maturity. Isaksson and Hallencreutz (2008) propose a maturity scale consisting of: Understand, Define, Measure, Communicate and Lead Change. The assessment is that there is so far no understanding of what sustainable development is in the context. Applying the same maturity scale on the WBCSD Roadmap shows some understanding, but the definition of sustainability could be put into question. Crudely put the Roadmap states that cement sustainability is business as usual (BAU) while reducing the carbon footprint by using new materials and by Carbon Capture and Storage – BAU with focus on end of the pipe solutions. This indicated that the global cement industry still struggles with understanding what sustainability means.

Investing in Carbon Capture and Storage (CCS) will be expensive. The WBCSD roadmap envisages that in 2050 about 500 Million tons of CO₂ will be handled by CCS. Current projected costs are hard to assess, but some put the price increase because of CCS to 2-4 times the price of cement. Based on a typical cement price of 100 US\$/ton this would mean some 100 to 200 billion US\$ per year. This might be an occasion where the Clean Development Mechanism (CDM) could make sense. Taking the example of sandcrete blocks one possibility could be investing in providing cheap aggregates, promoting the use of hollow blocks and studying if the locally produced vibrating equipment could be improved for better compression. It is probable that investing in cement reduction in different applications could be a strong alternative to CCS. This might not be so attractive for the cement industry, but provided cost cutting and possibly increasing the cement price could compensate for reduced volumes (Isaksson, 2016).

With a decision to focus on People and Planet and on the vital stakeholder needs sustainable development could be focused on what matters most, which should make change more resource effective.

6. Conclusions

The results from the review of the Block Excellency project indicate that there are clear synergies in working for improved customer value in parallel with improved climate performance. Systematic quality work can play an important role in supporting sustainable development. The main contribution could be to convert the quality principle customer focus to stakeholder focus with the addition that focus should be on satisfying stakeholder needs. The priority of needs could be set based on input from the SDGs and the planetary boundaries. Planet level stakeholders are such as the atmosphere and the biosphere. People as stakeholders can be divided into different groups. The needs of those living in extreme poverty have priority as indicated in the SDG target 1.1 – “By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than \$1.25 a day”.

The suggestion from Isaksson (2018a) that all companies should focus on how their effects are on climate, biodiversity and poverty, has been tested on sandcrete production in Dar es Salaam. Effects on biodiversity were excluded. Sustainability in the context has been defined as affordable blocks with a low carbon footprint. The performance has been measured using the value per harm indicators (Isaksson et al. 2015) MPa*tons per price and per carbon footprint with the addition that the block compressive strength should be above 2.2 MPa. Best performance has been defined for MPa*tons, but not for price or for carbon emissions. However, since cement drives both cost and the carbon footprint the cement performance in MPa*tons or relative to the benchmark 270 MPa*tons can be used to describe excellence for sustainability. Having this target makes it possible to measure the performance in the studied system. Results indicate that cement productivity as % of benchmark is 10-30% for the studied blocks. The sustainability maturity of the system has been assessed as being on the lowest level where there still is a lack of understanding of what sustainable development is in the context. The same seems to apply for the entire cement industry that is focused on solving the problem by end of the pipe solutions such as carbon capture and storage without any clear focus on improving customer value. Considering the general importance of climate focus and the very high impact that the cement industry has on global warming, being responsible for about 7% of global carbon emissions, the low level of maturity is surprising.

It is discussed that some of the enormous investments planned for Carbon Capture and Storage (CCS) in the global cement industry, instead via the Clean Development Mechanism, could be used to reduce costs and carbon emissions in the sandcrete production system. This could support customers, the climate and the small-scale local manufacturing that provides considerable opportunities for low skill labour.

The overall conclusions is that by converting customer focus to critical stakeholder needs focus, enables operationalization of sustainability, which then leads to the possibility of using principles, practices and tools from quality management to support sustainability.

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