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Research Article

Six Sigma DMAIC for Shaking Stagnant Construction Cultures – A Conceptual Perspective

Abstract

Cultural barrier is always perceived as the prime challenge for modernizing idle construction markets. Unsurprisingly, most changes in construction hinge on understanding the benefits of sustainable transformation. Persistent attempts in stagnant construction cultures have materialized in some noted changes. Successful sustainable transformation in such economies appears to be chiefly impeded at the execution level. The Kotter's model for change is globally accepted approach for comprehensive implementation of major business transformations. Modern organizational change initiatives typically embrace the notions of Six Sigma in a broader sense. This concept paper propose the use of Six Sigma DMAIC technique for reforming stagnant construction cultures. A case study from a challenged construction market is referred to for potential implication.

Introduction

Sustainable construction is a comprehensive process pillared on adopting the principles of sustainable development over the entire construction cycle [1]. As such, all costs – direct and indirect – should be considered for objective comparisons between construction alternatives. Sustainable gains of non-monetary nature over the life cycle of a structure or project need to color business decisions. Globalization has driven the need for sustainable transformation in numerous idle construction markets. Economies in these markets are socially, technologically and often politically challenged beyond traditional and gradual local solutions for reform. Mousa [2] has analyzed common barriers impeding sustainable construction development in challenged economies using aggregated STEP analysis. He also scrutinized the mechanics of idle construction markets for a more rigorous business mitigation of the root causes. Mousa [2] has also proposed the use of Kotter's model for a paradigm sustainable change in these economies. The change process should endure the three stages of the model: unfreeze-change-lock. The Egyptian concrete market was referred to as an example of unprivileged construction cultures. It is the author's opinion, however, that pertinent literature demonstrated a disproportionate emphasis on management and business dimensions for sustainable construction transformation. In this study the use of Kotter' model for change combined with Six Sigma DMAIC is advocated as an efficient management tool to carry out the desired sustainable construction transformation in stagnant cultures. The study provides practitioners with a perspective for potential business resolutions at the conceptual level. It is hoped that this proposal is further evaluated and implemented in local contexts. Some level of market-dependent treatment is apparently needed.

Characteristics of a Stagnant Construction Culture

Numerous studies have closely investigated sustainable transformation of construction markets particularly in emerging and challenged economies. This interest is fueled by the burgeoning global concerns and challenges on several fronts: energy, environment and natural resources. The following summarizes the nature and mechanics of stagnant construction cultures, barriers to sustainable transformation, and past attempts to tackle the problem.

Nature and mechanics of the problem

Stagnant construction cultures intuitively oppose sustainable transformation attempts in most any form: products, practices, and regulations. The majority of developing countries have idle construction markets - globally perceived unattractive except for mega projects. Numerous literature have repeatedly highlighted the unsustainable characteristics of such markets. In a broader sense, these construction practices includes dated building codes and specification, weak enforcement of construction regulations, absence or scarcity of sustainable solution, lack of awareness of energy and environmental concerns, limited understanding of durability and life cycle concepts, market monopoly and absence of healthy competition [2,3]. These economies are apparently unappealing to sustainable materials due to the low intensity of competition with traditional (existing) materials. The concept of competitive strategy is described as the search for a favorable competitive position in an industry [4]. In any industry there are five forces that are likely to determine the nature and structure of competition: threat of new entrants, threat of substitutes, bargaining power of customers (buyers), bargaining power of suppliers and the rivalry among the existing competitors [5]. The dominant presence of unsustainable/traditional practices in stagnant cultures poses a market threat to introducing sustainable solutions. In such economies, prime market stakeholders are unaware of the superiority of sustainable gains and, hence, oppose change. The overwhelming power of "old-school" customers and suppliers impedes the bargaining power of new market entrants (sustainable solutions). Driven by the low market demand, investors in new construction solutions become unmotivated to take any risk.

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This value-deficient environment creates uncompetitive (stagnant) market with stakeholders unable to recognize the benefits of a healthy competition on the long term [6]. These evident mechanics of stagnant construction markets limit global competitiveness and universal business attraction.

Common market barriers

The concept of replacing a well-established material with a more sustainable substitute – perceived as a rival –intuitively faces resistance in any construction market. Pertinent literature has diagnostically highlighted local barriers with recommendations to promote sustainable construction practices [7-10]. More generically, Du Plessis [1] investigated these barriers in developing countries. Typical sustainability barriers in challenged economies are grouped in four categories: political, economic, sociocultural and technological (Table 1). This grouping allow investigating these barriers using PEST analysis [2]. From a business standpoint, studying the culture and readiness of construction markets for sustainable transformation gives better insight into identification of the impediments and resolutions.

Attempts for transformation

Numerous studies have closely investigated the modest presence of sustainable construction materials and practices in stagnant cultures. The multidimensional nature of sustainable transformation has been investigated with emphasis on one or more of the following: materials, structural design, architectural design, energy, environment, policies, management, strategic planning, life cycle, durability, and economy. In doing so, the adopted approaches utilized surveys, value engineering, and risk management, identification of sustainability barriers, and rating level of understanding, comparative analysis, policy reviews, case studies, and strategic frameworks (Table 2). Some studies employ more than one of these tools.

Table 1: Typical sustainability barriers in stagnant construction cultures.

Aspect	Barrier
Political	Transparency
	Legislative changes and restructuring
	Business environment
	Sustainable legislations
	Law enforcement
	Protection of investment
	Current construction permitting process
	Political instability
	Political vision and will
	Bureaucracy
Economic	Available natural resources
	Alternative materials
	Local competitiveness
	Universal competitiveness
	Market control
	Importing sustainable materials
	Importing new material/technology
	Availability of business information
	Local market practices
	Monopoly
Sociocultural	Perception of natural resources
	Perception of sustainability
	Perception of value engineering
	Perception of environment
	Perception of quality of life
	Perception of value of research
	Perception of cost (focus on initial cost)
	Current construction practices
	Consumer awareness
	Media/communication channel
	Illiteracy
	Population
	Professional training
	Common work culture
	Embracing corporate social responsibility
Technological	Alternative material/technology
	Importing new material/technology
	Training on new material/technology
	Embracing new material/technology in building codes
	Local R&D and innovation
	Utilization of natural resources

Sustainability Perception in Stagnant Construction Culture

The Egyptian concrete market is presented herewith as an example of unprivileged developing economies that are in dire need of sustainable construction development. Unlike modern markets, the Egyptian concrete market relies primarily on the use of the dated site-mixed concrete (SMC). The use of ready-mixed concrete (RMC) is very limited - predominately used in large scale projects. For further details the reader is referred to Zidan et al. [11], who scrutinized the local construction industry in Egypt. A detailed survey on the Egyptian market was further conducted by Mousa [2] for gauging receptiveness to sustainable construction practices and materials. The study attempted to examine the root causes for the modest presence of RMC and supplementary cementitious materials (SCMs) in construction. Both unstructured interviews and a questionnaire were performed. The pool of respondents is comprised of 8 developers (10%); 12 consultants (15%); 16 contractors (20%); 12 technical officers (15%) and 32 site engineers (40%).

Highlights of questionnaire

Selected results are discussed with emphasis on gauging the awareness and perception of sustainable materials amongst the respondents. The responses to the following questions are statistically presented in Figure 1:

How do you rate your understanding of the term “durability”?

How do you rate your understanding of the term “sustainability”?

Do you think the use of traditional/mediocre quality concrete has a negative impact on the structure’s life cycle?

Do you think the use of traditional/mediocre quality concrete has a negative impact on the environment?

Do you think the use of traditional/mediocre quality concrete has a negative impact on the natural resources?

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Table 2: Summary of selected literature on sustainable construction transformation in challenged markets.

Study Nature	Region/Country	References
Questionnaire – developers awareness	Malaysia	Abidin and Abidin [25,26].
Questionnaire – barriers	Malaysia	Ismail et al., Samari et al. [27,28].
Proposed remedial actions	Malaysia	Shari and Soebarto [29]’
Proposed change in policies	Malaysia	Idris and Ismail, Ismail el al. [30,31].
Survey – value engineering	Malaysia	Fathoni et al. [32].
Questionnaire – barriers	China	Shi et al. [33].
Opinion – performance based design	Africa	Ngab and Bindra [34].
Questionnaire – prioritizing sustainability barriers	Uganda	Alinaitwe [35].
Questionnaire and interviews - barriers	Ghana	Djokoto et al. [10].
Questionnaire – general awareness	Chile	Serpell and Kort [36].
Opinion – enforcement of policies	Latin America	Gomes and da Silva [37].
Discussion – Brazilian perspective	Latin America	John et al. [38].
Survey and case study	Lebanon	Majdalani et al. [39].
Strategic Framework	Jordan	Alsubeh [40].
Proposed holistic strategy	Developing countries	Du Plessis and Du Plessis [1,41].
Proposed indicators for sustainable improvement	Developing countries	Ofori [42].

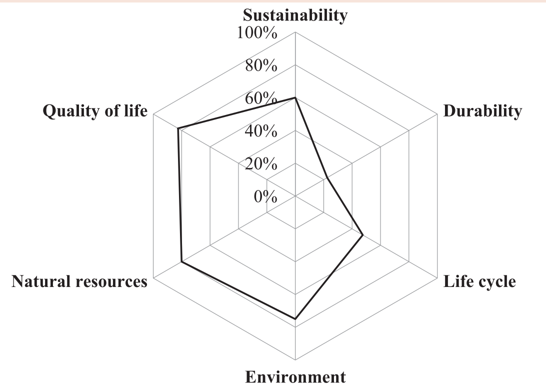

Figure 1: Presentation of poor understanding of sustainable construction concepts in the Egyptian market. (100% is lowest level of understanding).

Do you think the use of traditional/mediocre quality concrete has a negative impact on the quality of life?

The sum of responses indicating poor/lack of understanding (“indifferent”, “unsure, and “no”) are mathematically presented as a percentage of total responses to the question (Figure 1). Approximately 80% and 40% indicate a reasonable level of understanding (answers were “yes” and “somewhat”) durability and sustainability, respectively. This huge difference underscores the incomprehensive understanding of durability as a component of sustainability – the larger umbrella. With about 50% -80% responses indicating poor understanding of the negative impact of mediocre concrete on life cycle, environment, natural resources and quality of life, the outcome of the survey is unarguably shocking. Amazingly enough, 80% of the correspondents perceive initial cost of construction as the total cost (results not shown). In a broader sense, the ambiguous interpretation of the concept of value and gain (results not shown) coupled with the poor understanding of sustainability components explain the unwelcoming market to sustainable construction solutions. Such figures are reflective of the dicey future of sustainable concrete in the Egyptian market. Detailed discussion of the survey is in line with the presented summary [2].

Rating sustainability understanding

The questions evaluating the level of understanding of the problem and potential change are populated and statistically analyzed. The five possible answers (“indifferent”, “unsure”, “no”, “somewhat”, and “yes”) to fourteen questions are sorted from the least meaningful to what is judged to align with universal practices and adequate understanding (Table 3). A Likert-Type Scale of (4) was used to rate the relative level of understanding (RII) of sustainable concretes and related concepts. A score of 4 implies high understanding (definitiveness) of the examined aspect or concept, whereas a score of 0 is given to extremely poor understanding/attitude (imprudence/passiveness). The answers that show reluctance, misinforming, and mediocreness in awareness are given scores of 1, 2 and 3, respectively. The rationale of the proposed rating scheme is based on the assumption that uninformed market player are easier to influence once educated than those who are careless (negligent) or cynical (skeptical). The rating is computed in a reverse order such that low RII indicates limited/incomprehensive understanding and vice versa. The RII is calculated as follows [12]:

$$RII = \frac{\sum W}{AN} \qquad (1)$$

Where: w = sum of scores awarded a response times the number of respondents

A = largest integer given to responses (4)

N = total number of respondents (80)

The results summarized in Table 3 are reflective of the unsustainable construction practices in Egypt. Evidently, good understanding of notional econo-environmental aspects of using sustainable concrete appears to be absent – just like it is in many other developing countries. Figure 2a is an aggregation of the five types of responses for the fourteen questions. With approximately 60% of the participants described as imprudent, reluctant or misinformed, the desired sustainable construction transformation appears to be very challenging. Comparatively, only about one-quarter of the respondents exhibited definitiveness. Figure 2b depicts the percentage of answers to the fourteen questions indicating poor understanding of sustainability concepts (“indifferent”, “unsure”, and “no”). This

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Table 3: Relative level of understanding (RII) of sustainability aspects in the Egyptian construction market.

Concept/Aspect	RII	Level of Understanding
SMC & quality of life	0.29	14
SMC & natural resources	0.32	13
Gauging role of government	0.38	12
SMC & environment	0.48	11
Stagnancy of code of practice	0.49	10
Sustainability	0.53	9
Status of SMC in global markets	0.54	8
RMC vs. SMC - negative impacts	0.56	7
RMC enhancing construction schedule	0.56	6
Real cost of RMC	0.57	5
SMC & life cycle	0.64	4
Maintenance	0.64	3
Cost vs. value	0.74	2
Durability	0.81	1
RMC added value*	0.97	-

* High level of understanding: applies only to those used RMC – included for comparison only

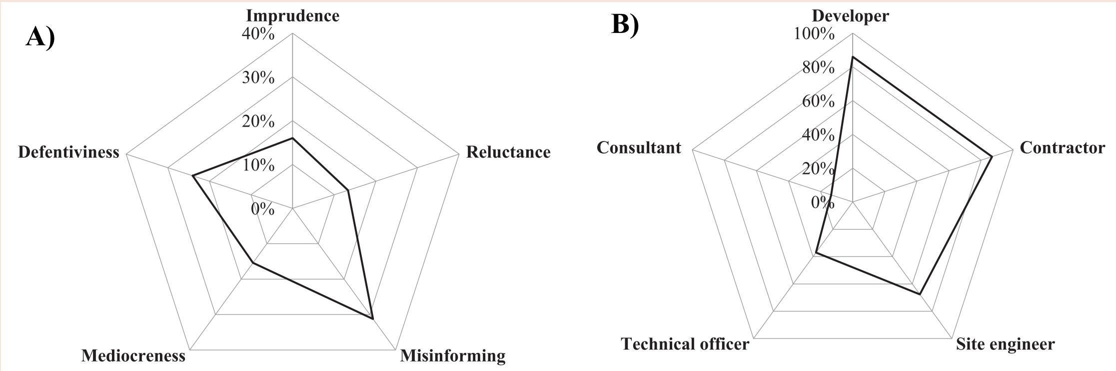

Figure 2: Culture of concrete market in Egypt: (a) attitude of participants (collective); (b) poor understanding of sustainable construction (by group).

is presented by group. With the noted inadequate appreciation to sustainability among site engineers, contractors and developers, it is unsurprising that this attitude drives a negative culture that is quite influential on the Egyptian concrete market. These alarming indicators are likely to be more daring if the survey was conducted among illiterate or working class in the construction industry. Figure 2 vividly provides representative awareness mapping of sustainable concrete and related sustainability concepts in the Egyptian market.

Major findings and reforming indicators

The presented case is exemplary in terms of flawed market understanding of modern construction industry and deficient acknowledgement of the business benefits of sustainability. The conducted survey reveals numerous negative (unsustainable) market inclinations. Holistic understanding of the real cost, life cycle and superior characteristics of sustainable concrete amongst the overwhelming majority of the stakeholders - and even some practitioners - is apparently absent. The study postulated that ameliorating construction in Egypt (stagnant markets) is inevitable. A swift market transition to sustainable concrete – including the use of SCMs and blended cements – is a crucial strategic decision for modernizing the construction market. RMC must be the vehicle for the transformation. The mainstream customers in this market are, however, either unable or unwilling to realize the benefits of using sustainable concrete. Therefore, they disregard its leverage over the predominant traditional concrete (SMC). They are generally preoccupied with the fallacy of unnecessarily overpriced sustainable concrete, and, hence, RMC is perceived a luxury not a necessity! The cultural dimension (level of understanding of sustainability) coupled with lack of business incentive are definitely major impediments to sustainable construction in Egypt. The totality of the survey-supported findings is quite in line with those frequently reported in other developing countries.

Six Sigma Dmaic for Shaking Construction Stagnancy

Background

Change is a perpetual and instrumental business characteristic for survival of an industry or product [4]. A robust executable plan is required for efficiently carrying out change. Kotter proposed a three-phase model to create lasting business transformations: creation of the change environment (unfreezing), engaging and enabling participants (changing), and sustain the change (locking success). Organizational transformation may not necessarily fail due to an improper vision, mission, or plan. Most failures generally occur during execution [13]. There is a need to discern between managing change and leading change. Only the latter can make the difference that is meant to last via overwhelming all sources of inertia and stagnancy. Holding this understanding, a feasible business implementation in sustainable construction transformation is yet to be demonstrated. The problem with past reforming efforts in stagnant cultures resides in their inability to instill and manage the desired changes. Therefore, even with Kotter's model of change, a robust implementation is needed for a self-driven improvement momentum that could ensure "locking success". This approach shall better be complemented at the action level with total quality management techniques such as Six Sigma [14]. Six Sigma, first introduced by Motorola in the mid-80s, is a set of techniques and tools commonly used in the large corporations and industrial organizations for quality improvement. The process is based on the statistical foundation of Carl Friedrich Gauss (1777-1855). The use of Six Sigma as a management tool has its merits in the development of quality culture. Davison and Al-Shaghana [15] have demonstrated via a survey on non-six-sigma and six-sigma corporates that the latter exhibit higher mean cultural scores. The burgeoning literature on Six Sigma can be classified into two major groups: the systematic (statistical) and the management approaches used in Six Sigma [16].

DMAIC is a cyclical (loop) Six Sigma process that is commonly used as an integral part of modern total quality in major organizations. It is comprised of interconnected phases: Define, Measure, Analyze, Improve and Control. DMAIC Method is typically used to eliminate defects. The method lends itself well to improvement of existing processes falling below expected quality or specification [17]. Six Sigma DMAIC technique have exhibited a paradigm cultural shift associated with management, innovation and leadership (cultural) and financial befits in numerous applications. Driven by the origin and needs, this success is evident in manufacturing and technology world [18,19]. Equally successful, Six Sigma DMAIC has shown undeniable success in financial corporations and trade [14]. Even in the health business, DMAIC has empowered the management team to improve the culture in an institute for transfusion medicine [20]. DMAIC is generally a favorable choice to improve the culture of companies with stagnant market and low competitiveness [21].

The use of DMAIC process in construction is relatively limited and more recent as compared with other industries - particularly high-tech and manufacturing processes. Parallel to the direct use of Six Sigma DMAIC technique as a statistical tool to reduce defects in construction (e.g. design, materials and products), the versatility of this technique in managing change and ensuring continuous quality improvement is very promising [22]. To this end, the former is the mainstream DMAIC implementation in construction. This could be attributed to the complex nature, restriction on automation, strong impact of environment and unrepeatability of construction activities [23,24]. However, DMAIC methodology is a more applicable improvement tool in the construction industry than other Six Sigma techniques [22]. Six Sigma DMAIC can be used to improve critical to quality (CTQ) parameters and cost savings in cell site construction Six Sigma [16]. DMAIC can effectively increase quality and quantity at the same time and, thus, it warrants technical and financial success of construction projects [22]. In view of this, it is the opinion of the author that DMAIC could be utilized to revive stagnant construction cultures.

Conceptual proposal

The following is an attempt to propose the use DMAIC for improving the construction culture in Egypt using. DMAIC is conceptually incorporated into Kotter's change model as a management tool. Hence, this approach should be perceived complementary to the use of the Kotter's model suggested by Mousa [2]. The actions of DMAIC cycle hosting the three phases of the model are generically depicted in Figure 3. More specifically, the use of DMAIC for the Egyptian concrete market is suggested to include the following:

Define:

a. **Unfreezing Phase:** Unsustainable concrete should be identified to be discontinued within a species time period. The use of sustainable concrete must be the norm in the construction. Encompass environmental protection, preserving natural resources, maintaining real estate capital, ensuring transparent and proper construction practices, and elimination of monopoly among cement producers. Vividly set the context and objectives of this desired change. The material production and construction strategies must be consistent with the demands of customers and the enterprise policies within the desired transformation (change model). Form a council for sustainable construction (CSC) comprised of selected members from market stakeholders, governmental organization, and independent consulting members.

b. **Changing Phase:** Underline the most critical reasons behind unsuitable practices in the construction market (critical to quality). Appointed representatives of CSC are entitled to closely monitor the sustainable aspects of construction-related activities from cradle (permitting) to grave (handover).

c. **Locking Phase:** Set privileges and limits of authority of CSC in proposing sustainable practices to warrant continuous improvement.

Measure:

a. **Unfreezing Phase:** measure current characteristics that are critical to quality of construction. Gauge production capability and associate risks. Holistically assess construction permitting process and collaborate with relative parties.

b. **Changing Phase:** Perform a thorough reevaluation of the building code and construction regulations. Develop rating system for contractors and suppliers. Statutory actions must include performance-based design with mandatory use of RMC. In this context, the use of SMC in structural elements is considered a violation to issued construction permits.

c. **Locking Phase:** Estimate and disseminate private and public savings (gains) due to switching to sustainable construction solutions.

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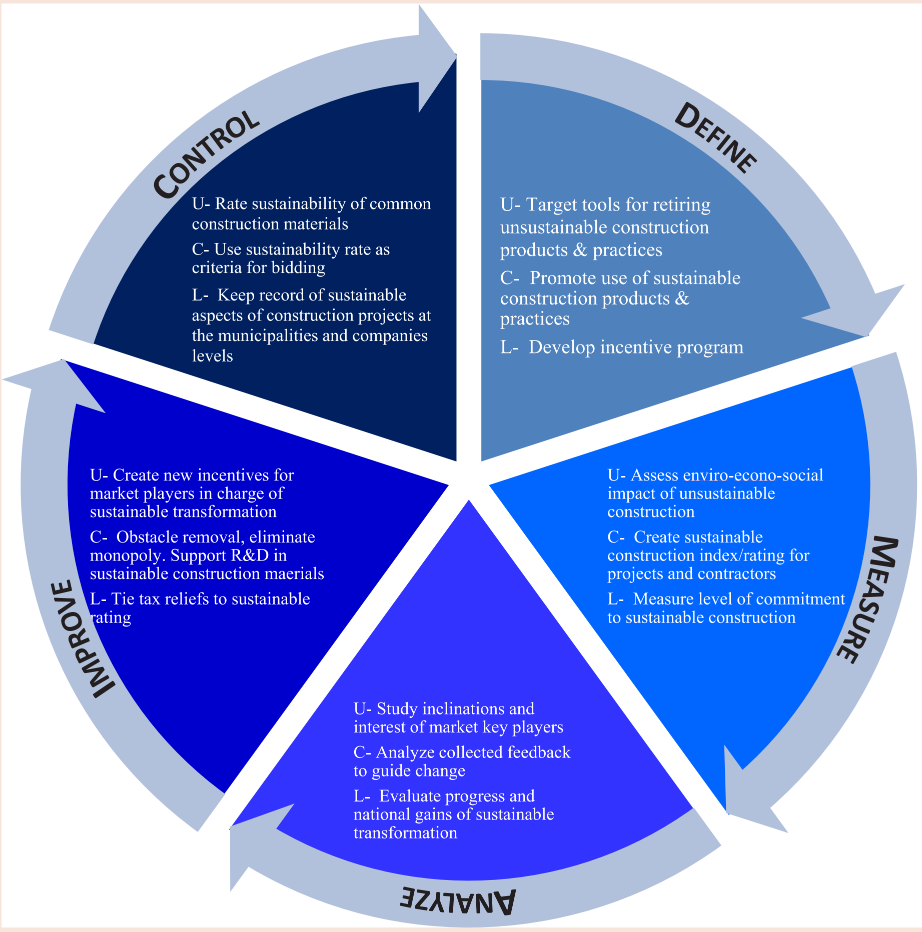

Figure 3: Incorporation of Six Sigma DMAIC into Kotter's Model to change stagnant construction cultures. (U: unfreezing; C: changing; L: locking success).

Analyze:

a. **Unfreezing Phase**: use analytical and statistical tools to develop and design construction alternatives that meet the goals and criteria of the transformation model. This may require optimization and manufacturing using local materials and additives.

b. **Changing Phase:** Involve public and private R&D centers for developing new technologies and recycling locally available construction materials.

c. **Locking Phase:** Allocate national research grants for utilizing local sustainable materials. Funding should be commensurate to the success in utilization of local resources and operational savings.

Improve:

a. **Unfreezing Phase:** Improve construction system and remove defects, flaws and inefficiencies. Elect alternative(s) that best suited per analysis in the previous step.

b. **Changing Phase:** Include a section in building codes on sustainable and green materials and how to rate them. Conduct regular updates on sustainable construction in the building codes and construction regulations.

c. **Locking Phase:** Reward parties using sustainable concrete (construction material) with tax reliefs, preferred prices of raw materials and reduced energy (fuel) rates. Embrace construction industry reform under the umbrella of corporate social responsibility of large corporation.

Control:

a. **Unfreezing Phase:** verify the design production and construction to ensure maintained quality in accordance with the goals of the transformation model. Empower CSC to implement a holistic vision for promotion and use of more sustainable materials. RMC must be compulsory in construction. Adopt legislative measures to eliminate monopoly in construction.

b. **Changing Phase:** Restrict execution of the national projects to eligible rated contractors and suppliers. Approve, suspend or terminate construction activities as per the issued sustainability regulations. Penalize violators or forfeiting permit, increase price of bag cement. Spend collected fines from violators on awareness, incentives, grants and training.

c. **Locking Phase:** Continue providing incentives to sustainable and green building communities. This applies to all involved stakeholders including end users.

Embracing sustainable development as a national theme and a core value of all stakeholders is instrumental for amelioration of the construction culture. The monetary value of the benefits of sustainable transformation is deemed more convincing to the vast majority of practitioners. Other business benefits of the transformation are discussed by Mousa [2]. For future research, it is expected to customize this approach to respective construction markets.

Closing Remarks

It is the author's perspective that potential construction transformation in challenged economies largely hinges on gauging - and subsequently promoting - the level of understanding of sustainability related concepts among the stakeholders. Modernizing idle construction markets requires critical identification and subsequent elimination of non-sustainable materials and practices. Utilization of Six Sigma is proposed as a complementing managing tool to the Kotter's model for leading changes in stagnant cultures. The use of the Six-Sigma DMAIC technique warrants continuous amelioration in construction. The technique has been globally recognized for its technical benefits as well as financial leverage. In this paper, the integration of a management tool into a model for change is proposed at the conceptual level. The use of such a powerful management technique is instrumental for a paradigm shift and strategic change in construction at the execution level. However, the proposed approach is merely deemed thematic with generic merits. Further manipulation and application is pending courageous initiatives from pertinent parties. In this regard, the governmental and organizational roles are unequivocally imperative. The business benefits of the advocated sustainable construction transformation is likely to warrant "locking" success.

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