The Journey of Exploring 'Construction as Biological Cells' for Improving Construction Quality: Aritculating the research paradigm

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Abstract
Quality problems in construction is commonplace including defects. This study reports the journey to date of using a novel approach to explore solutions with *construction as biological-cells* simile. Ontological and epistemological issues regarding this approach is discussed arguing for postmodernism for comprehending *reality*, creating *knowledge* by applying logic (reason) to questions constantly in order to develop justified beliefs. *Intuitive* and *reflective inferences* have been made throughout when using *simile* as when synthesising the *Readiness-Growth-Rest* model and associated concepts published earlier explaining the approach using the simile *methodology as spiral* under the umbrella of the simile cum metaphorical approach established for such studies by the authors. The study advocates the use of this method for exploring solutions to perennial problems explaining the challenges with the simile *methodology as spiral* and how it could be used for advancing the notion of *theory as scientific practice*.

Keywords: cell, metaphorical analysis, production management, quality management, simile

1. The Context
Construction is plagued with defects almost cancerous in nature without a cure in sight. In this regard, the notion of cell division in biological cells with a remarkably low defect rate has inspired an investigation into how such is possible. Could those in construction benefit by understanding this process, and in some way, replicate it …? Others have benefitted learning from nature (Benyus, 2002; El-Zeiny, 2012; Gruber et al., 2011; Martinez-Boubeta et al., 2013) so would this be possible in construction particularly when managing quality as defect free? A seemingly impossible and irrational task given that construction is quite different to biological cells. However, the promise of a new line of inquiry labelled as the *simile cum metaphor* approach provides hope as evidenced by Abeysekera's (1997) study on Brickwork as Chaos, and Monetary Retention as Cash Cow, Steroid, Beast, etc. in Abeysekera's (2008) study; and more recently Abeysekera's and Shelke's (2013, 2015a, 2015b, 2017, 2018) study of *construction as biological cells* provide inspiration and confidence in the pursuit of finding a fresh approach for improving process quality..

Notably, despite the collective wisdom on quality management through ISO 9000 and the like, there is still a need to improve construction quality judging by the spate of defective work in construction. Various studies have estimated rework costs are in the range of 10% to 20% of the project cost (Josephson, Larsson, & Li, 2002; Love & Li, 2000; Love, Teo, & Morrison, 2017; Rosenfeld, 2009) which of course may vary from country to country and form project to project. These are the direct cost of quality, and can only increase further if the intangible cost of poor quality is also considered. Accordingly, as hinted above, it would be useful to learn from nature as to whether it would be possible to improve the status-quo. It is in this regard that the *simile cum metaphorical* approach provides the nutrients to pursue a new line of investigation to develop new insights on how to improve practice. As

such, this paper examines the journey thus far with the simile *construction as biological cells* hoping to improve current practices on quality management with a special focus on minimising defects.

2. Aims and Objectives

As noted above, the objective of this paper is to describe the journey thus far exploring the simile *construction as biological cells* – it's birth, the challenges, the research paradigm, and future with the aim of developing a management framework for the elimination (or reduction) of defects during the construction stage *sparked* by the remarkably low defects rate in the biological cell proliferation process.

3. The journey – Research paradigm issues

3.1 The spark – Use of simile and the birth of the *construction as biological cells* simile

The inspiration for this study came from the use of simile and metaphor for research and teaching by the first author. The roots of this approach can be traced to the first author's study on Sri Lankan brickwork using reflecting on the simile *Brickwork as Chaos* (Abeysekera, 1997). The second study involved building theories on monetary retentions vis-à-vis the similes - *Retention as Cash Cow, Steroid, Beast, Stress and Chaos* (Abeysekera, 2008) based on research undertaken on monetary retentions. In the former study, Abeysekera investigated strategies for managing Sri Lankan brickwork with unprecedented and disorderly variations in brick and joint sizes including wall widths. He was inspired by Chaos **Theory** almost halfway through his study when he realised that what was studying was a very chaotic phenomenon. The discovery of *chaos theory* ***sparked*** a new line of investigation and an approach for finding solutions to a perennial problem. Paradoxically, this study found that despite the chaos, i.e. the disorderliness of brickwork operations, there was an underlying order while proposing a framework for finding the way through this chaos. In the second study mentioned above, i.e. on retentions, the attempt was to capture and condense a large body of evidence-based-knowledge to tell a *story* on monetary retentions generating new insights on how to manage retentions.

On both occasions, the first author contends that the *similes* were born out of adversity through *intuitive and reflective imagination and inference* (Evans and Frankish, 2009); it seems relatively simple now but their synthesis was challenging then requiring wild but creative flights of imagination. Encouraged by these pursuits, the first author argued that this approach may be a useful way to capture and condense the extensive knowledge on the *nature of construction* when faced with the daunting task of introducing the topic to first year construction management students at University of Southern Queensland. It transpired that simile and metaphor may provide some relief in encapsulating such a large body of knowledge into just one lecture! Accordingly, the topic was introduced through what was labelled as *images of construction* such as *Construction as Business, Construction as Machine, Craft and Industry* and so on. These *similes* proved very resourceful, and insightful too. Further explorations lead to the synthesis of the *construction as biological cells* simile as construction 'cells' are replicated in similar ways to biological cells (symbolically) to create a multi-cellular structure. Indeed, it appeared to be an interesting and powerful simile to explore the nature of cellular construction. While this lay dormant for a while, it was only through further exploration with the assistance of the second author who was employed in a quality management role in a first-tier construction company that it was discovered that biological cells do proliferate with a remarkably low error/defects providing the ***spark*** for the exploration of a seemingly **irrational but interesting challenge** in order reduce (or eliminate) defects in cell replication. Thus, began this study.

3.2 Study of *Construction as Biological Cells*: The initial research agenda

As noted above, the confidence to explore this simile was sparked by the discovery of the low defects rates of biological cells. Accordingly, it was fundamentally important to understand biological cell theory (BCT) – a seemingly daunting task for those with academic qualifications in engineering and construction management. Initial investigations revealed that construction cells do share properties similar to biological cells (Abeysekera & Shelke, 2015a), and it was useful to explore factors responsible for the defect free (i.e. quality) replication of biological cell. These investigations lead to the discovery of three

main concepts: (a) Embedded design (b) Uniform rate of cell proliferation, and (c) Cell cycle control with the following objectives set to guide the investigation:

1. Undertake a detailed study of BCT	
2. Understand similarities of construction cells with biological cells	5. Establish quality management practices for managing quality in construction cells
3. Compare current practice with cell theory concepts, processes, and procedures	6. Synthesise potential drivers and solutions for change
4. Understand the reasons for deviations between cellular practice and construction practice	7. Establish the relevance of the newly identified drivers/solutions to construction

One of the challenges faced initially was the inability to see how this research could be conducted. As noted, the discovery that biological cells proliferate with a remarkably low error rate sparked the investigation and the need to investigate BCT was triggered by it. The desire to synthesise a suitable set of concepts came by reflecting on the *brickwork as chaos* study whereby concepts such as universalism, geometry of order, orderly chaos, etc. were synthesised for the development of the eventual framework. However, in this study, the researchers weren't sure whether this would be possible although a first round of study came up with the three concepts mentioned in the introductory paragraph. On reflection, the approach adopted seems to be conveyed by the simile *methodology (map) as spiral cone* described below.

3.3 Methodology (map) as spiral

Fig. 1: Methodology (map) as spiral

The sub-objectives set up earlier (see 3.2) is almost in a sequential and chronological order with one completed before the next is accomplished. Setting up all objectives accurately in one attempt is difficult if not impossible due to the lack of clarity what and how it needs to be done. This approach seems analogous with climbing a spiral (see Figure 1) in that the very nature of the spiral is such that it is difficult to see the destination when standing on one; the only way to see the top is to traverse spiral by spiral from one to another. Moreover, it is only when one spiral is traversed that the next can be seen albeit in a hazy environment but one with a sense of freshness as when the sun shines through on a misty morning. On further reflection, the road to success wasn't a straightforward path nor a simple input-output mechanism but one which was difficult to see with each spiral of knowledge helping to see the other filled with new discoveries, new concepts and development as shown in Figure 2 with the refined objectives as noted in Table 1

Table 1: Spiral of knowledge

1. Review Biological Cell Theory (BCT)	6. Document current quality management practices (as a participant observer)
2. Synthesise relevant concepts from BCT for exploration	7. Understand process mechanisms for cell division vis-à-vis BCC
3. Review literature on the use of simile and metaphor including similarities and dissimilarities between simile and metaphor	8. Synthesise a cell-based framework for managing quality in construction through intuitive and reflective inferences
4. Establish the feasibility of exploring the simile and metaphor particularly the construction as biological cells simile	9. Explore the application of its relevance including the relevant biological cell based concepts for construction
5. Understand the similarities of construction cells with biological cells	10. Establish the relevance of the newly identified drivers/solutions to construction and synthesise potential drivers and solutions for change

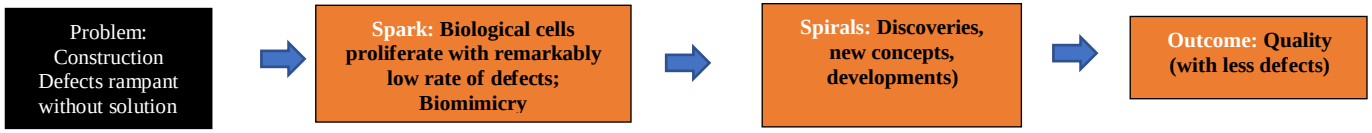
3.4 The simile cum metaphorical approach

Essentially, the approach adopted above involves comparing two seemingly dissimilar items to understand the similarities if possible and thereby generate new ways of thinking about items to generate new insights approaches for construction both in relation to technology and management with the intention of developing innovative solutions to perennial problems, or even frameworks for *understanding reality* in insightful ways. It is in this regard the use of *metaphor and simile* becomes a resourceful approach for understanding construction phenomena.

Table 2: The journey to date: Discoveries, new concepts, and developments

	Pursuit/Publications		Knowledge area	Discoveries/New concepts/Developments	Methods (mainly as participant observer)
	Summarised name	Year			
Seventh cycle	**Biological Cell Surveillance: Implications on Construction Cells**	2018	Cell Cycle Surveillance Mechanism	Process stress, process memory, distress signalling to ensure process stop	Reflective case analysis of tunnel project based on synthesized concepts
Sixth cycle	**Construction as Biological Cells: An Exploratory Study**	2017: Journal paper		Synthesis of a new model for managing construction: **Readiness-Growth-Rest (RGR)**	A reflective analysis of papers from 2013 to 2017
Fifth cycle	**BCT-based interventions and the impact on quality**	2017		Transient cell cycle arrest (TCA), readiness checks, embedded design; NCR based cell TCAs	Case study of a large transmission tower construction project
Fourth spiral	**Understanding the relevance of BCT and BCC for solving quality problems in construction**	2017	BCT and BCC	Risk assessment associated with lack of initial construction cell which exists as an abstract form given the loss in translation of design intent; dual rate and multi-phase approach with initial low rate to perfect the replication leading to stable build rate; congruity between design codes and translated codes at the construction coal face	Reflective case analysis of tunnel slab construction in large project to understand relevance of BCT and BCC; comparison of the current Quality Management practices in large projects with that employed in the biological cell
Third spiral	**Implications of the Biological Cell Cycle (BCC) for managing quality in construction**	2015	Biological cell cycle (BCC)	Biological cell control mechanism; embedded design imprinted through a ***multi-staged cyclic*** process with *gated* controls for detecting design deficiencies (different to PDCA cycle); process ***halted*** when defects detected and corrected.	Intuitive and reflective analysis of quality issues (Evans & Frankish, 2009) ; further exploring the notion of construction cell as biological cell
Second spiral	**Can construction cells be similar to biological cells?**	2015		***Types*** of construction cells identified; uniform rates of cell proliferation in construction cells with rate variations seemingly connected with defects; possibility to identify embedded designs with repetitive cells even in remotely possible cases; **simile cum metaphorical paradigm relevant** for *cell-based construction*	Multiple case studies with examples drawn to support the use of the simile cum metaphorical approach
First spiral	**Managing Quality in Construction:** Construction as Biological Cells	2013	Biological Cell Theory (BCT)	Cell - a basic unit of construction; cell proliferation – uniform with variations leading to cancer; process – driven by an embedded design	Case study of a large tunnel construction project with quality problems and significant variations in construction output seemingly correlated with number of NCRs

Source (of spiral): https://hu.123rf.com/profile_anhoog?mediapopup=11121167



3.4.1 Ontological issues

A *metaphor* is the expression of an understanding of one concept in terms of another concept, where there is some similarity or correlation between the two; it can also be used to understand one concept in terms of another as in *she is a peacock* or *time is money*. Similar to metaphor, *simile* is also a comparison between two things but expressed by the use of words *like* or *as*. Some common examples are 'he is as busy as a bee' (working very hard) or 'she is tough as nails' (having physical strength).

Both metaphor and simile compares two different things in interesting ways but both are different in nature: Simile uses words such as *like* or *as* to draw a comparison and a metaphor simply states the comparison without using *like* or *as*. Accordingly, *Construction as Biological Cells* is a simile although it is pointed out by some that *simile* falls under the broad category of metaphor both of which is a trope – a figurative use of an expression Black, 1993; Lakoff, 1990; Lakoff & Johnson, 1980 cited in (Jacobs & Heracleous, 2006). Can the power of such expression be used to understand *reality?* What can be said to exist?

According to Babbie (2001), nature of reality is more complex than what can be imagined. Three different viewpoints are presented, namely, *premodern*, *modern*, and *postmodern* views of reality. According to the premodern view of reality, it is claimed that 'our early ancestors all assumed that they saw things as they really were'. They would say that gods reside in trees and if trees were felled, those who do would be cursed. However, as humans evolved, such notions were challenged; they came to recognize that there were other views. This is the modern view of reality as different people have different views; there is nothing right or wrong although it seems to be a view that focusses largely on rationalism, logic and science to inform reality. A rose is a rose although in reality some may view it as beautiful but others as a thorn. In contrast, the postmodern view, according to Babbie (2001) holds that gods do not exist, neither does a rose; 'all that's "real" are the images we get through our points of view'. It seems to be all in the minds of human beings. While an attempt is made to understand what is "really" happening, as human being, they 'bring along personal orientations that will colour what they observe and how they explain it. There is ultimately no way people can step outside their humanness to see and understand the world as it "really" is – that is independently of all human viewpoints' and that 'there is no "objective" reality to be observed in the first place; there are only our several subjective views'.

In this regard, the authors contend that the nature of reality as understood through the *simile cum metaphorical* approach aligns with the *postmodern* view of ontology. In this sense, reality is seen as a projection of human imagination according to Hussey and Hussey (1997, p. 51), as in the use of the simile *construction as biological cells* – an image of construction similar to *Brickwork as Chaos or Retentions as Beast, Steroid, Cash Cow etc*. as referred to by (Abeysekera, 1997, 2008). It is an interesting *image* to be explored for creating new knowledge on *quality management* inspired by previous studies in construction management as noted above and described later with the power to develop innovative solutions perennial construction problems by making a difference to practice.

3.4.2 Epistemological issues

Creating knowledge has been a perennial challenge with significant ongoing debate among philosophers on *Theory of Knowledge* - on the nature of *theory*, its form, the manner in which knowledge should be created. Interestingly, *epistemology* is the branch of Philosophy concerned with the *theory of knowledge*. Strikingly, its body of knowledge is vast, so to profess knowledge about it would be false; yet, the situation demands a basic understanding of this complex branch of study with regards to methods, their validity, justified beliefs and opinion but from the context of a practical discipline such as construction management. Epistemology is said to address such questions as: *What does it mean to say that we know something? How do we know that we know?*

In other words, *knowledge* is about *knowing*, and in the context of this study, author's take the pragmatic position that what is important to practitioners is to *know* how to manage construction quality in ways that

we will not encounter quality problems, or else to find ways to prevent the occurrence of existing quality problems – say defects, for example. One wonders whether we really *know* judging by the plethora of quality problems we encounter on a daily basis (Love et al., 2017). Perhaps, it is due to the *partial knowledge* we have and our *beliefs* are not *justified*. Accordingly, one may argue that theoretical underpinnings connected with quality management are weak. Thus, what needs to be borne in mind is that when using simile particularly the simile of *construction as biological cells* for creating new knowledge, it would be necessary to address issues related to epistemological questions as raised in the aforementioned paragraph.

It must be said that there are many ways of *knowing* such as authority, intuition, tenacity or even experience. Interestingly, according to the Webster's New World Dictionary, the word science which is derived from the Latin word *sciens* means 'knowing'. However, what makes science different to other ways of knowing is that 'science applies logic [reason] to questions constantly' for right understanding (Shoemaker, Tankard Jr, & Lasorsa, 2003). It is proposed therefore that knowledge created **must be science** if it is to be of value to professions involved with the built environment. Professions that are backed by knowledge (as science) could then be referred to as scientific, as in scientific engineering (as against engineering) analogous with 'scientific medicine' or 'scientific farming' (Miettinen, 2001). Accordingly, professional practice must necessarily become *scientific practice;* indeed, it is said that practice that is not driven by science is akin to a quack-doctor practicing medicine Berg (1995) as quoted in (Abeysekera, 2008). Accordingly, when exploring the simile *construction as biological cells*, we assert that what is required is to apply *logic* to questions constantly in *justifiable* ways with a 'specially firm determination not to persist in error if any exertion of hand or mind can deliver us from it' as noted by the Nobel Laureate biologist Peter Medawar with respect to the scientific method (Abeysekera, 2008). This does not necessarily mean that this study advocates the scientific method per se for creating knowledge but rather a case of drawing useful aspects from the scientific method for generating justified beliefs from the imagination/point of view of the researchers while aligning with the ontological view of post modernism; the 'truth' in this sense is seen as an imagination of the researchers: There is no *objective reality;* there are only our several subjective views.

4 The future – Methodological issues

Although the initial spark was the discovery that biological cells proliferate with a remarkably low error rate, the exploration of construction as biological cells has created a number of opportunities to explore further. One of the principle outcomes thus far is the synthesis of a new framework for production management called the Readiness-Growth-Rest model shown in Figure 2 (Abeysekera & Shelke, 2017). Whilst the model can be explored in relation to time, cost, quality and safety perspectives for achieving successful project outcomes, this study focuses on quality with a focus on minimising defects. This approach does not necessarily fit in with either an *inductive* or a *deductive* approach in the purest sense but the investigation in the future would fall broadly within the deductive approach but the approach in essence is different as shown in Figure 2.

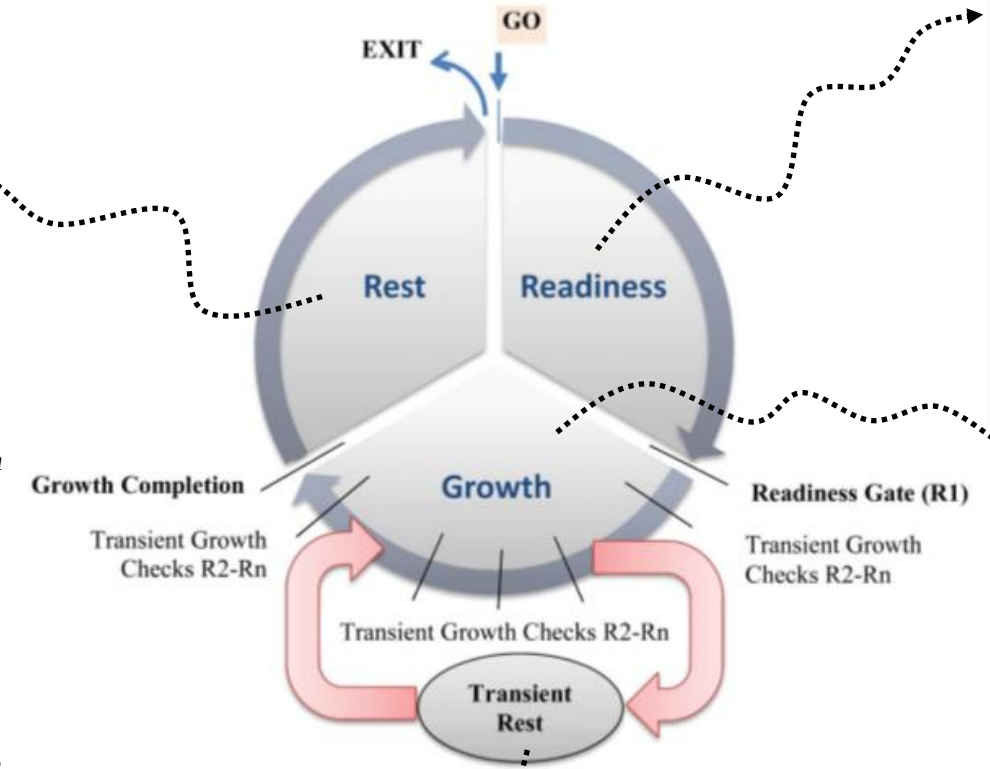
Problematic phenomenon (observation) ➡ **Generation of new concepts/models** (creating theory mainly through conceptual observations, reflections and synthesis using the simile cum metaphorical approach but partly through empirical observations/validation) ➡ **Establishing the link between the model** (with associated concepts) to **future practice** in a way that we could call "practice as scientific practice" (see explanation in the paper)

Figure 2: Research Paradigm in a nutshell

In order to advance the study further five methodological approaches have been proposed herein from which one has to be selected. These approaches are listed next for exploring the RGR model and the cell-based concepts which is to be finalised/chosen in due course with further reflection and analysis.

***Rest* concepts**

- *Perfect cell replication (no defects or time-related defects)*
- *Gate failures*
- *Abnormal cell proliferation rates*
- *Cancerous cells: Detection and destruction*
- *Cell senescence*



***Readiness* concepts**

- *Embedded design (EMD) for process*
- *EMD for quality (nature, form, style)*
- *EMD feasibility, suitability, acceptability*
- *Trialling and testing of EMD*
- *Process readiness*
- *Readiness gate(s)*

***Growth* concepts**

- *Uninform/multi-rate cell proliferation*
- *Process stability*
- *Process stress - Distress signalling to induce transient rest*
- *Abnormal rate of cell proliferation (low/high)*
- *Cell surveillance (EMD compliance, translation, transliteration, real time)*
- *Growth gates (multiple)*
- *Process memory (data analytics)*
- *Transient gate(s)*
- *Functional redundancy Feedback stabilization*
- *Emergent or self-organization*

***Transient-Rest* concepts**

- *Cell senescence (Transient rest - a forced state of rest)*
- *Cell progress arrest (embedded design is not replicated correctly*
- *Cell triggers for process arrest (e.g. NCR threshold, process stress vis-a-vis cell instability)*
- *Cell repair/restoration*

Figure 3: A conceptual framework for exploring RGR model to achieve Quality (zero defects)
Source of RGR model: (See, Abeysekera & Shelke, 2017)

Option 1: As participant-observer (PO) re-evaluate case study projects using RGR model
This study has thus far used data connected with three large projects viz. tunnel slab construction, coal export terminus, and a 275kV transmission line tower erection. The first author has been involved with all three projects as the Quality Coordinator for these project. Accordingly, one option is to re-analyze these projects with the new findings with the aim of changing existing practice. The basic question to answer is 'what the PO would have done differently to reduce the quality problems encountered in these projects?' The results would then be evaluated seeking views of senior project personnel to establish the feasibility of the proposed solutions.

Option 2: Apply RGR model to a new project and assess impact (as in action-research)
Use the RGR model along with the new concepts and apply these to a new project. This will require negotiating with project personnel to establish what is acceptable and what is not. This will give an understanding of its application feasibility. If benchmarking data are available, it may be helpful. Further discussions will be held with project personnel throughout the project and at the end to understand their perceptions on whether in fact, the application of the model along with the new concepts had made a difference.

Option 3: Semi-structured interviews and focus group meetings to evaluate RGR
Undertake a survey to evaluate the feasibility model implementation along with the associated concepts. Experienced and well-respected participants will be selected along with focus group meetings with selected/invited participants. The focus will be the usefulness of the model and the concepts with the goal of reducing quality defects.

Option 4: Application of RGR (and concepts) to problematic processes as a PO (similar to Option 1)
Focus on three repetitive processes (in essence of a cellular nature) which are known to produce defects (with high frequency and impact) and assess the suitability of the RGR model (and concepts) to understand their relevance for reducing defects. Historical data pertaining to defects (for example, processes that results in higher number of NCRs, high quality costs, etc.) will be used for the selection of repetitive processes. Problems arising will be viewed through the model developed with the application of the concepts with the hope of bringing about change. The results will be evaluated seeking views of senior project personnel to establish the feasibility of the proposed solutions.

Option 5: Application of RGR (and concepts) to problematic processes and assess impact (similar to Option 2)

Option 6: Application of RGR (and concepts) to an on-going project as a PO (as in options 1 & 2)

Option 7: Application of RGR (and concepts) to an on-going project and processes (as in options 1 & 2)

These options need to be evaluated in due course selecting the best option to assess the relevance of the RGR framework and the associated concepts.

6. The research paradigm in a nutshell

This study has shown how similes could be used for investigating a perennial construction phenomenon and the ontological and epistemological considerations when using this approach. It argues that the approach is neither inductive nor deductive presenting it as a hybrid approach for building *theory as practice* particularly *practice as science* to generate *scientific-practice*. The *methodology (map) as spiral* reflects on the nature of the challenge with methodologies presented as options (1 to 6) with one to be selected. Different research methods such as interviews, action research, and case study etc. may be used to achieve original study objectives. As noted herein, once a suitable option is selected and explored, it is hoped that it would generate new knowledge on how to manage quality in *cellular-construction* with a greater reduction of defects than now possible.

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