A theoretical approach to construction project progress drawing on complexity and metaphysics

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A theoretical approach to construction project progress drawing on complexity and metaphysics

Dr Glenn Parry

Abstract

This paper examines the current literature and debate surrounding the development of an alternative theoretical model of the firm from the perspective of construction metaphysics. In setting the context of the theoretical model, use is made of complexity theory alongside the identification of construction industry characteristics which differentiate it from other ‘manufacturing’ activities, processes and operations. These factors, it is believed may provide justification for the use of an alternative theory of construction, and as such, this paper critically examines the case for its development.

Process metaphysics provides a framework with which to view the management of the early stages of the construction project. Mathematical descriptions of possible process pathways are presented for projects that are making progress, making no progress or are failing. Finding these trends in project data, using pattern recognition, may provide a greater understanding of the scope and scale of complexity in construction and may therefore assist in developing an improved capability to send an ‘early warning’ for the future success or failure of major capital projects.

Keywords: Lean, metaphysics, complexity, theory
Introduction

The construction industry does not have a strong reputation as a leader in quality, efficiency, cost estimating or cost management (Flyvbjerg et al. 2003; Ive et al. 2004). UK Government, the largest single domestic client, has tried to direct the road to improvement in the UK (Egan 1998; Latham 1994). It has been proposed that a new approach to thinking about the industry may facilitate change (Koskela 1999). Metaphysical discourse in academia is resurgent, despite a long battle (Carnap 1937; Price 1997) and as such there has been a revived growing debate and protracted academic discourse on the metaphysics of construction and the need for new theories of production or construction to support a renewed drive for greater performance improvement.

On the basis of a literature search and review coupled with extensive discussions both in academia and in the UK construction industry, the authors have developed a meta-level temporal project model which it is hoped will make a significant contribution to the ongoing debate.

Construction Metaphysics

The metaphysical world may be divided into substance metaphysics and process metaphysics (Koskela and Kagioglou 2005). Substance metaphysics is derived from the Aristolean view that the world consists of substance, things, and its research imperatives seek out the smallest fundamental particles and explanations at the lowest level, an approach to research that has been successful in the scientific world, bringing with it seminal ideas such as those of Newton.

Process metaphysics is traced back to Heraclites [535-475 BC] and consists of flow and change and the idea that phenomenon are artifacts of time and space. Researchers look for context at the macro process level, providing a basis for the work, amongst others, of Einstein on relativity and quantum theories. Koskela and Kagioglou (2005) argue that the
conventional production view has been based primarily at the substance metaphysics level, and points to the work of Shingo who notes that process and operations are phenomena which lie on different axis as their flows are dissimilar (Shingo 1988). Indeed, much of modern thinking is substance based and only relatively recently has process based thinking begun to emerge. Koskela lays down a challenge that it is not sufficient to consider only the production of things as ‘being’, but also the need to address the ‘becoming of things’, that is to take the process view. Pettigrew (Pettigrew 1997) supports this ontological position by noting that in their theorizing and empiricism, most social scientist do not appear to have given consideration to the impact of ‘time’ and subsequently stresses the need for further research to explain the links between context, processes and outcomes.

Five guiding assumptions form the basis for conducting processual research (Pettigrew 1997) namely: study processes across a number of levels of analysis, as there are numerous contexts, internal and external, that shape the process e.g. economic, social, political, competitive, structural and environmental; study in the past, the present and the future as antecedent conditions shape the present and emerging future; search for holistic rather than linear explanations; recognize that context and action are inseparably intertwined; note that links between multiple levels of context can only be shown through temporal identification of patterns.

**Differentiation of Construction**

Koskela proposes that there is a need for an alternative theory of construction (Koskela 1999) separate from existing theories, mostly from the field of economics (Conner 1991; Cook 1997; Gilbreth and Gilbreth 1922; Hopp and Spearman 2000; Porter 1985; Shewhart 1931). The need, Koskela argues, stems from the assumption that reported problems of construction are attributed, not to implementation issues, but to the presently accepted underlying doctrine of the industry. This doctrine states that the transformational view prevails, that is the current practice of construction equates project management methods
to task management. Task management assumes that certainty prevails in production. This is in contrast to the observed variability in construction production where task management becomes mutual adjustment by construction site teams. Hence, performance problems are not problems of implementation, but of driven by the pervading underlying theory.

The research in this area divides the nomenclature ‘construction industry’ into ‘construction’ [the context] and ‘industry’ [the agents] (Bertelsen 2004; Emmitt et al. 2004; Green 1996). Works examines construction from the perspective of value management i.e. by referring to the learning process between clients, professional’s service firms and industry (construction companies). The work also examines construction from the viewpoint of applying the principles of value engineering to the construction process itself. Within the context of developing an alternative Theory of Construction it is maintained that industry practices relating to the application of value analysis/value engineering have been covered extensively in the literature as it is analogous to a conventional manufacturing process. Furthermore as the construction industry continues to evolve and reconfigure it is anticipated that an increasing volume of construction components will be manufactured offsite for onsite assembly, (at lower overall cost), and delivered from an increasingly more responsive and efficient upstream supply chain. However, it is stated that there will always remain elements of a construction build that are not amenable to the application of alternative manufacturing processes, practices and techniques and it is these aspects of the build process which reflect the unique characteristics of the construction industry which differentiate it from most others (Ballard and Howell 1998; Koskela 2004).

In developing an alternative theory of construction Koskela suggests that the TFV [transformation, flow and value generation] theory of production is appropriate and relevant as a starting point. However, this does not appear to be significantly different from adopting an approach based on ‘Lean’ principles’ i.e. customer value, identification
of the value stream, ‘flow’, ‘pull’ and pursuit of perfection which is not a theory of a firm, but rather a process methodology (Womack and Jones 1996). Lean concepts have been widely applied over the last ten years and have frequently provided a basis for the transformation to continuous improvement manufacturing and service cultures based around customer ‘pull’ rather than the traditional manufacturing ‘push’ processes and practices of mass production (Koskela 2004). However, ‘Lean’ is considered by Koskela to be too imprecise to form a valid and mature theory of production. Koskela cites the combination of one-of-a-kind (non repeatable) production, fixed but frequently unique site based production operations and the setting up and subsequent dismantling of project teams in what are essentially temporary organisations, as the set of characteristics peculiar to the industry (Koskela 2000).

Unlike most manufacturing based industries, the nature of the construction process integrates product development with production as an ongoing simultaneous and continuous process, but finds them ‘unhappy bedfellows’ (Bertelsen 2004). Consequently the build process is characterised by ‘on the hoof’ product development, extensive fire fighting and escalating non budget costs all set within a culture of supply chain conflict and a willingness to resort to litigation as a matter of course. In rapid product development activity the Lean approach has demonstrated considerable success in reducing time to market when applied to new product development for mass production (Womack and Jones 1996; Womack et al. 1990). Compression of the innovation process, (shortening the product development pipeline), has become a major strategic and operational objective for many firms. Best practice has been reported for successful application of ‘lean’ during new product introduction (Goldratt 1997; Haque et al. 2000; Karlsson and Åhlström 1996; Reinertsen 1997; Reinertsen and Shaeffer 2005). Meeting this objective is frequently achieved by parallel processing activities and by developing ‘best practice’ process models. A significant problem with this approach results from models having to be bespoke for each company as their shape and sequence depends on the type
of new product being developed and hence they may have little that is generalisable for application in construction (Cooper 1988). Most of the process models are not developed to guide the management of new product development in every situation. For instance, if a new product concept does not pass the ‘concept’ stage gate, then most of the process models do not describe what the next step might be.

Bertelsen proposes that construction is a special kind of production and argues that construction is the production of unique products of art on a very large scale (Bertelsen 2004). This may differentiate it from new product development for mass production. The aesthetics of a building are part of its value and will be judged by all who see it, and therefore the argument of building as art may be sustained. As Owen comments ‘…artists work mostly subjectively with the motivation of self-expression to produce works fulfilling aesthetic and intellectually stimulating objectives…(the perceived similarity between designers and artists stems from a common use of visual media to communicate ideas), but the fundamental methods, results and – most important – goals are quite different’ (Owen 2004). The authors are inclined to the view that if construction as art significantly differentiates construction from other forms of production then the case for a new theory of construction is substantially strengthened. However, the definition of a theory of a firm addresses two central questions namely:

(a) why does the firm exist?

(b) what are the determinants of their scale and scope?

The underlying assumption of all economic theories is that firms exist to make money and, as construction industry companies must make profit to survive, it is reasonable that this should hold true of a theory of production in construction (Conner 1991). In contrast, common perceptions of art, or artists, suggest that the commercial rewards are very much secondary to the creative process although it is noted that many contemporary artists achieve a significant level of wealth within their lifetime.
So far none of this work presents a compelling case to support the view that construction as a form of production is unique, but it is accepted that construction does have a distinct set of characteristics. It is claimed that greater complexity supports the argument that construction should regarded as a separate entity from other forms of production in that, as such, it can be viewed as a complex system of seven flows (Koskela 2000) and has represented the client in nine-dimensions (Bertelsen 2004). It might therefore be concluded that at this juncture that a case can be made for regarding construction as distinct from other industries, but not unique. The suggestion that construction displays a greater degree of complexity than conventional production systems merits further consideration.

**Complexity: an overview**

Complex systems stem from the work on non-linear systems in the sciences to understand and describe the function of the living world. A complex system may be described as one made of a large number of interdependent parts which together make up a whole that is interdependent within some larger environment (Anderson, 1999). Subsets of these are complex adaptive systems. Four tests for whether a system is complex adaptive are proposed (Pascale 1999). First there must be many agents acting in parallel. Second, there are multiple levels of organisation. Third, the system is subject to the laws of thermodynamics and must be replenished with energy to prevent it slowing down. Finally, pattern recognition is employed by the system to predict the future and learn. Many systems are complex (they meet some of the criteria), but not all are adaptive, meeting all of the criteria. In context of industry production and process it is proposed that complexity may be measured along three dimensions (Daft, 1992). The vertical axis shows the number of levels in an organisation, on the horizontal is the number of departments or job titles and on the third axis is the spatial complexity, perhaps of different geographical locations.
Emergent complexity, illustrated by the combination of simple shapes to form complex fractal patterns, is driven by a few simple objects that combine to generate infinite variety (Pascale 1999). Inherent in this natural phenomenon is the finding that it is not possible to see the final outcome at the start as there are infinite possibilities (Kao 1997). When applied to production processes, the challenge for managers is to set the direction for the future and adapt to environmental changes (Santos 1998).

Generative complexity takes place in the boundary between rigidity and randomness - applied to production process, if applied processes are too rigid a company will fail owing to a lack of creativity, too random and a company may invest too quickly or expand too rapidly - there are numerous examples of failed companies who could not find a balance (Pascale et al. 2000; Santos 1998). The boundaries are where change is managed and these are set out in procedures.

Procedures are defined as organisational design statements, and capture the methods or process to execute a task (Rogers, 1995). These are written by organisations to manage aspects of operations and many procedures in place today are still dominated by hierarchical command-and-control structures from the past (Brodbeck 2002; Mercer 1999; Rogers 1995). Rigid, rule bound structures are incapable of adaptation to meet new situational requirements but provide management with a sense of control (Stacey 2000). As organisations introduce rigid procedural structures they often depersonalise the social elements and practices that had developed (Rogers 1995) and create instead a rule based system that neutralises adaptability and innovation thereby inducing a state of “trained incapacity” in the employees (Stacey 2000).

Complexity theory can influence the design and development of procedures which place a greater emphasis on the impact of natural human behaviour - the natural drivers to ‘get the job done’. In this regard procedures could be developed to promote self organising frameworks utilising natural laws which in turn drive simplicity and generate greater influence without the need for ‘force’ or through detailed bureaucratic dictat (Anderson et
al. 1999; Harald et al. 1999; Sherman and Schultz 1998). This approach uses the language of complexity theory and describes how things ‘fit’ into business landscapes of market opportunities and competitive dynamics (Kauffman 1995). Self-organisation is seen as a default natural state, which sets a new aim of aligning the formal organisation so that structures, systems and processes fit the goals, rewards and structure of the informal organisation (Coleman 1999). Managers often get in the way of activities that self organise and could self correct (Weick 1979). The behaviour of individuals is self-organising when people (or agents using the language of complexity) are empowered and free to network with others and cross organisational boundaries to pursue their goals (Coleman 1999). Most procedure is routed in a linear cause-and-effect theory, but an approach could be taken that utilizes inherent self motivational desire. Increased effectiveness can be achieved through identifying formal and informal organisational structures and employing processes that fit within each in terms of goals, rewards and structures (Brodbeck 2002; Drago 1998).

Complexity theory identifies the gatekeepers of an organisation as those that stand at its boundaries and translate information between the internal and external world (Lissack 1997). It is the nature of these gate keepers interactions with other business units, suppliers and customers that we wish to standardise without resort to the application of rigid procedures that would destroy the evolutionary nature of the system. Furthermore, competitive advantage may be gained through creating the capability to continuously adapt and co evolve within the environment thereby embedding a system capable of undergoing continuous metamorphosis in order to respond to a dynamic business landscape (Brodbeck 2002; Lewin et al. 1999). Within the context of developing such a dynamic response it is recognised that time to market is critical, though it is maintained that managing quick-response product development is difficult (Gupta and Wilemon 1990; McDonough III and Barczak 1992; McDonough III and Spital 1984; Thomke and Fujimoto 2000). This difficulty demands that gate keepers develop procedures which allow them to quickly integrate, to take action both internally with other business units and externally
with different customers and suppliers. This speeds up the creation of an operating system and infrastructure which will facilitate the manufacturing and delivery of the product to its required specification and quality standard.

Organisations may increase their effectiveness if they are able to achieve good ‘fit’ between their structures and organising mechanisms and the context in which they operate, including such factors as environmental volatility, company size and age (Drago 1998). Fitness for purpose is therefore closely related to the flexibility of procedures or a procedures capability to encourage employees to self-organise as change occurs. Such procedures, modelled on complexity theory, would suggest an improved capability to adapt and also to provide continuous fit between structure and context (Brodbeck 2002).

Two aspects of procedural design have been identified and can be divided into procedural requirements [form of conduct] and process requirements [method of doing] (Anderson 1999). Three main requirements are proposed for procedure: the presence of a reward and penalty mechanism; consistency within the business setting [standards]; fairness in application [transparency]. With regard to process requirements the following conditions are pre requisite: relevant and timely performance measurement; strong communication and staff involvement; authority to act. The authors are of the view that these requirements have resonance with the upper hierarchy needs in the motivational literature (Alderfer 1969; Kanfer 1998; Maslow 1954) and that benchmarking against industry standards is portrayed as a natural desire for self appraisal that both encourages greater competition and fulfils esteem and self-actualisation needs (Anderson 1999).

Steve Miller, a Managing Director for the Royal Dutch Shell Company remarked “The leaders provide the vision and are the context setters. But the actual solutions about how best to meet the challenges of the moment have to be made by the people closest to the action” (Pascale 1999).
Complexity and the Construction industry

The construction process appears to have a strong comparative fit with the description given of a complex system by Anderson and Daft. Whilst the proposed axis of variables is resonant with the structure of the construction industry, it does not fully capture the added process, operational and supply chain complexity manifested by this industry. For example to deliver major projects numerous ‘new’ companies are formed to create a consortia of construction firms who bid as an integrated resource for major capital projects. These companies must rapidly metamorphose into an integrated unit and develop systems, structures and procedures that possess the capability to support the geographic location of a project, or adapt to deliver goods and services to the project location. In the case of road/rail projects, the location may also be considered as constantly in motion. These structures rapidly co-evolve around the requirements of the project and will terminate, at least geographically, once the project is completed.

Lene Dammand Lund brought together ideas from a number of sources (Lewin 2001; Owen 2003-2006) to produce an analysis of the design process (Lund 2005). Examining the work of Fredrick Winslow Taylor [1856-1915] Lund identified and evaluated the underlying concept of linear reductionism and its application to management, whereby the operating system may be optimised through an analysis of the constituent parts such that this optimisation leads to an executed plan, shown schematically in figure 1 (Taylor 1911).

![Figure 1. Reductionism Management Strategy (Lund 2005)](image-url)
Lund challenged the reductionist approach by identifying four factors that add to complexity in construction management: defining the goal is part of the process, such that it is rarely a ‘fixed’ objective through time; there are many participants and they may all have different criteria for determining a successful outcome. This will have a profound effect on operational efficiency if ‘players’ within the supply chain are pulling in different directions; resources are shared and most participants are involved with more than one project. In this situation the deployment particularly of scarce and skilled resources away from the project further aggravates an increasingly complex supply chain. In this case non adherence to sensitive critical project planning paths will significantly de-stabilise and disrupt project management and project completion; the context is very uncertain i.e. the characteristics of the construction project supply chain tend to impact negatively on project continuity.

It is thus argued that the reductionist [Aristolean] model cannot be applied in the case of construction. In the case of a major project the end result cannot be fully explained by an analysis of its parts as the system behaviour is not predictable. The authors contend that management in the early stages is therefore, about creating an environment which nurtures good decision making, supporting the notion that a process overview, [the Heraclitiic approach] using metaphysical terminology (Koskela and Kagioglou 2005), is more appropriate and therefore more desirable. A point illustrated by Lund, figure 2.

![Complex Management Strategy based on emergens](Lund 2005)

Figure 2. Complex Management Strategy based on emergens (Lund 2005)
To create the conditions for value creation, Lund extends the work of Owen (Owen 2003-2006) to produce a pathway for the development of an understanding of the parameters and characteristics of the problem/solution space during the construction process Figure 3.

Figure 3. Problem to solution pathway (Lund 2005)

In the closed loop process presented in Figure 3, the analysis pathway is divided into four phases. In phase A the problem is defined. During phase B, the problem is analysed and an understanding of its context and solution requirement are developed. At phase C, possible solutions are identified before specifications are defined in phase D, thence looping back into a new phase A where the specifications are evaluated, this in turn leading into a new definition of the problem. This analysis pathway illustrates how a problem may be continuously redefined by its proposed solutions set and presents the character of emergens. What Lund (Ibid) presents is a picture of a process flow for construction which illustrates at an early stage in the construction process, the presence of a complex system exhibiting unpredictable behaviour that requires, the need to adopt a Heraclitic strategic viewpoint proposed earlier (Koskela and Kagioglou 2005).

At what Lund described as the ‘point of no return’, the process must reach an operational imperative where decisions must be made to get work done if the building is to be
completed. At this critical stage an Aristolean reductive approach to strategy becomes appropriate, figure 4.

![Figure 4. A simple model of a building project (Lund 2005)](image)

Whilst the management theory developed in Lund’s work is based on taking a design perspective within the construction supply chain, the authors believe that it is broadly applicable across construction, as is the challenge posed on how this theory may be applied. This combination of effects may present a basis upon which to build theory and we will develop this through a theoretical model application.

**A theoretical application**

In any construction project the initial specifications generate a great number of project variables. Some are known and are considered at the outset, such as the proposed form of the structure, or detail issues associated with the height of the walls. However, there are others that are as yet unknown, and of concern is their potential impact on the project outcomes. Many of these variables display complex interrelationships and dependencies such that they may directly affect each other in a number of different ways. The potential effect may be known at the outset, such as the ambiguities surrounding the final location of electrical points. Others become known at a relatively early stage, such as those relating to the location of the building. Others are decided at a very late stage in the project, such as wall treatment and colour and some may never be resolved, such as space
utilisation. Taking specific examples, the depth of foundation is determined by both the nature of the ground and the height, construction and weight of the building and thus the decision on foundations must be made informed by the building that it is to support. It cannot be expedited until the other variables are decided, or at least tightly defined. Once the foundation has been dug and finished, a set of associated limits is placed on the variation that may occur within the dependent associated structures, such as the walls. These limits are not absolute as, finance being no object, any structure may be altered or removed and rebuilt, but it is precisely this scenario that is to be avoided in order to complete projects on time and to cost.

These variables can be expressed mathematically. Within any project there will be a significant number of input variables, $V$. Some are known, $n.V_K$, and some unknown, $n.V_U$. Initially, therefore, there are three states of interrelatedness to consider: $V_KV_K$, $V_KV_U$ and $V_UV_U$. Each variable has a certainty value, $c$, according to how well it is understood or known, thus $V_K = c$ and $V_U = 0$ and hence $V_KV_K = c$, $V_KV_U = 0$ and $V_UV_U = 0$. This infers that only what is known can be managed.

It is feasible to utilise the problem solution pathway, figure 3, to determine more known variables from the unknown. As time progresses, during a successful project, more unknown variables become known and a greater degree of certainty is achieved. This concept of 'convergence' can be represented by attributing the scale on the axis to the number of project variables, identifying three possible pathways that the authors have named ‘Heraclites pathways’. Figure 5 illustrates these alternative pathways.
In figure 5 a dotted line represents incoherence between variables, becoming progressively more coherent as we approach greater certainty. Initially, the interrelatedness of project variables is not understood. Eventually the line becomes solid as greater certainty and fewer variables are achieved. Following pathway 1, the problem solution set becomes more certain and the number of project variables is reduced as decisions are taken and progress is made. Eventually the variables will tend to zero as the building is completed.

The circular pathway, labeled 2 in figure 5, represents a situation in which each problem set is either not resolved or produces an equal number of solutions, leaving the project constrained within in a continuous loop with no sight of future completion. Pathway C shows a failing project. Each problem/solutions set leads to more variables and if decisions are not taken the project goes out of control as certainty is not delivered.

We can express the Heraclites pathways mathematically. This trend towards certainty can be stated $n.V_k \rightarrow 1$ and $n.V_u \rightarrow 0$. Pathway 2, where no progress is made can be stated $n.V_k + n.V_u \rightarrow n.V_k + n.V_u$. The trend to wards failure is thus, $n.V_k \rightarrow \infty$.

It is proposed therefore that three conditions may arise: the project is stalled in a continuous loop; the project will spiral out of control; conversely the project will spiral into control. What would be beneficial from the perspective of construction project
management is the ability to rapidly assess the likely direction a project is taking at an early stage in the construction process by determining their status against the three conditions defined above. In such a situation an additional diagnostic capability could be developed to influence the bid/no bid decision at the project bidding stage, influence risk management and provide greater clarity to decision making and subsequent corrective action particularly during the operational construction phases.

This approach relies heavily on sound project information management, particularly in terms of relevance, quality and timeliness. Of particular significance is the need to determine which key performance indicators (existing or new), will identify whether a project is on an inward spiral, outward spiral or circular pathway. There is a distinct possibility that an entirely new set of metrics may need to be identified outside of those traditionally applied by the construction industry. That is, those which will provide indicators to determine divergence, convergence or stasis. In this respect this approach differs significantly from a conventional Aristolean [substance] view of project management in so far as the nature and characteristics of these variables are as likely to be qualitative as quantitative i.e. the variables relate to process and focus on how things are done. It may also be appropriate to consider the challenge laid by Pettigrew and give ‘more time to time’ and so temporally displacing the variables (Pettigrew 1997). By adding a time dimension it is possible to transform Heraclites pathways into three dimensional models using a third axis. Putting the variables from figure 5 in the X, Y plane and displacing through time on the Z axis, we can describe orbital lobes for the bounded ‘Heraclites pathways’, figure 6.
Figure 6. Heraclites pathway’s: (a) Heraclites divergent Cone, (b) Heraclites Cylinder, (c) Heraclites convergent cone.

Figure 6 describes the orbital lobes for three bounded process pathways:

(a) a divergent cone describes the space in which a process is becoming more uncertain and may fail

(b) a cylinder maps the space of a helical pathway process in which no progress is being made

(c) a convergent cone describes the space for a process that is leading to project success.

Using these models outer project limits can be set, such that staying within the three dimensional parameters set by the ‘Heraclites cone’ will engender more effective project management thereby increasing the probability of desirable project outcomes but where operating outside these limits will increase the risk of project failure. In essence, the model attempts to illustrate that there are a large number of potential pathways within the cone limits and that the three dimensionality facilitates the selection of alternative process methodologies, shown in figure 7.
The schematic shown in figure 7 may be used as the basis for analysis. The model will simulate the outer cone limits that indicate potential failure, initially based on a set of known variable outcomes. Inside this larger Heraclites cone, multiple orbits will be described by tracking the various sub-projects within a build process. The certainty value of $V$ and the ability to manage the outcome of each variable is the key first step. Our $V$ variables are then plotted and interdeterminacy examined. Overtime, the project pathway will be revealed. Analysis of form will demonstrate the nature of the path. Work making progress spirals inwards, work falling behind spirals outwards and work making no progress will produce a helix.

Mathematically we can describe spirals using the radius $r(t)$ and the angle $t$. Spirals have the general polar form $r(t) = ft$ e.g. $r(t) = at$ where $a$ is a constant, $r(t) = t^2$, $r(t) = \ln t$, $r(t) = \sqrt[3]{t}$ etc. For the simplest ‘Archimedes’ spiral, where successive turnings of the spiral have a constant separation distance, the parametric equations are:

(1) $x = t \cos t$ ;

(2) $y = t \sin t$ ;

(3) $z = t$ .

We may also express the helix using the parametric equations:
(1) $x = r \cos t$;
(2) $y = r \sin t$;
(3) $z = ct$, for $t \in [0, 2\pi]$

where $r$ is the radius of the helix and $2\pi \epsilon$ is a constant giving the vertical separation of the helix's loops.

By utilising the parametric equations to analyse and look for patterns within data it should be possible to diagnose the trends within a number of process pathways.

Thus the theory is applied in order to demonstrate how a project's progress may be expressed mathematically, by attaching a value to all variables and provide the conceptual basis for an alternative perspective, via the ‘pathway analysis’ models to refocus project management on process options. The dominant conventional Aristolean approach is replaced by a hybrid Aristolean - Heraclitic (three dimensional) model in order to more fully reflect the true nature and scope of the project variables aggravating complexity in large scale construction projects. This new analytical model is consistent with Pascale’s (1999) fourth test for complexity in so far as: pattern recognition’ by necessity will embrace a variety of pathways, therefore prediction would be more onerous, but would open up a greater number of learning opportunities to improve performance through the longer term. The authors believe that this would support the progress towards change in industry doctrine and underlying theory by considering the ‘how’ as well as the ‘what’ in project delivery.

**Conclusions and future work**

This paper gives some consideration to the notion that the construction industry displays a number of significant differentiators which distinguish it from other industries. As yet, the authors have failed to find any compelling evidence to confirm that the construction industry does indeed display a sufficient number of unique characteristics to enable to
creation of a distinct theory of construction. However, the argument for construction as a separate entity from other production forms remains extant and the literature on complexity has been explored within the context of the construction process.

A process metaphysics based approach has been suggested in attempt to develop a framework within which to view the management of the construction process, particularly in its early stages, when there are a greater number of unknown variables to consider. Process pathways, name Heraclites pathways are described for projects that are making progress, are failing or are in stasis. These pathways were displaced through time giving rise to their further description in three dimensional space as orbital lobes in the form of cones and cylinders. Mathematical formulas that may be used for the identification of these pathways are presented. Finding these trends in project data using pattern recognition would provide evidence for the fourth test of complexity and may give an early indication for the future success or failure of a project.

Future work will examine the practical application of this theoretical approach. For example the process metaphysical context provided, may be used to develop an analysis of the approaches used to costing within the construction industry. The work presented may have wider potential for application across the spectrum of construction project management. In addition, research will continue into the analysis of a theory of construction, specifically focused on exploring, understanding and describing the elements that differentiate this industry from other manufacturing/operations based sectors.

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