Construction as Production by Projects

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Abstract

This paper responds to the invitation to debate the theory of production in construction from the advocates of lean construction (LC), and in particular, to their critiques of the theory of project management represented in the PMI's PMBoK, and the "economics-based" approach to construction project management presented by Winch. The paper reviews the theoretical and practical contributions of LC before moving on to address the specific criticisms made. The paper then suggests that LC theory has its own limitations and requires further development in the areas of the definition of process, the concept of organisation, the theorisation of risk and uncertainty, and its unitary concept of value.

Keywords: Lean construction; construction project management; transaction cost economics; value; risk and uncertainty.

1. Introduction

The organisation of the construction process is the subject of intense debate and intensive research in a number of countries. The aim of this paper is to respond to the invitation to constructive dialogue from the advocates of lean construction (LC) and, thereby, to move the debate onwards in the development of a perspective which views construction as a distinctive mode of production by projects. Lean construction (LC) synthesises an original perspective based on a *transformation/flow/value* view of the construction process with distinctive operational methods such as the *last planner* approach to construction project planning. In sharpening their development of the concepts, explanations, and implementations of LC, its proponents have developed a number of critiques of different perspectives on the management of construction projects. Engagement with two of these critiques in this paper, it is hoped, will facilitate the development of a theory of production applicable to the construction process to move on. These are :

- the critique of the economics-based approach [1]
- the critique of project management theory [2]

2. The Theory of Lean Construction

The work of Lauri Koskela is an ambitious attempt to provide a theory of production applicable to construction. His principal contribution is contained in his doctoral thesis [3], and elaborated in a number of subsequent publications [e.g. 4, 5]. Koskela's thesis draws on a wide range of literature in production and operations management to develop a three-part theory of production which he calls transformation/flow/value (TFV). The literature review identifies three different perspectives on the production process that have been deployed during the 20th century – the transformation concept; the flow concept; and the value concept.

The *transformation concept*, Koskela argues, focuses on the transformation of materials from one state to another. Economically, it is associated with Walras' production function, while in production terms it is associated with the scientific management approach of people such as Taylor. Its basic tenet is the detailed pre-planning of the production process which is broken down into a series of tasks, each of which is progressively optimised. One result of the concern to optimise individual task execution is the recommendation that tasks with different characteristics be buffered from each other. While this approach has many advantages, particularly associated with the development of sophisticated production technologies, it also suffers some significant disadvantages such as rising costs of work-in-progress created by the buffers, the risk of sub-optimisation at the system level, and inflexibility in response to changing market demands. So far as the design process is concerned, the transformation concept is represented in attempts to standardise the design process and to apply project management techniques.

Koskela argues that the *flow concept* takes a very different approach. Here the principal influence is the Toyota Production System. From the flow concept point of view, the objective is the minimisation of waste. Analysis of work flows designed around transformation concept principals reveals that materials typically spend very little time actually being transformed, and most of their time waiting to be transformed, being moved, or being inspected or otherwise controlled. The argument is that by focusing on reducing time taken to flow through the manufacturing system as a whole, greater economy can be obtained than by focusing on the efficiencies of particular sub-processes. The key to this reduction is to reduce variability in the execution of particular sub-processes rather than to increase their efficiency. Coupled with simplification of production processes, this attention to cycle time can lead to greater flexibility as well as greater system-level efficiencies. In the design process, the flow concept is represented in the use of concurrent engineering and related techniques.

For Koskela, the *value concept* derives from the quality movement originated by Shewhart and contributes by bringing the customer into the perspective. Flows and transformations of materials are only of value if the resulting product meets the needs of those who are expected to purchase it, and so the definition of customer requirements is central to the value concept. Once those requirements have been effectively captured in the design process, the role of the manufacturing is to meet the requirements processes of quality management and control. Within

design, the value concept is represented in requirements capture processes where techniques such as quality function deployment are appropriate.

3. The Practice of Lean Construction

The TFV conceptual framework supports a variety of different tools and techniques that allow the principles to be applied to the management of construction projects as part of the Lean Production Delivery System (LPDS) [6]. The best known of these is *last planner* [7] which was developed "in-house", and is a way of buffering task execution by only allowing those "quality assignments" which are completely ready to be started in the context of effective lookahead planning, and close monitoring of "per cent plan complete". Other applications are taken from mainstream lean manufacturing such as value stream mapping [8], and from developments in design management such as dependency structure matrix [3], and in supply chain management [9]. A number of other organisational innovations are also recommended such as involving downstream players in upstream decisions; deferring commitments to the last responsible moment; aligning the interests of participants; and the effective use of buffers.

The last planner approach to construction planning is an important innovation, and anecdotal evidence suggests that it is diffusing well. Many of the other elements of the LPDS are widely accepted as having the potential to improve significantly the management of the construction project process. There are, perhaps, at least two surprising omissions from the LPDS toolbox. The first is the apparent lack of attention paid to new forms of organisation of the project to form the context for the implementation of the LPDS. For instance, the use of supply chain clusters based on Thompson's [10] principle that appropriate organisation designs cluster together those functions which have the greatest interdependence, and hence the greatest requirement for mutual information processing. Different applications of this concept have been developed by Lahdenperä [11] and Gray [12], and applied with apparent success [13]. While Koskela [3] does discuss Lahdenperä's new construction mode, and the *demarche séquentielle* [14], these innovative ideas do not seem to have been taken forward into the LPDS. A second is the lack of attention paid to the work of Goldratt – particularly the theory of constraints [15] and its project-specific application in *critical chain* [16]. Critical chain directly addresses the problem of slack in task execution time estimates, and suggests trust-based relationships as the solution, while introducing resource constraints into project planning – a revolution in a context when construction project planners have typically assumed infinite resources.

4. The Critique of the "economics-based" Approach[1]

In developing their concept of LC, its proponents have provided a detailed critique of what they call the *economic-based approach* to analysing production in construction [1]. They choose as

[1] All citations in this section are to [1] unless otherwise specified.

representative of this approach *Managing Construction Projects: an Information Processing Approach (MCP)* [17], and make a number of critiques to the effect that it :

- Focuses on transactions rather than production;
- Focuses on information flows rather than materials flows
- Places uncertainty reduction at the heart of the process
- Deploys a tectonic approach to organisation

4.1 The Focus on Transactions

The LC critique argues that the focus on transactions means it "views production as a series of transfers", and that it "disregards the flow aspect of production" meaning that production is "organized just on the basis of purchasing costs". These assertions display a misunderstanding of transaction cost economics (TCE), because transactions are defined as "changes in ownership" through "purchasing", and it is held that TCE argues that "those organizational forms that minimize transactions costs are in the long run preferred" [3 p. 104]. However, Williamson defines a transaction as occurring whenever "a good or service is transferred across a technologically separable interface. One stage of activity terminates and another begins." [18 p.552]. A technologically separable interface is one that is not constrained by the nature of the production technology – in other words, the production technology chosen does not foreclose the possibility of allocating two different parts of the production process to different parts of the organisation, or to separate organisations. Thus, the theory focuses on the question of whether to purchase or not - the classic make/buy problem - not on purchasing alone. Rather than being "fully compatible with the decomposition principle of the transformation model of production", TCE is – arguably - a critique of the focus on the costs of decomposed transformations alone, without taking account of the cost of coordinating *between* those transformations. Through a TFV lens, TCE can be seen as posing the question of how flows within and between organizations are to be organized – or "governed".

The argument that the sole focus of TCE is on transaction costs also displays a misunderstanding – "transaction cost economizing needs to be located with a larger economizing framework and the relevant trade-offs need to be recognized" (*ibid*). Thus, the fundamental insight of the transaction cost approach is that in order to economise on the total cost of a good or service, *both* production costs and transaction costs must be taken into account. While a traditional economic analysis can identify the most efficient choice of production technique, it cannot explain the most effective use of that production technique. Thus total costs are the sum of the costs of production and the cost of governing the transactions inherent in that choice of production technique. A production technique that has the lowest production costs might not be the economising choice if transaction costs are also taken into

account[2]. The resolute focus on transaction costs rather than production costs in TCE research is simply a strategy of focusing on where it makes its distinctive contribution.

The structure of *MCP* is based on an earlier analysis [19] of generic project processes, and only one of the four generic business processes[3] is developed drawing on TCE. It is never argued that the costs of buying should be the sole basis for the organization of production in construction. The argument in *MCP* is simply that they need to be taken into account in a full theory of construction production, the conceptual link between the TCE contribution and the rest of the theory is made through construction project organizations being information processing systems. Unless the argument is that construction production should be organized in a fully integrated Soviet-style *Kombinat*, then the make/buy problem is central to the organization of production in construction and any theory of construction as production needs to include an analysis of how transactions in the flow of production are governed through markets, hierarchies and various hybrid forms.

4.2 Organisation as an Information Processing System

It is argued that *MCP* views "organization as only an information processing system [and] the production of goods and services, the *raison d'être* of the organization (in normal cases), is abstracted away". Again, this is not the position argued in the book. The full argument is developed in [20] on metalworking production which fully analyses both information *and* materials processing and the relationships between them in terms of the information flows initiating and controlling the materials flows. However, MCP is about *project* management, which is, in essence about the *coordination* of the activities of all the resource bases mobilized on the project which are responsible for materials processing as well as a variety of information transformation tasks such as in design. This is made clear in [17 table 15.1], which summaries the differences in responsibilities between the project manager and the resource-base managers working on the project. *MCP* is not intended to cover how bricks should laid or structural joints detailed – these are the responsibilities of the managers of the resource-bases engaged to carry out these tasks. The task of the project management function is to coordinate these transformations so that they move into the flow of the project life-cycle. This coordination task is essentially an information problem – who should do the task, when they should do it, can it be started now, and has it been completed fully to the specification?

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[2] Winch [51] provides an analysis of UK rail maintenance projects arguing how the failure to take into account transaction costs in outsourcing led to serious inflation of total costs.

[3] These four are "defining the project mission"; "riding the project life-cycle"; "leading the project coalition" and, under discussion here, "mobilising the resource base".

4.3 Uncertainty Reduction as the Principal Challenge

The objective of uncertainty reduction, it is argued, "in and of itself is not the objective, but it is rather a means for getting the facility built, generating value and reducing waste". I totally agree with this statement, but submit that the principal obstacle to achieving these worthy aims is the uncertainty pervasive to decision-making on the project. Construction project clients and their suppliers engage in a "future perfect" strategy [21] of conceiving where they want to be at a specified point in the future in terms of value added and budget spent, and then, in essence, working backwards from that point. We, by definition, cannot know the future, and so the journey through time from the present state which we can know about to that desired future state can be a long and fraught one, with many surprises along the way. Only to the extent that the past is like the future can the information that we already have tell us about the most appropriate path to take to that future, and we can never be sure how like the past the future will be. On some projects, this is a high proportion of all the information required, on others it is a relatively low proportion. Some elements of information, such as the structural properties of a specified steel can be expected to change little in the future; other elements, such as the condition of the ground are less predictable, while elements such as the spot price of bricklayers two years hence may be subject to considerable change. These factors are handled within the concept of risk – the condition of uncertainty where enough information is available to assign a probability to the occurrence of an event – but many aspects of uncertainty on projects are not amenable to the *meaningful* assignment of probabilities. They remain *unk-unks*. The vital issue that a project manager has to address is how representative is past data for the particular project that he or she has been asked to manage – a problem that is captured in the concept of "mission uncertainty" [17 p. 7].

The advocates of lean construction argue that "decisions in a project are ordered so that each decision is based on information produced in earlier decisions, and produces information, in turn, for subsequent decisions". This is true, but it does not then follow that "each decision can be made based on all information needed, without any uncertainty,"[4] because the information to hand is frequently only part of the total information required for the decision – this is Galbraith's [22] definition of uncertainty. Information is arriving all the time on the project as "news" about the possible range of future states [23], and some of it will not be as envisaged when the commitment to a particular course of action was made. The LC view of information processing on the project is inherently a backward looking one, and not one that looks forward to the completed asset that will generate value for the client. It is suggested that any remaining uncertainty can be reduced to variability and handled using analysis techniques such as queuing theory. Where this can be done – typically when operations are repetitive – it is of course advantageous to use queuing theory and related techniques derived from operations research. However, most operations on projects are not repetitive for the simple reason that this is why

[4] They do recognise that there are practical limitations to this condition – the argument here is about epistemological limitations.

they have been organised as projects. The whole point about projects is that they are about unique activities – repetitive operations are not appropriately organised in project mode. This, of course, begs the question of whether all construction production should be organised in project mode, and there are clearly some forms of construction production, such as housing [24], where this is inappropriate. It is also the case that repetitive transformations within a unique project such as shear walls [25] are appropriately organised in non-project mode. None of this gainsays, however, the fundamental argument that a construction project is essentially a proposition about a unique future state, and that uncertainty in decision-making is inherent to the process of achieving that future state.

4.4 The Tectonic Approach to Organisation

The tectonic[5] approach to organisations was initially developed in [20] and argues that information processing in organisations cannot be directly managed, but is managed through changes in organisational structure in terms of both internal and inter-organisational arrangements. The point is reinforced in MCP through the metaphor of the river where what is of interest is the flow of water which has the potential to provide power, transport, food and the like, but this potential is realised and enhanced by alerting the structure through which the water flows by constructing dams, weirs, bridges and the like. It is argued by the advocates of LC that "this approach neglects the management functions of (production) system operation and improvement". I submit that it does not, because production system operation and improvement – to the extent that it is about materials flows – *is* susceptible to direct management. Hounshell's magisterial history of the American system [26] shows how this was done during a profound revolution in manufacturing techniques. However, these changes in manufacturing techniques need to be placed in the context of the revolutions in business organisation which enabled them [27]. Manufacturing techniques for optimising materials flows can only function in the organisational context of the information flows that support them [20].

5. The Critique of Project Management Theory

Implicit in many of the responses in the previous section is a difference of perspective on the nature of project management and organisation. The advocates of LC have addressed these issues in a brave paper[6] [2] which takes the Project Management Institute's body of Knowledge (PMBoK) as its principal point of reference[7], complemented by reference to Turner's [28]

[5] "tectonic" in this context means "a series of arts which form and perfect vessels, implements, dwellings and places of assembly" (*Oxford English Dictionary 2nd ed.*)

[6] Brave, because it was presented by Greg Howell at the Project Management Institute Research Conference.

[7] There are other project management bodies of knowledge which have much in common with the US one.

influential text. They argue that the implicit theory behind these texts is symptomatic of a focus on the transformation view alone where management is about planning, executing, and controlling in a cybernetic model of the process. This is particularly manifest in the decomposition of the total process inherent in the development of the Work Breakdown Structure (WBS).

Perhaps the most obvious critique of this position is that few – if any – researchers in project management take the PMBoK as a theoretical orientation for their work. PMBoK was developed as part of the strategy of achieving full professional status for project managers as the basis for certification programmes for aspirants. Its efficacy in doing this is debatable [29], but beside the point here. In the context of the debate about theory in project management it is an irrelevance, as most researchers would accept Morris' critique [30] of its limitations as a theory of project management. However, the LC critique cannot be dismissed as easily as this. The substance of their critique focuses on the centrality of the WBS in PM theory, because this forms the basis for the classic project management tools such as critical path analysis and earned value analysis. It is true that WBS is inherently a decomposition, but LC techniques also decompose the process in, for instance, value stream mapping [8 fig 2] and process flow charting [25 fig 8]. The point is not the act of decomposition, but what is then done with the decomposed structure.

In critical path analysis, the WBS is used to identify sequential dependencies between tasks and to indicate expected task execution times. This information is then used to find the longest route through the network thereby created which identifies the critical path, or shortest possible time for total project execution. The LC approach also requires this information, but applications such as MS Project provide it more neatly than in, for instance, process flow charts [25]. The other main type of information mapped in the LC approach is who is to do the work. Conceptually, the supplier of the task execution services is handled in PM theory within the organisational breakdown structure (OBS), and is implemented in the resourcing tables of MS Project. This information can then be used for resource levelling, as well as in the much more sophisticated applications of critical chain (which is a resource-constrained critical path) such as ProChain. Where operations are repetitive - such as in the shear wall and pipe support examples - scheduling techniques such as line-of-balance may be appropriate. The advantage of applications such as MS Project is that they add analytic intelligence to the process representations (e.g. critical path, resource levelling) which is absent from the LC applications. It can also be suggested that critical path network and line-of-balance are inherently about flows as work moves from one task to another. The choice of tools and techniques for process representation and analysis is a pragmatic one – the argument here is that there is no theoretical reason to reject those tools and techniques based on the WBS. A more valuable strategy would be, therefore, to follow Goldratt's approach of enhancing these tools to meet contemporary requirements, rather than to trying to develop new tools from scratch for use within the LPDS.

However, this debate about tools and techniques misses a rather more important issue – what is theory in project management about? Many of the comments above in response to the LC critique of *MCP* have implied that the there is a misunderstanding in what project management

is about. The argument in *MCP* is that it is inherently an organisational innovation, a position derived from a reading of the history of project organisation [30, 31]. The tools and techniques which are so often synonymous with "project management" are simply that – tools and techniques, and not the core of what project management is about. Projects as a distinctive form of organisation emerged during the 19th century as society started to create complex systems, and were developed and formalised in the US aerospace sector in the post-war period. They are now rapidly diffusing in a large number of industrial sectors [32]. In a very important sense, they are a response to the transformation-orientated organisational forms that emerged with the development of new volume production techniques such as the American system and mass production. As Womack and Jones argue, "the concept of a project engineer to oversee the entire value stream foreshadows the lean principles described in this book" [33 p 156].

The perspective on project management underlying *MCP* draws on the work of authorities such as Morris [30] and Turner [28] to theorise project organisations as temporary systems for the definition and execution of unique, time-limited objectives which are capitalised by clients. In order to achieve these objectives on behalf of clients, project organisations mobilise the *resources bases* which act as the permanent repositories of the human and physical resources required for project definition and delivery. These resource bases may be internal or external to the client organisation – in construction they are almost always external. It is the resource bases which are responsible for the transformation of materials – project organisations and their managers are the coordinators of the flows of information that govern the transactions between resource bases and responsible for ensuring that the value originally identified in the investment appraisal for the project is captured by the client. This position accepts that not all construction production is appropriately organised in projects – housing production, for instance, is outside the scope of *MCP*. As the project organisation moves through the project life-cycle, project managers deploy a variety of tools and techniques for the planning and control of the flow of information that coordinates the transformation and flow of materials within and between resource bases. However, such a mechanistic approach is inadequate, and leadership remains essential for organisational and cultural coherence in definition and execution. MCP concludes by arguing that effective construction project management needs to be design led (i.e. focused on value for the client) and performance driven (i.e. focused on effective and efficient processes).

6. Engaging with the Theory of Lean Construction

The range of reference underpinning the TFV approach is wide and it is, perhaps inevitably, more syncretic than synthetic at this stage of its development. A review of the history of manufacturing and the application of its development to construction which provides the historical context for this critique is provided elsewhere [34]. I will leave also for others the task of detailed examination of the review and analysis underpinning the three pillars individually and in comparison, and focus in this paper on what I consider to be some conceptual weaknesses that all three conceptual pillars share :

- The focus on the physical processing of materials as an engineering problem;

- The absence of a concept of organisation in the analysis;
- The lack of any analysis of the implications of risk and uncertainty;
- The unitary concept of *value.*

6.1 Production as Materials Processing

The overwhelming emphasis – either explicitly or implicitly - of the TFV approach is on the processing of materials as a technical problem in engineering. This is manifest in both the selection of the sources for the development of the three pillars, and in the overall tenor of the argument. While attention to the physical processing of materials needs to form part of any theory of manufacturing for the production of artefacts, it can only form part of an overall theory of production for two reasons. The first is that not all production is of artefacts – many phases in the production process involve no physical transformation at all, and many firms in the construction industry supply services to the client such as consultancy rather than artefacts such as shear walls. Second, and more generally, important shifts are taking place in the market for manufactured goods, where, increasingly, what is purchased by the client is the service that the artefact provides, not the artefact itself, in *integrated solutions* [35].

Koskela's analysis does encompass design processes, but the notion of design appears to be limited to fitness for purpose defined in engineering terms as opposed to design as symbolic value defined in cultural terms. Clark and Fujimoto [36] argue persuasively, based on their extensive work in the automobile industry, that the essence of successful design is *product integrity* which has two facets. The first is *internal,* and is essentially the same at the familiar fitness for purpose criterion. The second is *external* and refers to the consistency between the product's performance and customer expectations which include measurable performance criteria, but also synergy with the customer's lifestyle and aspirations. Koskela does not argue that design is the same as manufacturing, rather he suggests from a value perspective that it is "analogous to mining…. The issue is to find the ore (requirements) and to have it processed so that no metal is rejected in slag (avoidance of loss), and to produce an end result with as little impurity as possible (optimization)" [3 p. 118]. This conceptualisation of the design process finds little resonance with the analysis of the design process articulated by such authorities as Lawson [37] as a messy process of finding solutions to wicked problems, and I submit, presents a very limited notion of what the design process in construction is about. Although more recent formulations by LC [6,1] have suggested that effective design has more emergent properties than this citation suggests, there is still a strong sense here of the now discredited [38] design methodologies approach.

6.2 The Organisation of Production

A notable feature of the principal contributions to current debates on the transformation in manufacturing associated with the Japanese challenge over the last 20 years is the considerable attention paid to organisational issues. The contributions from both Harvard and MIT which

have led this debate all combine analysis of flows of information and materials with analysis of changes in forms of organisation. The reason for this is that processes cannot exist on their own – they are always embedded in an organisational context, and that context is as important an influence on how information and materials flow as the configuration of machine tools on the factory floor [20]. While it is certainly possible to analyse operational flows in isolation from their organisational context using techniques derived from operations research, any implementation of the results of such analysis, or indeed the implementation of any new technology designed to improve that process, requires organisational change to provide the context for the effective use of that technique [20]. This lack of attention to organisational issues is surprising given that last planner [7] is, in essence, an organisational innovation in that it proposes weekly meetings to determine which "quality assignments" can be scheduled for the following week's work.

This analysis of structure and process in organisations draws on the contingency approach to organisation design authoritatively reviewed by Mintzberg [39]. Despite its importance to research in the development of lean processes, the reference to this literature is both very limited, and a misinterpretation. The contributions of Thompson and Galbraith – two of the leading contributors to the contingency theory of organisation – are discussed solely in terms of their relationship to the transformation concept of buffering [3 p. 44]. The term does not appear in the index of Galbraith's major synthesis of his contribution [22], nor his more recent management guide [40]. The misinterpretation of Thompson's [10] discussion of buffering is of greater interest in the context of this paper, because Thompson's principal concern is how organisations seek certainty in the face of exogenous uncertainty in order to protect their technical core, and buffering of that core from the external environment is one strategy for doing this. In this sense, last planner is a classic buffer technique in that quality assignments are those assignments that have had the uncertainty associated with their execution minimised.

6.3 Risk and Uncertainty at the Heart of the Organisation of Production

This point leads us nicely to the third critique of the TFV which is the lack of any conception of uncertainty or risk, where risk is uncertainty to which a probability distribution can be assigned. A basic tenet of organisation theory is that one of the major – arguably the major – influence on the design of organisations and the production systems they support is the level of uncertainty that they face. This uncertainty may be environmental [41], technical [42] or transactional [43], but it is pervasive. It is particularly pervasive in project organisations due to their non-repetitive nature – indeed risk management is arguably the most important development in project management tools and techniques since the 1960s [30]. Stinchcombe [44] argues in his comparative analysis of the construction and car industries that it is the level of uncertainty that contractors face, and therefore, their need for flexibility that most clearly distinguishes them from car manufacturers.

One of the major changes in the environment for organisations and their production systems over the last 40 years since the era of the contingency theorists is that levels of uncertainty have

increased as organisations' abilities to buffer themselves from those uncertainties have decreased. The dynamics of change in the market environments and technologies of production have intensified across all sectors, and construction and the other project-based industries face relatively high levels of uncertainty compared to other production sectors. I submit that any viable theory of production must have a concept of uncertainty at its heart – in other words, we need a theory of how production systems vary contingently with the levels of market and technological uncertainty that they face as part of any theory of production.

The fundamental role of uncertainty in the design of production systems means that information is critical. Uncertainty is defined as the difference between the information required for a decision and the information available for that decision [22]. Decision-makers coping with uncertainty are forced to make provisional decisions which are then adjusted as uncertainty-reducing information arrives as "news" [23]. While the physical act of production in manufacturing and construction inevitably involves materials flows, those materials flows are connected with the organisation within which they are housed and the markets which they are intended to serve through information flows. Thus, I submit, any theory of production needs to be a theory of both information and materials flows in the process – what has been called the *tectonic* approach to production [20].

6.4 The Unitary Concept of Value

The LC approach stresses the importance of the generation of value through the construction process – it is the third pillar of the TFV theory. More recent work on *revaluing construction* [45] has identified three dimensions to the value concept applicable to the construction process :

- The contribution that the asset created by the process makes to the client's business processes
- The contribution that the process makes to the supplier's business processes
- The contribution that the asset makes to society as a whole.

The fundamental issue is that these three dimensions of value exist in all projects, yet they are not necessarily aligned. A major issue in realising value in the constructed product is that they are typically seen as artefacts with a cost, rather than assets worthy of properly evaluated investment. One reason for this is that there is remarkably little research on how buildings add value for clients – the state of the art is reviewed in Spencer and Winch [46] and Macmillan [47]. In societal terms, a new road may add value for the government that constructs it and the travellers who use it, but can destroy value for those who live near it, or who value the natural environment that it destroyed. For this reason, stakeholder management [48] is a vital element in construction project management. Within the supply chain, the capture of greater value for one actor in the process – typically in the form of profits – can be at the expense of another. This is why a theory of how to align incentives within the project value system is a central part of construction project management theory [49] in order to avoid the cycle of adversarial relations

and over-engineering [17 fig 6.5]. The members of the project value system are typically independent organisations which must make a profit from their participation in that system or die – a coalition of interests, rather than a team is the appropriate metaphor for the construction supply chain, even where there are formal joint venture arrangements in place as part of *integrated teams*. Thus value in the construction process and product is inherently contested, and we need to develop methods of ensuring that incentives are aligned both within the project coalition, and between the project coalition and external stakeholders. A unitary concept of value derived from quality management is, I submit, inadequate for such a task.

7. Conclusions

There is much agreement between the two positions articulated in this paper, although debate inevitably emphasises disagreement. Certainly, last planner is an important and distinctive innovation in construction project planning, and the other techniques adopted for the LPDS are appropriate. It was suggested that additional techniques such as critical chain could also be adopted with benefit. It was also suggested that the existing project management toolbox still has much to offer – arguably what is at issue is how it should be used, not whether it should be used. The TFV theory is based on a refreshing reading of the production and operations management literature, and moves the debate on the organisation of production in construction forward considerably. It was argued, however that it would benefit from further development because of the strong focus on the physical processing of materials as an engineering problem; the absence of a concept of organisation in the analysis; the lack of any analysis of the implications of risk and uncertainty; and its unitary concept of *value*. We need theories of production, because without them we cannot determine which tools and methods it is appropriate to adopt from manufacturing industry, and which are inappropriate due to the site specific nature of construction [5, 34], but such theories need to be based in the social science of organisation [50] as much as in the techniques derived from operations research which form the principal foundations of LC [3, 4].

The theory underlying MCP has been elaborated elsewhere [19, 20, 34, 49]. The aim of this paper has been to engage in a debate with the advocates of lean construction as we jointly and severally attempt to develop a theory of construction as production by projects. Arguably, the most important thing that construction can learn from manufacturing production is something that it gave away in the first place – the fundamental role of project forms of organisation and their effective management in the production of unique, site-specific products under time constraints.

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