THEORY BASED PRODUCTION AND PROJECT MANAGEMENT

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ABSTRACT: This paper gives an overview of an ongoing project endeavouring to advance theory-based production and project management, and the rationale for this approach is briefly justified. The status of the theoretical foundation of production management, project management and allied disciplines is discussed, with emphasis on metaphysical grounding of theories, as well as the nature of the heuristic solution method commonly used in these disciplines. Then, on-going work related to different aspects of production and project management is reviewed from both theoretical and practical orientation. Next, information systems agile project management is explored with a view to its re-use in generic project management. In production management, the consequences and implementation of a new, wider theoretical basis are analyzed. The theoretical implications and negative symptoms of the peculiarities of the construction industry for supply chains and supply chain management in construction are observed. Theoretical paths for improvements of inter-organisational relationships in construction which are fundamental for improvement of construction supply chains are described. To conclude, the observations made in this paper vis-à-vis production, project and supply chain management are related again to the theoretical basis of this paper, and finally directions for theory development and future research are given and discussed.

Keywords – Keywords: agile project management, metaphysics, production management, supply chain management, theory

1. INTRODUCTION

The mainstream view within construction and across other sectors has traditionally been that there is no explicit theory of project management or production management, and even that there is no need for theory in construction management. This notion is being challenged in the project “Theory-based project and production management”, carried out by the Salford Centre for Research and Innovation (SCRI) in the Built and Human Environment, University of Salford. The aim of this paper is to give an overview of the theory of project and production management, as

it stands today, and consequent need for a theoretical renewal of the field.

The structure of the paper is as follows. The status of the theoretical foundation of production management, project management and allied disciplines is first discussed, with emphasis on metaphysical grounding of theories, as well as the nature of the heuristic solution method commonly used in these disciplines. Then, on-going work related to three aspects of production and project management is reviewed from both theoretical and practical orientations: production management, project management and supply chain management. With regards to production management, the consequences and implementation of a new, wider theoretical basis to production management in construction are analyzed. Next, the emergence of information systems agile project management is documented and its characteristics analysed, with a view to its re-use in generic project management; comments on the need for future research are given. Concerning supply chain management, first, the peculiarities of the construction supply chain are discussed. Next, the negative symptoms of the peculiarities and their implications for managing supply chains and inter-organisational relationships in practice are observed. Directions for fundamental improvements of inter-organisational relationships in the construction supply chain are found in four theories: transaction cost economics (TCE), production and operations management (POM), language/action perspective (L/A), and network theory. The paper concludes indicating directions for further theory development in construction, based on the observations made regarding the three perspectives introduced in this paper: production management, project management and supply chain management.

2. THEORY

In the following, we treat production management and project management as one entity. In the production-based approach, projects are conceptualized as temporary production systems. Project management can thus be equated with production management. The crucial question is: what are the most fundamental theories and principles covering production management, and consequently project management?

At the outset, it is useful to review the theoretical basis of the conventional doctrine of project management (Koskela & Howell 2002). Arguably, it holds that production is a transformation of inputs to outputs – this is the theory of project. The theory of management consists of particular theories for planning, execution and control. Regarding planning, the conventional theory, management-as-planning, implies that planning is the core task of management. Execution is conceptualized as one-way communication (orders), within classical communication theory.

For control, the thermostat model suggests changing the performance level for achieving a predetermined goal in case of a deviation.

Table 1. Ingredients of a new theoretical foundation of production and project management

Subject of theory		*Relevant theories*
Project, production		Transformation Flow Value generation
Management	Planning	Management-as-planning Management-as-organizing
	Execution	Classical communication theory Language/action perspective
	Control	Thermostat model Scientific experimentation model

However, we contend that this conventional theoretical foundation is insufficient, even counterproductive, and must be augmented (Koskela et al. 2002). Regarding the theory of project and production, the (partial) models of operations as flow and value generation add the consideration of time, variability and customer (Koskela 2000). Similarly, the theoretical foundation of management has to be extended. The approach of management-as-organizing adds the idea of human activity as inherently situated (Johnston & Brennan 1996a). Thus, planning should also focus on structuring the environment to contribute to purposeful acting. Concerning managerial execution, in the language/action perspective, described by Winograd and Flores (1986), action is triggered by explicit commitments (promises) resulting from two-way communication. The scientific experimentation model of control, presented by Shewhart and Deming (Shewhart & Deming 1939), focuses on finding causes of deviations and acting on those causes. The scientific experimentation model thus adds the aspect of learning to control.

However, it has emerged that it is necessary to investigate even deeper foundations for production/project management than theories, namely the metaphysical commitments underlying our approaches (Koskela & Kagioglou 2005). Since the pre-Socratic period of philosophy, there have been two basic views on the metaphysical (or ontological) question: What is there in the world? One holds that there are things, that is, atemporal entities in the world. The other insists that there are processes, that is, intrinsically temporal phenomena. These metaphysical assumptions tend to strongly influence how the subject of the inquiry or action is conceptualized. The thing-oriented view seems to lead to analytical decomposition, the requirement or assumption of certainty and an ahistorical approach. The process-oriented view is related to a holistic orientation, acknowledgement of uncertainty and to a historical and contextual approach. The theories discussed may be classified according to their metaphysical choices. Generally, the traditional approach is characterized by a substance (or thing) based ontology, whereas the new

approaches subscribe to process ontology. However, the ontological choices affect the practical procedures not only through the mediation of theories, but also directly. How these theoretical foundations are being implemented in various production related contexts will be illustrated in the next sections.

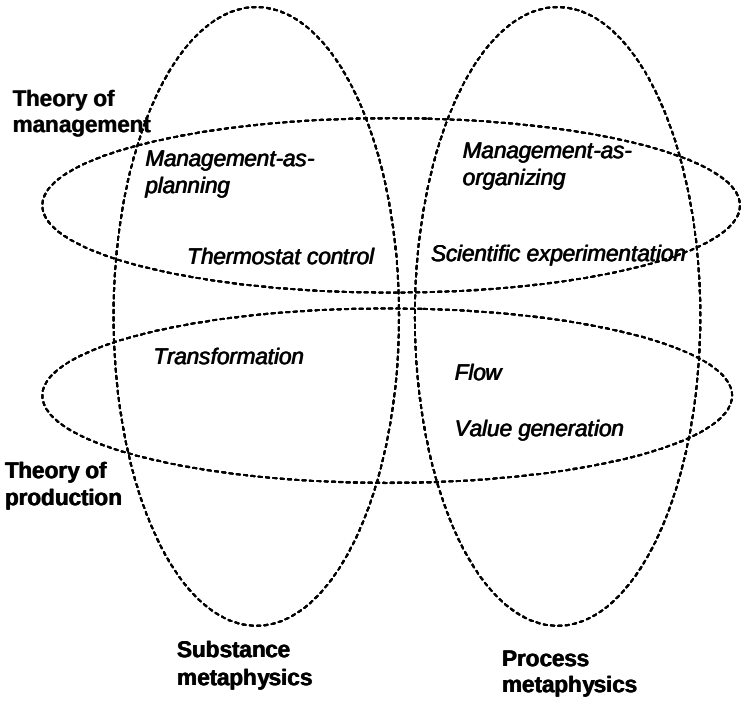

Fig. 1. Metaphysical assumptions divide theories of production and project

In the following, the challenges posed by the theoretical needs are illustrated. Especially, the issues concerning management theory are discussed from the point of view of production management. The shift from substance to process metaphysics is discussed in terms of project management. In the framework of supply chain management, the various theories on project and production are taken as the starting point.

3. PRODUCTION MANAGEMENT

Conventional production management is essentially about planning, i.e. manipulation of that representation (management-as-planning). Here, management at the operations level is seen as consisting of creation, revision and implementation of plans. A criticism about this type of management is that the plans 'push' tasks to execution without taking the status of the production system into account. It leaves the tasks of management essentially uncoupled from everyday activity. The construction industry demands another approach, where human activity is core and production is responsive to the situation in question

(management-as-organizing). Here 'pull-systems' take this situation into account, authorizing the release of work on the basis of system status.

However, in construction, it is normal to create a conceptual plan using a push-system type of scheduling in order to determine the logical sequence of works and identify the interdependence among the activities. In this phase, adoption of a 'diverging/converging' planning process (Laufer 1997) is useful to analyse a companies' resources and supply data for the decision-makers to choose the best way for the project be carried-out. At this time, the project is in its conceptual and definition phase and the activities are of a 'push' nature, in order to create the logical sequence of process mentioned before. Here critical activities, bottlenecks, milestones, and project buffers are defined. The construction industry uses a variety of methods to facilitate the scheduling of project activities. Nowadays there are two main methodologies for scheduling work in construction: activity-based scheduling and location-based scheduling. The first one deals with a network of activities following a logical sequence and the respective duration of each activity. Among the main methods of activity-based scheduling are Gantt Charts, CPM, PERT, Critical Chain, etc. On the other hand, location-based scheduling assumes that successive activities use the same and consistent resources from unit to unit in multiple locations. Examples of the latter include: Line-of-Balance, Vertical Production Method, Time-Location Matrix Model, etc (Kenley 2005). All these methods have a characteristic: the use of a push-driven system. These methods assume that all resources required to execute an activity that is about to start will indeed be available at that activity's start time, i.e. each activity passively waits for its ingredients (instructions, labour, materials, equipment, and space) to become available (Tommelein 1998). An exception within these methods is Critical Chain, which can be used in either a 'push' or a 'pull' manner. The nature of Critical Chain is that the process can be pulled by the maximum capacity for work at the bottlenecks.

At some stage within the project process it is necessary for the management method to migrate from a push-system to a pull-system. It is suggested that the optimal time for this transition is when the execution phase starts, because feedback then becomes more frequent. Push-systems control the release of jobs by controlling a Master Production Schedule. Projects which focus too much on the Master Plan, rather than on the milestones lead to 'making-do[1].' type of waste. A pull technique is based on working from a target completion date backwards, which causes tasks to be defined and sequenced so that their completion releases work. Working backwards from a target completion date eliminates work but does not add value (Ballard 2000). For implementation of pull-systems, improvements are needed in the areas of: work flow reliability in the site assembly process, and a reduction of the time required from order to delivery of materials at the site. The

[1] Making-do - Tasks are started without all their standard inputs (materials, machinery, tools, personnel, external conditions, instructions, etc.) (Koskela 2004)

benefits of pulling are: shorter projects and reduced working capital tied up with inventories of materials; less labour time spent handling materials; and less loss, damage or misplacement of materials (Ballard 1998). For a pull-system to be successful, it is important to achieve synergy among all organizations that do the work within the phase. Thus, teamwork techniques need to be implemented for planning and controlling the execution phase, e.g. the Last Planner System. Table 2 shows some relevant differences between push and pull-systems.

Table 2. Push vs. pull systems comparison

Push Systems	**Pull Systems**
Schedule work releases	Authorize work releases
Based on market focus	Based on client focus
Stock piling	JIT deliveries
Inflexible	More flexible
Value is implicit	Pressure for higher value

'Management-as-planning' is understood to be a recurrent formulation of management at the operations level in terms of the creation, revision and implementation of plans. It assumes that everyday activity itself is mediated by representations of the world and effected by the implementation of plans. On the other hand, there is 'management-as-organizing' where "attention is paid to structuring the physical, political and cultural setting of action, in recognition that purposeful action is an interaction between intelligent agents and structured environments, rather than just an information process. In short, management is seen as organizing things[2] rather than planning or scheduling them" (Johnston & Brennan 1996b).

Based on these descriptions we can assume that the 'management-as-organizing' approach is strongly linked with pull-systems. This way of management takes into consideration the organizational environment structure and not just a probabilistic scheduling of the activities as it is done in 'management-as-planning'.

4. PROJECT MANAGEMENT

Traditional project management assumes that project requirements can be identified early in the project and that they will (or even must not) change. The requirements are then decomposed into 'manageable tasks' and a detailed plan derived to ensure that each task (or 'thing') can be achieved in an efficient and low risk manner. This understanding of a project transformation has led to project failures, particularly in the information systems industry; agile project management techniques have developed as a result and enable requirements to emerge and 'pull' the

[2] We assumed here that the authors meant by 'organizing things', the resources' organization, e.g. labour, materials, equipment, space, etc. It is a different view to 'substance metaphysics'.

project, instead of the project plan ‘pushing’ a set of pre-(mis)understood outcomes. Thus value is resolved by project end instead of defined at project start.

Iterative and incremental development methodologies were first defined by Shewart in the 1930s and then expanded upon by Deming in Japan (Deming 1986). Indeed, the Plan-Do-Check-Act (PDCA) cycle is still being used in Toyota product development (Liker 2004) and conforms to the scientific experimentation model of control. However, in the field of information systems, anarchic ad-hoc code and fix developments of the 1960s led on to the welcome embrace of Royce’s waterfall development method in 1970 (Royce 1970). Unfortunately, the iterative aspects of Royce’s paper were largely ignored or misapplied; rigid adherence to early definition and fixing of system and software requirements resulted in errors being propagated and compounded throughout projects, leading to widespread failures in delivered value. Several voices (notably Gilb’s and Boehm’s) were raised against such an approach to information systems development in the 80s and early 90s (Futrell et al. 2002).

The work of Imai, Nonaka and Takeuchi (Takeuchi & Nonaka 1986) was a catalyst to the establishment in 1990 of a US DoD and National Science Foundation funded study at Lehigh University to investigate the competitive environment of 2005 and beyond. This study was a response to the comparative progress made by Japanese industries and led on to the development of an Agile Forum for manufacturing in 1992. Coincidentally, in 1990 DeGrace and Stahl (1990) analysed the Waterfall model used in information systems development and found it wanting; in Japan the Waterfall model was reduced to four overlapping phases (as in Sashimi).

Sutherland (2001) merged Scrum with his earlier work with other agile processes in 1993 and spread its use to a number of corporations. In 2001 the term ‘Agile’ was adopted as an umbrella term for advanced software development methodologies which were largely rooted in the early 1990s. The Agile Movement became particularly active within the information systems industry from early 2003. The use of Scrum for software development project management was then popularised through Schwaber and Beedle’s book (Schwaber & Beedle 2002). Whilst some continued to eschew the information systems waterfall method, it was not until 2001 that a ‘Manifesto for Agile Software Development’ (Agile Alliance 2001) evolved through the efforts of leaders in the field and the term Agile grew to encompass many of the existing methodologies.

Most projects are, to some extent volatile and subject to unforeseeable chaotic inputs and emergent requirements. Project managers are expected to do their best to ensure that these changes can be mitigated and that the project can ‘run to plan’. Where agile thinking differs, is that change is recognised as inevitable and therefore embraced as an opportunity for enhancing customer-perceived value. This is particularly important in the case of information systems as they are so difficult to visualise or predict (Humphrey 1995; Wegner 1995; Ziv & Richardson

1997). In the case of construction, research shows that, as late as the start of construction, significant uncertainty remains as to what is to be constructed (Howell et al. 1993). Indeed, other sources point to the nugatory nature of excessive front-end design (Baker et al. 1986; MacCormack et al. 2003).

Agile project management can be seen as ‘management as organising’, indeed, an agile project manager is very much seen as a facilitator who enables small, self-organising multi-disciplinary teams to decide for themselves how they satisfy their value goals. However, the feedback loops in agile project management do not fulfil a thermostat model in terms of flow control but are more of a lens which focuses and re-focuses on the required value delivery (Koskela & Howell 2002).

If change if so inevitable and over-specification nugatory, why do we try so hard to plan to the last detail and then to follow that plan at all costs? There are many published answers to those questions but a common theme is that we can better understand complexity through decomposition, thus minimising risk, controlling scope, and enabling measurement of progress. However, changes throughout the project demand that we consider scope control as an ongoing task, defining project scope only as far as we are currently truly able to comprehend and prioritise it from the perspectives of value realisation and risk mitigation. We can then use project team (including the customer) learning for control and feedback. Thus we are compelled to treat the project as a process and not as a serious of pre-scoped milestones, i.e. gateways.

Agile methodologies commonly control scope through the use of value prioritisation techniques, such as YAGNI (You Aren’t Going to Need It) or MoSCoW (Must have, Should have, Could have, Want but won’t get this time). Temporal control of projects is necessary because of budgetary implications and knock-on effects - Scrum and some other methodologies, such as Dynamic Systems Development Method (DSDM) use the concept of time boxes which are often rigidly enforced. Many argue that such agile thinking should be restricted to small, low consequence projects. However, larger projects have been tackled, for instance with up to 800 developers within a ‘scrum of scrum’s (Schwaber & Beedle 2004). There are many partial accounts of significant improvements in information systems deliveries through the use of agile techniques, however, impartial academic studies are hard to come by.

As Scrum can be considered as a ‘management tool’ (Boehm & Turner 2004), it can be easily used beyond information systems (its origins lie in Japanese manufacturing product development). Similarly, DSDM has been used, for instance in construction, organisational development and infrastructure projects (Stapleton & Consortium 2003). However, these ad hoc uses do not (yet) help us resolve the underlying theory of agile thinking. Projects tend to be complex by their nature and it is necessary for humans to manage that complexity in a manner that will deliver the required end result. It may be that, by decomposing customer-

recognisable value rather than the fragmentary components of a project we maintain greater mental awareness of the process, rather than devoting our efforts to produce some‘thing’ of immediate import. However, further research is necessary to validate such a supposition.

5. SUPPLY CHAIN MANAGEMENT

In the construction supply chain, production has been mainly been viewed as consisting of independent transformations. Many activities are outsourced to subcontractors, and materials and components are purchased separately from suppliers who are relatively isolated from the main production system of the main contractor delivering the end product to the client. This disintegrated approach to production causes fundamental problems when trying to change from transformation and “push” towards value, flow and “pull” production (Koskela 2000).

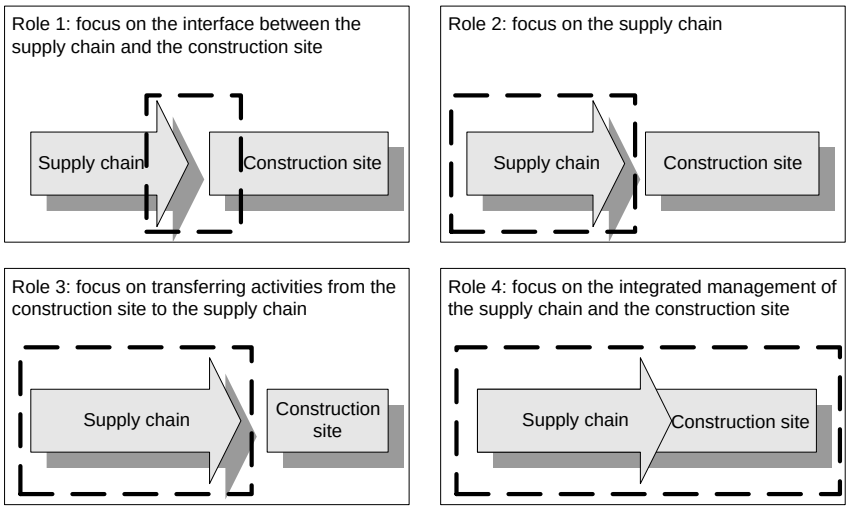

Fig. 2. Four roles of supply chain management to integrate the supply chain and the construction site (Vrijhoef & Koskela 2000)

Construction clients, as well as supplying parties have reacted to these peculiarities of production in construction in different ways, and developed various strategies to cope with the (negative) effects of the peculiarities within their businesses and processes (Vrijhoef & Koskela 2005). For instance, project-independent approaches to construction have been applied to increase the “stabilisation” of the production environment, by increasing the use of off-site production and strategic multi-project procurement. In most cases, this lead to increased levels of integration and alignment between the different “stages” in the supply chain, e.g. between materials supply and the construction site. These approaches have mainly been aimed at the resolution of problems caused by on-site production, one-off production and temporary production organisation (Fig. 2).

New approaches to production in the construction supply chain have lead to, or required new ways of organising inter-organizational relationships (IOR) in the supply chain. These can be observed from four perspectives (Table 3): transaction cost economics (TCE), production and operations management (POM), language/action perspective (L/A), and network theory. The perspectives are partly competing and incomplete as well as complementary with respect to the understanding of IOR in construction supply chains (Vrijhoef et al. 2003).

Table 3. Comparison between different approaches to IOR in construction supply chains

Theory	**Conceptualization**	**First principles**	**Major principles / relationships**	**Primary prescription for organizing**
TCE	Transactions between buyer and seller, characterized by asset specificity, uncertainty and frequency	Minimize transaction costs	Optimal governance structure determined by lowest transaction costs	Depending on level of transaction costs: market or hierarchy as governance
POM	Three different concepts: transformation, flow, value generation	Get the product produced; minimize waste; maximize value	Principles associated to each concept: for example, "reduce variability" to the flow concept	Organize in a way for achieving the primary concern: getting the product produced, minimizing waste or maximizing value
L/A	Conversation; sending and receiving orders between individuals and organizations	Avoid breakdowns in conversation	Create commitment and trust through conversation	Organize in a way allowing for conversations to take place in their complete form
Network	Networks of actors	Maximize value by information exchange and decreasing opportunistic behaviour	Complex products and their development and manufacturing processes demand for third type of governance	Organize by creating or modifying networks

These four perspectives still do not give a complete theoretical framework for the full understanding and improvement of construction supply chains. However, from the four perspectives, indications of various related and additional theories, concepts and influences can be derived and identified. These theories, concepts and influences can be arranged in larger theoretical “streams”, progressively developing theoretical models for supply chain management and integration, building upon previous work to

chart the field of construction supply chains, such as by London and Kenley (2001). These attempts show that it is, and will probably keep being, an ongoing activity to try and establish a “virtually complete” theory, and a corresponding interdisciplinary research agenda for construction supply chain research (O'Brien et al. 2002). Nevertheless, this calls for further theory development, and further introduction of new complementary theoretical concepts to a multiple theoretical approach to the construction supply chain, and production and project management in construction in general, to enable fundamental improvement of construction practice in the supply chain.

6. CONCLUSIONS

The need for better production/project management is acute and much discussed in many fields, such as construction and information systems development. Can this need be resolved by addressing individual problems and resolving them through respective intervention in some aspect or part of the project or production system (such as a better method)? Or is a holistic change needed, pertaining to all parts and aspects of the system? The difference of these two approaches is aptly described by Papert (2000) in relation to school reform. One can take two approaches to reforming schools - or indeed anything else. The *problem-solving* approach identifies the many problems that afflict individual schools and tries to solve them. A *systemic* approach requires one to step back from the immediate problems and develop an understanding of how the whole thing works.

Based on the considerations above, we contend that in the case of project and production management, the systemic – or theory-based - approach shows more promise than the problem-solving – or method-based - approach. We have been tinkering with methods for decades, without realizing that the progress has been limited by our implicit theories and their underlying ontological assumptions. We have neglected to develop new theories and ontologies, which would inherently also stimulate and justify novel and powerful methods. As a result, at least a part of our problems are self-inflicted, caused by commonly used, but counterproductive methods, based on deficient theories. But if our problems are theory-driven, so should any methodical renewal be theory-based.

The suggested way forward is thus to create a theoretical foundation for project and production management, to form a focal point for academic research and teaching. Such a goal is of course not novel at all, but in the case of project and production management, its adoption is bound to stimulate new dynamism to these fields.

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