DEVELOPING PRODUCTION THEORY: WHAT ISSUES NEED TO BE TAKEN INTO CONSIDERATION?

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ABSTRACT

The aim of this paper is to establish key issues that a theory of production should address, to conceptualize these issues and to sketch an account of their interaction. Aristotle's analyses of knowledge and causality are used, in conjunction with Wittgenstein's concept of language games, to integrate the insights of transformation-flow-value (TFV) theory and the language action perspective (LAP) within a framework derived from Liker (2004). Building on Liker, we identify four language games that are necessary for production:

1. drawing on scientific knowledge to determine the best physical arrangements for the achievement of a pre-given value;
2. two value discourses which determine
   (a) the target value for (1) and
   (b) the human relations which will enable the achievement of (1) - Liker's 'long term philosophy' and 'developing people and organization', plus the Language Action Perspective;
3. a discourse of learning and knowledge with the aim of continual improvement.

Four of the key concepts used in these games are identified (flow; work, knowledge and commitment) and related to the functions of management. Finally, an overall theoretical framework is proposed.

KEYWORDS

Production Theory; Lean Theory; Lean Construction; Value; TFV Theory; Language Action Perspective

INTRODUCTION

A theory, by its nature, represents reality by identifying certain phenomena and abstracting away others. Which phenomena could a theory of production include? How can we best conceptualize these phenomena? How can we account for their interaction?

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However, as we shall argue below, a production theory is not simply an attempt to represent reality, but is in itself an exercise in production. Furthermore, it involves right action: conformity to a set of values.

The theory proposed here is intended to bring together the various strands of thought that make up the theoretical developments in Lean Construction thinking, set in the context of analysis of the Toyota Production System. In doing so, it is intended to provide a framework for further theoretical development. The resulting theory will stand, not simply as a guide to Lean thinkers and practitioners, but as an answer to calls for a theory of organization that takes adequate account of the activity involved in production (Barley and Kunda 2001).

PRODUCTION PHENOMENA

In this section, we attempt to identify necessary production phenomena through an examination of previous work.

Koskela (2000) proposes that in effect there are three existing theories of production, whose central concerns are transformation, flow and value, respectively. The development of TFV logically requires the synthesis of these three approaches. While transformation is seen to be the basis of most thinking in construction and project management, the development of lean construction theory has focused primarily on flow and value (Koskela and Howell 2002). Both theories address the design, control and improvement of production systems.

The Flow (F) theory treats the production process as a complex of flows and is built around the fundamental principle of reducing waste. This leads to two further principles:

1. Reduce lead time; and
2. Reduce variability (Koskela 2000).

The formulation of Value (V) theory was intended to accommodate Shewart's (1931) quality perspective, formulated as five principles:

(1) Requirements capture;
(2) Requirements flowdown;
(3) Comprehensiveness of requirements;
(4) Capability of subsystems;
(5) Measurement of value (Koskela 2000).

While the flow concept has continued to lead to further developments (e.g., Bertelsen et al. 2006) the transactional phenomena included in the value concept have been addressed through an alternative language action perspective (LAP) (Macomber and Howell 2003, Slivon et al. 2010), while the notion of value itself has been subjected to critical scrutiny (Emmitt et al. 2005, Thyssen et al. 2010).

Clearly, skilled linguistic action is essential to elicit design requirements (1), while the negotiation of requirements flowdown (2), the communication of comprehensive requirements (3) and the assessment of customer satisfaction (5) are directly addressed by the LAP oriented promise based management (PBM) approach. Other, product realisation, aspects have much in common with F theory. Thus the statistical process control method can be conceived of as addressing a further dimension of flow variability.

Liker (2004) suggests that the Toyota Production System (TPS) functions on the basis of 14 principles, categorised under 4 headings: long term philosophy; right process; developing people and partners; and continuously solving root problems. If long term philosophy and developing people and partners are considered as sociological values issues (Rooke et al. 2010), it can be argued that TPS has 3 leading features: the management of process flows, the development of values, and continual learning. Thus, we find at least the following phenomena:

- transformation of materials into products of greater value
- the temporality of this process
- capture and communication of customer requirements
- the assurance that customer requirements have been met
- negotiation between participants in the production process
- fundamental values
- learning

PHILOSOPHICAL ORIENTATION

As stated in the introduction above, we are concerned with creating a theory that can conceptualize phenomena in a way that will enable us to improve production. Thus, our theorizing is constructive in nature, intended as prescriptive, rather than descriptive, as in positivist interpretations of scientific activity.

Our approach to theory building is based in an understanding of language which draws our attention to the fact that language is [1] a form of action and [2] fundamental to thought. Society and science would be impossible without language. Wittgenstein (1958) uses the metaphor of language games to model the ways that language works, pointing out that to take terms from one game and use them in a game to which they don't belong generates confusion. Ryle (1963) refers to this type of error as a category mistake, using the example of a visitor to Cambridge who, after being shown around the various colleges asks 'But where is the University?', not realising that the colleges make up the University. Our problem then is to identify the language games that will best enable us to analyse and improve production. A key insight is that questions can be either of two types: empirical or conceptual, the former are answered by investigating phenomena in the world, the latter by examining the language we use (Winch 1990). Further important work has been done by Searle (1975) who claims that linguistic action can take only one of five forms:

- Assertive, committing a speaker to the truth of an expressed proposition;
- Directive, intending to cause a hearer to take a particular action;
- Commissive, committing a speaker to some future action;
- Expressive, expressing the speaker's attitude and/or emotion;
- Declarative, causing an actual change in reality.

In order to specify these language games, we borrow a number of concepts from Aristotle. With his four causes (effective, material, formal, final) Aristotle (1960) gives us an idea of the kinds of language games which might make up a theory of production. These are:

Effective cause - cause as it is understood in modern science, the necessary and sufficient conditions for an event to occur;

Material cause – what the object is made of;
Final cause – the purpose or reason for an event or object;
Formal cause – the form that a thing takes.

Formal cause is subject to some difficulty and dispute. The idea comes from Plato, whose theory of pure forms is rejected by Aristotle. It refers to the form that something takes. In Plato it leads to a philosophical dualism which is rejected in the linguistic philosophical position underpinning this paper (Wittgenstein 1980). Here we will take it to refer to the structure an event or object. Clearly, there is a difference between discussing the structure of a physical object, such as a girder and the structure of a social arrangement, such as a promise.

Aristotle (1976) also identifies five forms of knowledge, of which three have been of particular interest to recent commentators:

Episteme: demonstrable knowledge (for instance scientific laws);
Phronesis: knowledge of good action (for instance, morality and politics);
Techne[5]: productive knowledge (for instance, art, craft and technology).

Much recent discussion has focused on the relative emphasis that should be placed on these three forms of knowledge and the type of language games that they underpin (Dunne 1993, Flyvbjerg 2001). By contrast, the approach taken here is to understand how the three forms relate to each other; specifically, how episteme and phronesis are necessarily constituents of techne.

The crucial distinction is that episteme proceeds from a single point of view. Phronesis, by contrast must take account of other minds than that of the analyst. This has consequences for both design (deliberation starting from a final cause) and rhetoric (advocacy for a course of action). Thus, in the discussion of value below, it is not sufficient to determine a putatively objective standard of value; value must always be measured with reference to the individual(s) receiving the benefit (Grönroos 2011). A similar argument applies to knowledge. While we take knowledge to entail a sense of objectivity, in that for a phenomenon to be accepted as knowledge, it must meet a public test, it is always subjectively experienced, it must be known by *someone*. While it has been argued elsewhere that knowledge can be embedded in the physical properties of objects (Rooke et al. 2010) this knowledge only exists in an objective sense, it can only be *known* when a human being interacts with the object.

PRODUCTION THEORY

Modern science consists primarily in the analysis of effective cause (though also includes material and formal cause, the latter understood as definition). But final cause has no part in modern scientific explanation, which has no interest in phronesis or techne and is thus unconcerned with problems of value.

In contrast, a theory of production (techne) must concern itself with all four causes. Production must have a final cause and must employ physical means to achieve it. In a modern context, it must also involve sophisticated forms of

[5] 'Techne' is often taken to refer to practical 'hands on' work, as is its meaning in modern Greek, perhaps most closely related to Ryle's knowing how. We take the view that this was not Aristotle's intention, for him techne was an intellectual virtue equivalent to episteme and phronesis, which is how we use it here.

organization, whose success depends upon phronesis. In production, the final cause should control all activity. This control should take two forms:

1. Customer satisfaction must be at the centre of the analysis; and
2. Other stakeholders must also be satisfied.

We do not have to explain final cause in terms of the other three causes: this is impossible. Final cause is dealt with more fully under the heading of value below.

Building on the TPS, TFV and LAP, we can thus identify four language games that are necessary for production:

1. drawing on scientific knowledge to determine the best physical arrangements for the achievement of a pre-given value, crucially this involves a focus on temporality;
2. value discourses which determines
    a. the target value for (1) and
    b. the human relations which will enable the achievement of (1) - Liker's 'long term philosophy' and 'developing people and organization', plus the Language Action Perspective;
3. a discourse of learning and knowledge with the aim of continual improvement (of which the present discussion is part)

These are dealt with in the three following sections.

Since the controlling idea is the final cause, the principles of production theory are expressed as prescriptive statements (instructions or guidance), rather than as propositions.

PRODUCTION SCIENCE

In order to determine the best physical arrangements for the achievement of a pre-given value, we draw on heuristic principles of F theory, the foundation of which is to reduce waste. Secondary principles include: reduce lead time and variability. There is a third level of heuristic principles, which have not been fully integrated into the theory (Koskela 2000) and which include Liker's principles two to eight (Liker 2004).

However, it is clear that elements of the V theory also belong to productions science and that these are, in many ways the most developed. Thus, the quality control tools developed by Shewart are concerned with the physical properties of the production process (capabilities of sub-systems). It is also arguable that they treat production as a flow, though not in the same way as flow is currently conceived in the F theory. The two secondary principles of F theory identified by Koskela (reduce lead time; reduce variability) are concerned with controlling the temporal dimension of flow. However, a flow must also have spatial dimensions and material form and quality control is focused on some of these; specifically, the spatial and material qualities of a product, as measured against a set of design specifications.

V theory also draws attention to physical properties of communication which are already conceptualised in terms of flow (incentive flowdown). While communication is primarily the concern of the Value and Learning games, these physical properties cannot be ignored. Thus, for instance, sufficient spatial and technological provision must be made for adequate communication.

The analysis of work or operations (in Shingo's terms, flows centring around the worker) is also a proper subject for production science, though it is primarily of interest in the game of learning and knowledge management.

VALUE DISCOURSES

By 'value discourse' we mean a conversation to determine the criteria (standards, rules) by which human activity or its product is to be judged (and therefore governed). Human activity is of two types: making (techne); or action (phronesis).

If production science is concerned with the physical scientific aspects of techne (which belong to episteme), then value discourse is concerned with determining the final causes that govern the application of this science in any particular case. As Aristotle (1976:VI:4) observes, techne cannot be entirely a matter of scientific generalisation, it must also deal with the specifics of unique situations. The needs and desires of customers and other stakeholders form a large part of these. Nevertheless, some epistemic observations are possible.

The term 'value' is ambiguous in management studies and has been subject to much discussion within and outside of IGLC (Emmitt et al. 2005, Rooke et al. 2010, Thyssen et al. 2010, Grönroos 2011). Several distinctions need to be carefully made between sets of criteria for:

1. the value of the end product for the end customer, which we will call the **benefit**;
2. the value of goods and services to those who do not directly benefit from them;
3. benefits which accrue to **stakeholders** in the supply chain other than the end customer;
4. the performance of producers

Set 1 can be determined by requirements capture performed as an analysis of the benefits that the customer will receive from the end product. It is subjective in the sense that this value is unique to the customer and cannot be compared with the value another might get from the product. However it is objective to the extent that the specifications which deliver the customer value can be defined. An argument put forward by Grönroos (2011) amounts to stating that this definition of value is incompatible with a view that value is created in the production process; he argues that only potential value is created in the production process, true value is only realized by the customer. However, a supply chain analogy, which treats each operation as a customer to the previous operation and supplier to the next would seem to satisfy this criticism. Following Parsons (1968) we can see that the end product may be either a source of satisfaction in itself, or a means to future satisfaction (e.g., a tool).

Set 2 introduces the market mechanism which effectively establishes exchange value. It is based on the principle of offer and acceptance, leading to a **commitment** to deliver. It has the additional objectivity of allowing comparison between the value attributed to a product by different people, either different customers or customers and suppliers.

Set 3: the benefits accruing to other stakeholders are of various types and there are various types of stakeholder. For those directly involved in the production process benefits are of two types: cash or other payment (2); or satisfaction gained directly from involvement in the project (job satisfaction/working conditions). A stakeholder analysis is important here.

Set 4: we can identify 3 sets of criteria for evaluating the performance of producers:

(a) production knowledge and skills (techne)
(b) fundamental values (phronesis)
(c) communication and learning skills

Production knowledge is examined above under the heading of production science. Fundamental values are discussed by Liker in his treatment of TPS values (Principle 1). Production, communication and learning skills are treated below.

LEARNING AND KNOWLEDGE MANAGEMENT

Learning is integral to F and V theories and to Liker's account of TPS. In V theory this is expressed in the Shewhart cycle. Liker introduces Senge's organizational learning theory, but there are many relevant approaches, including 'active' learning (Kölb 1984) and 'action' learning (Revans 1998). Issues of organizational culture and politics need to be taken into account here.

Knowledge can initially be divided into knowing how and knowing that (Ryle 1963). Knowing that is informed on the one hand by theory and on the other by genchi genbutsu (going and seeing the reality for oneself). The latter recognises the contingent nature of techne, the former its epistemic dimension. Knowing how is achieved through participant observation. Both knowledge how and the contextual knowledge that achieved by genchi genbutsu can be judged according to the criterion of Unique Adequacy, requiring competence in a setting (Rooke and Kagioglou 2007). Both kinds of knowledge can be stored in the physical properties of objects (Rooke, et al 2010). The curation of knowledge - that is the traditional discipline of information management - though visual management provides important additional techniques where the emphasis is on accessibility and knowledge flow. It is less often remarked that knowledge-how is also embodied in the form of automation and Toyota's particular approach of autonomation (Ohno 1988). Thus, while learning is a purely human phenomenon, which can only be dealt with in the context of a humanistic 'other minds' discourse, the issue of knowledge management has important epistemic elements.

RELATING THE CONCEPTS

Figure 1 represents a first attempt to relate some of these important techne concepts. These are criteria, rather than descriptive propositions, as they would be in natural science. Three types of criteria are identified: for the product; for the production process (including the work that drives that process and the human relations that make it possible); and for the broader human relations that provide the context of production.

Determining the criteria for the product (or service) requires stakeholder and benefits analyses. The identified benefits and dis-benefits inform the design.

The design of the production process, which is the focus of interest here, requires the consideration of both episteme and phronesis, science and value discourse. The four key phenomena on the bottom level of the diagram are set on a continuum between pure episteme and pure phronesis.

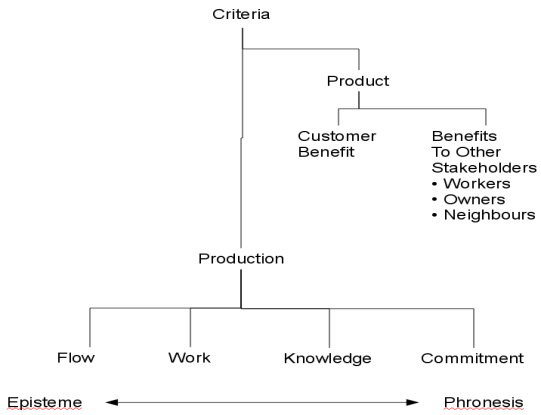

Figure 1: Criteria for Techne: Summary of Production Theory Phenomena, showing how episteme and phronesis contribute to techne

ANALYSIS OF THE FUNCTIONS OF MANAGEMENT

If management is seen as the design, control and improvement of production systems, then the following observations can be made.

DESIGN: Design is knowledge work, which is to say that its product is **knowledge**, it is primarily a learning process (the analytic reasoning involved being a type of learning). However, knowledge must be curated and communicated, requiring also the study of both rhetoric (value discourse criteria 4c above) and information **flows** (the physical requirements - production science) and information flows.

CONTROL: Control is primarily about getting commitment from others (value discourse criteria 2). The work of achieving sound commitment is studied in the language action perspective (Howell, et al 2004). Where the flow of design knowledge has broken down, this is often where to look for the problem.

IMPROVEMENT: The aim of production improvement is to improve flows, so that they contribute more effectively to the creation of benefit. This is done, either directly, or by improving the work methods which drive them by increasing relevant knowledge.

THE FOUR LANGUAGE GAMES

The four production theory language games and key prescriptive principles that derive from them are given below. This list provides both a prescriptive checklist for improving production and a framework for classifying production studies. It incorporates the four major aspects of the TPS recognized by Liker (2004) while providing a more theoretical analysis of these. The Flow analysis remains largely faithful to Koskela's (2000) characterization of F theory, but incorporates the importance of conformance to specification emphasised by Shewhart (1931). Other elements of V theory are distributed between the other three language games. LAP (Howell, et al 2004; Macomber and Howell 2003) provides the basis of the Relationships language game.

BENEFIT: A benefit is either a direct advantage or an aid to better achievement of purpose

- The purpose of production is to deliver customer benefits.

- Benefits to other stakeholders must be taken into account.
- Dis-benefits to all stakeholders must be taken into account.

FLOW: Production consists of physical flows with spatial and temporal dimensions.

- Reduce waste
  - Reduce lead time
  - Reduce variability (including variation in product quality)

NETWORKS OF COMMITMENTS

- Adhere to a sound long-term philosophy
- Respect your people, partners and suppliers
- Seek and make reliable commitments
- Develop people, teams and leaders who understand the work and follow the philosophy

KNOWLEDGE: Knowledge 'that' and knowledge 'how'

- Go and see for yourself what the problem is
- Learn through action
- Understand the whole system in terms of its flows, benefits and relationships
- Manage the company's knowledge

CONCLUSION

In this paper we have sought to integrate three major approaches: TFV, LAP and The Toyota Way. Two philosophical resources have been utilized to provide a basis for doing this. First, we have assumed that a production theory is a kind of techne, a theory of making, rather than the kind of descriptive theory typical of natural science (episteme). This means that the principles of the theory are prescriptions, rather than descriptive propositions. Second, we have assumed that production theory is best understood as a series of language games, rather than as a single theoretical edifice. By analysing the TFV, LAP and Toyota Way approaches, we have established the need for four such language games: production science; benefits analysis (value criteria 1-3); commitments analysis (value criteria 4); knowledge analysis.

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