



Citation for published version:

Codinhoto, R, Koskela, L, Tzortzopoulos, P & Kagioglou, M 2007, 'The method of analysis in production management', Paper presented at 15th Annual Conference of the International Group for Lean Construction, Michigan, USA United States, 18/07/07 - 20/07/07.

Publication date:
2007

Document Version
Peer reviewed version

[Link to publication](#)

University of Bath

Alternative formats

If you require this document in an alternative format, please contact:
openaccess@bath.ac.uk

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

THE METHOD OF ANALYSIS IN PRODUCTION MANAGEMENT

Ricardo Codinoto¹, Lauri Koskela², Patricia Tzortzopoulos³, and Mike Kagioglou⁴

ABSTRACT

The method of analysis was developed by ancient Greek geometers to identify and solve problems related to geometry. From that period, well known scientists such as Newton and Descartes have applied the method. More recently, Polya has presented the method of analysis as a heuristic template to solve mathematical and other problems. Despite its continual epistemological dilution, the method has also been used to explain the cognitive process of designing. In this paper it is claimed that the method of analysis can also explain production management. It seems that the method of analysis has been used across different levels of management in production, i.e. from a holistic/strategic perspective through to detailed levels. Therefore, the aim of this paper is to discuss whether the method of analysis provides a partial theoretical foundation for production planning. The research approach is literature review with an emphasis on the method of analysis and synthesis. The conclusion is that the method of analysis and synthesis adds to the theoretical explanation of both design and production.

KEY WORDS

Analysis and synthesis, production planning

INTRODUCTION

The importance and need for clear theoretical foundations for production has long been recognised. Although considerable steps have been recently taken forward, there are still issues that can add to the generation of a more holistic understanding of production management. The development of the theoretical basis for production management is necessary to advance our understanding and conceptualisation of production processes and, therefore, to support the improvement of production planning practice.

Production planning has been articulated with a dominant focus on the transformation of inputs in outputs (Koskela, 2000). It has been argued that flow and value are relevant features of production that have been poorly considered in the current practice of planning (Koskela, 2000). Despite contributions in the area of flow management (e.g. Bertelsen *et al.*, 2006), a consistent understanding has not yet been achieved.

¹ Research Fellow, SCRI / HaCIRIC, School of the Built Environment, University of Salford, Maxwell Building, The Crescent, Salford, M5 4WT, UK, Phone: +44 (0)161 2953507, e-mail: r.codinoto@salford.ac.uk

² Professor, School of the Built Environment, University of Salford, Maxwell Building, The Crescent, Salford, M5 4WT, UK, Phone: +44 (0)161 2956378, e-mail: l.j.koskela@salford.ac.uk

³ Academic Fellow, School of the Built Environment, University of Salford; Maxwell Building, The Crescent, Salford, M5 4WT, UK, Phone +44 161 2954284; p.tzortzopoulos@salford.ac.uk

⁴ Professor, School of the Built Environment, University of Salford, Maxwell Building, The Crescent, Salford, M5 4WT, UK, tel. +44 (0)161 2953855, e-mail: m.kagioglou@salford.ac.uk

This paper explores whether the ancient method of analysis and synthesis, developed originally by Greek geometers, is able to provide new insights to aspects of production management.

In prior research, Koskela and Kagioglou (2006) pointed out that the ancient method of analysis and synthesis can be explained by five main features, as follows.

- Types of analysis: there are two types of analysis: theoretical and problematical. In geometry, theoretical analysis aims at proving a theorem whereas problematical analysis aims at constructing a wished geometrical figure.
- The start and end points of analysis: The start point in theoretical analysis (i.e. the “desired thing”), is something we do not know whether it can be done or achieved. The end point consists of something admitted, that is, already known. In turn, synthesis provides the definitive proof that the “desired thing” is possible. Correspondingly, in problematical analysis, we do not know the desired thing, but assume it to be known.
- Types of reasoning: at least three types of reasoning are involved in the method of analysis and synthesis. Decompositional reasoning involves breaking down the “whole” into its parts and interrelationships. Regressive reasoning involves assuming the solution (as known) and then questioning what would be necessary to get to the solution. The enquiry goes on until something which is already known is considered as being first in order (e.g. for a design problem, this would be an existing requirement). Finally, transformational reasoning relates to a process of expanding the knowledge associated to the problem.
- The two directions of reasoning: there are two directions of inferences needed: backwards for the solution, and forwards for the proof.
- The strategy of reasoning: in the method of analysis reasoning is a heuristic, iterative process, i.e. there is no guarantee that a solution can be found in the first attempt, therefore, the method of analysis involves returning to the problem and revising it and starting again.

These features do not exhaust the understanding of the ancient method of analysis, but provide a concise starting point for our present purposes. One of the reasons why the method is not fully understood relates to the fact that the only existing wider description of the method is a text fragment from around 300 AD, which has been the subject of long discussions in philosophy and history of science (Hintikka and Remes, 1974).

Another reason relates to the fact that the ancient core understanding of analysis and synthesis has somehow been corrupted. It seems that after the great scientists, who propelled the Enlightenment, the term ‘analysis’ has been used to refer to different methods and, in some instances, without appropriate reference to its original concepts (as detailed in Codinhoto et al., 2006). Consequently, the method of analysis was transmitted in a rather superficial and impoverished form, as a generic method. The term analysis itself was “captured” to refer to algebra, especially analytical calculus.

Also, the historical connections on how the concepts have been understood have largely been lost during the modern times. It is argued in this paper that this state of affairs is not only an interesting finding in the history of managerial thought, but also, and more importantly, a major opportunity to consolidate and advance the theoretical and methodological basis of production disciplines.

Hence, this paper, which aims to discuss the method of analysis and its contribution to production, is structured as follows. First, the introduction highlights the features of the ancient method of analysis and synthesis. Next, a discussion of the relevance of analysis and synthesis as a theoretical basis for production management is presented. Finally, after discussing the significance of the findings, some general conclusions are provided.

RELEVANCE OF THE METHOD OF ANALYSIS TO PRODUCTION

What is the relevance of the method of analysis to production management? It can be hypothesised that if the features of analysis are theoretically relevant to production planning, those features would have surfaced in recent empirical and conceptual literature on production planning and management. Thus, our first approach is to check whether we can find statements from prior literature that would support the claim that the different features of analysis, separately, provide theoretical ingredients for understanding and conceptualising production planning and management in construction.

The Types of Analysis

As discussed earlier, there are two types of analysis: theoretical and problematical. These are, in Polya's (2004) terms, the problem to prove (in geometry, a theorem) and the problem to find (a solution to a mathematical problem). Now, the task is to investigate whether this dichotomy corresponds to empirical or conceptual statements on production planning.

In production management the two types of analysis can be recognised in strategic and detailed planning. In this sense, the problematical analysis aims at proving a strategy, whereas theoretical analysis aims at outline a plan.

For instance, Wideman (1990) says in relation to strategic planning:

"In large complex projects there is a need to do initial project management planning - in short, planning the plan."

In this sense, Wideman describes the process of finding a solution. Therefore, the resulting strategic plan is the starting point of the theoretical analysis which will be carried out, for instance, by planners in the construction site.

Thus, the occurrence of the two types of analysis can be recognised in production management.

The Start and End Points

In production planning the start point of analysis relates to the goal to be achieved, which is the end point of the schedule, or a predetermined cycle time. The former relates to the calendar and the focus of analysis will be to discover if (considering the existing company's resources/capacity) the time between now and the deadline is enough to achieve the goal. The latter does not have relation with the calendar and the focus will be to discover if the predetermined interval of time is enough to achieve the goal. In this sense, although the planning goal is known (the desired thing) its feasibility remains unknown.

On the other hand, the ending point of analysis is something already known and in terms of production planning refers to the starting point of the schedule. In the case of production planning, the end point of analysis can be either the day in which production starts (considering a time window between now and a point in time in the future), or the

information regarding the necessary “resources” to produce something in a predetermined period of time.

In relation to the start and end points, the method of analysis can be viewed as corresponding well with production planning.

Types of Reasoning

Decompositional Analysis

A configurational (or decompositional) analysis is usually also involved in the method of analysis (Hintikka and Remes, 1974). In geometry, decomposition is used to break a geometrical figure on its parts. In production, decomposition is used to breakdown the product into its constituent parts as the production process is broken into its related operations, activities and tasks.

In the Work Breakdown Structure (WBS) technique, each planned outcome across each root node within each different level can be considered as the desired end (Wikipedia Contributors, 2007) (e.g. the whole building, the conclusion of one store or simply a wall). Therefore the plan obtained by using WBS is the result of a decompositional approach to the problem. It is not difficult to see the similarity of the ancient and modern views on decomposition.

Regressive Analysis

In planning Kahkonen (1993) describes:

“In practice, the planner attempts to produce a feasible plan or schedule. While preparing a plan or schedule, he or she needs to take all relevant factors into account in order to ensure that the plan or schedule is logically correct. Within this process, the identification of activity dependencies is very important. Activity dependencies set constraints on the order of activities, the start and finish of activities and the overlap of activities.”

In production, the idea of starting from the end and working then in the identification of the sequence and dependencies of the tasks, activities and operations to achieve the long term goal is well known. This form of reasoning has been the basis of well known techniques in production planning, such as Gantt charts, PERT networks (Program Evaluation and Review Technique) and critical paths. The common feature in these is that they endeavour to provide the chain of means and ends. Again, the similarities between the ancient and the modern conceptions are plain.

Transformational Analysis

The transformative or interpretative reasoning may be the least understood feature of analysis, at least of those discussed here. The use of auxiliary lines in geometrical analysis (Hintikka and Remes 1974) can be viewed to fall into this type. Beaney (2003) refers to the work of Frege and Russell, who suggested transforming statements to be analysed first into their correct logical form.

However, in contrary to Beaney, Polya (2004) relates all these issues as a process of expanding the knowledge associated to the problem (or theorem). Namely, a transformation of information or knowledge does not destroy the input, as is the case regarding physical transformations. Thus, any transformation or new interpretation leads to expanded knowledge.

The use of transformational analysis is necessary when the information provided to solve a problem is not enough to solve it. Therefore, the analyst job is: a) to identify which is the missing information, i.e. the analyst deviates his/her attention from the original problem to a secondary one; b) to identify if the missing information can be gathered, derived or generated from the information provided or from similar problems already solved (e.g. using existing theorems); c) to solve the secondary problem aiming to find the missing information; and d) to return to the original problem.

Polya (2004) provides an example of what is meant by transformational analysis in geometry. Considering that the original problem is to identify the length of the segment 'x' being provided 'a', 'b' and 'c' (Figure 1a). The obvious solution is to use Pythagoras theorem i.e. $a^2 + b^2 = c^2$. However, the missing information is the length of the segment 'd' (this is the auxiliary line), which can be obtained from solving a secondary problem i.e. the triangle 'abd' (Figure 1b) by using Pythagoras. Thus, once the secondary problem has been solved, the analyst can return to the original problem.

Accordingly, transformational analysis is clear in geometry, but less so in other fields. However, the following advice of Shingo (1988) can perhaps be seen as an instance of transformational analysis: *"It is important not to limit ourselves to considering only immediate goals but rather to remember that one objective is but a means for achieving higher level goals. This attitude, which frequently leads to truly dramatic improvements, should not be forgotten."*

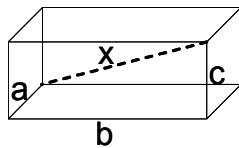


Figure 1a

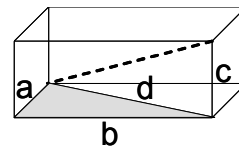


Figure 1b

Two Directions of Reasoning and Their Unity

Hendrickson and Au (1998), discussing basic concepts on the development of construction plans, present an example from Sherlock Holmes of what can be considered reasoning backwards: *"Most people, if you describe a train of events to them, will tell you what the result would be. They can put those events together in their minds, and argue from them that something will come to pass. There are few people, however, who, if you told them a result, would be able to evolve from their own inner consciousness what the steps were which led up to that result. This power is what I mean when I talk of reasoning backward (Doyle, 1930)."*

Furthermore, in relation to the cognitive process related to planning, Morris and Ward (2004) referring to Simon (1978) describe:

"...planning can be likened to a search through a space of connected problem states, with the efficiency of the search improved by using a range of different heuristics to think forwards from the given information of a problem and backwards from the goal of a problem."

The consideration of two directions is evident and can be seen in different approaches to production management. As argued by Koskela and Kagioglou (2006) the Vee model is one example which implies the use of the two directions of reasoning. In terms of design and production, an application regarding the Vee model can be drawn. In Figure

2a the left tail refers to design and represents the specification stream. The right tail refers to prototyping and/or production and represents the test, verification and validation stream. The same analogy can be drawn in relation to production planning (Figure 2b). The left tail represents the planning activity across different levels of plans and the tip of V refers to the assignment stream. The right tail represents the monitoring stream.

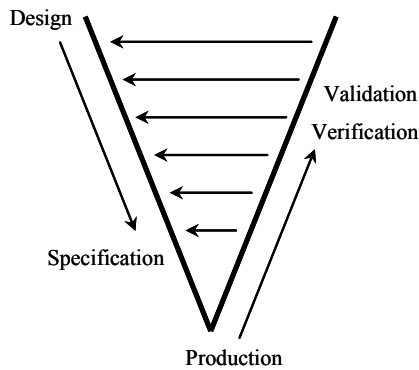


Figure 2a – The Vee model applied to design and production

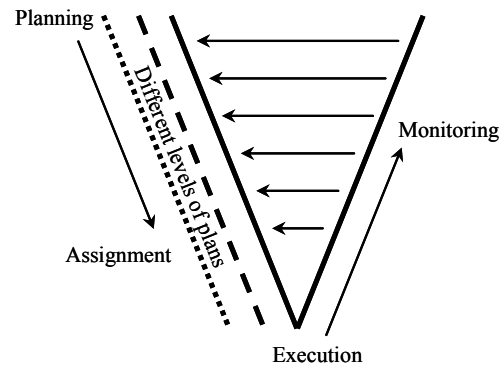


Figure 2b - The Vee model applied to planning and execution

Another example relates to the use of simulation or virtual prototyping through 4D or nD modelling (Lee *et al.*, 2003). This technology aims at making possible to revise, redrawn, re-plan and mainly testing the combination of solutions against the overall objectives and constraints of the project before the execution starts.

Considering these examples, it is clear that the idea of two streams is evident in the method of analysis and in production management.

Strategy of Reasoning

The method of analysis does by no means ensure that a solution can be found. Rather, the method leads to a heuristic approach: we may be compelled to return to the problem and revise it, and start afresh.

A production planner often relies on a heuristic approach, i.e., using selected rules, strategies or principles serving to stimulate the investigation in search for a solution. Hendrickson (1998) says:

“Heuristic approaches are also possible to the time/cost trade-off problem. In particular, a simple approach is to first apply critical path scheduling with all activity durations assumed to be at minimum cost (Dij). Next, the planner can examine activities on the critical path and reduce the scheduled duration of activities which have the lowest resulting increase in costs. In essence, the planner develops a list of activities on the critical path ranked in accordance with the unit change in cost for a reduction in the activity duration. The heuristic solution proceeds by shortening activities in the order of their lowest impact on costs. As the duration of activities on the shortest path are shortened, the project duration is also reduced. Eventually, another path becomes critical, and a new list of activities on the critical path must be prepared.”

The iterative process is evident both in the ancient method of analysis and production planning methods.

SUMMARY OF MAIN ISSUES

For all the features contained by the ancient method of analysis, explicitly or implicitly, we can identify current, corresponding ideas and concepts, as summarized in Table 1. Consequently, it is justified to hold the method of analysis as contributing to the establishment of theory of production management. Interestingly, almost without exception, the modern concepts and practices have been forwarded by their originators without any reference to the ancient counterparts.

Table 1. Overview on the method of analysis and corresponding recent developments

Feature	Method of Analysis	Corresponding features in production planning
1 Problem to Prove/Find	Theoretical and problematic form of analysis	Strategic and detailed planning of project or production
2 Start / End	Starting: we do not know whether it is possible or can be done Ending: something already known	The starting point of analysis is the end point of the schedule.
3 Decomposition	“In the context of geometry, the question is about investigating from which parts... a figure is made up, and which relations exists between those parts...”	Work break down structure
4 Regressive analysis – solution backwards	“...which is sought to be already done, and we inquire from what it results, and again what is the antecedent of the latter, until we on our backward way light upon something already known and being first in order...”	Gantt Charts and CPM networks
5 Transformation	Auxiliary lines in geometrical analysis	Understanding of higher level goals
6 Direction of analysis	Backwards for the solution; forwards for the proof	Vee model adapted to design and production, and planning and execution.
7 Strategy of reasoning	The method is heuristic and iterative: we may be compelled to return to the problem and revise it, and start afresh	Heuristic approaches in planning

DISCUSSION

This paper is an initial exploration of how generic and powerful the method of analysis and synthesis can be across situations and contexts. From the discussion presented, it can be concluded that practically all features of the method of analysis can be found in production management. Therefore, in terms of lean processes, the method provides elements for further development and refinement of a better theory of production.

The prevalence of the features of analysis and synthesis in production management arguably derives from three issues. First, analysis and synthesis seem to deliver a detailed theory on what happens in value generation⁵. Let us recapitulate how Shewhart (1931), at the outset of the quality movement, characterised production:

⁵ Instead, the method of analysis does not seem to bear on the transformation or flow models of production.

“Looked at broadly there are at a given time certain human wants to be fulfilled through the fabrication of raw materials into finished products of different kinds. These wants are statistical in nature in that the quality of a product in terms of physical characteristics wanted by one individual are not the same for all individuals.

The first step of the engineer in trying to satisfy these wants is therefore that of translating as nearly as possible these wants into the physical characteristics of the thing manufactured to satisfy these wants. In taking this step intuition and judgement play an important role as well as the broad knowledge of the human element involved in the wants of individuals.”

The second step of the engineer is to set up ways and means of obtaining a product which will differ from the arbitrarily set standards for these quality characteristics by no more than may be left to chance.

Shewhart presents here *what* happens in production, but does not touch the issue of *how*. The method of analysis gives an elementary answer to this *how* question.

Second, the applicability of the method of analysis in production management derives from the affinity between designing and planning. If planning is interpreted as design of temporal process, instead of artefacts, we can hypothesise at the outset that the method of analysis is to a similar degree relevant to planning as it is to designing – it has been earlier argued that the method of analysis provides a proto-theory of design (Koskela & Kagioglou, 2006).

Third, as Polya (2004) has argued, the method of analysis can also be seen as a generic method of problem solving, and it is also in this role that various features of this method are used in production management. For example, the method of “5 Why’s” (Shingo, 1988) for finding the root cause of a problem equates to regressive analysis.

Thus, all in all, the expectation is that the explicit development and application of the method of analysis in production management can be used to stimulate advances in this field.

REFERENCES

- Ballard, H. G. (2000) “The Last Planner System of Production Control.” PhD. Thesis, Faculty of Engineering, The University of Birmingham.
- Beaney, M. (2003). Analysis. E. N. Zalta, The Stanford Encyclopedia of Philosophy.
- Bertelsen, S.; Koskela, L.; Henrich, G.; Rooke, J. (2006) "Critical Flow - Towards a Construction Flow Theory." In Proceedings:14th Annual Conference on Lean Construction, IGLC, Santiago, Chile. p. 31-51.
- Codinhoto, R.; Koskela, L. J.; Tzortzopoulos, P.; Kagioglou, M.. (2006) How analysis and synthesis have been understood in design. In: Proceedings: 14th Annual Conference on Lean Construction, IGLC, Santiago, Chile. p. 121-134
- Crawford, S. and Wiers, V. C. S. (2001). From anecdotes to Theory: A review of existing knowledge on human factors of planning and scheduling. Human performance in planning and scheduling. B. L. MacCarthy and J. R. Wilson. London, Taylor & Francis: 15-43.
- Doyle, A.C.. (1930) "A Study in Scarlet," *The Complete Sherlock Holmes*, Doubleday & Co., pp. 83.
- Hendrickson, C., Au, T.. (1998). Project Management for Construction: Fundamental Concepts for Owners, Engineers, Architects and Builders. Prentice Hall. Available at: <http://www.ce.cmu.edu/pmbook/>. Last access: 24/05/2007.

- Hintikka, J. and Remes, U. (1974). *The Method of Analysis. Its Geometrical Origin and Its General Significance*. Boston Studies in the Philosophy of Science. Dordrecht. 25: 144.
- Kagioglou, M; Cooper, R; Aouad, G; Hinks, J; Sexton, M; & Sheath, D; (1998). "Final Report: Generic Design and Construction Process Protocol". University of Salford, UK.
- Kahkonen, K. (1993) "Modelling activity dependencies for building construction project scheduling." PhD Thesis, Department of Construction Management & Engineering, University of Reading, UK.
- Koskela, L. J. (2000). *An exploration towards a production theory and its application to construction*. Espoo, Finland, Helsinki University of Technology. Doctor of Technology: 298.
- Koskela, L. J., Kagioglou, M. (2006) "The proto-theory of design: the method of analysis of the ancient geometers." In: *Proceedings: International Design Conference - Design 2006*. Dubrovnik, Croatia, May 15-18, 2006.
- Lee, A., Marshall-Ponting, A. J., Aouad, G., Wu, S., Koh, I., Fu, C., Cooper, R., Betts, M., Kagioglou, M., Fischer, M.. (2003) *Developing a vision of nD-enabled construction*, Construct IT Report, ISBN: 1-900491-92-3.
- Morris, R., Ward, Geoff (2004) "The Cognitive Psychology of Planning." Psychology Press, 2004
- Papert, S. (2000). "What's the big idea? Toward a pedagogy of idea power." *IBM Systems Journal* 39(3-4): 720-729.
- Polya, G. (2004). *How to solve it: a new aspect of mathematical method*, Princeton University Press.
- Shewhart, W.A. (1931) *Economic Control of Quality of Manufactured Product*. Van Nostrand, New York. 501 p.
- Shingo, S. (1988) *Non-stock production*. Productivity Press, Portland.
- Simon (1978) *Rationality as Process and Product of Thought*. *Journal of the American Economic Association*, 68, 1-16.
- Wideman, R. M.. (1990) *Total Project Management of Complex Projects, Improving Performance with Modern Techniques*. Presentations in five cities in India for The Consultancy Development Centre, New Delhi, India.
- Wikipedia Contributors (2007) "Work breakdown structure." *Wikipedia, The Free Encyclopedia*. Last revision: 17/04/07. Last accessed: 18/04/07. Available at: http://en.wikipedia.org/w/index.php?title=Work_breakdown_structure&oldid=123517290.