ON THE CATEGORIZATION OF PRODUCTION: THE ORGANIZATION – PRODUCT MATRIX

Trond Bølviken[1]

ABSTRACT

Lean Construction is both a theoretical and a (theory-based) practical approach to the construction industry. It is strongly inspired and influenced by Lean Production and the Toyota Production System adopted by manufacturing industries. However, in order for learning across industries, organizations or forms of production to take place, the similarities as well as the differences between the industries, organizations or forms of production involved must be considered and properly understood. A fundamental question for Lean Construction is therefore: "What Kind of Production is Construction?"

This paper reviews the literature on existing ways to categorize production before presenting a new model for such categorization: the Organization-Product-Matrix. Use of the matrix is exemplified through two examples, one on strategies targeting productivity and one on work-place safety.

KEY WORDS

Forms of production, production systems, production theory

INTRODUCTION

Lean Construction (LC) is both a theoretical and a (theory-based) practical approach to the construction industry. LC is strongly inspired and influenced by Lean Production (LP) (which originated in Japanese production theory and methods, prime examples of which are the Toyota Production System and Just in Time). An aim of LC is to learn from these insights so that they can be used to understand and improve the construction industry's project-based production. However, in order to ascertain their value for the construction industry, we need to consider and understand not only the similarities, but also the differences between the stationary industry where LP originated, and the construction industry, which is project-based. As put by Ballard and Howell (1998), a fundamentally important question for Lean Construction is therefore: "What Kind of Production is Construction?"

Koskela has argued for the importance of theory and of understanding the underlying metaphysics when seeking to improve the construction industry (e.g., Koskela, 2000; Koskela and Kagioglou, 2005). Although Røvik's (2007) primary concern is a somewhat different one[2], he nevertheless offers a contribution to the realization of why such understanding is so important. Røvik sees the translation and transfer of ideas as a process of decontextualization and (re)contextualization: First the ideas have to be taken out of their original context (decontextualized); then they

---

[1] Director, Strategy and Improvement, Veidekke Entreprenør AS, P.O. Box 506 Skøyen, N-0214 Oslo, trond.bolviken@veidekke.no (Veidekke Entreprenør AS is a Norwegian subsidiary of Veidekke ASA, a major Scandinavian construction and real-estate-development company)

[2] Røvik's topic is the supply, translation, transfer, demand for and use of ideas on organization

have to be adapted into the new context (contextualized). The whole process – from decontextualization to contextualization – will obviously be influenced both by our theories and by the metaphysics underlying these theories.

Production theory makes an important contribution through models that can be used to categorize and thus understand different forms of production. The present paper presents such models. First through a description of different models found in relevant literature, and then by introducing a new, additional model: the organization-product-matrix.

LITERATURE REVIEW

The literature on how to categorize production identified through the work with this paper can be divided into two groups: Works in which the authors present models designed to be used in the categorization of all types of production, and works in which the authors present lists of characteristics that differentiate construction from other forms of production. The identified models are presented in the following paragraphs, before a presentation of works discussing lists of differentiating characteristics leads up to the introduction of the new model proposed by this author.

WOODWARD (1965)

For Woodward, the main research question is the following: How and why do industrial organizations vary in structure and why do some structures appear to be associated with greater success for the organizations than others? (Dawson and Wedderburn, 1980) In order to analyze this question, Woodward needs to establish a model according to which the companies participating in her study can be categorized. She starts by observing that several people working within this field (incl. Taylor) come from a manufacturing industry background, and that they tend to generalize on this basis. Referring to Dubin (1959) she analyzes different dimensions that can be part of a model used to categorize different companies:

- Tools, instruments, machines and technical formulas versus the body of ideas and the methods employed (a sub-division of her definition of 'technology')
- Different phases in 'a natural history of industry'
- One-of-a-kind production to meet customers' individual requirements versus standardized production
- Continuous production versus production in more or less frequent intervals (a sub-division of standardized production)
- Diversity of products versus relatively little flexibility in the production facilities
- The making of integral products ('The Manufacturing Industry') versus the making of dimensional products measured by weight, capacity or volume ('The Process Industry')
- Jobbing versus batch versus mass production

- The production of parts versus the production of products (parts can more easily be standardized)

She concludes by establishing the following eleven categories (The list also reflects a chronological development and increasing technical complexity):

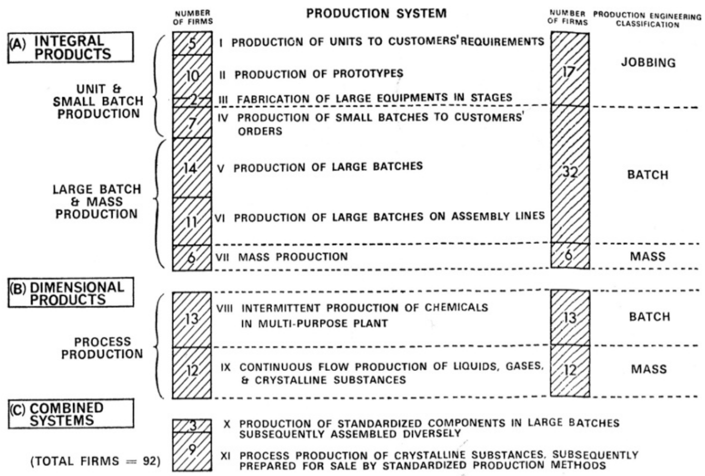

Figure 1: Production systems, Woodward (1965), p. 39

HAYES AND WHEELWRIGHT (1979 A. AND B, 1984)

For Hayes and Wheelwright the goal is “the understanding of the strategic options available to a company, particularly with regard to its manufacturing function.” They present the following two-dimensional product-process matrix:

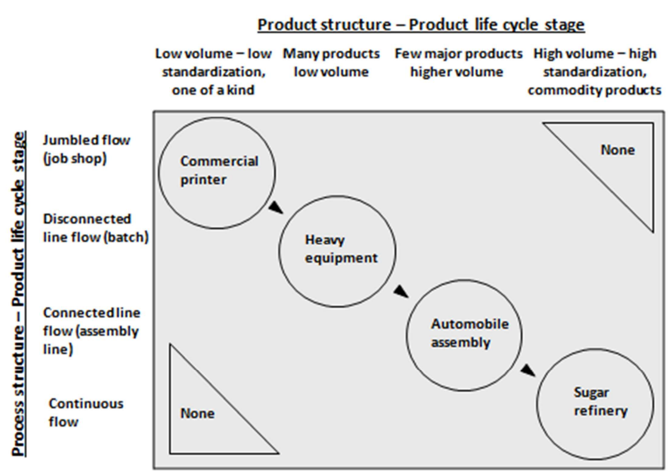

Figure 2: The product-process matrix, Hayes and Wheelwright (1979 a. and 1984 p. 209)

The matrix is used to analyze where different companies are located within the matrix, why they have this location, and in which direction they should or should not move. Al though they find the diagonal from the upper left to the lower right side of the matrix to be the most likely position of a company, they also analyze good reasons why companies could choose positions above or below the diagonal. They find that "an industry usually progresses down the diagonal of the matrix." Looking at the home building industry in the USA, however, they find that the products have become less standardized, and that the industry therefore has moved in the opposite direction. The reason for this, they find to be ”the inability of the market to standardize."

Hopp and Spearman (2008) warn that the product-process matrix only presents part of the picture. Modern manufacturing try to combine high-volume flow lines with flexibility and customization (what we can call mass customization).

SANDRETTO (1985)

For Sandretto the goal is to analyze what kind of cost-accounting system is best suited for different production processes. As a part of this analyses he presents the following product-process matrix. Each of the rectangles represents a cost-accounting system.

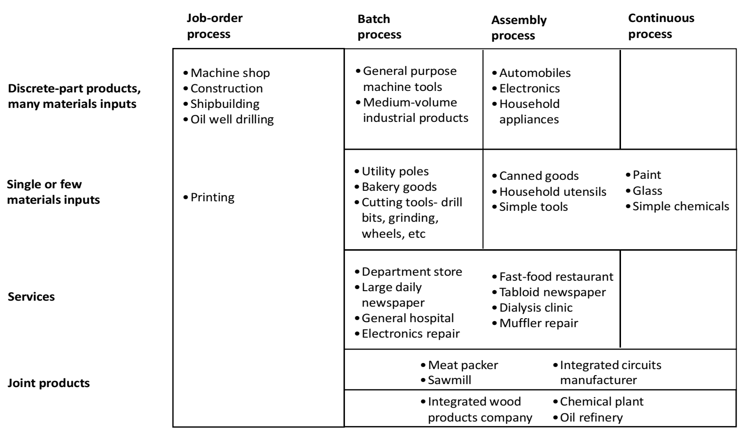

Figure 3: Classification of Products and Companies, Sandretto (1985)

SCHMENNER (1993)

For Schmenner the focus is to explore the choices made by production / operations managers, and to identify how these choices can be improved. He makes a basic distinction between manufacturing and service operations. Schmenner analyzes manufacturing through a product-process matrix inspired by Hayes and Wheelwright (1979 a. and b.):

Schmenner also gives a description of five aspects that differentiate projects from other manufacturing and service operations:

- The manning is constantly changing
- A variety of specialized talents are called for
- Significant degree of up-front planning
- Constant coordination

- The means by which resources can be husbanded is generally by stretching out the timetable

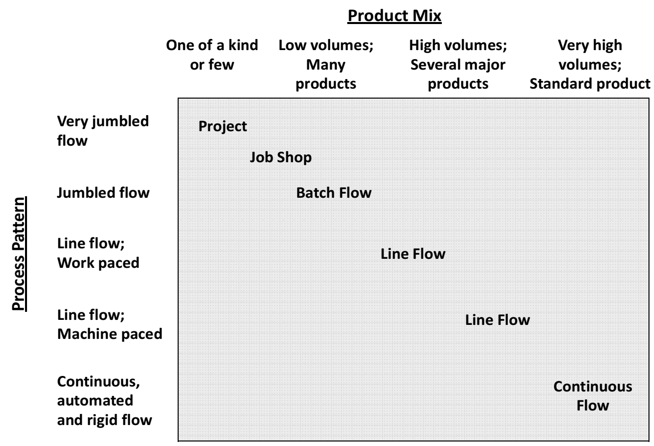

Figure 4: The product-process matrix, Schmenner (1993), p. 14

Production processes should lie along the diagonal. Processes above or below this diagonal will not be cost optimal.

The service operations are analyzed through the following two-dimensional matrix:

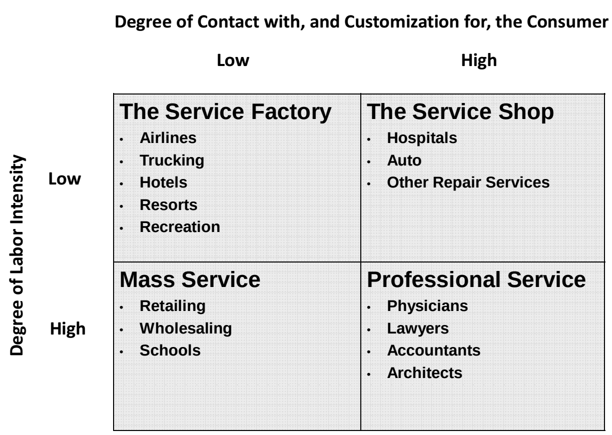

Figure 5: A matrix of service processes, Schmenner (1993), p. 22

BALLARD AND HOWELL (1998)

For Ballard and Howell the goal is to understand and improve construction (by making it “lean”). Because construction and manufacturing both share and have differentiating characteristics, the improvement strategy for construction is seen as twofold:

- To make construction more like manufacturing and to adopt improvement approaches from manufacturing

- To identify and understand "the remainder", that is, the characteristics differentiating construction from manufacturing, and to improve construction by means addressing these characteristics

To what degree there might be conflicts between these two strategies is not discussed.

Ballard and Howell identify the following four ways to categorize types of production:

1. Use Schmenner's (1993) product-process matrix
2. Divide production into product-based flow, process-based flow and fixed position manufacturing
3. Divide production into extraction, fabrication and assembly
4. Divide production according to two types of flow: Flow primarily based on the alignment of machines, and flow primarily governed by directives

CHANG AND LEE (2004)

For Chang and Lee the aim is to explore the nature of construction technology and production systems, and on this basis to identify improvement strategies for the construction industry. They present the following two-dimensional matrix:

	Technical Complexity	Product Complexity
Unit Production	Low	High (Integral Product)
Mass Production	Medium	Medium (Components)
Continuous Process Production	High	Low (Dimensional Product)

Figure 6: Technical and Product Complexity Comparison, Chang and Lee (2004), p. 81

The matrix demonstrates that unit production (as found e.g., in the construction industry) is characterized by low technical but high product complexity. In contrast, a continuous production process is characterized by high technical but low product complexity.

LISTS OF DIFFERENTIATING CHARACTERISTICS

Several authors have presented lists of characteristics that differentiate construction from other forms of production. Koskela (2000) summarizes such lists presented by several authors (p. 145). Koskela uses the term "peculiarities" and concludes that among the most important distinguishing peculiarities of construction are one-of-a-kind production, site production and temporary project organization (p. 257).

Bølviken (2006) also presents a list of peculiarities that distinguish construction from other production, criticizing Koskela's view that the peculiarities should be eliminated, reduced or mitigated. Bølviken argues that the peculiarities of construction need not only represent disadvantages to be met with defensive strategies (elimination / reduction / mitigation); they can also represent advantages that can form the basis for proactive improvement strategies. A similar line of thinking can also be found in Ballard and Howell (1998), and it is also consistent with Woodward's (1965) observation that people who have worked in this theoretical field have tended to generalize on the basis of the manufacturing industry.

THE ORGANIZATION – PRODUCT MATRIX (OPM)

Even though from a theoretical perspective Bølviken (2006) argues that the project need not be a basic characteristic of construction, this is still the case seen from a practical and empirical perspective. Whether the production is conducted by permanent or by project organizations remains one of the primary dimensions for distinguishing between different forms of production, and concerns a range of perspectives (organization, manning, planning, management, leadership, etc.).

The difference between production of similar or of one-of-a-kind (unique) products is seen by many authors as one of the important dimensions for distinguishing between different forms of production. If we combine this with the organizational dimension described above, we get the following organization-product-matrix (OPM), where each of the four fields in the matrix identifies one form of production. The matrix combines two of the three most important "peculiarities" found by Koskela (2000) to distinguish construction from other forms of production.

Any industry or production operation can be analyzed through its position in the matrix. But the OPM is a categorization / model of the real world. It is therefore also a simplification. Most real-world production operations do not fit 100 % into one of the four forms of production. They will typically belong predominantly to one of the four forms, and have additional traits from one or more of the others. For example, construction is mainly project-based production, but it also has elements of production by rotating labor (e.g., fixed ways to organize projects) and order production (e.g., specialized construction). A production operation can also be placed on the border between production forms. For example, mass customization can be placed somewhere between mass production and order production.

	Similar Products	Unique Products
Permanent Organization	Mass Production	Order Production
Temporary Organization	Production by Rotating Labor	Project Production

Figure 7: The Organization-Product-Matrix

EXAMPLES ON USE OF THE MATRIX

In the following two examples on use of the matrix are presented, the first example is on productivity strategy, the second on workplace safety.

EXAMPLE 1: PRODUCTIVITY STRATEGY

Each production form can be associated with a specific basic productivity strategy:

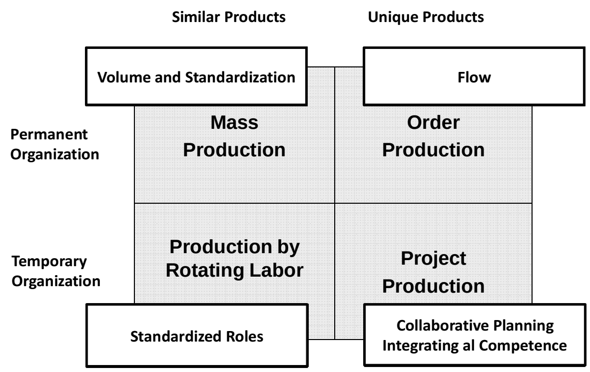

Figure 8: Basic Productivity Strategies

Ohno (1978) describes volume and standardization as the basic strategy for mass production, and flow as the basic strategy for order production. Ballard (2000) describes collaborative planning as a basic strategy for project production.

Any strategy to improve an industry or a production operation will have two basic options:

1. To maintain the position of the industry / operation in the matrix and seek to make improvements within this framework
2. To move the industry / operation to a different position in the matrix

This author sees Lean Construction in general, and the Last Planner System[3] (Ballard, 2000) in particular, as examples of option 1, as the goal is to improve the construction industry on the basis of an understanding of "construction's differentiating characteristics" (Ballard and Howell, 1998).

A huge effort has been put into prefabrication and modularization strategies in construction, over a considerable period of time. Compared to the invested efforts (both by industry and academia), the success has been limited. This limited success can be explained in two ways: The first is that basically, prefabrication and modularization are strategies that seek to move construction from one field in the matrix (Project Production) to another (Mass Production or Order Production). The success of the move has been limited due to particular traits or peculiarities of the construction industry. Alternatively, the limited success for prefabrication and modularization strategies can be seen as a consequence of an attempt to insert the basic productivity strategy of one field into another. Such attempts are likely to be unsuccessful, simply because they fail to understand and accept that a fundamental

[3] Last Planner is trademarked by the Lean Construction Institute.

productivity strategy of a given field specifically addresses challenges and characteristics associated with the production form in question. This productivity strategy is therefore very unlikely to address the challenges and characteristics of other fields.

Ohno (1978) describes the market and economic background for the strategy that resulted in the Toyota Production System: After World War II Japan had neither the market size nor the financial resources to establish mass production of cars based on the Ford System. On the other hand, the Japanese had a strong wish to produce cars at low costs and good productivity. The answer to this paradox was to establish a system of order production with the same productivity as, or better than, mass production. By creating an order production system with market pull (no car to be produced without an order), continuous flow and waste elimination, Toyota was able to compete with the American car industry (that was based on mass production and the Ford system).

EXAMPLE 2: WORKPLACE SAFETY

The use of the organization-product-matrix is not limited to the analysis of productivity strategies, however. Strategies designed to improve work-place safety can provide another example of the use of the matrix. As in the analysis of productivity strategies, the matrix can be used to identify one basic safety strategy connected to each field in the matrix:

CONCLUSIONS

Learning across industries, organizations or forms of production (or across any other boundary) requires that the similarities as well as the differences between the industries, organizations or forms of production involved are addressed and understood. The organization-product-matrix is a tool that can contribute to such understanding, and can be used to identify and analyze different strategies and their relevance to different forms of production.

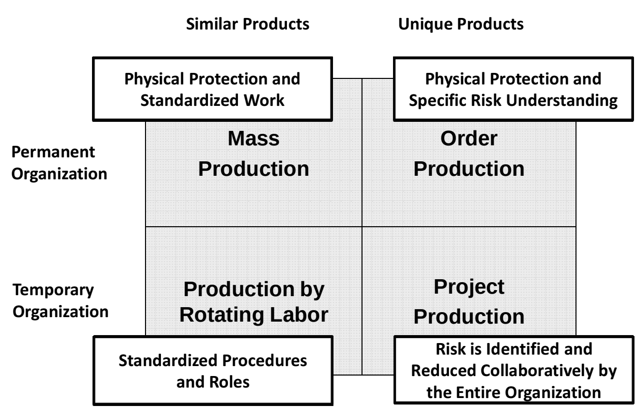

Figure 9: Basic Strategies for Safety Improvement

REFERENCES

Ballard, G. and Howell, G. (1998). “What Kind of Production is Construction?” *Proceedings of the 6th Conference of the International Group for Lean Construction*, Guaruja, Brazil.

Ballard, G. (2000). *The Last Planner System of Production Control*. School of Civil Engineering, The University of Birmingham, UK.

Bølviken, T. (2006). “10 Statements on Production and Construction Theory.” R. Sacks and S. Bertelsen (Eds.), *Proceedings of the 14th Conference of the International Group for Lean Construction*, Santiago, Chile, (pp. 67 – 73).

Chang, A. S. and Lee, K. P. (2004). “Nature of Construction Technology.” S. Bertelsen and C. T. Formoso (Eds.), *Proceedings of the 12th Conference of the International Group for Lean Construction*, Elsinore (Helsingør), Denmark, (pp. 74 – 83).

Dawson, S. and Wedderburn, D. (1980). “Introduction” to the second edition of Woodward (1965).

Dubin, R. (1959). *Working Union-Management Relations: The Sociology of Industrial Relations*. Prentice Hall, Englewood, N.J.

Hayes, R. H. and Wheelwright, S. C. (1979 a.). “Link Manufacturing Process and Product Life Cycles.” *Harvard Business Review*, January – February 1979.

Hayes, R. H. and Wheelwright, S. C. (1979 b.). “The Dynamics of Process-Product Life Cycles.” *Harvard Business Review*, March – April 1979.

Hayes, R. H. and Wheelwright, S. C. (1984). *Restoring our Competitive Edge. Competing through Manufacturing.* John Wiley & Sons, New York, USA.

Hopp, W. J. and Spearman, M. L. (2008). *Factory Physics.* Third edition. McGraw-Hill, Boston, USA

Koskela, L. (2000). *An exploration towards a production theory and its application to construction.* VTT publication 408, VTT Building Technology, Technical Research Centre of Finland.

Koskela, L. and Kagioglou, M. (2005). “On the Metaphysics of Production.” *Proceedings of the 13th Conference of the International Group for Lean Construction*. Sydney, Australia.

Ohno, T. (1978). *Toyota Production System. Beyond Large-Scale Production.* English edition by Productivity Press, New York 1988.

Røvik, K. A. (2007). *Trender og translasjoner. Ideer som former det 21. århundrets organisasjon.* Universitetsforlaget, Oslo, Norway.

Sandretto, M. J. (1985). “What Kind of Cost System Do You Need?” *Harvard Business Review*, January – February 1985.

Schmenner, R. W. (1993). *Production/Operations Management.* Fifth edition. Macmillan Publishing Company, New York, USA.

Woodward, J. (1965). *Industrial Organizations.* Oxford University Press, Oxford, UK. Second edition 1980. Reprinted 2004.