HOW CONSTRUCTION FLOWS HAVE BEEN UNDERSTOOD IN LEAN CONSTRUCTION

K. Kraemer[1], G. Henrich[2], L. Koskela[3] and M. Kagioglou[4]

[1] *Research Assistant, SCRI, University of Salford-UK. M5 4WT*
[2] *PhD Candidate, SCRI, University of Salford-UK M5 4WT*
[3] *Professor, SCRI, University of Salford-UK M5 4WT*
[4] *Professor, SCRI, University of Salford-UK M5 4WT*

Email: K.M.Kraemer@salford.ac.uk

Abstract:
The flow concept emerged in construction nearly fifteen years ago. It considers production as a process of value adding activities (i.e. transformation) and non value adding activities, such as: waiting, transport and inspection. However, since the foundation of the International Group for Lean Construction (IGLC), where the flow concept has an established understanding, researchers have interpreted flow in the most different ways. Thus, this paper seeks to produce a content analysis of IGLC conference papers from 1993 to 2001 regarding construction flows. Doing this, the authors captured both historical and current understanding about construction flows and related concepts, which provide basis for future research on production management in construction.

Keywords:
Flow, Lean Construction, Theory of Production

1. Introduction

The flow concept was first presented in the Koskela (1992) seminal work towards a new theory of production in construction "Application of the new production philosophy to construction". After this was created the International Group for Lean Construction (IGLC) in 1993 aiming at improve construction process through lean production techniques, by this date used just in manufacturing. Since the first IGLC conference many authors intend to improve production performance by suggesting the use of the flow concept. The consolidation of the flow concept was achieved with the TFV theory of production in construction (Koskela, 2000).

In the major part of the 20th century until these days, construction industry has used the traditional Transformation concept to manage production. This concept views production as pure transformation of inputs into outputs. It suggests

decomposing the total transformation hierarchically into smaller transformations (e.g. tasks), and minimizing the cost of each independently (Koskela, 1999).

However the transformation concept has three main deficiencies; it does not identify: first, that there are other events in production than just transformations; second, which it is not just transformation that adds value for the product, but also the product has to match the customer requirements; third, how not to use resources without need or how to make sure that all customer requirements are assemble in the best way. Thus, managing production with the traditional concept (i.e. Transformation) can become inefficient and ineffective (Koskela, 2000).

In the early industrial engineering framework, another concept of production has been proposed in scientific terms. This concept viewed production as a flow – what means that in addition to transformation there are non value adding activities, such as waiting, inspection and moving. In the Flow concept the main objective is to eliminate non value adding activities (or waste) from production or try to minimize them, e.g. reducing variability. As a result, it is expected some improvement such as lead time reduction, variability reduction, flexibility, and transparency (Koskela, 2000).

Value is the third concept of production analysed by Koskela (2000) and it has existed since 1930'ies. The Value concept focus on match all customer requirements in the best way possible (design and production), therefore creating value from the point of view of the customer.

It is argued that these concepts are needed and they should be used at the same time in a complementary way. Consequently, transformation – flow – value concepts of production become the TFV theory of production which it has been built by Koskela since the early 90's. The most important contribution of TFV theory is in bringing interest to modelling, structuring, controlling and improving production from all these three point of view and a new insight showing that there are three fundamental phenomena in production, which should be simultaneously managed (Koskela, 1999).

However, the Flow concept has been interpreted in the most variety of ways for researchers in the IGLC conferences and sometimes even being misunderstood. Thus, it is important clarify the concept due to help to create a common understanding and an opportunity to new contributions. Concerning about that, this paper aims to produce a content analysis regarding different interpretations about flows and related concepts.

2. Different flow views in construction – conceptual analysis

As mentioned above, the flow concept has been treated in the most different ways. The authors analyzed them through a literature review in the IGLC conference proceedings and their occurrence was subdivided according with five main interpretations, described as follow:

2.1 Value adding and non value adding activities

A first interpretation of flow in construction is part of the TFV theory of production (Koskela, 2000) which views production as a flow composed of value adding activities (transformation) and non value adding activities (waiting, inspection and moving). It is related to the continuous motion proposed by Henry Ford. Continuous motion suggests keeping everything in motion and taking the work to the man and not the man to the work (Ford and Crowther, 1988). It sees idleness of time as waste e.g. when a workman needs to wait for a material or assistance. Thus, the Toyota Production System, influenced by Ford ideas, proposed a continuous process flow that has as first objective – identify and eliminating all waste that adds cost without adding value (Liker, 2004).

The flow concept views production as a flow – what means that in addition to transformation there is non value adding activities. Its main objective is to eliminate or minimize the share of non value adding activities, e.g. moving. As a result, it is expected some improvement such as lead time reduction, variability reduction, flexibility, and transparency (Koskela, 2000).

The basic core of adding and non value adding activities is to reduce or eliminate waste.

2.2 Even Flow

A second context in which flow is treated in construction is even flow. Even flow means leveling production rates and resources crews aiming at a continuous production process. It is linked to linear scheduling due to shared objective of planning production aiming at a smooth production process.

The most popular linear scheduling in construction is Line of Balance. Originally derived from manufacturing industry and was developed by US Navy Department in 1942 for planning and controlling of repetitive or one-off project. Later, was developed by Nation Building Agency (in United Kingdom) for repetitive housing projects (Arditi and Tokdemir, 2003). Line of Balance method propose planning activities in accordance to production capacity, in other words, how many units a crew can produce in a certain amount of time. These information are shown

graphically in axes of “time x units”. This graph is presented in an easy way that allows the foreman to observe the progress of each activity and it gives real information for a possible decision making along the process. A common characteristic of LOB is the typical unit network that represents the logical sequences of individual activities in one of the many units to be produced and their relationship and/or interdependencies (Suhail and Neale, 1994).

However, the Line of Balance method has some limitations due to being originally designed for simple repetitive production processes. Firstly, it can show only a limited amount of information and a limited degree of complexity. Secondly, LOB can fast identify any delay in a unit or others changes in the activities but cannot preview any accompanying delay in the total project completion (Suhail and Neale, 1994).

Even flow aims at leveling production rates to generate a smooth and continuous process.

2.3 Variability

A third view of flow is variability. This view concerns about how variability influence in the process of production; i.e. the input and output of activities from one workstation to another considering delays that will increase the lead time. Although, construction has a peculiarity in location, once the product being build is quite often fixed and materials and crews are the ones moving through it (Koskela, 2000, Tommelein et al., 1999).

Variability is the quality of non-uniformity of a class of entities (Hopp and Spearman, 2001). There is variability in all production systems and its have a great impact on performance. It is important to understand and manage variability to achieve an effective production management. In production, there are two types of variability: process time and flow. Process time variability refers to the job at individual workstation and it causes are natural (i.e. minor fluctuations in process time due to differences in operators, equipment and materials), random outages, setups and workers availability (Hopp and Spearman, 2001).

Process time variability refers to the job at an individual workstation, but that workstation delay can influence the following workstation in the line, resulting in another type of variability – flow variability. Flow variability in construction refers to variability caused by continuous process fed by diverse activities with different inputs (specialty unit workers) in different locations (floors). As a result of variability at least one penalty will occur in production, such as: increase lead time and high levels of work-in-progress, wasted capacity, or lost output. One

important fact is that variability occurring in the initial activities in the process is more disruptive than in the final activities (Koskela, 2000).

Flow variability aim at reduce or eliminate variability from the production process.

2.4 Seven Preconditions

A fourth understanding of flow is the seven preconditions. The seven preconditions are the number of pre-requirements to start any activity in construction and the faulty of one of these preconditions result in making-do kind of waste (Koskela, 2004a).

Construction is an assembly type of production with diverse flows connecting to the final product. To identify material flows in construction, Koskela (2000) compared car production with site construction. In car production, there are two material flows: the flow of components to an assembly line and the flow of the car body through the assembly line. In a site construction, there are three material flows: the flow of the components to the site, the flow of location where all resources advance through the installation workstation and the flow of assembly that differs from the car production because the building is stationary. In this case the building is built up through different assembly phases.

Activities in construction are mainly of assembly which requires a number of inputs. These inputs are all imperative pre-requirements to start an activity and they also have a high degree of variability due to construction peculiarities. Nevertheless, these preconditions or sub-flows can be material (e.g. components) and immaterial (e.g. information, weather).

Koskela (2000) identified seven preconditions to start any activity in construction and faulty of any preconditions can generate making-do kind of waste. Making-do can be understood as waste when in a particular situation an activity is started without all inputs necessary or when an activity that is happening is continued even when one of the inputs run out. When this kind of situation happens, the waste might manifest as rework, increase of variability, poor quality and longer lead time (Koskela, 2004a). The Last Planner System (LPS) of production control, developed by Ballard and Howell since 1992, has in its core the planning of short term activities that only allow assignments to be realized when the prerequisite activity and inputs are accessible (Ballard, 2000).

The seven preconditions try to avoid making-do kind of waste and they are:

- Construction design (information)

- Components and materials
- Workers
- Equipment
- Space
- Connecting works – previous work
- External conditions – such as weather, government rules, licenses

2.5 Value flow

The fifth understand is Value flow. Its objective is to make essential activities of any service or products to be worked on continuously without interruptions.

Value flow is proposed by Womack and Jones (2003) as one of the principles to Lean Thinking. The authors suggest that design, order and supply of any product or service can be made to flow, once applied with others lean principles such as value, value stream, pull and perfection. Value flow seeks to make the value steps flow. To allow the value flow the authors suggest three steps. First define the value stream and identify the essential activities for the production from the beginning to end. Second is to structure the process considering interrelationships and correlations between departments or other that can affect the continuous flow; e.g. rearrange workstations to be more close to each other and eliminate barriers inside the company that are related to the product. Third is to rethink the specific process practice and tools to eliminate wasted motions; interruptions, batches and queues (Womack and Jones, 2003).

However, considering the way that Lean Thinking is presented led the reader to think that the simple application of these five principles can provide the foundation to become lean. Lean Thinking lacks an adequate conceptualization of production that has led to a misunderstanding of concepts such as value. Regarding generality Lean Thinking suggest that you can apply these principles to any kind of service or product but as Koskela identified the application is limited to the transformation of mass production (Koskela, 2004b). Considering construction that has peculiarities like stationary building where the workstations are the ones moving through and its repetitive activities in different locations it is not possible to apply the flow principle.

Value flow aim at generate a continuous process of product/service.

3. Research Method

3.1 Objective

The objective of this paper is to identify a number of differing ways in which the term “flow” has been used within the papers published at the International Group for Lean Construction conferences. Doing a conceptual analysis in the literature, the authors came up with five different ways that flows can be understood, as presented above. In brief those are: adding and non value adding activities, even flow, variability, seven preconditions and value flow. Nevertheless, some of the flows citations have an erroneous way of understanding. The authors expect clarify these meanings to understand the past and ongoing research to better development of this field in the future.

3.2 Search procedures

Due to the characteristics of this research, the most appropriate method is content analysis. Content analysis is a method that allows a quantitative research aiming to produce a common or differing understand from the data, which can be used as a basis for interpretation (Easterby-Smith et al., 2002). Content analysis has different approaches depending on the objective such as: word counts and key words counts in context, thematic content analysis, referential content analysis and story grammars and the structure of narrative.

Referential content analysis is used to establish how an existing event is represented (Lewis-Beck et al., 2004). It is a tool that considers the complexity of understanding because of existing backgrounds and different ways of describing the same thing.

3.3 Coding procedures

Search for the conference papers was made using the book “Lean Construction” (Alarcon, 1997) for the papers from 1993 to 1996 and in the International Group of Lean Construction conference proceedings for the subsequent papers until 2001. The primary qualification was gathering all papers that mention the word “flow” independent of its meaning. After that, were considered just papers about production, withdrawing other papers containing isolate subjects such as design, supply chain, etc. Then, a deeper analysis was made regarding the context of the word “flow” where its meaning must fitted in at least one of the five concepts presented early in this paper (adding and non value adding activities, even flow, variability, seven preconditions and value flow).

4. Research results

The total number of papers presented in the IGLC conference until 2001 is 207. From this 207, ninety-nine papers mention about flow under the five main concepts presented above. Among the papers qualified for this analysis the flow concepts had also a different theory-based, context, or meanings as discussed below:

- Flow concept misunderstanding – papers which consider flows between conversions, instead along them. This misunderstanding can be due to the Stanford Report written by Koskela that in the page 19 where is mentioned "…the model (conversions) abstracts away physical flows between conversions…"(Koskela, 1992). Flow is a different way to see production as something continuous that includes all activities even the ones that add or non value adding.

- Value flow is the concept used in a paper where the author suggests three main flows to construction considering project as a whole: business, job site, supply chain.

- Even flow. One paper from 2001 was related to an even flow production that has some similarities to the Line of Balance – even flow, but is actually a system created in the industry for production control named even flow production.

- Work flow is defined as "the movement of information and materials through a network of production units, each of which processes them before releasing to those downstream" by the Lean Construction Institute in Kim and Ballard (2000) conference paper. But sometimes seems that in some papers the word workflow is used in a generic way that led to think with they are meaning continuous, without interruptions.

- Inflow in the paper can be understood as a prerequisite to the activity /task.

- Continuous flow was understood as a prerequisite for Lean.

- Resource flow is understood by Ballard as material, equipment and crew, but in some papers the usage of this term seems in a generic way what can confuse readers.

- Information flow – some papers refer to this flow for improvement of communication with IT or just to bring transparency.

- Cash flow - it is suggested to include money factors within lean to reduce future variability and sometimes can be cited as a requirement for cash.

5. Resume of the data collected

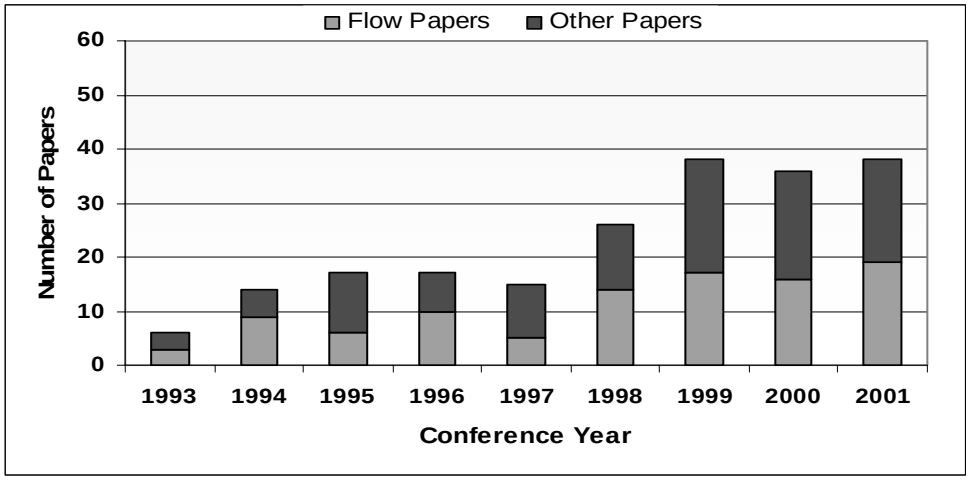

Fig. 1. Flow papers in the IGLC conferences

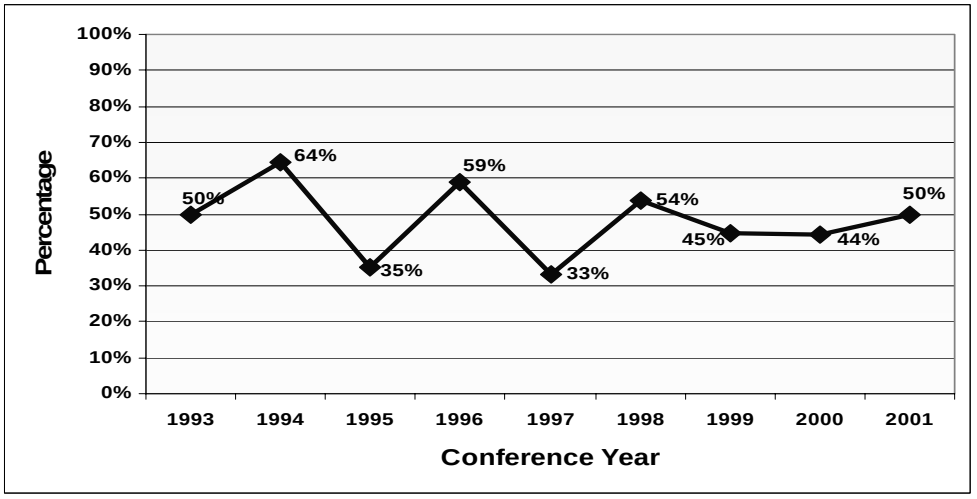

Fig. 2. Percentage of flow papers occurrence per conference

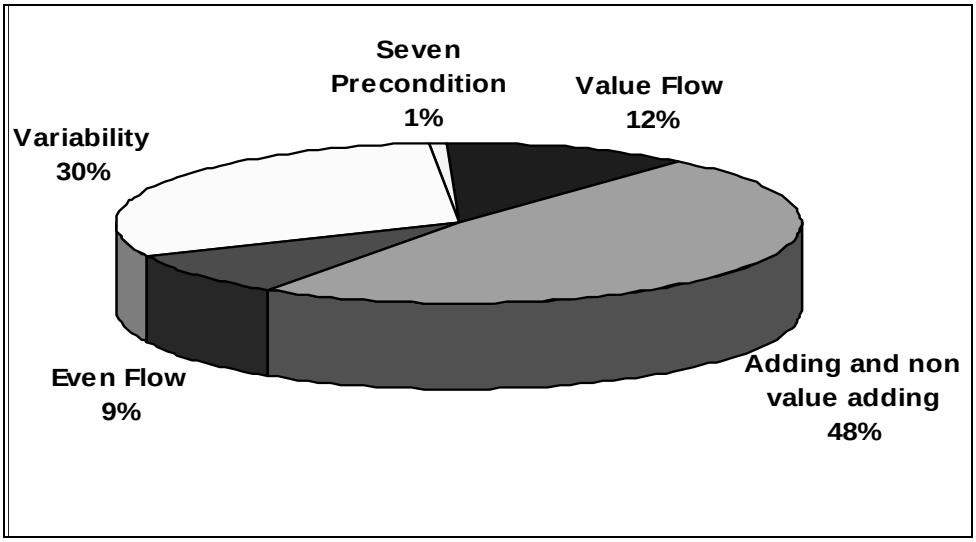

Fig. 3. Share of the 5 main concepts – all conferences

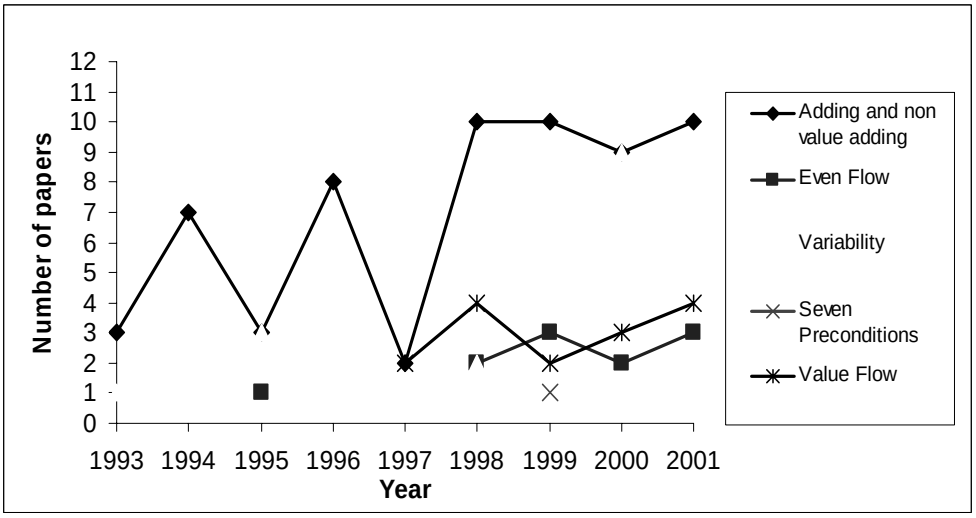

Fig. 4. Share of the 5 main concepts – all conferences

6. Conclusions

Based on the graphs plotted with the data collected we can conclude that:

- The proportion of papers that mentioned flow per conference floats a little, having an average of 48 % of the total conference papers. This is nearly half of the total papers amount, meaning that lean construction researchers are concerned about the flow concept although sometimes they misinterpreted it.

- Although the seven preconditions being focus of attention by some researchers nowadays, it explicit appeared one unique time in 1999.

- Regarding even flow, there was a single paper in 1995 and then it stayed latent for two years, becoming the target of attention again and consolidating itself in the IGLC group since 1998, mainly because of the line of balance scheduling method.

Figure 3 shows that roughly half of the papers that mentioned about flow are mainly based on the TFV theory of production, consequently on the adding and non value adding activities concept. This means that the other half of papers about flow belong to the other four concepts, which its big majority are bygone or not very suitable for construction; as demonstrated throughout the paper. In conclusion, we need to create a conceptual clarity for flow analysis which could be done with a stronger theoretical foundation.

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