3D CONCRETE PRINTING IN THE SERVICE OF LEAN CONSTRUCTION

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1 LEAN CONSTRUCTION AND 3D CONCRETE PRINTING

The adoption of lean philosophy in construction has been proven to be advantageous throughout the literature. Yet the actual implementation of some of its essential principles is not quite manageable. In fact, the lean ideal consisting of giving the customers what they want instantly and without waste seems to be far from realization in a traditional construction environment. The traditional use of formworks cannot ultimately satisfy a customer interested in a sophisticated architecture due to the resulting increased complexity and augmented cost. Also, the construction of a simple housing would span around 6 months on average. Thus, delivering maximum value to the customer in terms of fast construction and minimum waste remains difficult to fulfil using traditional construction methods.

Therefore, approaching the lean ideal necessitates an introduction of new methods and technologies in construction. In the light of this, 3D concrete printing, an automated construction technique, appears to be a feasible solution. The technology consists of building structures through a computer-controlled, form-free deposition of concrete layer by layer. 3D concrete printing significantly reduces construction cost and duration and allows easily printing the finest details of a sophisticated architectural design. This implies that it creates greater value in the eyes of the customer and serves the ultimate lean goal. In only one research, additional contributions that relate to lean principles including quality at bay, waste, standardization, continuous improvement, and target costing have been highlighted. Nevertheless, despite the strong correlation between 3D concrete printing and lean philosophy, no other similar research has yet been conducted.

2 RESEARCH AIM AND METHODOLOGY

Given the above-mentioned relationship and the lack of a corresponding proper investigation, the aim of this paper is to elaborately show how 3D concrete printing complements the lean philosophy.

The study is based on drawing the value stream maps of the construction process of a residential house using both methods, the traditional method and 3D concrete printing. In order to achieve this goal, these steps were followed:

1. A literature review was conducted to explore the various contributions 3D concrete printing has helped realize in the construction industry.
2. An actual building project was then used to collect data on production rates necessary for mapping the value streams.
3. Value streams were mapped for the construction process of a residential house assuming similar phases of slab-on-grade construction for both methods.
4. The value stream maps were compared and the relationship between traditional construction methods and 3D concrete printing was emphasized.

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3 RESEARCH FINDINGS

3.1 Value Stream Maps

After making some assumptions and performing the required calculations, the value stream maps were drawn for the conventional construction method and 3D concrete printing, as shown in Figure 1 and Figure 2 respectively.

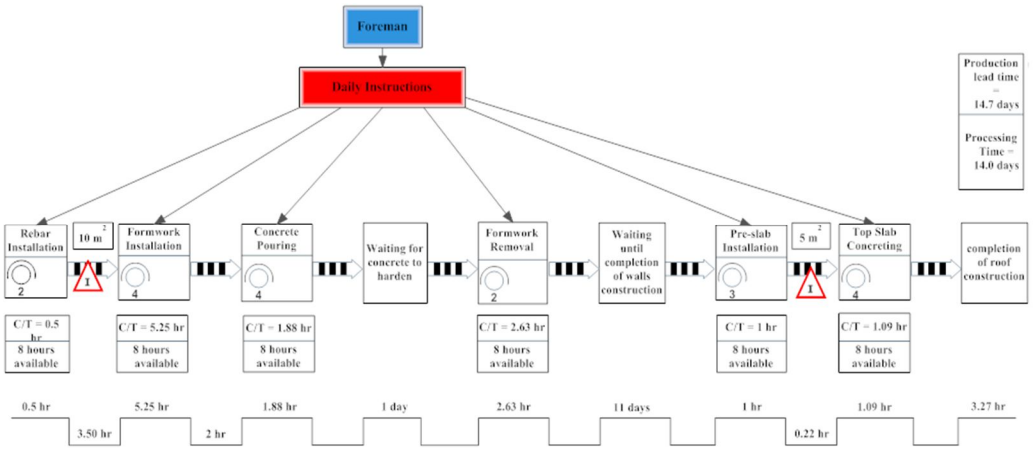

Figure 1.VSM for Conventional Construction

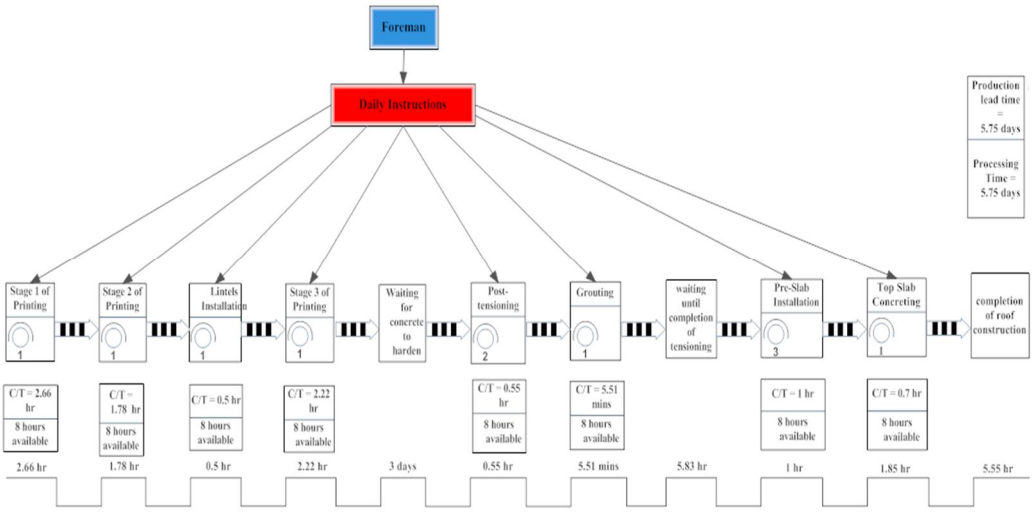

Figure 2.VSM for 3D concrete printing

3.2 Comparison and Conclusions

The examination of the maps revealed a 60% reduction in construction duration when using 3D printing. Moreover, production lead time in the conventional method is greater than the actual processing time with approximately one-day difference. This difference, which is classified as waste, is eliminated in 3D printing resulting in a more lean process. It should be noted that 3D printing helps eradicate other types of waste including movements of labourers and transport of materials. In addition, in a form-free construction, problems that might occur during concrete pouring are visible and, thus, can be directly treated before another layer is deposited. In fact, 3D printing makes it mandatory to stop and fix problems because one defective layer at the bottom of a wall disrupts the pattern of all the subsequent layers, thus forcing in-station quality control. Finally, 3D printing requires much less workers, eliminates some activities, necessitates less supervision, produces less waste and others reducing the overall construction cost. Therefore, 3D concrete printing brings a lot of value to the customer, and hence helps approaching the lean ideal.