THE EFFECT OF ECONOMIC VARIATION IN CONSTRUCTION PROJECTS ON CONTRACTOR FIRMS

Kajsa Simu[1] and Helena Lidelöw[2]

ABSTRACT

Lean is about finding a flow efficient way to deliver value to the client. To do so reducing variation is vital. The construction industry is project-based and variation in project deliveries is more the rule than the exception. Being able to predict economic variation in projects is important for contractors and other project-oriented firms since it affects the total turnover for the firm. The aim of this research is to capture the variation in economic profit in a project, estimate the effect this variation has on the aggregated firm level, and discuss the implications for flow efficient operational strategies to adhere. Economic reports were collected from 1000 projects, throughout 2 years at a large Swedish contractor. The data contains quarterly economic prognoses and results per project. From the data, the variation in profit was deducted. The variation was used in a statistical model of the firm, reflecting five levels of financially liable units. The results show that variations in the economic results on the project level are evened out on the firm level. Thus, the reduction of variation sought in Lean implementation does not emerge as positive in accounting. Measuring economic results on the project level drives a focus on resources in the value chain. This is a hindrance for implementation of a flow efficient operational strategy as Lean. Therefore, key performance indicators capturing flow efficient strategies for control on project and firm levels need to be developed.

KEYWORDS

Flow efficiency, operations strategy, project coverage, variation control.

INTRODUCTION

The construction industry is project-based and large contractors handle thousands of projects every year. In each of those projects there are uncertainties, which lead to variation in both the prognosis of and the actual economic result (Winch 2006). When compiling the economic results in single construction projects into a firm result, the large variation on project level is evened out. The profit in a specific construction project can be described as a ratio (%) between the profit sum and the contract total. The aim of this research is to quantify the profit in construction projects and use this quantification to describe the effect of profit variation on the economic result at a

[1] Ph.D., Adjunct Lecturer, Kajsa Simu, Construction Management, Dep. of Civil, Environmental and Natural Resources Engineering, Luleå University of Technology.

[2] Associate Professor, Senior Lecturer, Helena Lidelöw, Timber Structures, Dep. of Civil, Environmental and Natural Resources Engineering, Luleå University of Technology.

contractor. Furthermore, the effects of decreasing the variation on project level are described.

The question in focus is to find the standard deviation in profit for single construction project results. We will also use our data to visualize hypothetic result in the case of a decrease in standard deviation.

For every project there is a primary budget made for the tender with the aim to give the client a price for the project. Budgets in the planning and execution phase of the projects are based on a work breakdown structure (WBS) e.g. (Jongeling and Olofsson 2007) where resources and activities are described at a detailed level. With a well set up budget for the construction project where the time schedule and the activities are correlated, it is possible to prognosticate with acceptable certainty. The first step in prognosis work is to check the baseline i.e. how much work has been done in terms of time, usage of materials, and resources. The next step is to make an assumption of how much work is still to be done. The final step is to compare what has been done and what is still left to do in relation to the available budget and timeframe. Prognoses for the projects are made several times a year. The economic result for the construction firm is aggregated from the projects (Nordstrand and Revai 2002). At each organisational level there is a percentage for covering the overhead costs, Table 1. Small firms with few organisational levels have lower overhead costs.

Table 1: Profit and overhead at different levels in the organisation (Nordstrand and Revai 2002)

Organizational level	Overhead (%)	Profit (%)
Project	0	8
Business unit	-1,5	6,5
Division	-3,0	3,5
Region	-1,0	2,5
Firm	-0,8	1,7

One way of accounting in large construction firms is to use percentage of completion methods i.e. to account the results for the year when construction was actually made. The reason for this is to account for projects that have a longer duration than a fiscal year and are a substantial part of the construction firm's turnover. If positive results accounted for in one year end up as negative results the next year, both the loss of positive results as well as the actual negative result need to be covered. The alternative to percentage of completion methods is to only account for projects that have been finished the actual fiscal year (Karlsson 2009).

Uncertainties in construction are more the rule than the exception in many aspects, not the least in economic control. The levels of economic uncertainty are related to the phase of the project. Close to finishing the project the economic results are more certain than in the early phases where lack of information gives a variety of options and hence also a variety in deliveries. In practice there are indications that there is an underestimate of cost and an optimistic view of the economic outcome (Winch 2006).

THE ECONOMIC LOGIC OF CONSTRUCTION IN CONTRAST TO LEAN

PREDOMINANT ECONOMIC LOGIC OF CONSTRUCTION

The economic logic at the construction firm level is predominated by transaction cost economics (TCE) and project-oriented models (Bygballe et al. 2012). The focus is on each stakeholder or each project separately and often results in a resource efficient, static operations strategy (Koskela and Ballard 2006). The project oriented model has focus on delivering; functionality to the client according to the contract and economic results to the owner of the project, most often the construction company. The focus is on each project separately and the projects are most often viewed as unique and not repeatable. The transaction cost model has a primary focus on minimizing the transaction cost between different stakeholders and actors within the project as well as between firms related to the project, but generally neglects the production cost inside the firms (Koskela and Ballard 2006). This gives an economic focus that work best with a low uncertainty and that focus on finding the best solutions for each new situation (Bygballe et al. 2012).

LEAN AS A FLOW EFFICIENT OPERATIONS STRATEGY

There is seemingly a contradiction between the resource efficient focus promoted by the transaction cost economic models employed in construction and the flow efficient focus promoted by Lean production and Lean Construction advocates e.g. (Koskela and Ballard 2006). It is argued that the traditional management of construction projects need to be revised in favour for more emphasis on total cost and value for end users (Zimina et al. 2012). Using Lean as the firm operations strategy means supporting the flow of operations and the value flow towards the client. According to Liker (2010) the key to flow-efficient operations is to find the single unit for flow. Still and despite the single unit – flow is hard to put in practice. Some of the requisites that need to be in place are the measurement method, to focus on reduction of products in work and reduction in throughput time. It is also difficult to convert a total flow into single units since all problems that are a hindrance for the work will make the flow stop – there are no buffers. To measure flow efficiency in operations it is vital to measure throughput time rather than bottom line results as the bottom line results seldom tell anything about the progress in the operations. As part of a firm strategy, flow efficiency is more difficult to imitate since it requires the coordination of many resources forming a complex pattern, rather than exploiting a single resource (Junnonen 1998). Non-imitable resources can constitute a competitive advantage (Barney 1991).

THE INFLUENCE OF VARIATION ON THE CONSTRUCTION PROCESS

Variation in a process has a major influence on throughput time and flow efficiency in the process. Variation appears in three categories (Modig and Åhlström 2012): resource variation, flow unit variation, and external factors. These categories were derived from process-based production as a contrast to project-based.

Resources

The resources to be able to operate a process could be material, machines or humans. All of these resources have differences in time needed to fulfil an activity. Processes follow certain rules that apply in every business no matter what kind of value is delivered to the customer. Flow efficiency is about creating as much valuable time as possible in relation to the total time spent to fulfil client needs. It is not necessary to increase the speed of doing the value creating activities – it is the time that does not create value that needs to be shortened. Flow efficiency is defined as the sum of value creating activities in relation to the throughput time. In all process flows problems with bottlenecks appear. The bottleneck is the point in the flow where there is a built up queue, the cycle time for that part of the process is lower than for the rest of the process. At those points there is less capacity and the consequence is that the overall throughput time increases.

For processes highly dependent on resources the variation in bottleneck placement and throughput time could be vast. Every resource in itself has a standard deviation in operations. When layered on top of each other, the variation in process output can be very large and affects the economic outcome of the project. Normally, a construction project is planned using activity-based planning where resources are matched to the expressed need in the activities e.g. (Ballard and Howell 1998; Jongeling and Olofsson 2007). However, these methods seldom address the standard deviation inherent in and between resources. Some of the variation apparent for resources is random variation that appears due to capacity and timing variation. Some of the variation is deliberately planned for to create certain client value. This variation is wanted in the production process and can be referred to as variability.

Units in the process

A flow unit is defined as the unit of measure for value creation. Dependent on the flow units' different attributes there is a variation in how the process proceeds. According to Little´s rule (Modig and Åhlström 2012) the variation in throughput time is related to the number of units in process and the cycle time. In the construction business the flow units are vaguely defined as is the cycle time. The product and the value delivered to the customer is the construction, the units that flow is added on to that construction instead of flowing towards the client. In factory manufacturing processes the product is flowing while the value is added on. In construction it is the resources that flow through the unit instead of the units that flow through the different resources, hence the difficulties to define cycle time. If there are many resources involved there is a high extent of handovers. In a construction project where the budget is based on a WBS the variation is high due to many different stakeholders that have different types of interdependencies amongst them. There is also a large extent of uncertainty in how to perform in each activity i.e. how to add value to the product. At site the ability to decide how to solve details in construction is high and also frequently used. Activities are neither standardized, nor repeatable and hence unpredictable regarding cost, quality and time – and consequently also cycle time. Each project is treated as a unique happening although there are large amounts of repetition in the processes performed. The Last planner system is presented as a method to meet and control those uncertainties in deliveries and address the need to meet the uncertainties where they occur – on site in the performance of activities (Ballard and Howell 1998).

External factors

Variation from external factors is due to things outside the control and influence of the process. Those variables affect the time to complete an activity or the time when the activity can be started. If the external variation gives that an increased and uncharacteristic demand for a certain activity comes up – the capacity to meet the increased demand is not available – the time to start and complete the certain activity will be influenced and affect the entire process. For construction and the activities on site the aim is to reduce those uncertainties and hence the variation. However, as indicated above, the variability caused by client needs within the targeted market segment is a variability that the production process should be robust enough to handle. Unwanted, random variation caused by the client e.g. late changes can be handled through an economic agreement regarding correctional and additional work, but it does not decrease the variation in itself. One way to reduce variation is to reduce the amount of activities performed at site. Another way is to have standardized routines for how to proceed with an activity. With prefabrication and standardised modules and procedures the variability due to external factors on site are reduced (Höök and Stehn 2008).

EMPIRICAL DATA

To estimate the variation in the economic result of building projects and construct a prediction of how the variation between projects causes variation in the economic result of the firm, data from 1027 construction projects were gathered. The construction projects were conducted by one single contractor, thus eliminating errors due to circumstantial factors, different measurement methods between projects, and reporting errors. The contractor has an annual turnover of 2,300 M€.

The construction projects produced buildings, bridges, foundation works, and civil engineering artefacts. Data was collected for the time period 2005-2007. Some of the projects had a longer time frame than one year. Only the final result was used in this research, however, the economic variation over time in the project was possible to follow. A histogram of the data is presented in Figure 1.

It is clear from Figure 1 that more than half of the construction projects are smaller than 500 k€. The distribution is skewed and the minimum contract total was 3 k€, while the maximum was 19.2 M€. The distribution of the profit in all construction projects in the data set is shown in Figure 2.

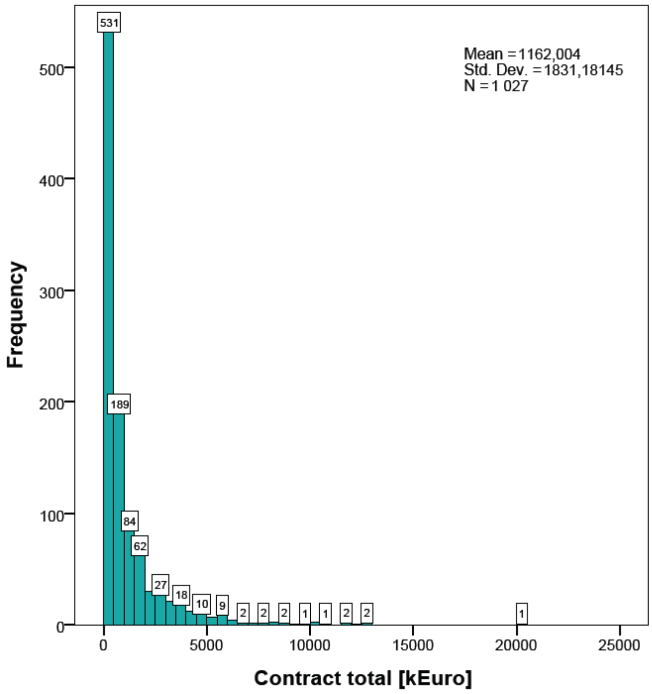

Figure 1: Construction project frequency dependent on total contract sum.

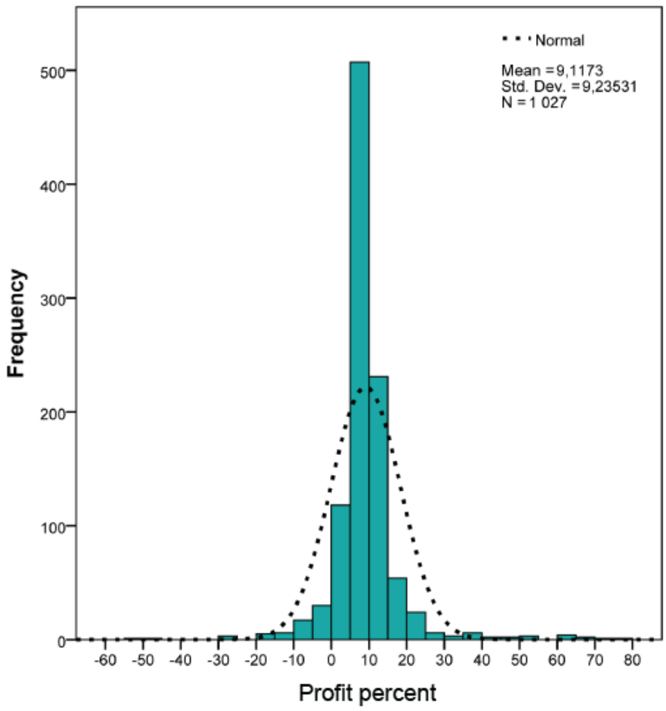

Figure 2: Construction project profit variation

Figure 2 shows that the mean profit in each project is 9.1%. The standard deviation is of the same order of magnitude yielding a very wide range with the minimum profit being -55% and the maximum 77%. The profit can be assumed to belong to a normal distribution $\xi \in N(9.1, 9.2)$. The profit in each construction project is furthermore assumed to be independent stochastic variables. These assumptions can be tested by examining if there is a difference between the profit in construction projects of different types e.g. between house-building and civil engineering projects. The test was not done in this research, but a visual examination of the profit in Table 2 shows that both the profit and the standard deviation of the profit is of the same order of magnitude regardless of construction project type.

Table 2: Construction projects sorted after type [k€]

Specification	Civil eng.	Housing	Foundation works	Misc. housing	Misc. foundation
Count	5	131	554	52	285
Average contract total	625	2739	862	153	971
Std.dev. contract total	308	3127	1288	136	1228
Average profit	7.9%	9.5%	8.7%	8.2%	10%
Std.dev. profit	10%	10%	8.3%	14%	9.3%

ANALYSIS

THE EFFECT OF VARIATION IN THE CONTRACTOR ORGANIZATION

The studied contractor had an organization during the years 2005-2007 consisting of five levels as outlined in Table 1:

- Project level, 1 project
- Business unit level, 12-18 projects/year
- Division level, 40-70 projects/year
- Regional level, 160-230 projects/year
- Firm level, 1,000-3,000 projects/year

Assuming that ξ is normally distributed and independent as a variable, the standard deviation of the profit distribution will decrease when grouping projects according to the central limit theorem, Table 3. Concurrently, the overhead costs will increase when moving up in the organization, as shown in Table 1.

Table 3: Change in standard deviation depending on organizational level

Organizational level	No of projects/year	Std. dev. profit	Accumulated overhead	Probability to cover overhead cost
Project	0-1	9.2	0	84%
Business unit	12-18	2.4	-1.5	99%
Division	40-70	1.3	-4.5	100%
Region	160-230	0.65	-5.5	100%
Firm	1,000-3,000	0.21	-6.3	100%

The precision in the profit prediction increases when moving to higher levels in the firm, since the standard deviation of the profit decreases. At the same time, the actual profit decreases due to added overhead costs. The probability of merely covering the overhead costs i.e. breakeven is 84% on the single project level, but 100% on the firm level given that the profit in projects $\xi \in N(9.1, 9.2)$. However, covering the overhead costs is not enough; firms must deliver profit. Regularly, contractors deliver an economic result of 3-5% each year. Given that the profit belongs to $\xi \in N(9.1, 9.2)$, a natural request from firm management would be to increase the profit to deliver a final result of 5% i.e. x should reach 6.3+5 ≈ 12%. In essence, project managers are asked to keep tighter cost control and make better prognoses in order to deliver the wanted economic result. Now, what is the probability that this will happen given $\xi \in N(9.1, 9.2)$?

Table 4: Probability for delivering certain profit in construction projects

Requested profit in construction project	Probability for delivering requested profit	
	$\xi \in N(9.1, 9.2)$	$\xi \in N(14.1, 9.2)$
5%	67%	84%
8%	55%	75%
10%	46%	67%
12%	38%	59%
14%	30%	51%
15%	26%	46%

According to Table 4, a request to deliver a profit of 12% on the project level has a probability of 38% given that $\xi \in N(9.1, 9.2)$. If the request instead had been to increase the profit ξ by 5 percentage units, it imply that the average value of the profit distribution should be ξ ϵ N(14.1, 9.2). Table 4 reports that the probability on project level to deliver an economic profit of 12% is roughly 59% assuming that the variation in profit remains at 9.2 percentage units.

The large variation in profit on project level becomes a hindrance to deliver a good economic result on the firm level. Although Table 3 showed that the variation is evened out when averaging project results on division, region, and firm level, the probability of actually delivering the needed profit on project level to take advantage of the averaging is 26-67% depending on requested profit according to Table 4.

PARAMETER STUDY OF THE VARIATION

To investigate the effect of project variation, a few hypothetical questions can be posed:

- Consider the case that the variation in the profit of construction projects can be decreased to 5 percentage units instead of 9.2 what effect would that have on the probability to deliver requested profit?
- Consider the case that the 50 projects with the lowest profit in the data set improved their economic result by 50% i.e. the lowest 5th percentile of the construction projects cut their losses in half. What effect would that have on the probability to deliver requested profit?

Decreasing the variation to 5 percentage units instead of 9.1 would increase the probability of obtaining profit of 5-9% as compared to the original distribution, but would decrease the probability of obtaining higher profit. This is due to the narrowing of the distribution, where probability points of higher magnitude is more difficult to obtain. However, the same reasoning is valid for the lower magnitudes i.e. the risks for low profit is lower with a smaller profit standard deviation. Thus, a strategy focused on decreasing the variation as such will probably result in a more stable profit prediction and decrease the risk for low profit in many projects, but the chance for obtaining high profit decreases, Figure 3.

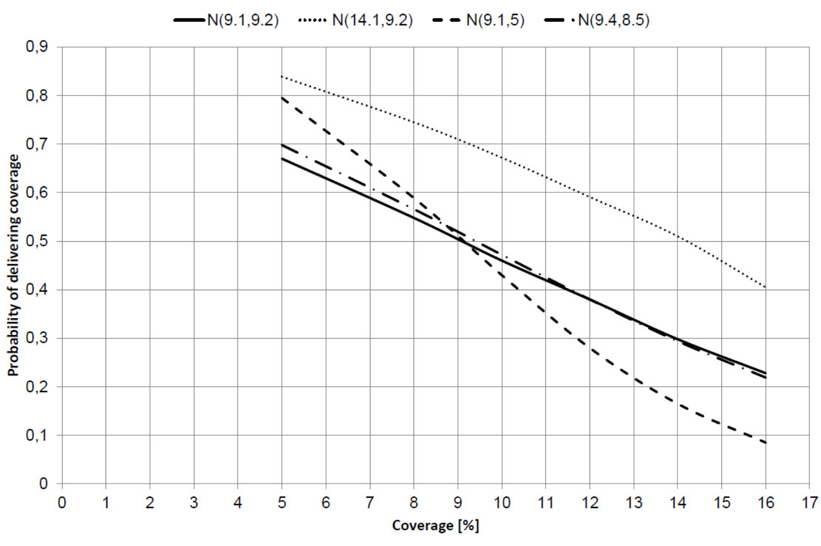

Figure 3: The effect of decreasing variation on construction project profit.

The probabilities for obtaining certain profit if increasing the average profit are higher than the original assumption, Table 4 and Figure 3. This is however not a very realistic scenario as it requires thousands of project managers to suddenly increase their profit by cutting costs and predicting every uncertainty in their projects, i.e. to have more predictable operations at site. A more realistic thought could be to identify and target high risk projects and increase their profit. As an example, the data set was changed so that the 50 projects with lowest profit cut their losses in half i.e. the profit was set to half its absolute value. The effect of this change was that the average profit increased from 9.1% to 9.4%, while the profit variation decreased from 9.2 to 8.5 percentage units. The probability that the projects on average will deliver 12% profit actually remains the same (38%), but this action, which was targeted at risk control, also leads to an increase in average profit. (Although a small change, this increase in profit equals 7MEuro for the case contractor).

DISCUSSION

Despite the large variation in economic results on the project level, it was shown that the variation in bottom-line results in projects does not have a great influence on firm level. There is a potential in contractors having greater certainty in profit prediction in projects, since it will increase the economic stability both at project and firm levels. Targeting high risk projects to cut their losses can be a fruitful way of working with decreasing variation. It is however not something that will make a large difference on the economic result of the firm since the variation in profit will decrease on higher levels in the firm. At least this is true if the economic measures and key performance indicators used today are applied. According to Liker (2010) the single flow-unit and how to define it is a key also to economic measures that support a Lean implementation. Following this line of argumentation, decreasing the variation in operations through increasing standardization, that influences Little´s rule, the number of flow-units and the cycle time is of importance (Modig and Åhlström, 2012). This research shows that from an economic viewpoint, using the accounting methods commonly applied, a Lean implementation might not show good results on the firm level. However, on the project level where the variation in operations is large, a Lean implementation can make a vast difference in certainty, control possibilities, and stability in processes. The results show that a decrease in variation in economic result is not enough to motivate a change to a flow-efficient operational strategy. Flow efficient operations need other arguments to become a reality in construction.

CONCLUSIONS

Variation and the control of variation are more important on the project level than on the firm level for large contractors. On the firm level the variation in profit is evened out and decreasing this variation does not lead to an improvement of the economic result of the firm. It is important to separate the variation in economic results from the variation in performing the value adding processes, i.e. the operations of construction. Average values and variation in profit are coupled to each other and any measures taken by the management will affect both. If a contractor wants to increase profit by reducing profit variation between projects, identification of high risk projects and economic control of these are suggested as a the first step rather than aiming to reduce variation in all construction projects at the same time.

The result on the firm level is directly coupled to the result on the project level. However, to merely focus on final results in each project is to suboptimize the resources at firm level. If aiming for a Lean implementation, key performance indicators on the project level need to be developed to measure flow efficiency as a complement to measuring the economic result. This is vital since one of the goals in Lean is to decrease variation in operations of construction and in so doing the variation in the economic results is also affected.

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