FACTORS THAT AFFECT THE PRODUCTIVITY OF CONSTRUCTION PROJECTS IN SMALL AND MEDIUM COMPANIES: ANALYSIS OF ITS IMPACT ON PLANNING

Nelia Valverde-Gascueña[1], Elena Navarro-Astor[2], Joaquin Fuentes-del-Burgo[3] and Juan Pedro Ruiz-Fernandez[4]

[1 3 4] *Politechnic School, Universidad de Castilla-La Mancha (UCLM), Campus Universitario, 16071 Cuenca, Spain.*
[2] *School of Building Engineering, Universidad Politécnica de Valencia (UPV), Camino de Vera s/n, 46022 Valencia, Spain.*

The study of productivity in the construction industry is gaining importance due to its positive effects on the economy of the construction companies and of the country as a whole. Nowadays, improving the productivity of building projects may have a direct impact in the survival of companies because of the great rivalry existing between them. In this paper we present the results of a research about the factors that impact the performance of construction works and, therefore, the planning and the building costs. Some of the considered factors such as technical faults in project documents, inspection delays or the workers' training and skills are included in a survey directed to building engineers working for small and medium building companies. The knowledge and appropriate management of these factors can improve the planning of the work during the project development phase and the execution phase. This will have positive effects regarding time shortening for the execution of activities and, as a result, cost reductions.

Keywords: building performance, construction planning, productivity, project management, SME.

INTRODUCTION

Productivity is one of the most important factors affecting the overall performance of any organisation, large or small (Kazaz and Ulubeyli, 2007). The construction industry represents a substantial portion of the Spanish economy; thus, research and development in this area may have an important impact on the national economy. Productivity in construction sites is important because it influences time and cost objectives (Moselhi and Khan, 2010). In fact, the percentage of projects exceeding cost or time forecasts is high (González *et al.,* 2010; Johansen and Wilson, 2006).

Nowadays, Spanish construction projects, even moderate in size, are generally multidisciplinary in nature and involve various contractors and subcontractors which carry out their job through a high number of operations planned to transform many resources (González *et al.,* 2010). These projects' productivity is a complex and multi-faceted issue; a concept that is difficult to measure (Chan, 2002). Whereas for some

[1] nelia.valverde@uclm.es

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authors productivity is defined as "achieving quantity and quality of results while controlling the inputs" (Ailabouni *et al.*, 2009), Chan (2002) found out that for the majority of site managers and supervisors, it means that work is completed within the time, cost and quality framework.

It is widely believed and studies have shown that the most significant factors affecting construction productivity can be influenced and improved through jobsite management efforts (Ailabouni *et al.,* 2009; Dai *et al.,* 2009). Acharya *et al.* (2006) also suggest that, during jobsite management, supervisor's experience plays a very important part for project execution. On the other hand, since jobsite productivity is simultaneously influenced by multiple factors that may differ within the same project or vary across different projects, it is extremely difficult to distinguish the influence of any single factor (Dai *et al.,* 2009). Fortunately, most significant factors can be addressed through careful planning and coordination among different project participants (Dai *et al.,* 2007).

All builder's effort and resources devoted to the planning phase of construction projects are justified because they will imply a profound study of the project, establishing a base from which to carry out an effective control (González *et al.,* 2010). The planner must ensure that plans are realistic and prevent excessive exposure to risks such as project running over time or cost or of compromising quality (Johansen and Wilson, 2006).

That planning must be carried out before the beginning of project execution has been already said and it is widely believed. However, many construction professionals and project managers still question the purpose of doing it or even doubt whether construction planning is possible (Carvajal, 2001; González *et al.*, 2010). This view is confirmed by Donyavi and Flanagan's (2009) results which indicate that SMEs do not undertake detailed site activity planning because of lack of people, skills and finance.

When planning the construction of a project, uncertainty appears due to the existence of a gap between the planned and final values (Carvajal, 2001). Some authors refer that in planning, it is quite common to estimate factors intuitively or subjectively, depending on planner's ability, project characteristics, estimators' knowledge or delivery time for purchasing information, materials or equipment (Blyth *et al.,* 2004, Navarro-Astor, 2008).

Although many factors are mentioned in the literature affecting construction productivity, research in this topic has been very limited or nonexistent for the Spanish construction industry. This research has been carried out in the Spanish autonomous region of Castilla-La Mancha, where 99.5% of the companies belonging to the construction sector are SMEs and 86.2% employ less than 6 persons (Instituto Nacional de Estadística, 2011). The definition considered for SMEs in this project, takes into account the number of persons employed, the annual turnover and/or the annual balance sheet as stated in Article 2 of the Commission of the European Communities (2003). Values are similar to those defined by Barrett and Sexton (2006) for SMEs in Great Britain.

The aim was to find out building engineer's opinions about the factors that impact the performance of construction works and their importance. They have also been asked about the strategies they follow in order to integrate the productivity factors in the planning.

CONSTRUCTION PRODUCTIVITY FACTORS

Directly or indirectly, every construction project is influenced by a wide range of factors. The loss of construction productivity is usually attributed to various factors, rather than a single one, but so far a universal group of factors with significant impact on productivity has not been found (Doloi, 2008). Furthermore, factors affecting construction labour productivity are rarely independent of the others; some factors may be the result of the same cause, or one factor may trigger the occurrence of others (Dai *et al.*, 2009). There have been decades of previous efforts in seeking a causal link between factors and productivity through quantifying factors and measuring their impacts on productivity (Chan and Kaka, 2007).

Construction materials planning and management influence site productivity (Doloi, 2007) because, as some authors reported, performance of construction works depends on material quality, adaptation, transportation difficulties within site, time and delivery methods (Crawford and Vogl, 2006, Dai *et al.*, 2007, Navarro-Astor, 2008). Supplier's timing is one of the elements frequently causing problems to building firms (González *et al.*, 2010). This situation might happen because material suppliers follow the just in time philosophy, avoiding stock costs and forcing clients to place their orders in advance, prior to the date when material is needed on site (Carvajal, 2001). Another important productivity factor is tool and machinery availability (Ailabouni *et al.*, 2009; Carvajal, 2001; Dai *et al.*, 2007; Doloi, 2008; Ng *et al.*, 2004; Rivas *et al.*, 2011) and the risk of not having it on site at the precise moment (González *et al.*, 2010).

Construction is highly dependent on people's effort and, according to Doloi (2008), manpower is the most complex resource and usually the most difficult to manage. That human resources represent one of the more significant productivity factors and that it is uncontrollable is well known (Dai *et al.*, 2007; Kazaz and Ulubeyli, 2007). Some writers have reported that labour costs account for between 30 and 50% of a project's total cost (Rivas *et al.*, 2011). Blue collar workers with insufficient training, skills, abilities and experience seem to be usually employed in construction projects in Spain, the UK and the USA (Carvajal, 2001; Chan and Kaka, 2007; Dai *et al.*, 2009, Navarro-Astor, 2008). When the norm becomes the hiring and employment of unskilled workers, the consequences are bad quality works and frequent work redone (i.e. rework), further lowering site productivity (Ardity and Mochtar, 2000). Other factors have been found such as work redone (Ng *et al.*, 2004; Palaneeswaran *et al.*, 2008, Rivas *et al.*, 2011), overcrowded work areas (Dai *et al.*, 2009; Ng *et al.*, 2004), crew interference (Chan and Kaka, 2007; Dai *et al.*, 2007; Ng *et al.*, 2004) or inspection delays (Dai *et al.*, 2007; Ng *et al.*, 2004).

Apart from the issues highlighted above, other critical factors are related with the quality of building documents such as availability of drawings, drawing errors, slow response to questions with drawings. This may cause undefined construction projects or project changes during the execution phase (Dai *et al.*, 2009, Motaleb and Kishk, 2010; Navarro-Astor, 2008). Work redone attributed to poor building designs impacts project performance, increasing the probability of exceeding cost and time objectives and causing contractual complaints (Acharya *et al.*, 2006; Palaneeswaran *et al.*, 2008).

RESEARCH METHODS

This research has been carried out following both a qualitative and a quantitative approach. In the first case, structured interviews were carried out with some of the participants in order to obtain deeper insight on the subject under study. In the second case, perceptions of site managers regarding productivity factors were expressed through numerical data based on a survey, and statistics was used for its analysis. Regarding data gathering, the instrument considered most appropriate has been a confidential survey which was personally distributed by electronic mail to all building engineers registered in the professional bodies of four provinces of Castilla-La Mancha: Cuenca, Ciudad Real, Toledo and Albacete. The format of the survey was split into two distinct parts. The first one gathered general descriptive information about the respondents, their job and the organizations they represented. These included, for example, their age, job function, work experience and type of firm.

The second part included 11 questions posed to gather participant’s views as to what factors would have greatest influence on improving construction productivity. Following other researchers’ similar procedure, these evolved from the literature review of past research (Moselshi and Khan, 2010). A Likert scale from 1 (being “no impact”) to 5 (being “very high impact”) was used to gather the respondent’s quantitative views. A short explanation of each factor was given to the respondents. Qualitative additional comments for each productivity factor could be written in the blank space provided under each question.

Factors considered and definitions provided were as follows:

1. Faulty works: poor executed works that have to be redone or repaired.
2. Overcrowded work areas: jobsite congestion due to excessive workers, materials, tools or equipment in reduced areas, which hinders average on-site performance results.
3. Crew interference: coincidence of two or more trades in the same work area.
4. Lack of on-site cleanliness.
5. Equipment unavailability: lack of appropriate equipment when needed or availability of inadequate equipment.
6. Inspection delays.
7. Project changes during execution phase.
8. Materials unavailability: lack of materials when needed due to poor planning or delays in delivery times.
9. Poor materials quality.
10. Lack of project information.
11. Poor workmanship.

In order to reinforce the qualitative survey results, and to obtain further information to the open questions included, a series of 11 confidential structured interviews were carried out with some of the participants. The interviews were recorded and fully transcribed.Once the quantitative data were collected they were tabulated, numerically and graphically arranged using an Excel sheet. Basic statistical parameters, which aim to synthesize the data in a representative value, such as the average value and the standard deviation, together with histograms showing results in percentage were used. This gives us a more appropriate vision and helps us when describing and interpreting the data for the decision-making.

ATLAS.ti software was used for analysing the open questions included in the survey and the structured interviews. The whole analysis was underpinned by an inductive approach using elements from the Grounded Theory such as the open coding and the constant comparison (Hunter and Kelly, 2008, Trinidad *et al.*, 2006). This allowed us to identify recurring themes, patterns, similarities and differences regarding productivity factors.

RESEARCH FINDINGS

The number of building engineers registered in the Professional Bodies of Cuenca, Ciudad Real, Toledo and Albacete is, 205, 322, 450 and 303, of which 27, 9, 49 and 56 respectively participated in the survey. Structured interviews were carried out to 2 building engineers in Albacete, 6 in Cuenca and 3 in Ciudad Real. In all, the sample size was of 152 building engineers of different ages, gender and professional experience. In relation to their occupation, 68 of them work as members of project management teams, 31 are site managers employed at contracting companies, 39 work for the civil service, 8 carry out different duties and 6 of them have not shown their usual job. The response index was 11.88%.

Quantitative results

Table 1 shows a summary of the results, including statistical values corresponding to each of the productivity factors under study.

Table 1: Data processing.

Factor	Frequency					Mean	Standard deviation
	1	2	3	4	5		
1. Faulty works	1.97	15.13	20.39	36.84	25.66	3.69	1.07
2. Overcrowded work areas	5.26	11.18	36.18	30.26	17.11	3.43	1.06
3. Crew interference	5.26	7.89	36.18	30.92	19.08	3.51	1.06
4. Lack of on-site cleanliness	4.61	14.47	33.55	30.92	15.13	3.38	1.06
5. Equipment unavailability	3.29	9.21	19.08	32.24	34.87	3.87	1.10
6. Inspection delays	8.55	23.68	21.05	27.63	17.76	3.23	1.24
7. Project changes during execution	2.63	10.53	17.11	24.34	42.11	3.96	1.14
8. Materials unavailability	3.95	8.55	13.16	28.95	44.74	4.03	1.14
9. Poor materials quality	9.87	21.71	27.63	24.34	15.13	3.13	1.21
10. Lack of project information	0.66	11.84	19.74	28.29	38.82	3.93	1.06
11. Poor workmanship	1.32	1.32	13.82	28.29	53.95	4.34	0.87

Considering that the mean value of all productivity factors is 3.68, those factors with mean values above it are those with stronger impact on building sites' performance. These factors ranked from higher to lower value are: (11) poor workmanship, (8) materials unavailability, (7) project changes during execution, (10) lack of project information, (5) equipment unavailability and (1) faulty works. The distance between the mean value of all productivity factors and their standard deviation may be considered large, indicating high reliability of the participant's responses. These results accord with those found in other researchers located in the USA (Dai *et al.*, 2009 and, 2007), México (González *et al.*, 2010) and Hong Kong (Ng *et al.*, 2004).

Factors with less impact on building sites' performance, with mean values below 3.68 are: (3) crew interference, (2) overcrowded work areas, (4) lack of on-site cleanliness, (6) inspection delays and (9) poor materials quality. In this case there is less distance between the mean value and the standard deviation than before, indicating more dispersion of the data. Compared to other studies (Dai *et al.*, 2009, Ng *et al.*, 2004), Spanish building engineers seem to give different weight to the effect of overcrowded work areas, crew interference and inspection delays.

Qualitative results

The inductive analysis of the survey open questions and the structured interviews has identified common responses among participants. Responses have been classified into two groups: actions carried out when designing site plans and on-site actions followed in order to take into account the productivity factor considered. We have named the first group "planning strategies" (see Table 2) and the second group "on-site interventions" (see Table 3).

CONCLUSIONS

According to the quantitative analysis, construction productivity factors with stronger influence on site performance are the following: faulty works, equipment unavailability, project changes during execution, materials unavailability, lack of project information and poor workmanship. Nevertheless, following qualitative results, some of these factors are not taken into account when carrying out the planning but are considered by site managers during on-site interventions. This is the case of faulty works, materials unavailability, project changes during execution and poor workmanship. Their impact on productivity is generally negative, even though in the case of project changes during execution, performance might improve if the alteration suggested allows a good execution.

In relation to the factors with lower influence on site performance these are: overcrowded work areas, crew interference, lack of on-site cleanliness, inspection delays and poor materials quality. Even though with a slight effect, a new negative factor appears in this research: lack of on-site cleanliness. In relation to poor materials quality, its lower value could be related to the increase in national regulations related to EC quality control requirements directed to construction materials manufacturers.

The qualitative research approach shows how Project Management Teams and Site Managers working for the constructing company have different points of view when planning and acting upon a productivity factor. For example, Project Management Teams do not seem to consider inspection delays, project changes and lack of project information, while, at the same time, they happen to be very important and out of control for Site Managers. This contradiction implies that there is potential for site productivity improvement through coordination among these construction professionals.

This paper represents a first step in finding opportunities for improvement in construction productivity in Spain. After identifying the productivity factors, managers can effectively act upon them in order to reduce costs, improve scheduling and finally obtain a more accurate productivity prediction when estimating construction costs.

Considering the rate of response and the regional area where this research has been carried out, we are not in a position to state that building engineering's strategies and on-site interventions in SMEs are different from the ones followed in big companies.

Table 2: Planning Strategies

Factors	Planning Strategies
1. Faulty works.	- Assign a period for revising and repairs (5 to 10 days or a month). - Assign lower performance levels in order to take up possible delays. - To budget a symbolic sum for unforeseen expenses proportional to the estimated execution cost. This would compensate the price rise that may come up.
2. Overcrowded work areas and 3. Crew interference.	- Draw diagrams showing the start and end of each work activity, number of workers involved and relations among them. - Plan considering works that can't coexist at the same time and space. When inevitable, reduce performance level of each individual unit. - Consider only important teams and their interference when planning.
4. Lack of on-site cleanliness.	- Include daily or weekly cleaning routines. - Considered in the Health and Safety Plan.
5. Equipment unavailability and 8. Materials unavailability.	- Previous market research of local company suppliers. - Make a list with the necessary machinery before each stage and plan to have it available immediately. - Record the moment when orders have to be placed, taking into account time for delivery to the site. - Taking into account known performance values, plan the building with available equipment in the company and prepare for that not available. - Carry out a purchasing and supplies plan.
6. Inspection delays.	- Not considered. Actions are improvised. - Incorporate a "Quality Control" section, recording the date and time when inspection is required. -Include plan of approvals or sample delivery of work done.
7. Project changes during execution and 10. Lack of project information.	- Not considered.
9. Poor materials quality	- Not considered.
11. Poor workmanship.	- Not considered. - Planning based on real performance values or assume longer execution deadlines.

Tabla 3: On-site interventions.

Factors	On-site interventions
1. Faulty works.	- Highest control over work areas. - Set standards for rejecting subcontractors. Carry out a final revision before subcontractors get paid. - Revise problematic works in advance together with the foreman in order to detect and avoid errors. - In buildings made up of repetitive units such as housing, execute a pilot unit with all crews involved, under close control of the site manager.
2. Overcrowded work areas and 3. Crew interference.	- Not planned beforehand but considered during building construction, trying to anticipate them in order to avoid problems. - Try not to overlap more than two trades. - Organize consecutive tasks on different floors or alternative days and reduce the number of workers per trade to the minimum. - Program different tasks where operatives may work when they are interrupted due to interference with other trades.
4. Lack of on-site cleanliness.	- Include a cleaning clause with penalty fee when hiring subcontractors. - For small building sites each trade must clean its own work area. For big sites, a cleaning crew is responsible for the whole site. - Assign areas for waste and debris storage, exit and disposal on site.
5. Equipment unavailability and 8. Materials unavailability.	- Short term planning for common materials and equipment. Long term planning for complex ones. - Take it into account when contracting. Include a penalty clause for failure to comply with delivery date. - Include necessary equipment in the budget and in the Health and Safety Plan. -Prepare a market comparative study with different suppliers in case something goes wrong. -Make up for lost time in site units where equipment is available.
6. Inspection delays.	- Inform the Project Management Team a few days in advance. - Schedule weekly site inspection visits, fixing day and time, without changes. Study the meeting programs. - In case inspectors don't visit the site when agreed, works will continue.
7. Project changes during execution and 10. Lack of project information.	- Study the project in advance, measuring it. Ask the Project Management Team for a solution and order materials. - The construction company's building engineer should be able to make up for the lack of details and resolve. - Update the planning according to changes.
9. Poor materials quality	- Set approval and rejection standards. Inspection on receipt.
11. Poor workmanship.	- Try to hire subcontractors with work experience in similar jobs or known for good quality work. - Control work executed in the early phases and change team if not satisfactory. - Dismiss inefficient construction workers.

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