Evaluation of Factors Affecting Productivity in the UAE Construction Industry: Regression Models

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Productivity rates of construction trades is the basis for accurately estimating time and costs required to complete a project. This research aims at developing regression models for predicting changes in productivity, when the underlying factors affecting productivity are varied. These factors were broadly categorized as general work environment, organizational work policies, group dynamics and interpersonal relationships and personal competence of the employees as applicable to the construction industry in the United Arab Emirates (UAE). The most significant factors amongst these were determined through three surveys using the Severity Index and Chi Square computations for significance. The factors were regrouped into factors that afforded practical variation at site and productivity data was collected using different combination of the most significant factors of Timings, Supervision, Group Dynamics, Control by Procedures, Climate and Material Availability. Construction activities such as Excavation, Formwork, Reinforcement, Concreting, Block work, Plaster and Tiling were studied and the increase or decrease in productivity obtained was compared to the actual site average productivity; then analyzed statistically using the MINITAB 15 software, and linear regression models established. Validation was undertaken at four sites and it was observed that the regression models arrived at were capable of predicting productivity changes within ±15%.

Keywords: *construction, factors, performance, productivity, regression.*

Introduction

Productivity could be defined as “the ratio of output of required quality to the inputs for a specific production situation; in the construction industry, it is generally accepted as “work output per man-hours worked”. For example, excavation is measured in cubic metres per man hour and plastering is measured in square metres per man hour. Improved productivity helps contractors not only to be more efficient and profitable; knowing actual productivity levels also helps them to estimate accurately and be more competitive during bidding for projects.

This study focuses primarily on the construction industry in the United Arab Emirates (UAE). The construction industry in the UAE is a multibillion dollar industry, contributing approximately 8% to the nation’s GDP (UAE Yearbook, 2009). The UAE labour market is made up of a mix of 110 nationalities, common to the entire Gulf region and has unique characteristics, which affects the

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construction personnel and their productivity. UAE does not allow organized unions for workmen and official statistics on standard productivity rates are nonexistent. The UAE has a hot humid climate with temperatures reaching up to 48 °C during summer and relative humidity up to 80%. Most of the workmen are housed in labour camps with minimal messing facilities and allowed to go on leave once every two years. Workmen are subject to a sponsorship system and cannot change their jobs; cancellation of workmen category visa invites a six month ban from employment in the UAE. Employers and expatriate employees have all to comply with the Federal Labour Law No. 8 of 1980, which has set several comprehensive regulations that protect the rights of employers and employees including employee welfare.

Further the workforce is subjected to a combination of other influences such as different management styles (supervision staff is mostly Arabic), language barriers, cultures, customs, long separation from families, late payment of salaries and so on. Such influences have a direct impact on their productivity.

Despite technological innovations in building materials, mechanized shuttering, offsite precast fabrication, the industry is still very much labour intensive. Compared to the liquidity in the region; and the value of the contracts / construction projects, the cost of labour is relatively cheap. This stifles productivity initiatives as contractors would rather push in more people and get the job completed; rather than go into the hassles of increasing productivity. Therefore the study of productivity and ways and means to increase the productivity is important for the UAE construction industry.

This paper is a précis of the doctoral research aimed at establishing regression model/s which can predict changes in productivity of selected construction activities, when the underlying factors are purposefully varied.

It is structured as under:

- *Introduction*
- *Literature review*
- *Factors affecting construction productivity*
- *Field data collection*
- *Regression models for productivity*
- *Validation of models*
- *Conclusion*
- *Areas of future research*
- *References*

Literature Review

The literature review consisted of the review of the management theories – classical and human relations / motivational approaches to management together with the review of research on productivity by contemporary authors. The review of contemporary work culminated into three matrices depicting factors affecting productivity, motivating factors affecting productivity and factors compared over several countries. This literature review together with the experience of the researcher formed the basis of establishing the comprehensive listing of the factors affecting construction productivity (Table 1).

Management Theories

The *scientific management* advocated by Fredrick Taylor (1947), is the first of the ‘classical management’ approach and emphasized increasing productivity of individual workers through the technical restructuring of work organization and the provision of monetary incentives as the motivator for higher levels of output. Henri Fayol’s 14 principles of management together with the bureaucratic approach to organization somehow incorporated a mechanistic - negative view of human nature and led to the contrasting human relations approach.

Elton Mayo’s ‘*human relations approach’* following the ‘Hawthorne experiments’ concluded that people are motivated by other conditions than pay; these being the need for recognition and a sense of belonging (Roethlisberger and Dickson, 1939). Mayo’s understanding of the workplace as ‘people in a social environment’ has relevant applications within the construction industry.

Motivational Theories

Most authors agree that motivation symbolizes the drive behind human behaviour. Mitchell (1982) defines motivation as the ‘degree to which an individual wants and chooses to engage in certain specified behaviours’.

Abraham Maslow (1943) proposed the theoretical framework of individual personality development and motivation based on a **hierarchy of human needs**; knowing the employee and determining their most urgent needs and meeting his wants and desires, managers would be able to increase the efficiency of his employees.

McGregor (1960) concluded that a manager’s view of the nature of human beings is based on a certain grouping of assumptions (**Theory X**: people are generally lazy and **Theory Y**: people do want to work and are creative), leading to either an ‘authoritative’ or a ‘participative’ type of management respectively.

Fredrick Herzberg’s (1959) concluded that people have basic needs, which he called as **hygiene factors -** (company policy and administration, supervision, salary, interpersonal relationships, working conditions and security). According to Herzberg, hygiene factors do not motivate; if present, they prevent employees from becoming dissatisfied. On the other hand, absence of hygiene factors results in dissatisfaction and de-motivation. The second set of needs includes **motivators** (*achievement, recognition, work, responsibility, and advancement*). If resolved, motivators cause satisfaction of employees. Thus to effectively motivate employees, a manager must not only balance hygiene environment of a company, but ensure some motivators are available, thus finding relevant application in the construction industry.

The **Equity theory** of Adams (1963) is based on strong social norms about fairness and accepts that people compare efforts and rewards. A state of equity exists whenever the ratio of one person’s outcomes to inputs equals the ratio of another person’s outcome to inputs. Inequity creates tensions within individuals; thus a prudent management strategy would be to keep feelings of equity in balance in order to keep the workforces motivated.

Vroom's (1964) **Expectancy theory** suggested that employees constantly predict likely future rewards for successfully completing tasks, and if the rewards seem attractive, people become motivated to do the job to get expected rewards and suggested that the opposite is true as well. This theory finds extensive application in designing incentive schemes.

Works of Contemporary Authors on Construction Productivity

Olomolaiye et al (1998) stated that factors affecting construction productivity are rarely constant, and may vary from country to country – project to project, and even within a project based on circumstances. Olomolaiye (1990) found that good supervision was the most significant variable influencing percentage productive time and that fluctuations in productivity are primarily the responsibility of on-site management.

Herbsman and Ellis (1990) classified the critical factors affecting construction productivity as - technological factors such as specifications, design, location and materials; and organizational factors such as production, labour wages and relations and social factors.

Alinaitwe et al (2007) ranked factors affecting productivity in Uganda: - these were – incompetent supervision, lack of skills, rework, lack / breakdown of tools, poor construction methods, poor communications, inaccurate drawings, stoppages due to rejected work, political insecurity and harsh weather conditions.

Horner (1982) identified ten factors which affect construction productivity – quality, number and balance of workforce, motivation of labour force, degree of mechanization, continuity of work, complexity of work, required quality of finished work, quality and number of managers, and weather.

Kazaz and Ulubeyli (2006) ranked ten organizational factors based on a survey of construction companies in Turkey, which are – the site management, material management, work planning, supervision, site layout, technical education and training, crew size and efficiency, firm's reputation, camps and relaxation allowances.

Abdel-Wahab et al (2008) concurs with other researchers that skills development and training improves productivity and that effective utilization of skills rather than mere increase in the supply of skills is a key to productivity improvements.

Research undertaken by Ruthankoon and Ogunlana (2003), Ogunlana and Chang (1998), Price (1992) and Hague (1985) used the motivation theories of Maslow and Herzberg as a framework for their research.

Laufer and Borcherding (1981) indicated that financial incentives for the construction labour force are practical; they could raise productivity, lower production costs, shorten the construction time and increase the earnings of the workers.

Aiyetan and Olotouah (2006) established a relationship between motivation and performance of workers in the Nigerian construction industry. He listed the motivating factors as – overtime, health care, provision of transport, promotion, increase in salary, recognition, company policy, working conditions, relations with co-workers, work itself, responsibility, holiday abroad with pay, achievement, telephone services and sharing of profit.

Price (1992) indicated that there is a distinct relationship between remuneration, motivation and site efficiency. Schriver and Bowlby (1984) and Chang (1991) emphasized morale of workers as a key factor in measuring construction productivity.

Factors Affecting Construction Productivity

The literature review indicated in previous section, coupled with the experience of the author was used to establish a comprehensive listing of the *factors affecting productivity in the UAE Construction Industry* (Table 1) in four major interrelated categories factors; these are: Environmental, Organizational, Group and Individual Factors. Figure 1 depicts the four major factor categories affecting productivity, as established for this research.

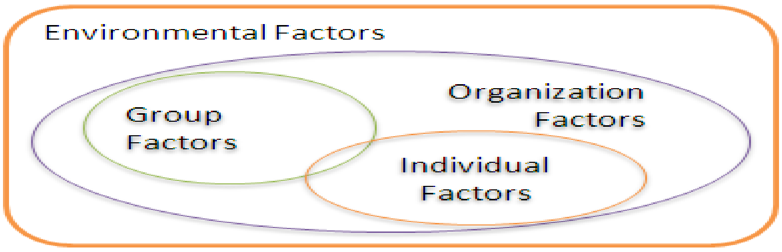

Figure 1: Major Categories of factors affecting productivity

Further the factors from Table 1 were transposed into a sixty-one **survey** questions and circulated to the purposefully selected key industry players – engineers, foremen and workmen from the construction industry. Sampling was aimed to have a comprehensive coverage of client, contractors, consultants and subcontractors. A snapshot of the survey questionnaire is presented in Figure 2. This survey result served as the first set of primary data for the research. The responses were treated with respect to both their significance as identified by the respondents together with how frequently the experience the factor on site. This was achieved by applying the 'Importance Index', 'Frequency Index' and ranked using the 'Severity Index' (see Table 2) used as described in Kadir et al (2005). These factors were considered as significant for further study and are presented in Table 2: Significant Factors affecting productivity.

For the convenience of field study, the significant factors were regrouped into factor variables and two perception surveys were conducted to establish the effect of each of these factor variables. Regrouping into factor variables helped purposeful variation of these and recording resultant effect on the productivity of construction operations on site.

Table 3 gives the seven factor variables with their weighted averages. The survey responses were subjected to **chi-square tests of significance**, which indicated that the factors groups identified in Table 3 – namely *Timings, Competence of supervisors, Salaries, Procedures, Group dynamics, Individual* *factors, Availability of material and Climate conditions* were indeed statistically significant.

The related computations on weightages and the chi-square statistic have been kept out of this paper for space restrictions.

Table 1: Comprehensive List of Factors affecting productivity

Environmental Factors	Group Factors	Individual Factors
• labour market characteristics • economic situation • safety and job security • minimum wages, salary payments • use of technology / level of mechanization • climate and weather conditions • client requirements / project specific requirements • site layout • political situation	• group structure or composition • individual skills within the group • overall skills of the group • nature of work / assignment • demography of team / nationalities • cultural differences • language barriers • frequency of changes	• level of academic / technical education / past training • past experience / age • overall competence and skills • motivation and morale • individual culture / attitude • individuals creativity • absenteeism • overall job satisfaction • overall communal feeling / belongingness • overall appreciation

Organizational Factors	

• work timings / working hours
• discipline / hierarchy order
• policies and procedures, method statements
• management involvement, accountability, transparency
• availability of materials / tools and equipment
• construction work complexity
• interruptions of work
• competencies of supervisors
    ○ leadership skills
    ○ systematic delegation
• level of communication
• brand name of company
	• reward schemes
	    ○ attainable goals and targets
	    ○ overtime
	    ○ instant cash award schemes
	    ○ contract system of work
	    ○ fair treatment of employees
	    ○ fulfillment of promises
	• appraisal / feedback schemes
	    ○ freedom of expression and grievances
	    ○ experience is valued
	• welfare schemes
	    ○ camp conditions
	    ○ lunch breaks / packets
	    ○ recreation

Survey Questionnaire

Name :
Company:
Title:

Ref.	Probable Factors affecting productivity	Degree of Importance					Frequency of Occurrence			Remarks
		5	4	3	2	1	3	2	1	
		Very Important	Important	Neutral	Not Important	Highly Not Important	High	Medium	Low	
1	Would Work Timings giving a proper balance between work and recreation affect									

Figure 2: Snapshot of Survey Questionnaire

Table 2: Significant Factors affecting productivity *(with ranks)*

No	Factors affecting productivity	Importance Index	Frequency Index	Rank
1	Proper Work Timings giving a balance between work and recreation and time with family	0.9025	0.7339	0.6624
2	Leadership Skills of supervisors	0.8437	0.7619	0.6428
3	Salaries on time	0.8496	0.7507	0.6378
4	Technical qualified / educated for the trade	0.8437	0.7507	0.6334
5	Reasonably well paying job	0.8462	0.7465	0.6317
6	Safe Secured Job	0.8412	0.7479	0.6291
7	Transparency and Accountability of each level of management	0.8555	0.7283	0.6230
8	Overtime Paid for work done beyond normal Working hours	0.8353	0.7381	0.6165
9	Materials available on time	0.8580	0.7185	0.6165
10	Defined policies and procedures by management	0.8185	0.7521	0.6156
11	Individual or Personal Skills	0.8050	0.7633	0.6145
12	Competence of supervisors	0.8244	0.7451	0.6142
13	Systematic method statements / procedures in place and known	0.8345	0.7353	0.6136
14	Knowledge of Work	0.8261	0.7423	0.6132

Formulae used (Kadir et al, 2005)

$$\textbf{Importance Index} = \frac{5n1 + 4n2 + 3n3 + 2n4 + n5}{5(n1 + n2 + n3 + n4 + n5)}$$

$$\textbf{Frequency Index} = \frac{3m1 + 2m2 + m3}{3(m1 + m2 + m3)}$$

Severity Index (rank) = Importance Index x Frequency Index

Where, n1, n2…. n5 = number of responses for "Very Important", "Important"…….“Highly Not Important” degree of importance respectively. n1, n2, n3, n4, and n5 each have a weight of 5, 4, 3, 2, and 1 respectively.
And, m1, m2 and m3 = number of responses for "High", "Medium" and "Low" frequency of occurrence, each having a weight of 3, 2 and 1 respectively

Field Data Collection

Field data has been collected from six construction sites of a "**case study**" contracting company in Abu Dhabi. To remove any possible bias in the productivity results, the workmen involved in the productivity studies on sites, have were unaware that their work is being recorded. Further, practical difficulties of raising wages to vary the factor on *Salaries* led to its inclusion within the *Timings* factor, which included overtime and fixed output based payments. The remaining six factor variables were subjected to three levels of variation as explained in Table 4. Productivity was measured for the seven construction trades of Excavation (cubic metres/man-hour), Formwork (square metres/man-hour) Reinforcement (tons/man-hour), Concreting (cubic metres/man-hour), Block-work (square metres/man-hour), Plastering (square metres/man-hour) and Tiling Works (square metres/man-hour).

Table 3: Factor variables for field data collection

Timings	Competence of Supervisors	Salaries
Morning Shifts	Team with Classified Supervisor	Incentive Given for Specific Amount of Job
Fixed Work at Any Hours	Known Team Members	Increase Rates
8+4	Supervisor Change	Fixed Daily Rates
8+6	Team Member Change	
8+2 Normal		**Materials**
Afternoon Shifts		Materials Available and Tracked
Night Shifts		Materials Not Available / Tracked
Systems and Procedures	**Group Dynamics**	**Climate Conditions**
Systematic Procedures and Work Instruction available	Groups with all Skilled Members	Hot / Humid Weather
Specific / Stringent HSE Requirements	Groups with Unskilled Members	Cold / Windy Weather
Specific / Stringent Quality Requirements	Groups with Mix of Skilled and Unskilled Members	Pleasant Weather

Table 4: Factor Levels used for Data Collection

No	Factors affecting Productivity	Levels / Values		
		1	2	3
1	Work Timings (T)	8+2 (Normal)	8+4 (Good)	Contract (Fixed Qty.)
2	Level of Supervision (S)	Average	Good	Excellent
3	Group Dynamics (G)	Unskilled	Mixed	Skilled
4	Availability of Material (M)	Not available	Normally available	Ideal Situation
5	Control by Procedures (P)	Lack of Procedures	Normal Control	Tight Control
6	Climate Conditions (C)	Extreme	Normal	Pleasant

A review of the minimum, maximum, range and the average productivity rates for all the trades under observation indicated large variation of productivity rates over sites and generally supported the fact that baseline productivity rate attached to an activity cannot be fixed, as there are several factors interacting with each other, affecting the overall productivity. The productivity figures also differed significantly with the existing database of productivity rates of the case study company, concurring with the results of Olomolaiye (1998). The reasons for this difference were attributed to technical problems associated with construction trades, based on the location of the site, soil strata, contract specifications and client involvement, besides the factor variables considered in the study.

To overcome this problem, the actual site productivity average was used as a base for comparison; further, as these trades have different units of measurement, the **output variable** measured and used in further statistical analysis was the "*difference in actual productivity minus the average productivity*" specific to the site. This independent, unit-free output variable was termed as "**percentage productivity change**". Data so obtained was subjected to homogenization within a band of ± 40%. The band of ± 40% was selected based on the variations seen in actual productivity on site, the presence of possible concurrent factors other than the six under study and the fact that around 74% of the results were within this band.

A total of **1090 data sets** were collected from six construction sites, and for the seven construction trades under study. The data was scrutinized for any abnormal readings using the baseline productivity and the site average comparisons and a set of **812** homogenized readings were subjected to further review and analysis. This data were then fed into the '**MINITAB 15'** software and a regression analysis was performed. The output variable was the "percentage productivity change" while the input variables were the six factors of *Timings (T), Supervision (S), Group Dynamics (G), Procedures (P), Availability of Material (M)* and *Climate (C).*

Regression Models For Productivity

Initial trial runs were made using 'MINITAB 15' software for a straight line overall model using all the trade wise productivity rates available in the data sets. However the coefficient of determination - R^2 returned were very low around 16%. Therefore a switch to trade wise productivity modelling was made, which then gave a better fit with a higher R^2.

Table 5: Regression Models for Construction Activities (using MINITAB 15)

Trade	**R^2 %**	**Final Regression Model having best R^2 value** *(Percentage Productivity Change Predicted = ..)*
Excavation	93.4	**= -0.0024+0.0806T+0.0190S-0.233G-0.157P+0.328C**
Formwork	75	**= -0.661+0.195T+0.140S- 0.0196G+0.0966P+0.0057C**
Reinforcement	73.8	**= - 0.748+0.150T+0.242S-0.0386G+0.0301P-0.0499C**
Concreting	78.5	**= -0.0283+0.0733T+0.143S+0.0514G-0.180P+0.0389C**
Block work	82.9	**= -0.480+0.138T+0.141S-0.128G+0.125P+0.0444C**
Plastering	92.6	**= -0.203+0.242T-0.0049S-0.0344G-0.0548P+0.0328C**
Tiling	83.1	**= +0.073+0.0050T+0.354S+0.0878G-0.282P-0.170C**

Note: Refer Table 4 for legend.

Although statistical texts indicated that an R^2 value of 80% and above is a realistic value to accept a regression model, some of the iterations resulted in one of the main factor variables being deleted out of the regression equation. In such cases, an R^2 value of less than 80% was accepted for the purposes of this research. Further a straight line regression was considered acceptable as higher non linear regression models investigated did not give appreciable change in R^2 values. The regression models acceptable with their R^2 values have been summarized in Table 5 above.

Validation of Models

Notwithstanding the selection of straight line regression, the expected real life productivity changes of ±25%; the acceptance of R^2 at 70%; the complex relationship between model and data, technical constraints on site and the subjectivity of the factors themselves, the validation of the model was set for acceptance at a band of ± 15%.

Four construction sites were chosen for model validation ensuring field variation of the factors affecting productivity similar to the one used during data collection and model formulation.

A total of **11** data sets constituting **1963** data readings were used for validation. The data was reviewed for consistency by first comparing the average site productivity and the productivity measures obtained actual on site and those predicted by the model. The validation band of ± 15% was chosen as explained above and the models were validated for use within ± 15% accuracy which is acceptable for field use on sites.

Conclusion

This research aimed at developing a regression model which can predict changes in productivity in construction, when the underlying factors were purposefully varied. The major category factors were broadly classified as Environmental factors, Organization factors, Group factors and Individual factors. The significant factors finally chosen for the field study was a result of two field surveys one – ranking results using the severity index encompassing both the significance and frequency of occurrence of the factors on site; and the other using the weighted averages for the magnitude of the effect of the factors on productivity. The most significant factors affecting construction productivity in the UAE have been established as – *Work timings, Competent supervision, Group dynamics, Control by procedures, Availability of material and Climatic conditions.* A comparison of these factors with the works of the contemporary authors reveals that these factors have frequent mention in most of the works regarding construction productivity. Although limited by the simplicity of assuming nonlinear regression models, the productivity models have been established for each of the seven construction trades of excavation, formwork, concreting, blockwork, plastering and tiling. The models have been validated using data for four construction sites in UAE and it is found that the models can predict productivity changes within ± 20% accuracy. The doctoral research is now concluded and fitting of non-linear regression models for the existing data was not undertaken for want of time.

Notwithstanding the complex nature of construction activities and the presence of numerous constraints outside the control of management, the models and the underlying implications can help construction personnel to achieve improved productivity rates on sites; i.e. to ensure favourable factors for achieving optimal productivity, keeping costs within budget, completing projects on time and ultimately helping contractors to run their business profitably.

Lastly, possible areas for future research have been suggested in the next section.

Areas for future research

The areas for refinement in the models and consequent future research arise from the practical assumptions in the study, field application of productivity on construction sites, and the considerations of non linear regression model and study of interactions of the factors affecting productivity. Additionally, future research could consider higher levels of variation 1-5 instead of 1-3 in this study, other factors affecting productivity, motivation levels for individuals and the group as a whole, benchmarking productivity rates across other contractors in the region and other countries and the inter-dependability of variables in concurrent construction trades and the project specific exigencies and unique events that may affect the baseline productivities for the site.

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