PREDICTING THE IMPACT OF COST AND TIME AS A CONSIDERATION FOR CONCRETE CONSTRUCTION (CONCRETE CONTRACTING IN HOUSING DEVELOPMENT PROJECT)

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ABSTRACT:
In the consideration of construction contracting in housing development, it is very vital and necessary to carry out a feasibility study and an in-depth analysis using the approach that has been well examined in this work. The result displayed shows the various outputs of the conventional method and the precast method of concrete construction which indicates that the precast method is mostly prefered in terms of speed, volatility and risk handling. Furthermore, other results available in this work indicates an overview of the necessary analysis that is needed to be carried out before a concrete construction project proposal submitted is considered for an award of a construction contract. Full detailed results are hereby presented.

***Keywords**: Housing Development, Mathematical Model, Precast Concrete Construction, Environmental Factors.*

INTRODUCTION:

A selective use of precast concrete within conventional building systems may have economic and managerial advantage even in the case of small and heterogeneous projects. Precast concrete is a construction product produced by casting concrete (cement, sand, granite and coarse aggregate) in a reusable mould or "form" which is then cured in a controlled environment, transported to the construction site and lifted into place ("tilt up"). In contrast, conventional (in-situ) concrete is poured into site-specific forms (formwork) and Cured on sites (Wiki,2013).

Conventional construction method is the process consisting of cast in situ constructions whereas the precast concrete construction only involves assembly of already casted concrete products in the site. By producing precast concrete in a controlled environment (typically referred to as a precast plant), the precast concrete is afforded the opportunity to properly cure and be closely monitored by plant employees. Utilizing a Precast Concrete system offers many potential advantages over site casting of concrete. The forms used in a precast plant may be reused hundreds to thousands of times before they have to be replaced, which allow cost of formwork per unit to be lower than for site-cast production. There are many different types of precast concrete, forming systems for architectural applications, differing in size, function, and cost. Precast architectural panels are also used to clad all or part of building facade free-standing walls used for landscaping, soundproofing, and security walls, and some can be pre stressed concrete structural elements. Storm water drainage, water and sewage pipes, and tunnels make use of precast concrete units (Kim,2002). Issues related to precast concrete construction is classified into direct and indirect issues. Issues directly related to precast concrete are Elements, connections, systems, production, handling, assembling and demounting. Issues indirectly related to precast concrete materials, technology, structural analysis, building physics and equipment.

Precast stone is distinguished from precast concrete using a fine aggregate in the mixture, so the final product approaches the appearance of naturally occurring rock or stone. More recently expanded polystyrene is being used as the cores to precast wall.

Using a precast concrete system offers many potential advantages over on-site casting. Precast concrete production can be performed on ground level, which helps with safety throughout a project.

There is greater control over material quality and workmanship in a precast plant compared to a construction site. Precast concrete construction have benefits over the conventional on-site concrete construction. The elegant benefits are high speed, good quality and neat construction finishing with less wastage.

Today precast concrete industry is highly customer focused. Many innovative technologies have been adopted and practiced in the industry. Thermal, acoustic, seismic resistant technologies and beautiful pleasing architectural precast facades to the building are already available and practiced in many countries. Precast concrete technology can be more popularized in most construction industry works with such innovative products and construction methods as sampled below.

Concrete materials: In precast the wastage is less than 1% as the majority of concrete mixing is done in factory and concrete is batched exactly according to the requirement. In conventional system wastage is usually 3-5%.

Reinforcement: In precast pretension slab are used, the entire load calculated is taken care by the strand itself and the rest of the reinforcement is just a welded mesh. In general the steel quantity is less than 1% of concrete volume. Wastage will be well controlled and even the generated wastage will be used for smaller precast components. In general the wastage will be 1-1.5%. In general steel quantity will be 1 to 1.5% of the concrete volume. Wastage in on-site construction will be much higher comparatively, and it will be 3-5%.

Steel mould: For precast one time steel mould has to be fabricated and it shall be used for more than 500 cycles and most of the time it will be multiples of 500 only. After the usage also the moulds shall be scraped which will generate at least 50 % of fund invested which is a credit point for Green Building. It is not applicable in convention on-site concreting system. Form-work: In precast very minimal form-work is required. In conventional system form-work are used for about 5 cycles and it has to be scraped. This is against Green Building environmental preservation as it consumes more timber woods.

Production Yard: In precast system separate production yard is required in conventional system rebar yard and formwork yard is required but can be on same site.

Scaffolding: In precast construction very minimal scaffold work required .In conventional system full-fledged scaffolding is required.

Logistics: In precast system logistics are required for lifting and transporting components such as hydraulic crane, trailer, workers etc (Wiki,2013).

In conventional system less logistics is required as most of the time manpower is used for lifting the material.

Cranes: In precast suitable cranes have to be used for lifting , storage and erection of components. In convention system one crane is required for lifting materials.

Manpower: In precast construction less manpower required at site and nominal manpower required at production yard. In conventional system huge manpower is required at site.

Quality: In precast the quality is 100% as its factory product. In conventional system quality is achieved about 75%.

Safety: In precast 90 % has safe and clean environment as most of the concrete, rebar and shuttering works will be handled separately at the yard.

In convention system only 50-60% clean environment is achieved.

Indirect cost: In precast big savings such as, plastering is not required when precast slab are used. Brick wall and plastering is not required when precast slab are used as walls. Moreover there is huge time savings, which means overheads, rent and other administrative charges have been saved and interest earned due to early payment by clients or early production for clients benefits them as well. In conventionals system the time overrun and delay has become unavoidable in most of the projects, which leads to additional overhead and other incidental expenses. Most of the projects suffer about 20 to 30% run off from the budget.

Precast components are used in various applications and projects of all types. Key components include **Wall panels**, which can include an inner layer of insulation and be load- supporting if desired, **Spandrels**, which generally span between columns and are used with window systems in office buildings or in parking structures, **Double tees**, so named due to the two extending "stems" perpendicular to the flat horizontal deck. These tees are often used for parking structures and buildings where long open spans are desired, **Hollow-core slabs**, which are long panels in which voids run the length of the pieces, reducing weight while maintaining structural strength, **Columns and beams**, including columns and a variety of beam shapes, **Bridge components** for both substructure and superstructure designs, including girders in a variety of shapes, box beams, and deck panels and **Piers, piles, caps** and other supporting components for bridges. Precast concrete components can begin to be erected shortly after foundations are ready and can be installed quickly, often cutting weeks or months from the schedule. This allows construction to get into the dry more quickly and enables interior trades to begin work earlier. The fast enclosure also decreases concerns for weather or material damage during erection, reducing the contractor's risks and costs (Wiki,2013).

This makes precast concrete easier to maintain than other façade materials. The panels' fewer locations for moisture possible with precast concrete can be included in the design. Efficiencies in component size, connections, delivery, and erection can be factored into the design, maximizing the benefits offered by precast concrete. Outline of the study is to illustrate the process involved in the implication of precast concrete products in construction industry and to compare the same with conventional construction methods. It focuses the various issues related directly and indirectly. A building example has been taken and the activities are scheduled for constructing the building by both conventional and precast concrete construction. Various factors affecting the construction process is analyzed and addressed. The cost of the project is calculated and it is compared with conventional to locate the differences, advantages and disadvantages of precast concrete construction. Architectural precast concrete panels can be sculpted to resemble a wide range of finish materials, including limestone and brick. This substitution ensures the building blends with nearby structures, whether contemporary or historic, or projects its own striking, cutting-edge appearance while meeting a tight budget. Precast concrete panels require caulking only every 15 to 20 years to maintain their reliability. This makes precast concrete easier to maintain than other façade materials (Ryan,2010).

DATA COLLECTION

From the statement of problem in the model formulation, data were used as a basis in building of the equation which researcher took to formulates the mathematical model including:

1) Collecting data regarding construction costs for each type of building and construction method.
2) Collecting data regarding construction times for each type of building and construction method.
3) Project duration

The three contractors were requested to submit construction estimations (costs in millions of dollars and construction periods) for each type of building and construction method. The collected data was summarized as shown next.

Table1: Contractor I (4 Teams) – Conventional Construction Method

House Type	Construction Time(Month/Unit)	Construction Cost (M$/Unit)	Construction Time/ Number of Team (Month/Unit)
1	8.4	2.42	2.10
2	7.8	2.10	1.95
3	7.7	1.45	1.93
4	6.3	0.95	1.58

Table2: Contractor I (4 Teams) – Precast Construction Method

House Type	Construction Time(Month/Unit)	Construction Cost (M$/Unit)	Construction Time/ Number of Team (Month/Unit)
1	4.9	3.3	1.23
2	4.4	2.83	1.10
3	4.2	2.82	1.05
4	3.2	1.55	0.8

Table3: Contractor II (5 Teams) – Conventional Construction Method

House Type	Construction Time(Month/Unit)	Construction Cost (M$/Unit)	Construction Time/ Number of Team (Month/Unit)
1	8.3	2.45	1.66
2	7.8	2.15	1.55
3	7.5	1.40	1.50
4	6.6	0.90	1.30

Table4: Contractor II (5 Teams) – Precast Construction Method

House Type	Construction Time(Month/Unit)	Construction Cost (M$/Unit)	Construction Time/ Number of Team (Month/Unit)
1	5.1	3.25	1.02
2	4.5	2.80	0.90

3	4.5	2.35	0.90
4	3.5	1.60	0.70

Table5: Contractor III (4 Teams) – Conventional Construction Method

House Type	Construction Time(Month/Unit)	Construction Cost ($M_\$$/Unit)	Construction Time/ Number of Team (Month/Unit)
1	8.5	2.4	2.13
2	8.0	2.0	2.0
3	7.0	1.5	1.75
4	6.0	1.0	1.50

Table6: Contractor III (4 Teams) – Precast Construction Method

House Type	Construction Time(Month/Unit)	Construction Cost ($M_\$$/Unit)	Construction Time/ Number of Team (Month/Unit)
1	5.0	3.2	1.25
2	4.5	2.85	1.13
3	4.0	2.25	1.00
4	3.0	1.5	0.75

(Data Source: Grit Ngowtanasuwan (2013), "Mathematical Model for Optimization of Construction Contracting in Housing Development", *Procedia-Social and Behavioral Sciences105 pg 94-105, ScienceDirect, Elsevier Ltd.)*

MATHEMATICAL FORMULATION

For a detailed analysis in the prediction of the impact of construction cost and construction time on precast and conventional concrete construction, we shall be using the multiple regression model equation since the building is solely a dependent on this two variables to be examined. Hence the mathematical formulation:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + e \qquad (1)$$

Where:

Y represents the dependent variable here called House Type.

X_1 represents the first independent variable hereby called Construction Cost.

X_2 represents the second independent variable hereby called Construction Time

X_3 represents the third independent variable hereby called Construction Time per number of Team

e represents the error terms in estimation

While a, b_1 and b_2 are the Estimators which will be computed from the data obtained.

Considering equation (1) above, we re-write as

$$e = Y - (a + b_1X_1 + b_2X_2 + b_3X_3) \quad (2)$$

Squaring both side of equation (2) and taking the sum of both side of the equation, we have

$$\sum e^2 = \sum(Y - a - b_1X_1 - b_2X_2 - b_3X_3)^2 \quad (3)$$

We let $L = \sum e^2$ (4)

$$L = \sum(Y - a - b_1X_1 - b_2X_2 - b_3X_3)^2 \quad (5)$$

To obtain the estimators from the data set that will be used for the analysis, we proceed to take the partial derivatives of equation 5 with respects to a, b_1, b_2 and b_3 and equating to zero. Thus we have

$$\frac{\partial L}{\partial a} = -2\sum(Y - a - b_1X_1 - b_2X_2 - b_3X_3) \quad (6)$$

$$\frac{\partial L}{\partial b_1} = -2\sum(Y - a - b_1X_1 - b_2X_2 - b_3X_3) \quad (7)$$

$$\frac{\partial L}{\partial b_2} = -2\sum(Y - a - b_1X_1 - b_2X_2 - b_3X_3) \quad (8)$$

$$\frac{\partial L}{\partial b_3} = -2\sum(Y - a - b_1X_1 - b_2X_2 - b_3X_3) \quad (9)$$

We normalized equation 6, 7, 8 and 9 by equating them to zero and thus proceed to obtain the estimators by crammers rule method which will be time consuming because of the purpose of the analysis we are doing and so we resort to using computational approach which is more robust and efficient.

METHOD OF ANALYSIS

For the purpose of this analysis based on the data set obtained and in establishing the relationship between the dependent and the independent variable, we shall be using the SPSS statistical soft ware which is more reliable and computationally efficient in achieving the desired results for Table1 and Table2.

RESULTS AND DISCUSSION

a) Conventional Constuction

Descriptive Statistics			
	Mean	Std. Deviation	N
HOUSE TYPE	2.5000	1.29099	4
CONSTRUCTION TIME(MONTH/UNIT)	7.5500	.88882	4
CONSTRUCTION COST(MILLION DOLLARS/UNIT)	1.7300	.65823	4
CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT)	1.8900	.22015	4

b) Precast Concrete

Descriptive Statistics			
	Mean	Std. Deviation	N
HOUSE TYPE	2.5000	1.29099	4
CONSTRUCTION TIME(MONTH/UNIT)	4.1750	.71356	4

CONSTRUCTION COST(MILLION DOLLARS/UNIT)	2.6250	.75084	4
CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT)	1.0450	.18009	4

The result above indicates the various spread out of the values in Table1 and Table2 are around their mean which shows the volatility and the risk in considering the independent variables in the project.
This information will serve as an intervention and a guide for decision and policy making in urban and regional development as well as real estate investment.

c) Conventional Construction

Correlations					
		HOUSE TYPE	CONSTRUCTION TIME(MONTH/UNIT)	CONSTRUCTION COST(MILLION DOLLARS/UNIT)	CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT)
Pearson Correlation	HOUSE TYPE	1.000	-.930	-.992	-.927
	CONSTRUCTION TIME(MONTH/UNIT)	-.930	1.000	.918	1.000
	CONSTRUCTION COST(MILLION DOLLARS/UNIT)	-.992	.918	1.000	.915
	CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT)	-.927	1.000	.915	1.000
Sig. (1-tailed)	HOUSE TYPE	.	.035	.004	.037
	CONSTRUCTION TIME(MONTH/UNIT)	.035	.	.041	.000
	CONSTRUCTION COST(MILLION DOLLARS/UNIT)	.004	.041	.	.043
	CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT)	.037	.000	.043	.
	HOUSE TYPE	4	4	4	4

N	CONSTRUCTION TIME(MONTH/UNIT)	4	4	4	4
	CONSTRUCTION COST(MILLION DOLLARS/UNIT)	4	4	4	4
	CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT)	4	4	4	4

d) Precast Casting

Correlations					
		HOUSE TYPE	CONSTRUCTION TIME(MONTH/UNIT)	CONSTRUCTION COST(MILLION DOLLARS/UNIT)	CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT)
Pearson Correlation	HOUSE TYPE	1.000	-.959	-.904	-.961
	CONSTRUCTION TIME(MONTH/UNIT)	-.959	1.000	.988	1.000
	CONSTRUCTION COST(MILLION DOLLARS/UNIT)	-.904	.988	1.000	.987
	CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT)	-.961	1.000	.987	1.000
Sig. (1-tailed)	HOUSE TYPE	.	.021	.048	.020
	CONSTRUCTION TIME(MONTH/UNIT)	.021	.	.006	.000
	CONSTRUCTION COST(MILLION DOLLARS/UNIT)	.048	.006	.	.006
	CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT)	.020	.000	.006	.
N	HOUSE TYPE	4	4	4	4
	CONSTRUCTION TIME(MONTH/UNIT)	4	4	4	4
	CONSTRUCTION COST(MILLION DOLLARS/UNIT)	4	4	4	4

	CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT)	4	4	4	4

The pearson correlation coefficients shows the various strength of the relationship between the dependent and the independent variables which are well defined in the conventional construction and the precast method of the first contractor.

e) Conventional Construction

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.993[a]	.987	.961	.25460	.987	38.069	2	1	.114

a. Predictors: (Constant), CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT), CONSTRUCTION COST(MILLION DOLLARS/UNIT)

b. Dependent Variable: HOUSE TYPE

f) Precast Concrete

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	1.000[a]	.999	.997	.06819	.999	537.108	2	1	.030

a. Predictors: (Constant), CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT), CONSTRUCTION COST(MILLION DOLLARS/UNIT)

b. Dependent Variable: HOUSE TYPE

The model summary result shows the various percentage variation of the independent variables on the house type using conventional construction method and precast concrete.

g) Conventional Construction

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.779	2.286		2.966	.207
	CONSTRUCTION COST(MILLION DOLLARS/UNIT)	-1.741	.553	-.888	-3.149	.196
	CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT)	-.670	1.653	-.114	-.405	.755
a. Dependent Variable: HOUSE TYPE						

h) Precast Concrete

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	14.703	.599		24.547	.026
	CONSTRUCTION COST(MILLION DOLLARS/UNIT)	2.987	.330	1.737	9.061	.070
	CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT)	-19.181	1.374	-2.676	-13.955	.046
a. Dependent Variable: HOUSE TYPE						

From the result obtained here, the various estimators obtained can be used to build a model equation for the two independent variable X1 and X3 in house type construction using conventional method and precast concrete.

i) Conventional Construction

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.935	2	2.468	38.069	.114[b]
	Residual	.065	1	.065		
	Total	5.000	3			
a. Dependent Variable: HOUSE TYPE						
b. Predictors: (Constant), CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT), CONSTRUCTION COST(MILLION DOLLARS/UNIT)						

j) Precast Casting

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.995	2	2.498	537.108	.030[b]
	Residual	.005	1	.005		
	Total	5.000	3			
a. Dependent Variable: HOUSE TYPE						
b. Predictors: (Constant), CONSTRUCTION TIME/NUMBEROF TEAMS(MONTH/UNIT), CONSTRUCTION COST(MILLION DOLLARS/UNIT)						

The results obtained here shows that the two independent variables X1 and X3 are good predictors for the construction of the house type using conventional method and precast method.

CONCLUSION AND CONTRIBUTION TO KNOWLEDGE

In the consideration for construction contracting in housing development, in-depth analysis and feasibility studies of this nature should be carried out on various contractors for both precast concrete method and conventional construction method to ascertain volatility, risk assessment and other vital factors which our results have clearly shown as it will serve as a guide in policy and decision making in urban and regional planning and most importantly in the real estate investment.

RECOMMENDATION

This detailed and in-depth analysis shall be applied to the other contractors for both conventional and precast construction method which will be a basis for consideration of construction contracting method in housing development project

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