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An Alternative Methodology to Obtain Quantity Takeoff by Using Linear Regression Techniques

By Yong Shi, CCP

Introduction

Quantity takeoff (QTO) is one of the most important and time-consuming activities in the construction process. Undoubtedly, each estimate should highly depend on the accurate quantity takeoff. Conventionally, QTO is performed by quantity surveyors who determine the necessary quantities based on 2D drawings manually from paper drawings or using quantity surveying software. The tasks are known as very time consuming, laborious and are always prone to errors.

Different from the traditional methods based on 2D drawings, this paper will investigate an alternative methodology to obtain QTO by using the linear regression model. Statistical methodology is widely used in the cost estimate [1-3]. In this study, the Partition was selected as the dependent variable to be investigated as a function of the independent variable GFA by using linear regression techniques

Data Description

The data base was collected from a condo project recently developed in Honolulu with its net GFA around 600,000 SF, with 8 floors and total 207 residential units. Instead of the traditional time-consuming method, a statistical methodology applied on the collection of QTO would be investigated in this paper.

The relationship between partition footprint length and GFA would be studied by using the regression techniques. Besides the total data base, a small portion of the data base was conducted by the regression model and then the regression results were inversely used to predict the total quantity. Obviously, it would be time-saving through this way comparing to that of the traditional method. Hence, two groups of samples, 10% and 20% of the total data base corresponding to 20 and 40 sets of data respectively, were randomly selected to be analyzed by the regression techniques. **Table 1** displays the descriptive statistics on the 20, 40 samples and total data base.

Correlation

The scatter plot of Partition versus GFA for 20, 40 and total samples is thus shown in **Figure 1** (a), (b) and (c), respectively. Obviously, it is indicated that a strong linear relationship would exist between Partition and GFA from the scatter plots. **Table 2** shows their correlation coefficient (ρ). It is found that all correlation coefficients are 0.98 which it is very close to "1" indicating that there is significant positive linear relationship between Partition and GFA. Based on the correlation results, a linear regression model would be undertaken for 20, 40 and total samples.

Regression Model

The high correlation observed in **Figure 1** strongly indicates that a linear regression would be an appropriate way of modelling Partition versus GFA. A simple linear model is developed by taking Partition as the dependent variable (Y) and GFA as the independent variable (X) shown in Eq. (1), $Y=\beta_1 X$, considering the fact that Partition quantity (Y) should be zero when GFA (X) goes to zero. **Table 3** shows the results of the linear regression analysis.

Model Diagnosis

Goodness of Fit. **Table 3** shows $R^2=0.99$ which means that 99% of the total variation in the dependent variable Y (Partition) is explained by the independent variable X (GFA) through the linear model Eq. (1). Therefore, it is concluded that Partition quantity could be predicted by the linear Eq. (1) with GFA as the input variable.

Test of Hypotheses. The output of the regression analysis in Excel produces t-statistic and p-value as displayed in **Table 3**. The p-value

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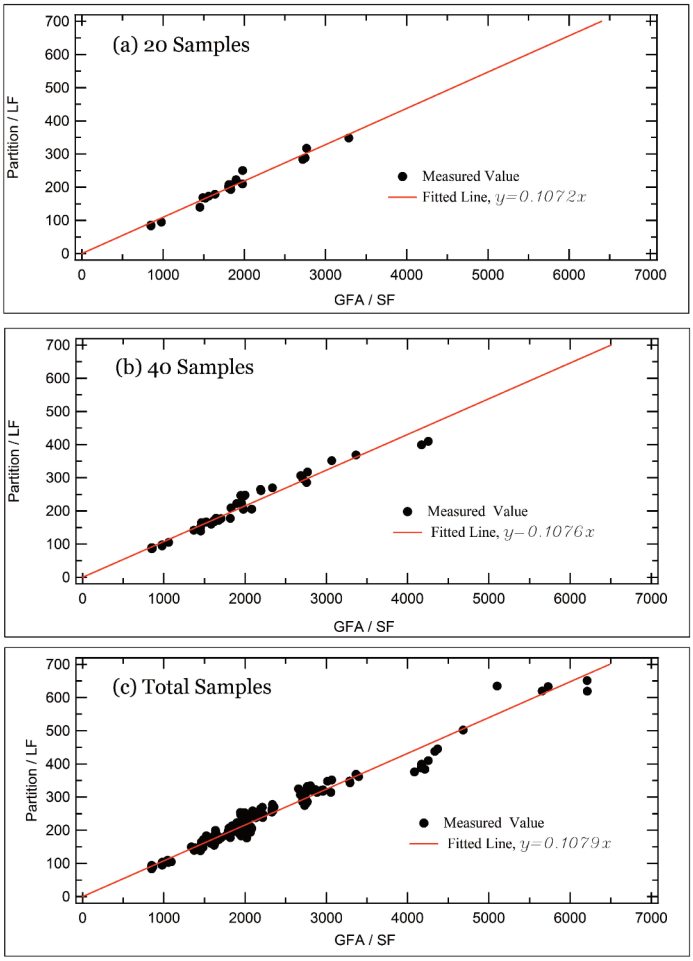

Figure 1: Scatter plot of Partition versus GFA for (a) 20 samples, (b) 40 samples and (c) total samples and the fitted lines.

	Partition (LF)			GFA (SF)		
	20 Samples	40 Samples	Total data (207 sets)	20 Samples	40 Samples	Total data (207 sets)
Average	201	205	228	1,841	1,900	2,100
Median	200	178	207	1,810	1,761	1,947
Minimum	83	86	83	850	850	850
Maximum	348	410	651	3,286	4,254	6,211
Total	4,022	8,219	47,193	36,810	76,009	434,677

Table 1: Descriptive statistics on 20, 40 and total samples.

	Correlation Coefficient (ρ)
20 Samples	0.98
40 Samples	0.98
Total Samples (207 Samples)	0.98

Table 2: Correlation coefficient of 20, 40 and total samples.

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3D metal printer arrives to College of Engineering through partnership with Pearl Harbor Naval Shipyard

Thanks to a partnership with the Pearl Harbor Naval Shipyard & Intermediate Maintenance Facility (PHNS), students and faculty in the College of Engineering at the University of Hawai'i at Mānoa will soon have a state-of-the-art 3D metal printer at their fingertips. The College of Engineering and PHNS will jointly utilize the Markforged Metal X 3D printer, valued at roughly $250,000 and purchased by Naval Sea Systems Command, for educational and research purposes.

In 2018, the two parties entered into a 3-year Education Partnership Agreement, allowing both organizations to collaborate on projects of mutual interest. The partnership kicked off with the development of a student internship course, currently run as one section of Mechanical Engineering (ME) 491, which allowed students to build real-world engineering experience by tackling real projects alongside professionals at PHNS as mentors. During the development of the course, the idea of obtaining the printer for everyone's benefit was floated, and after continued discussion, a plan was put in place to make it a reality.

Once in operation, the machine will be able to service a variety of needs for both organizations. PHNS personnel will be able to manufacture replacement parts, especially those that have long lead times or are obsolete, such as metal flanges, valves, brackets, and filter housings. Engineering students and faculty will be able to fabricate custom small metal parts for research and components for senior design projects.

"This new 3D metal printer will greatly expand our current collective 3D printing capabilities and design space that will create more opportunities for the College that currently do not exist," said Dr. Marvin Young, Adjunct Professor in the Mechanical Engineering department.

For PHNS, the collaboration will allow their personnel to develop new technologies for greater efficiencies at the facility, all while accessing a significant knowledge base through interaction with engineering faculty and students.

The printer will be housed at UH in the Engineering Machine Shop and will be fully operational at the beginning of the Fall 2020 semester.

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To watch Zoom meeting visit YouTube Link *https://www.youtube.com/watch?v=sWi61BG_i1g&t*

EAH held its first Zoom Meeting June 26,2020

Topic: Subterranean Robot Challenge DARPA

Speaker: Yun Chang, MIT Student

Yun Chang is part of the CoStar team winning 1st place in a DARPA (Defense Advanced Research Projects Agency) Subterranean Robot Challenge. The DARPA Subterranean (SubT) Challenge aims to develop innovative technologies that would augment operations underground. The SubT Challenge will explore new approaches to rapidly map, navigate, search, and exploit complex underground environments, including human-made tunnel systems, urban underground, and natural cave networks.

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The 2020 Joint Western & Mountain Districts Annual Meeting was a great success! A big thank you to our sponsors, exhibitors, speakers, volunteers, and attendees. We had over 600 registered attendees with most of our sessions attended by over 200 people. The Technical Compendium has been posted to the Western District website (*https://westernite.org/annual-meetings*).

The next section meeting is TBD. If you would like to be added to the ITE mailing list, please email Jasmine Teramae-Kaehuaea at *jkaehuaea@atahawaii.com.*

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Local Engineer Receives Prestigious Honor

The National Society of Professional Engineers (NSPE) has named Michael Silva, P.E., L.S., from Kula, Maui, Hawaii, to its 2020 class of Fellow members. The Fellow membership grade honors those active NSPE members who have demonstrated exemplary and devoted service to their profession, their Society, and their community. Since its establishment in the year 2000, slightly more than one percent of all NSPE members have advanced to this highest volunteer membership rank.

"Being recognized for your service to the engineering profession, your successful career, and your involvement in NSPE is a great honor and no small feat, especially when that honor is bestowed by your peers," said Amy Barrett, P.E., F.NSPE, the chairman of the executive committee of the Council of Fellows. "We are proud of this year's Fellows and their accomplishments and look forward to more great contributions from them in the future."

Among his peers, Silva is renowned for a dedication to engineering excellence that promotes the conservation and responsible use of soil and water resources. He is often requested to lead public and private sector commissions and service organizations aimed at planning for future infrastructure for Maui County. Currently, he is chairman of both the Maui County Public Works Commission and the Central Maui Soil and Water Conservation District. He also serves as president of the Hawaii Association of Conservation Districts while also representing Maui on the association board.

Silva is equally involved in Society activities, having been president of both the Hawaii Society of Professional Engineers and its Maui Chapter and continuing to serve on their executive committees. He promotes engineering scholarships at the local level and helps facilitate MATHCOUNTS competition. And since 2004, he has volunteered in the Maui Chapter's Career Shadowing Program and Math Matters Program. At the national level, Silva serves as Secretary/Treasurer for NSPE Western and Pacific Region (WPR), serves as HSPE's representative to the NSPE WPR, and represents Hawaii in the NSPE House of Delegates. He also served on the NSPE Candidate Screening Committee and has been an active participant at NSPE Professional Engineer Conferences nationwide.

Through his employment at Fukumoto Engineering Inc., Silva has distinguished himself as both vice president and project manager, having responsible charge of a number of key engineering and land surveying projects in Maui, Hawaii. These include state and county sewerage and water system improvements, roadway systems, public transportation facilities, and private resort site and utility improvements. Within his community, Silva serves on the board of directors for the J. Walter Cameron Community Center and the Maui Fair Alliance. In 2012, he was accepted into the Ka Ipu Kukui Fellow Program in recognition of his young leadership.

The National Society of Professional Engineers is a member-centric, nimble, future-focused, and responsive organization, serving as the recognized voice and advocate of licensed Professional Engineers. Through education, licensure advocacy, leadership training, multidisciplinary networking, and outreach, NSPE enhances the image of its members and their ability to ethically and professionally practice engineering. Founded in 1934, NSPE serves more than 23,000 members and the public through 52 state and territorial societies and over 400 chapters. For more information, please visit www.nspe.org.

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SEAOH Annual Convention

The 2020 SEAOH convention has been cancelled over COVID-19 concerns. SEAOH is considering partnering with another organization on a hybrid event with in-person sessions and on-line technical presentations in October 2020. More information to follow.

Next Meeting on August 5, 2020. For information, contact SEAOH President Danny Fujioka.

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An Alternative Methodology,
continued from Page 1

shown as "approximately zero" indicates the very strong evidence against null hypothesis and in favor of alternative hypothesis. In other words, the independent variable (GFA) is a statistically significant predictor of the dependent variable (Partition).

Model Prediction and Discussion

Based on the discussion above, the linear regression model shown in Eq. (1) has been statistically verified to describe the relationship between Partition and GFA. Therefore, we would use this equation to predict the total Partition quantity with GFA as the input variable and then compare the predicted value with the "true" value measured manually.

Table 4 shows the predicted value calculated by Eq. (1) with three different linear parameters obtained by the regression analysis on 20, 40 and total samples. Total GFA is the sum of GFA for all units while the corresponding total Partition quantity is the sum of all unit Partition quantity. In this study, the measured total Partition quantity is considered as "true" value in order to compare to the predicted value. Therefore, each of regression parameter is used to calculate the total Partition by Eq. (1). Three fitted linear equations given in **Table 4** for three sets of data are used to calculate the Partition value with the total GFA as the input variable. The error and relative error between the predicted and "true" value are thus deducted as shown in **Table 4**. It is observed that the relative errors on the total Partition value predicted by that of 20, 40 and total samples are 1.26%, 0.87% and 0.57%, respectively.

Furthermore, the next challenge is to evaluate the error of the final cost estimate caused by the error of the predicted takeoff quantity. Mathematically, it would be simply calculated by multiplying the predicted quantity error with the percentage of that item cost over the total cost. Taking this condo project as an example, the Partition cost would take around 5% of the total project cost. Therefore, 1.26% relative error of the predicted value under the 20-sample case would lead to around 0.063% relative error of the total estimate cost.

Conclusion

This paper presents an alternative methodology to obtain the quantity takeoff (QTO) by using the regression techniques which different from the conventional taking-off methods. In order to illustrate this methodology, this paper investigated the relationship between Partition quantity and Gross Floor Area (GFA) on a typical condo project by applying the linear regression model. Only small portion of the total data was randomly collected to be conducted by the linear regression analysis and the resulted linear coefficients were inversely used to predict the total Partition quantity with the total GFA as the input variable. The errors between the predicted values with that of "true" values obtained from the manually taking-off method were discussed. Based on the results, it could be concluded that this methodology would provide an alternative choice for quantity surveyors to perform QTO with less time-consuming comparing to that of conventional methods, and also conduct the quick QTO-checking in order to avoid human errors.

References:

1. Steven M. Trost and Garold D. Oberlender, 2003, Predicting Accuracy of Early Cost Estimates Using Factor Analysis and Multivariate Regression, **Journal of Construction Engineering and Management,** Vol 129, Pages 198-204.
2. Trefor P. Williams, 2003, Predicting Final Cost for Competitively Bid Construction Projects Using Regression Models, **International Journal of Project Management,** Vol 21, Pages 593-599.
3. Robert A Mckim, 1999, Statistical Bidding Models, **Cost Engineering,** Vol 41, Pages 40-44.

	Parameter estimate (β_1)	Standard error (σ)	Coefficient of determination (R^2)	t-statistic	P-value
20 samples	0.1072	0.0020	0.99	75	≈ 0
40 samples	0.1076	0.0014	0.99	75	≈ 0
Total samples (207 samples)	0.1079	0.0006	0.99	178	≈ 0

Table 3: Results of linear regression analysis on 20, 40 and total samples.

	Total GFA (SF)	Total Partition (LF)	
Measured Value	434,677	47,193	
	20 Samples	**40 Samples**	**Total Samples**
Fitted Linear Equation	$Y = 0.1072X$	$Y = 0.1076X$	$Y = 0.1079X$
Predicted Partition	46,597	46,782	46,922
Error	595	411	271
Relative Error	1.26%	0.87%	0.57%

Table 4: Predicted value by the case of 20, 40 and total samples.

About the author: Yong Shi, a graduate of University of Hawaii at Manoa with a master degree in Civil and Environmental Engineering (CEE), and accredited as a Certified Cost Professional (CCP). Mr. Yong Shi is a Senior Cost Manager at Rider Levett Bucknall (RLB) Honolulu, who has had over 10 years of career experiences in the field of construction cost management. Currently, he serves as the Director of Social Media of AACE Hawaii.

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Next meeting: August 6, 2020

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The continued health and safety of our membership is our top priority and we will continue to monitor the COVID-19 pandemic. Future ASCE Hawaii events, including our section dinner meetings, are still temporarily on hold. We will keep you informed via e-blasts and/or notices posted on our website at ascehawaii.org when they will be scheduled. Please continue to stay safe, watch out for each other, especially our kupuna, and continue to be vigilant about best health practices.

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