Variation Prognostic Model on Port Infrastructures: Employment of Principal Component Analysis for Factor Extraction Instigating Disparity on Planning and Implementation Phase

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Abstract. Port is a transportation and communication marine infrastructure that is established for ship berthing and dockage, loading and unloading of passenger, storage of goods and other operational agendas that would impact a region or country in terms of social and economic aspects. Variation order is the modification on the design whilst construction is on-going. This is inevitable in a project. Through the utilization of Principal Component Analysis with a Cronbach’s Alpha of 0.930 and Kaiser-Meyer-Olkin Value of 0.763, nine components weighted, these are Actual Concreting and Precasting on-site for Structure formation, Meteorological Conditioning affecting Weather and Tides, Test Pile Apportionment on Both design and construction, Off-shore soil in-situ Properties, Behaviour and Suitability on fills, Inaccuracy of Geotechnical, Topographical and Hydrographical surveys, Project Release and Initiation Timing on engineering departments, Sudden unforeseen Turbulences during Pile Driving, Coordination of Planning and Implementation Departments, and Unavailability of Material Specification to Actual site from design. After extracting the regressor, assessment of completed port projects with variation and multiple linear regression was then employed to generate the model. The model had an $R^2$ of 0.777 and an $R$ of 0.882. Finally, the model was evaluated and has shown a significant value. Hence, a satisfactory breakthrough in an attempt to develop a model regarding variation order on port projects was established.

Index terms: Port, Design and construction variation, Project management, Statistical model, Principal Component Analysis.

1. Introduction
Port design and construction engineering is not an ordinary methodology. Design considerations and foundation procedurals are dependent on the morphological, geotechnical, and sea level assessment of the probable area. Planners and designers have to conduct a site visit, topographical and hydrographical survey, geotechnical assessment of both the offshore and inland area that are to be affected and lastly the social, economic and environmental need for structuring or improvement of a port. A port foundation is commonly created through pile driving or reclamation. Variation order
occurs when there is a change of scope or change of work in the planned and designed port improvement or port expansion. Change is inevitable. Hence, this research was intended to provide a linear model and paradigm that could evaluate and approximately predict the percent variation of a port project. The percent variation that the researcher is pertaining is simply the quotient of the variation order amount over the project’s final cost, wherein the variation order amount is the difference of the actual cost of implementation and the projected cost. Principal Component Analysis is a statistical method that was utilized for highlighting and showing off strong patterns of set of data. This statistical procedure is usually employed in empirical data analysis and generation of predictive models. The eigenvalues, extraction, communality and factor loadings was analysed to weigh in the significant factors that will be beneficial for the model generation. The model generation will be done thru multiple linear regression and shall be evaluated.

2. Port projects’ variation order on financial cost and delays
Construction management in port and harbour is not a common field in engineering. Nearly all construction projects not only the port type one, would be expected to differentiate from the plan, scope and definition. From analysis, it revealed that the lower the project cost is, the higher in percentage was the variation order and it seemingly presented an approximately indifferent disperse in both negative and positive ways. Additionally, the R2 of the points below is 0.0075 which is close to zero, stating that there is no clear and direct relation between the two variables. The main implication it can tell is that at any amount of project, variation order is still existent and unavoidable. Since percent variation formula is derivative from the cost itself, then a higher variation order would mean that a larger final project cost will come out and that has no argument already. Evidently, the hypothesis of W. Smith [1] that the amount of variations indeed affects the magnitude of the cost under/overruns was also proven in his study. Majority of construction contracts gives space to the extension of construction period or duration. This is simply called as an extension of time. Variations may but not necessary affects directly to durations. According to the data gathered and its scatter plot, the variation order has no direct effect on the project delays, even project with minimal to almost no variation order experiences project delays, and they are of varying timeframe. Having a coefficient of correlation of -0.264 and a coefficient of determination of 0.07 or close to zero, delays and variation order has no affect with each other. Thus it would be suggested to further investigate the two variables’ influence and effect to each other.

3. Validation, demographics and principal component analysis
Out of 53 factors, 40 factors had passed the content validation. The Cronbach’s Alpha was achieved with a value of 0.907 for pilot test and 0.930 for the final instrument used which clearly signifies that the instrument is strong and is suitable for PCA. The Kaiser-Meyer-Olkin and Bartlett’s Test of Sphericity are intended to check the sampling adequacy if it is fit for principal component analysis utilization. An assessment close to 1.00 shows that configurations of correlation are comparatively intact. On the other hand, studies suggests that the Kaiser-Meyer-Olkin value should not be less than 0.50 to state the adequacy of sample size [2]. KMO of the Variation Factor Assessment on Port Projects had sustained a good value of 0.763 and the Bartlett’s test was significant too based on level of confidence of 0.05 implying that it was an identity matrix. The respondents that participated in this survey had significant working experience in both design and construction phase of a port project, which are significantly port engineering professionals. Principal Component Analysis starts by recognizing a group of variables in which its variance in accordance to the researcher’s objective judgment could be embodied further significantly through a lesser group of factors or components. Hence, the outcome of PCA displays what variables may be characterized by which components, and which variables shall stay as individual variables due to inadequate representation of their information by the factor solution. The average communality of factors upon exception was 0.751 by which the conventional applicable standards about communality values is an extraction value of not less than 0.50 in first iteration. Rotation proposes the characteristic
of the variables which are in extreme behaviour and brings out the maximum potential of the bearing of every factor on one of the extracted variables whilst reducing the bearing on the entire remaining factors. Varimax is the most accepted rotation that is being utilized for factor analysis, at most. In varimax, a basic solution implies that every variable is composed of a fewer amount of heavy bearings and a huge number of zero or minor bearings. Furthermore, the factors may frequently be construed from the disagreement of less variables with positive loadings to less variables with negative loadings [3]. To create significant components and avoid the complexity, the final factor loading is set to 0.7 (table 1).

| Comp. 1 | Comp. 2 | Comp. 3 | Comp. 4 | Comp. 5 | Comp. 6 | Comp. 7 | Comp. 8 | Comp. 9 |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| (37) .83 | (16) .88 | (21) .84 | (31) .84 | (9) .79 | (7) .75 | (26) .79 | (8) .79 | (4) .74 |
| (39) .79 | (17) .87 | (22) .78 | (32) .77 | (5) .75 | (27) .74 |         |         |         |
| (35) .76 | (15) .76 |         |         |         |         |         |         |         |
| (36) .70 | (18) .70 |         |         |         |         |         |         |         |

4. Extracted Factors

Actual Concreting and Precasting On-site for Structure Formation (ACPS) is the first component that was generated, consisted of four variables carrying a factor loadings of above set standards which are incorrect selection of type of formworks to be used (82.8%), corrosion of reinforcement (79.1%), type of concrete pouring (75.8%), and cold-joints on precast (70.4%). Concreting procedural is an integrated part in all type of civil engineering structuring, port areas are mostly constructed using concrete and precasting, for beams, decks, slab, RoRo ramps and other integral parts of a port. Meteorological Conditioning Affecting Weather and Tides (MCWT) is a formed component consisted also of four variables which are calamities such as typhoons (88.3%), sudden climate changes in area (86.5%), changes in sea or tidal waves (76.4%), and changes in sea level or elevation itself (70.1%). Since port is an offshore structure, civil engineering methodologies are much more taken care of in this specialized area of a project as compared to vertical structures. Tidal settings and elevations are easily affected on changes of weather and so it is evidently certain that the said group of factor will cause a variation order. A study regarding causes of variation order conducted also signified that weather conditions are top factors that causes variation order in construction projects, which was agreed by the consultant and contractor itself [4]. Test Pile Apportionment on Both Design and Construction (TPAB) is a component composed of two variables only that relates solely to test pile only, which are no assigned test pile on design plans (83.5%) and no test prior driven prior to construction (78.4%). Test pile is very significant prior to final driving of pile in actual implementation. In this way, an adjustment can be proposed prior to final purchase up to drive of the set of piles. The pile testing is to examine such flaws in both pile and mistakes in bedrock projection from surveys before turbulence must exist on the final pile driving. Off-shore Soil In-situ Properties, Behaviour and Suitability on Fills (OPBS) is a component having also two variables that has a loading of greater than 0.7, these are instability of soil strata underneath water (83.9%) and not suitable rock and sand and gravel fill for the soil (76.9%). These properties are being collected from a subsoil investigation or geotechnical investigation. This investigation shall be executed to find description for characteristics, natural properties, load bearing capacity and settlement capacity of the soil before designing of pile or reclamation rock, gravel and selected fills. Inaccuracy of Geotechnical, Topographical and Hydrographical Surveys (IGTH) has a factor loading of 79%, geotechnical surveys are much needed for pile type projects which shall determine the maximum elevation by which the bedrock will be reached, this is the basis of the designer to determine the applicable length and bearing capacity of a pile shall be specified. Hydrographical survey is like a topographical surveys wherein it shows the contour and elevation of the oceanographic surface and as well as the in-land part. From here the area of the proposed project will be assigned, elevations with less disparities at every
horizontal proximity is better. Since these surveys are highly needed and highly studied for basis of design, an error or inaccuracy with the actual would mean it will largely affect the designated pile lengths or fill volumes. Project Release and Initiation Timing on Engineering Departments (PRIT) is a component pertaining to construction management technicalities and not to port structuring itself, it contained two variables which are overlapping of projects (75%) wherein new projects were to be implemented while some are still on-going on the said port and rush projects in both department occurs (74.8%). Although if to look at it objectively, it is not merely dependent or pin-pointed to the departments per se, it’s just that the frequency, distribution and timing of port project for initiation are at times not in balance based on the merging of the two factor. A previous study had shown also that part of variation order consequences is project time pressure which can synonymously pertain to this component [5]. Sudden Unforeseen Turbulences during Pile Driving (STPD) is a component regarding unexpected instances or trouble that happens on the site itself during driving and pitching of pile which are crane/barge movement when driving affecting misplacement of pile (79%) and pile breakage when driving (74%). Crane/barge movement of the pile driver could affect the bearing capacity to be transferred to the pile and possibly misplace or misalign the positioning of pile if encountered, the movement is majorly caused by the waves of sea but can sometimes be affected by the gravity of the barge, pile and machine itself. There are also times in construction site where excessive strength in driving of pile happens thus resulting to a significant breakage or damage to pile. Hence, these damages will count for variation order. Coordination of Planning and Implementation Departments (CPID) has a 0.7 factor loading and it was entitled by the factor alone itself already which is coordination of the two engineering departments responsible for the port projects (78.9%). The coordination of the two department will be seen only during a project commencement if there is a variation order occurrences that will to alter the design to fit for the actual conditions. This was somehow showed in a study previously, that reasons for variation order are disputes between management parties, conflicts on projects and lack of value engineering or merely the coordination and unambiguity between the two significant department [6]. Unavailability of Material Specification to Actual Site from Design (UMSA) pertains to material specification unavailability in the actual construction (74.3%), both in the pileworks and reclamation activity in constructing a port, this issue may arise. This could be tedious in the part of the designer since a pile’s change in cross-sectional area would also mean a modification on a bearing capacity and thus a new plan for pile layout as well, evidently will account for a variation order. In terms of reclamation, armour rocks and core rocks sizes and quality differ from the designated versus the actual available.

5. Variation Prognostic Model
Through assessment of completed port projects with variation order. A model generation has been initiated thry multiple linear regression. All factors was tested and has significantly above zero \( R^2 \) and adjusted \( R^2 \) which signifies its positive correlation to the independent variable and thus, all is accepted for final modelling. Multiple regression permits to establish the overall fitness. It is probable to determine true parametric values in factor analysis with Likert scale data, if presumptions on skewness, and amount of classifications were satisfied [7]. The generated variation prognostic model has a coefficient of determination of 0.777 and adjusted value of it at 0.677 and coefficient of correlation of 0.882. There is also an indication that the generated prognostic model from the extracted components predicts the dependent variable significantly well with \( F(9,20) = 4.830, p < .000074 \) which shows overall that variation prognostic model scientifically forecasts the outcome percent disparity and displays significant fitness for the gathered data. Below is the model generated based on multiple linear regression utilizing the nine emerging factors from the Principal Component Analysis Extraction using beta coefficients.

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\text{% Var on Port Proj} = 0.112 \text{ACPS} + 0.172 \text{MCWT} - 0.115 \text{TPAB} + 0.464 \text{OPBS} + 0.252 \text{GTH} - 0.004 \text{PRIT} + 0.047 \text{STPD} + 0.157 \text{CPID} + 0.189 \text{UMSA}
\]
The model was evaluated using a different set of projects. Hence, the p-value is less than 0.05 wherein \( p<0.037 \) and is within the confidence interval level. It also signifies that the entire methodology used is a good fit for the type of study and can be re-done to other infras with regards to variation order. This is a breakthrough in employing factor analysis processes as regressor extraction for modelling percent variation order, which is a turmoil that cannot be avoided in all types of construction projects. Based on the paradigm on Figure 1., the variables that affect variation order can be categorized into five areas, this just simply illustrates the wide scope of a variation order since all aspects of a project will indeed affect the modification from the initial plan to the finality of the implementation. It can be stated that variation order is a complex thing to solve in construction industry but in anyways can be mitigated if turbulences could be deeply evaluated. The study is a different approach in dealing for variation order for the reason that it has attempted to quantify such. Previous literature had attempted to assess only qualitatively variation order in the sense that causes and effects were evaluated. In a deep matter, variation order is also a quantitative aspect, since each changes are clearly being felt by the cost of the project. The study opened a way for more profound evaluation of variation order in the path for it to be projected scientifically thru the use of Principal Component Analysis and Multiple Linear Regression.

**Figure 1. Variation Prognostic Paradigm on Port Infrastructures**

### 6. Conclusion
Considering all the input of the study, it is considered as an accomplishment to achieve the main objective which is to generate a model through utilization of Principal Component Analysis that will determine the percent variation of a port project between the design and construction phase. The other most extensive provision of the study is the revelation of the components and factors of such that influences variation order on port projects and the attempt to quantify it scientifically to provide approximation on projects. Granting that the statistical outcomes established on this research pertaining to variation orders, this paper is however capable as a reliable reference or guide in observing and investigating variation from the design phase and construction phase of any type of a
project, purposely moreover for a port structure. Nonetheless, the discovery and apprehension of such influential causative factors and scheming for contingencies and preclusion of the said obstructions prior to its occurrence can be beneficial and contributory to a project’s accomplishment and accuracy of its planning, design, scheduling and projected costing to its actual implementation, construction and financing of a port project.

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