analyzed with subjective measurements. On the contrary, an objective approach is used in this research. This study aims at exploring their contributions and interrelationship, and hence classifying and defining the project natures by using the factors devised. The proposed approach in defining building projects enables construction planners to distinguish the differences between building projects from the view of production processes and to improve resources allocation.

Key words: Characteristics of Projects, Complexity, Factor Analysis.

Introduction

With the scarcity of land supply, complex high-rise buildings are prevailing to cope with rapid population expansion in Hong Kong. In the Hong Kong's building market, composite developments have been becoming more popular, for which residential and commercial facilities are provided in a single development. The merge provides convenience for people to cope with the busy and dynamic life in Hong Kong, and becomes a special feature in housing development in the world. Consequently, different structural layouts have to be used for the upper and lower structures in order to meet the functional requirements. This induces new challenges for construction management and there are needs to identify the complexity of building projects to facilitate construction planning. This study attempts to explain a new approach in defining the characteristics and nature of building projects by using factor model derived by factor analysis. The analysis re-groups project data into meaningful factors and enables practitioners to differentiate natures of building projects from the view of production processes and to improve construction planning and resources allocation.

Multi-Function Building Developments

Multi-function building developments are known as composite developments in Hong Kong. The developments usually consist of large and deluxe commercial complex, shopping malls, car park, or resident clubhouses built underneath residential tower blocks. The arrangements have achieved two major objectives. Firstly, the composite developments are very welcomed by people in Hong Kong since it provides residents with necessary facilities and support for their daily life. This is a special living style in this small but dynamic metropolis. Secondly, the rent generated from commercial facilities provides attractive returns on investments. Hence, the composite developments maintain the cutting edge in the competitive property market from the mindset of developers. Figure 1 shows a typical arrangement for a composite development. The building structures can be divided into three major areas. They are podium floors, transfer plates and residential tower blocks. Generally, skeleton structures which can allow flexibility for space planning are used for podium structures. Shear walls and core walls structures which wind bracing, provide partitioning and fire protection requirements are used for residential tower blocks. Transfer plates are then constructed to separate and transfer the loadings of the residential tower blocks to the podium structures. In order to maximize rental returns, podium floors usually occupy nearly all the site area leaving limited space for contractors to set up site production facilities. Site production planning is becoming more complex. The characteristics of a building project may not be identified or defined easily with the multivariate project information.

Characteristics of Building Projects

It appears that "complexity of building project" has been used as the discussion point in construction management. Critical managerial decisions such as construction methods, staffing, mechanical plant allocation and site production layout planning are subject to the characteristics and nature of a project. However, complexity is an intangible perceptive different among people and regions (Pariff & Sanvido 1993). Project complexity has been observed and included in various researches. Chan and Kumaraswamy (1996) reported that project complexity has moderate significant on project delays. Baccarini (1996) commented that project time and project costs increase when project complexity increase. Santana (1990) had divided construction projects into three categories in terms of the scale of complexity measured from results of opinion surveys. Tam (1992) addressed that complexity of project is one of the six constituent variables in the discriminant function model for predicting contractor performance in Hong Kong. Chan (1995) opined that staffing is subject to the complexity of a project. Griffith and Sidewell (1995) stated that complexity of design is one of the factors affecting buildability. In studying project performance and project success, Chan (1997 and 2004) reported that project complexity is one of the project-related factors. However, it is difficult to measure project complexity and Baccarini (1996) commented that the study of project complexity has received little detailed attention. Generally, project duration and project costs or contract sum have been considered and used as indicators for project complexity. However, this may not be sufficient to describe modern multi-function building developments as explained above. Also, it is necessary to review the degrees of complexity from the perspective of production. Thus, the effects of working space and site conditions should also be included when defining project complexity. In this study, the characteristics of building projects are reviewed and studied by using factor analysis.

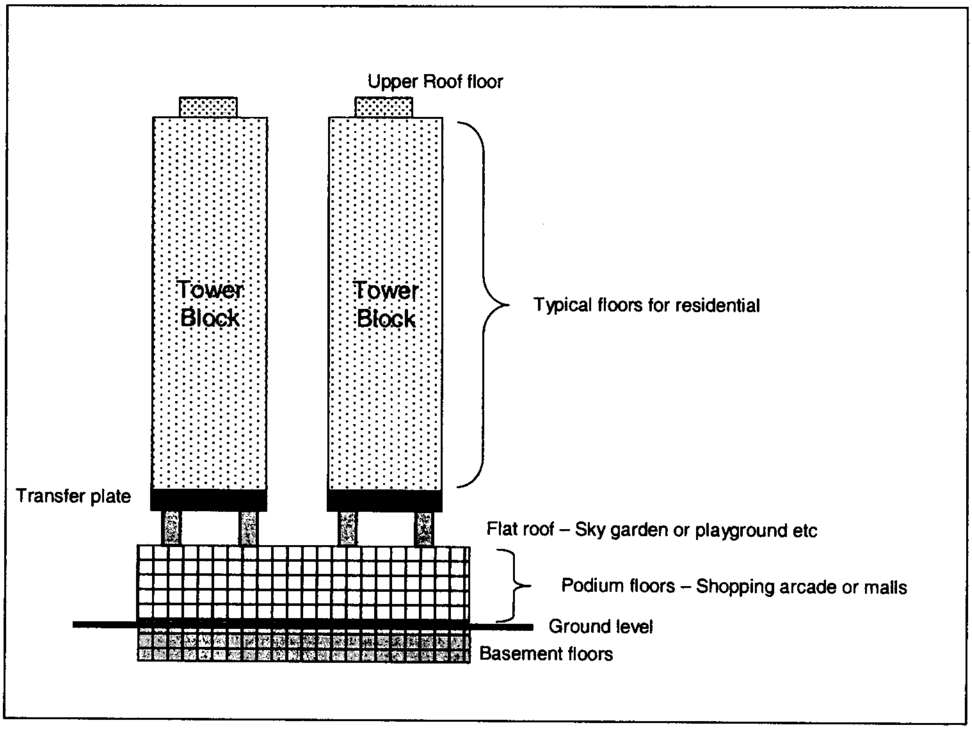

Figure 1 : A Typical Arrangement for Multi-function Development

Variables for Defining Project Characteristics

Time and cost are the basic and common variables used to define the nature, scope, characteristics and complexity of a project. It is no doubt that they are vital and critical factors in numerous studies about construction management. On the other hand, opinion surveys have been used to obtain and build up subjective scales to measure the degrees of complexity. On the contrary, an objective approach is used in this research. Six groups of factors including 35 variables are identified after interviews with practitioners and study on previous researches. This study aims at exploring their contributions and interrelationship, and hence classifying and defining the project characteristics and natures by using the factors devised. The variables identified are shown in Table 1. They are essential project information in relation to site production planning which can be extracted from contract documents, construction drawings and planning documents.

Table 1: Factors for Defining Project Characteristics

Data Group	Variable	Unit of Measurement
Basic Project Information	• Contract Duration • Contract Sum • Building Height • Number of Storey • Number of Buildings • Building Usage	• months • million of dollars • square meter • meter • number • Likert Scale (1-6)
Floor Area	• Total Floor Area • Basement Floor Area • Podium Floor Area • Transfer Plate Area • Total Typical floor area • Ground Floor Area • Area of Typical floor(s)	• All in Square meter and measured from construction drawings and site layout plans
Building Structure	• Form of Structures • Transfer Structure • Transfer Beam • Transfer Plate • Basement Level • Podium Floor Level • Number of Typical Floors	• Likert Scale (1-6) • Likert Scale (0,1 & 2) • Yes/No (1/0) • Yes/No (1/0) • number • number • number
Site Space	• Site Area • Working Space Area • Sloping Area • Access Length • Ratio of Working Space to Site Area • Ratio of Working Space to Tower Block Area • Ratio of Site Area to Tower block Area	• square meter • square meter • square meter • square meter • ratio • ratio • ratio
Contractual arrangement	• Contract Type • Client	• Likert Scale (1-2) • Likert Scale (1-3)
External environment	• Site Location • Site Entrance • Surrounding Road • Traffic Condition • Adjacent Building Structure • Adjacent Infrastructure	• Likert Scale (1-3) • number • number • Likert Scale (1-3) • number • number

Factor Analysis Model

3-Factor Model

Factor analysis is a data reduction technique to re-structure or reduce a pool of variables into meaningful "factors" representing a group of variables. It means that the relationships between the variables are explained by the factors which are usually fewer in the number than the original variables. The simplified factors can provide a better view or an overall picture for users to interpret their meanings and contributions on the subject matter in the study. The generalization of the factor model for deviation scores is shown below (Gorsuch 1983):

$$X_{iv} = w_{v1}F_{1i} + w_{v2}F_2 + + w_{v3}F_{3i} + \ldots + w_{vf}F_{fi} + w_{vu}U_{iv}$$

Where:

X_{iv} is individual *i's* score on variable v

i is the i^{th} element, i^{th} individual

v Number of variables

w_{vf} is the weight for variable v on factor f, the factor loadings

f number of factors

F_{1i} to F_{fi} are subject *i's* score on the f factor, (score of i individual on f factors)

w_{vu} is the weight given variable *v's* unique factor

u number of unique factors

U_{iv} is the individual *i*'s unique factor score for variable v

Table 2 : Factor Loading for the 3-Factor Model

Variables	**Factor Loading**		
	Factor 1	**Factor 2**	**Factor 3**
Podium Floor Area	0.886		
Transfer Plate Area	0.724		0.389
Site Area	0.698	0.632	
Total Floor Area	0.530	0.404	0.417
Podium Floor Level	0.308	-0.786	0.305
Working Space Area		0.754	
Access Length		0.727	
Number of Buildings	0.616	0.702	
Building Height			0.900
Number of Typical Floors			0.849
Contract Sum	0.557		0.601
Contract Duration			0.409

Notes: For clarity, loading with values smaller than 0.3 are not shown

30 project samples were collected for this study. After the compilation of the project data, four projects were excluded from the analysis as outliers since the scales of these projects were very small when being compared with other project samples. During the analysis, some of the variables, which had fewer contributions or were insignificant to the factor model, were removed from the analysis. A 3-Factor model consisting of 12 variables has been derived. The factor loadings which explain the contributions of the variables to the model are shown in Table 2.

Factor Meanings

The meanings of the factors can be interpreted with reference to the variables included and their factor loadings in the respective groups. The naming and meanings of the 3-Factor model for the multi-function projects are described below.

i) Work Quantity Factor (WQF) – This factor is dominated by floor areas to be constructed for a project. Also, the "Site Area" is also included. The "Podium Floor Area", which forms the unique feature of multi-function buildings, has the highest contribution of 0.886 to this factor. This affirms that the differences between the developments can be distinguished by the presence, extent and scope of podium floors. Similarly, the "Transfer Plate Area", which has been employed specifically for separating podium structures and residential tower blocks, is included with a high contribution of 0.724. The presence of the podium floors and transfer plates for a development usually implies that it is a large scale development. The "Total Floor Area", which describes the total floor areas to be constructed, has a moderate contribution of 0.53. This implies "Total Floor Area" is significant but is not the leading factor to describe the characteristic of a project. The "Site Area" describes the site space available for a development and is different from the other floor area variables in this factor. The variables included in this factor are able to differentiate the scale of building projects in terms of floor areas or site area thus can be named as "Work Quantity Factor".

ii) Site Layout Factor (SLF) – This factor includes variables affecting the layout of a building project. The contributions of the variables are high and are within a small range between 0.702 and 0.786 (using the absolute values). It is observed that "Podium Floor Level" has a negative loading. This explains the relationship between working space and the podium floor area. In Hong Kong, the total floor area to be constructed is governed by plot ratios, which is defined as the ratio between the total floor area and the site area. With reference to Figure 1, if the number of podium floor level of a development increases, either the floor area of each podium floor or the typical floor area decreases as to meet the plot ratio imposed for the project. In this case, if the working area decreases, the floor area for each podium floor increases and thus the podium floor levels decreases. Consequently, the "Podium Floor

Area" and the "Podium Floor Level" has opposite sign in their factor loading. Site planners have been aware of the distributions of working space which could affect the configuration and utilization of working space. In this connection, the inclusions of the "Access Length" and "Number of Buildings" are appropriate since the spread of working space can be explained by the layout of buildings and the "patterns" of the site access. However, it is noted that "Number of Buildings" also has a moderate contribution to the "Work Quantity Factor" since the total floor area to be constructed is highly correlated with the number of buildings to be constructed. The variables included in this factor are able to differentiate the working space and the building layout of building projects in terms of the site space related variables and thus this factor can be named as "Site Layout Factor".

iii) Building Height Factor (BHF) – The four variables included in this factor cope with findings for researches in relation to the prediction of project duration (Chan & Kumaraswamy 1995; Chan 1999). Bromilow (1969 & 1974) has set an exponential relationship between time and cost and is shown below.

$$\mathbf{T = KC^B}$$

where:

- T = the duration of the construction period from possession of site to practical completion, measured in working days;
- C = the final project cost in A$ million adjusted to a price index;
- K = a constant describing the general level of time performance is or an A$ one million project; and
- B = a constant describing how time performance is affected by project size as measured by cost.

Chan and Kumaraswamy (1995) have extended the relationship between project duration and number of stories adopting the approach developed by Bromilow.

$$\mathbf{T = FS^G}$$

Where:

- T = the duration of the construction period from possession of site to practical completion, measured in working days;
- S = the number of stories of a building
- F = a constant correspond to the K in Bromilow's formula
- G = a constant correspond to the B in Bromilow's formula

The inclusion of the four variables therefore affirms their relationships in previous studies. The "Contract Sum" has a moderate contribution to the "Work Quantity Factor" since project cost has strong relationship with floor area as illustrated by general practice in estimation. The "Building Height" and "Number of Typical

Floors" are similar and give indication about the height of a building. Since they are dominant variables in this factor and are able to differentiate the height of building projects; hence this factor can be named as "Building Height Factor".

Interpretation and Application of the Factor Model

Contributions of the Factors

The contributions of the factors in the 3-Factor model are shown in Table 3. The factor model can explain 71.06% of the variances of the project samples. It is interesting to note that the three factor groups have the same ability to explain the variances between the projects. In other words, all of them can provide useful information for planners.

Implications of Factor Scores on Construction Planning

In the factor analysis, factor scores are computed for each project case. In construction planning, planners can identify the characteristics of building projects by reviewing their factor scores. Figure 2 show the plots of factor scores for the project samples. It is shown that a project may have a high score on one factor but with a small score for the others as shown in Table 4. The differences between three project samples are explained in the following paragraphs.

Table 3: Percentage of Variance Explained by the 3-Factor Model

Factor	**Rotation Sums of Squared Loadings**	
	% of Variance	Cumulative %
Work Quantity Factor	24.99	24.99
Site Layout Factor	24.04	49.03
Building Height Factor	22.03	71.06

Table 4 : Factor Scores for Project Samples

Project Case	**Work Quantity Factor**	**Site Layout Factor**	**Building Height Factor**
1	2.505	-.554	.133
7	.644	-1.030	2.208
26	-1.400	2.541	1.216

1) Project Case 1 has a very high (highest in this example) WQF score and a low SLF score. This indicates that the work content is very high. In construction planning, planners have to consider the sufficiency of site supervisory staff to cope with the high work contents. The low SLF implies that this is a moderate confined site with restricted access; construction work may have to be separated

into several stages as to allow more working space for setting plant and machinery and maintaining the maneuverability of site access. On the other hand, traditional construction method can be applied since the BHF score shows that the project consists of typical high-rise buildings.

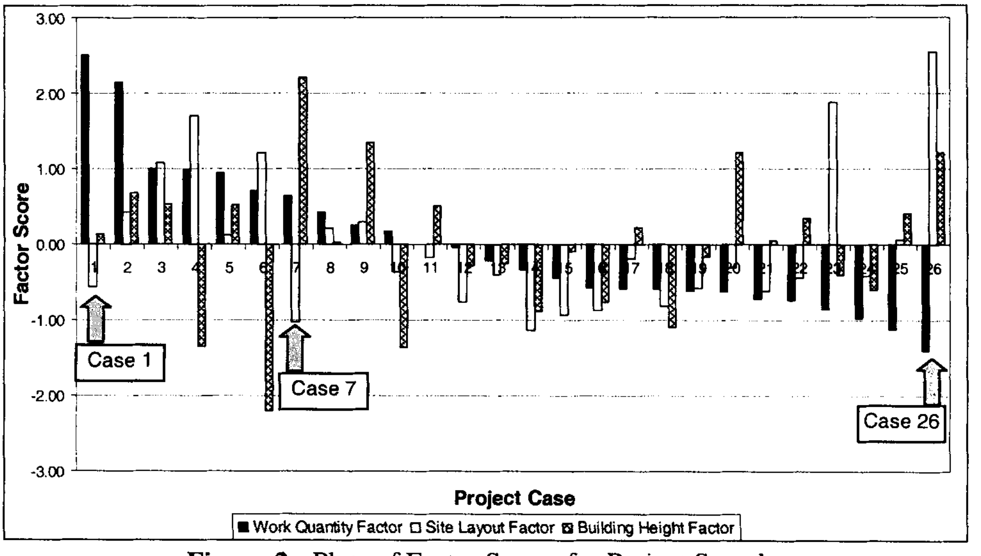

Figure 2 : Plots of Factor Scores for Project Samples

2) Project Case 7 has a very high (highest in this example) BHF score and a very low SLF score. This project consists of super high-rise buildings with very confined working space. Mechanized and standardized method of construction has to be considered to reduce congestion in site traffic and storage and achieve high productivity. In this case, the contractor had adopted prefabrication techniques to overcome the constraints.

3) Project Case 26 consists of buildings with building height approaching to super high-rise buildings and has a very high SLF (highest in this example). However, this is a relatively small project in terms of work contents as reflected in the WQF score. The large site space provides planners a high flexibility in site production planning. As the contract sum is relatively small, traditional construction methods such as traditional timber formwork system and concreting by using tower cranes and skips would be a better choice as to minimize construction costs.

The above illustrations demonstrate that factors scores are useful quantitative scale for assisting contractors in project planning. There is a potential to fine tune the factor model to cover different types of building projects and to explore further other potential variables to be included in the model.

Conclusion

This study has introduced an objective framework to define characteristics of building projects using factor analysis technique. A 3-Factor model with 12 variables has been derived. The factors derived are: the "Work Quantity Factor", "Site Layout Factor" and "Building Height Factor". The factor model is able to simplify the project information into a more coherent data structure and to differentiate the scale of building projects, working space and height of building. Planners can use the project factor scores to interpret the project characteristics and thus to assist in decision making for site production planning.

The factor model developed is based on project information extracted from project documents and construction drawings. This differs from subjective models generally used by previous studies. This avoids the use of traditional literary descriptions for comparing building projects such as, "complex", "large scale" and "tall building" etc. The 3-Factor model therefore provides simplified and unbiased information to users. The factor scores provide quantitative scale to measure the differences between building projects in the respective areas. The findings provide a strong foundation and support for the use of the factor scores in classifying building projects in future researches.

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