Economy Scale Analysis of BOT Projects

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ABSTRACT

The implementation of Build-Operate-Transfer (BOT) projects is a trend in last two decades around the world. The merits of BOT scheme are the utilization of managerial expertise and ample funds of private sectors. Lately, the ministry of education is ordering the colleges and universities to build the student dormitories by BOT approach in Taiwan. However, it is not a very successful policy after these years. Most of the projects lack of sound financial feasibility analysis, especially in the risk analysis and optimization analysis. Hence, only few of them are successful for the time being.

In most cases, the college authorities will request the project company to provide minimum bed numbers for students in advance. And, the project company should also provide three different types of bed rooms in college dormitory; one bed room, two-bed room, and four-bed room. Hence, there is a need to determine the optimal mix of room types, total bed numbers, and total construction cost. A linear programming model is then established for the analysis of the optimum economy of scale of the BOT dormitory projects.

A university dormitory BOT project at Taiwan is used as an empirical analysis. The university authority of BOT project asks for 1420 beds at least for the project. The results show that the optimal scale of the project is 737 two-bed rooms and 6 one-bed rooms. The total construction cost will be 462 million NT$. If the resources are unlimited, the best mix of room types is all for two-bed room. In case of limited land size and the insufficient project budget, the optimal mix of room types and optimal scale of the project will then be subject to change.

Keywords: linear programming, optimal project scale, BOT, optimization analysis, financial analysis

INTRODUCTION

Taiwan has promoted BOT projects for two decades. Taiwan government discovers that mega-scale infrastructure projects are not easy to success due to the difficulty in risk management of projects. Consequently, the investors lost their faith in large-scale BOT projects in Taiwan. They relocate new targets for investment. The college dormitory projects are their options for running BOT projects. It seems to them project size does matter. Smaller projects are much easier to manage. The economy of scale of the projects and the optimal mix of room types are two major issues to consider in term of cost reduction and revenue increasing. Economies of scale, in microeconomics, are the cost advantages that a business obtains due to expansion.

A BOT college dormitory project at National United University in Taiwan is considered. College authority had conducted a feasibility study of the project by a local engineering consultant firm. The engineering consultant firm concludes that this project is financial infeasible. We strongly believe that this conclusion is due to improper engineering design in planning stage. Too large room area, no optimal mix of room type, and poor

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project location are the reasons for financial infeasibility. Hence, we propose new site plan and an optimal analysis of room allocation. Through these efforts, the project become financial feasible.

MODELING

Linear programming (LP) is a mathematical technique for optimization of a linear objective function, subject to linear equality and linear inequality constraints. Linear programming can be applied to various fields of study. Most extensively it is used in business and economic situations, engineering problems, transportation, energy, telecommunications, and manufacturing. It has proved useful in modeling diverse types of problems in planning, routing, scheduling, assignment, and design.

In general, linear programming determines the way to achieve the best outcome, such as maximum profit or lowest cost, in a given mathematical model and given some list of requirements represented as linear equations. Linear programs are problems that can be expressed in canonical form:

$$\text{Maximize} \quad C^T X$$

$$\text{Subject to} \quad AX \le B \qquad (1)$$

X represents the vector of variables (to be determined), while C and B are vectors of (known) coefficients and A is a (known) matrix of coefficients. The expression to be maximized or minimized is called the objective function ($C^T X$ in this case). The equations $AX \le B$ are the constraints which specify a convex polyhedron over which the objective function is to be optimized.

The integer LP used in this study is shown as follows:

```
max=A1*x1+A2*x2+A3*x3;
 s.t.
 x1+2*x2+4*x3>=1420;
 C1*x1+C2*x2+C3*x3<=BC;
 @gin(x1);
 @gin(x2);
 @gin(x3);
 End
```

A1= rent of one-bed room,
A2= rent of two-bed room
A3= rent of four-bed room
X1= total room number of one-bed room
X2= total room number of two-bed room
X3= total room number of four-bed room
C1= construction cost of one-bed room
C2= construction cost of two-bed room
C3= construction cost of four-bed room

EMPIRICAL STUDY

The case of university dormitory of National United University (NUU) at Taiwan is for illustration as an empirical study of this paper. It is a BOT project.

Input parameters

Input parameters of the National United University dormitory BOT project are shown as Table 1. The parameters in original case are proposed by the local engineering consultant firm. The parameters in revised case are from the assumption by the authors. One of the authors is a professional architect in Taiwan.

Table1. NUU input parameters

	Original Case		Revised Case	
Single bed room	**140 rooms**	**17m2/per room**	**Determined by LINGO**	**13m2/per room**
Double beds room	**300 rooms**	**23m2/per room**	**Determined by LINGO**	**18m2/per room**
Four beds room	**180 rooms**	**40m2/per room**	**Determined by LINGO**	**26m2/per room**
Public area	**25% of room area**		**30% of room area**	
Direct construction cost	**18500 NT$/m2**		**22700 NT$/m2**	
Bath room	**Included in construction cost**		**40,000 NT$/ per room**	
Project life	**50 years**		**38years (same as operation period with no salvage value)**	
Rent for one bed room	**4500 NT$/month**		**5000 NT$/month**	
Rent for two bed room	**6000 NT$/month**		**6500 NT$/month (3250 NT$ ea.)**	
Rent for four bed room	**6400 NT$/month**		**9000 NT$/month (2250 NT$ ea.)**	
Promised rooms for rent	**=1420, (98.57%)**		**>1420, every additional 50 beds reduced 5% of guarantee.**	

Results

In order to enhance the financial feasibility of the BOT project, we re-design the site plan with considering the proper room size and land used. This is a first step required in financial analysis of BOT project. A right design could reduce the construction cost and increase revenue. We establish a financial analysis model to calculate the cash flows of the project, and the profitability indices as well.

Eight profitability indices are adopts, net present value (NPV), internal rate of return (IRR), average times interest earned (ATIE), average debt coverage ratio(ADCR), average return on total assets (AROA), average return on equity (AROE), self liquidity ratio (SLR), and profitability index(PI). IRR and NPV are for project perspective. ATIE and ADCR are for banker perspectives. AROA and AROE are for stock holder perspective. SLR and PI are used also for project perspective.

Figures 1~8 show the profitability indices of the revised case with re-design site plan. These figures provide strong evidences that there exists an optimal economy of scale of the project.

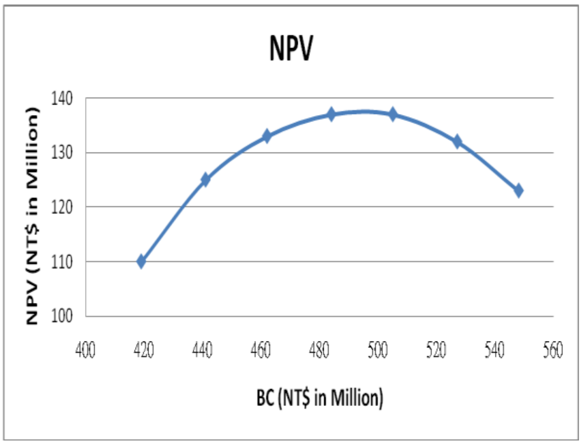


Figure 1: Net present value of the project

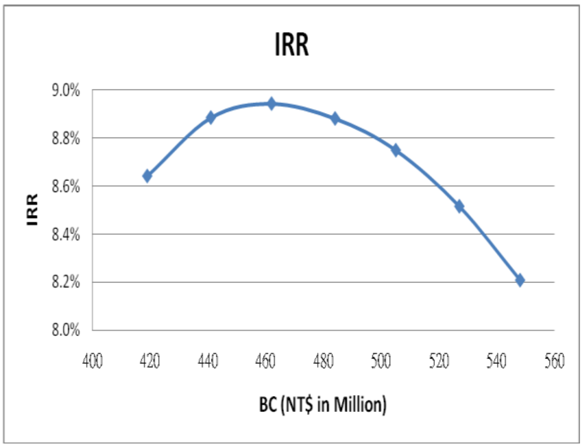


Figure 2: Internal rate of return of the project

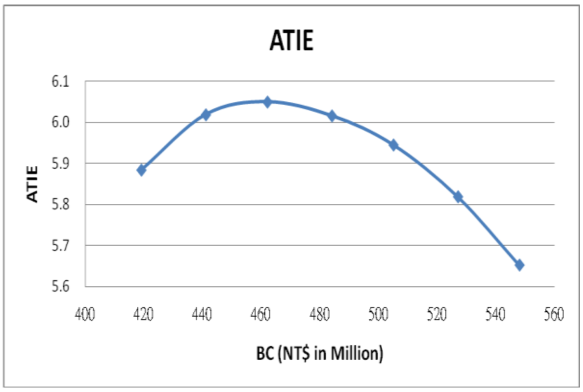


Figure 3: ATIE of the project

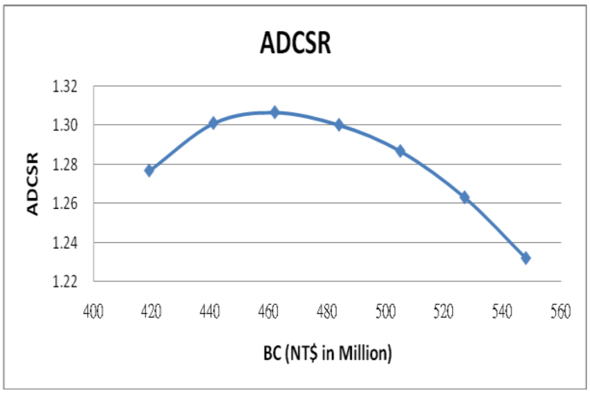


Figure 4: ADSCR of the project

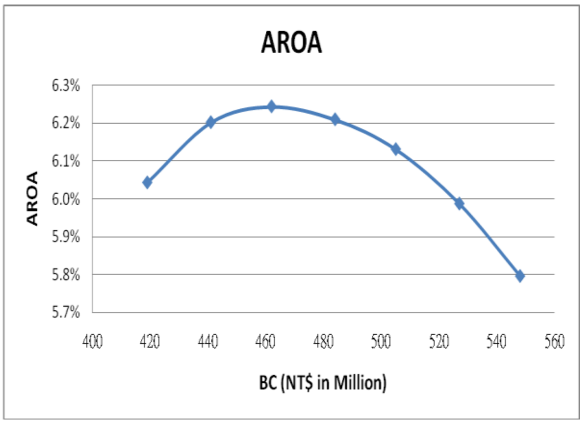


Figure 5: AROA of the project

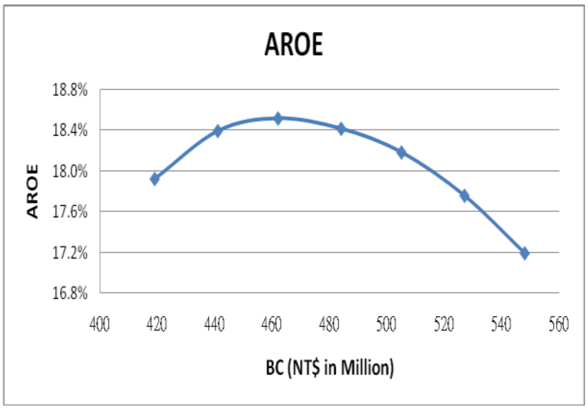
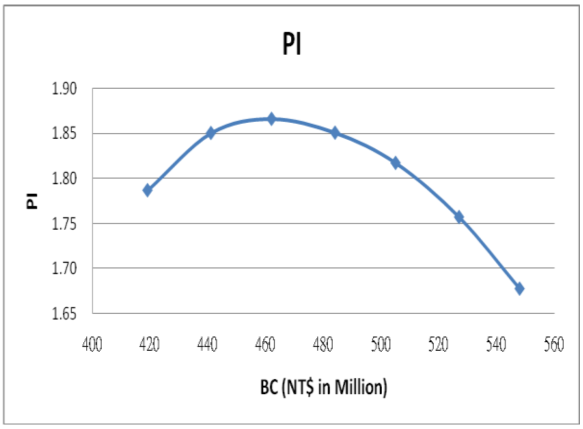


Figure 6: AROE of the project



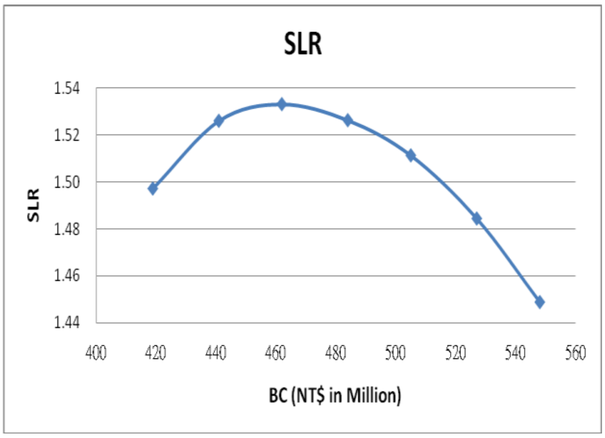
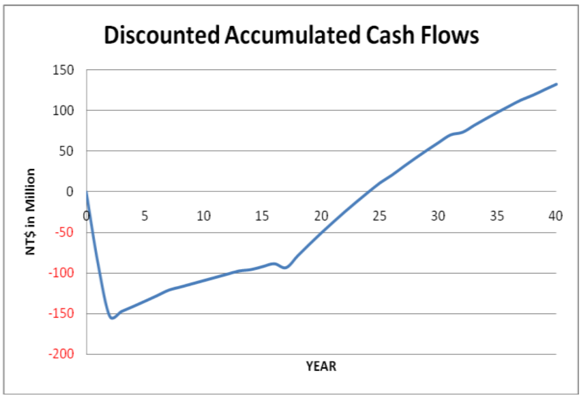


Figure 7: Profitability index of the project

Figure 8: Self liquidated ratio of the project

The financial characteristics of the BOT project is shown in figure 9 and figure 10. It seems that this project is quite promising. The pay back period is about 23 years for discounted cash flow. And, the pay back year is about 19 years for non-discount cash flow.



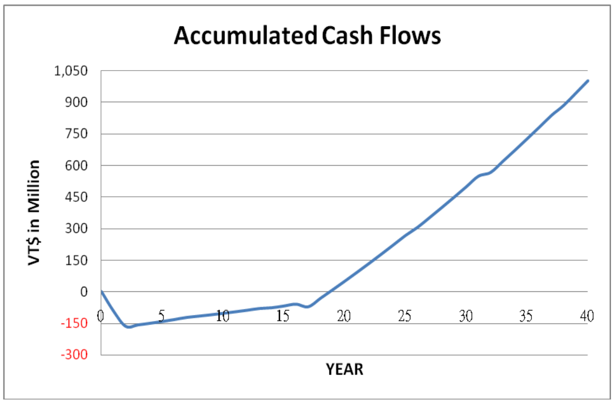


Figure 9: Discounted accumulated cash flow

Figure 10: Accumulated cash flows

We rearrange the results into table 2. The best case is BC-2. Most of profitability indices are best except NPV. This final analysis results of revised case shows that the optimal mix of room types are 6 one-bed rooms and 737 two-bed rooms. No four-bed room is required. The total construction cost is about 462 million in NT$.

Table 2: Investment amount and the profitability indices of the project

Cases	BC (Million)	O	T	F	Total Area (m2)	Bath room (No)	Project Perspective		Bank Perspective		Stock Holders perspective	
							NPV (Million)	IRR	DSCR	TIE	ROA	ROE
BC+6	548.21	7	875	0	20783	882	123.26	8.210%	1.2320	5.652	5.80%	17.19%
BC+4	526.91	10	838	0	19965	848	132.35	8.516%	1.2631	5.818	5.99%	17.76%
BC+2	505.41	13	801	0	19143	814	137.05	8.750%	1.2867	5.945	6.13%	18.19%
BC0	483.88	3	774	0	18328	777	136.60	8.881%	1.3001	6.016	6.21%	18.42%

BC-2	462.37	6	737	0	17510	743	132.89	8.943%	1.3066	6.050	6.24%	18.52%
BC-4	441.28	1	698	6	16711	705	124.54	8.885%	1.3010	6.019	6.20%	18.40%
BC-6	419.76	1	566	72	15949	639	109.60	8.642%	1.2768	5.884	6.04%	17.92%

Note: O is one-bed room. T is two-bed room. F is four-bed room.

CONCLUSIONS

In this study, we conclude that it is crucial to have a right design before conducting financial analysis for the BOT projects. Wrong design of project may result in the financial infeasible of the project for this case. The reason for not conducting the design work well is that the design fee is a sunk cost for the project company. This sunk cost may cost the project company a fortune. However, we suggest that to incorporate a good designer is important to enhance the financial feasibility of the project in the planning stage.

We also find that in the empirical study an optimal economy of scale does exist. This optimal project scale depends upon site plan, room type, rents for each room type, and other factors in this modeling. The assumptions of project parameters will influence the outcome of optimal economy of scale.

REFERENCE

- Dias, Antonio Jr., Ioannou, Photios G., Debt Capacity and Optimal Capital Structure for Privately Financed Infrastructure Project, Journal of Construction Engineering and Management, Vol. 121, No. 4, December 1995, 404-414.
- Xueqing Zhang, "Financial Viability Analysis and Capital Structure Optimization in Privatized Public Infrastructure Projects", Journal of Construction Engineering and Management, Vol. 131, No.6, pp. 656-668(2005).
- .Sandalkhan Bakatjan, Metin Arikan, and Robert L.K. Tiong, 2003, "Optimal capital structure model for BOT power projects in Turkey", Journal of Construction Engineering and Management, Vol. 129, No.1, pp. 89~97.(2003)