A DSAS-Based Minimum Makespan Model for Multi-location Investment Using Fractional Programming

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Abstract

This study focuses on an enterprise that wants to expand its business to multiple cities in global and to be one of well-known multinational enterprises (MNEs). Suppose the enterprise utilizes the wholly owned market entry strategy, as well as the decentralized synchronized (market) advancement strategy (DSAS) to achieve the purpose. DSAS refers to expanding business by decentralizing the available amount of capital budget into each planning investment location and investing them concurrently. Consider the MNE hopes each planning investment subsidiary gleans a specific target return within a constant time horizon. Under DSAS, this paper proposes an optimization model to find the optimal allocation policy of capital investment, which minimize the time required to realize the MNE's concerned objective. Due to the nonlinear characteristics of the proposed models, a solution procedure developed upon the piecewise-linear approximation and fraction programming approaches is used for resolving the proposed model.

Keywords: multinational enterprises, multi-location investment, decentralized synchronized advancement strategy, fraction programming

1. Introduction

Choosing an appropriate resource allocation and/or transfer strategy is one of important decision-making issues on a MNE intending to successfully invest multiple international cities. Few studies put attention on this issue. In the case of investing multiple cities, scheduling investments with budget constraints is the same as modeling a resource allocation problem of multiple projects. Traditional models to such a related issue is on the concept of selecting and/or scheduling projects limited to available amount of resource. On the pure project selection model, it fail to consider all projects to be done even the resource is scarce. Specially, in the case of common resource being renewal, it necessitates to schedule projects (see for example [1]). Although the project selection and scheduling models have been popular, those models lost to take account of multiple grades corresponding to quality standard (see for example [2]).

Except the aspects mentioned-above, a significant gap is both above traditional models not incorporating the soft factors, such as control competence of organization, into the model to predict a project's implementing performance. Chang and Chen [3] proposed an alternative insight, termed Project Advancement (PA), to extend the view of point of project selection and/or scheduling. Not concerning here with the detail introduction and discussion of PA, but we would like to focus on the application of project advancement strategies defined in PA. PA suggests four types of project advancement strategies, including centralized sequential advancement strategy (CSAS), decentralized synchronized advancement strategy (DSAS), and type I and type II mixed advancement strategies (Type I , Type II MAS). We will introduce these project advancement strategies in detail in the following section.

When one plans to do multiple projects, PA suggests choosing an appropriate project advancement strategy to avoid or decline the influence of ill noises resulting from internal and external environment. Owing to the high complexity of choosing an appropriate project advancement strategies, this paper will focus on modeling a DSAS-based and budget-constrained multi-city investment problem. The paper will be organized as follows: Section 2 states the four types of project advancement strategies; we term them market advancement strategy here. Section 3 describes the problem considered here, and Section 4 models the problem on mathematical form and examines the theoretical results. Finally, we propose a resolving procedure based on well-known Fractional Programming in Section 5.

2. Market Advancement Strategy

When a MNE plans to operate in a wholly-own-based multi-location investment environment for expanding its operational scale of globalization, the decision-makers have to further select a suitable resource-allocation and/or transfer strategy. In this paper we slightly revise the idioms of four types of project advancement strategies defined in PA to be more suitable in term of the context here. Also, we termed them the market advancement strategies.

Centralized sequential advancement strategy (CSAS): It refers to centralizing the available amount of capital budget into a planning investment location, and then transferring a specific portion of the reward, gleaned by investing in this location, onto another location once the target return of this location has been gleaned or a scheduled time limit has been run out. The investment continues by such a rule and gradually expands the MNE's globalization.

Decentralized synchronized advancement strategy (DSAS): It refers to expanding the MNE's globalization by the means that decentralizes the available amount of capital budget into all planning investment locations and concurrently invests them at the beginning of implementing the investment program.

Mixed advancement strategy: It represents a mode of consisting of both CSAS and DSAS. Consider the investment locations: Cities A, B, C and D, and divide the four investment locations into two groups: {A & B} and {C & D}, which are referred to as "X" and "Y" respectively. Type I MAS means that deploy the CSAS within Groups X and Y, while going ahead between Group X and Y with the DSAS. Whereas, Type II MAS is deploying the DSAS within the Groups X and Y, while going ahead between Group X and Y with the CSAS.

3. The problem

Consider an enterprise that wants to expand its business to multiple cities in global and to be one of well-known multinational enterprises (MNEs). In order to reach this goal, suppose the MNE determines to adopt the market enter strategy of wholly-owned, as well as the market advancement strategy of DSAS. Assume the demand rate of city j ($j = 1,2,...,J$) will increase in a large amount when time horizon T_j has elapsed, and then the potential competitors will competitively enter the market at that time. So the MNE should expand its investment up to a certainly substantial capital cost within time horizon T_j in order to enhance the global competition advantages. Letting $s_j(T_j)$ is the necessary capital cost of city j before time horizon T_j has elapsed, $\widetilde{c}_j$ the total amount of capital cost invested at the beginning of investing in city j, and R_j^{target} the target return (after being taxed) of investing in city j, which needs to be gleaned when T_j has elapsed. Accordingly, the relationship between R_j^{target} and $\widetilde{c}_j$ under adopting DSAS is as Formula (1).

$$R_j^{target} = s_j(T_j) - \widetilde{c}_j,\ j = 1,2,...,J \qquad (1)$$

Moreover, we consider two cost drivers of capital investment. They are respectively "environment investment for sale (EIFS)" and "environment investment for production (EIFP). Let $EIFS_j$ be the amount of environment investment for sale in city j and $EIFP_j$ the amount of environment investment for production in city j, then

$$\widetilde{c}_j = EIFS_j + EIFP_j,\ j = 1,2,...,J \qquad (2)$$

Here we assume that the MNE has budgeted for $EIFS_j$ for any j and therefore it is a constant. Based on this premise, the second the MNE has to do is to find the optimal $EIFP_j$ and then funds the total amount of $EIFP_j$ for all j, called $EIFP^*$. When the available amount of capital investment budget is less than $EIFP^*$, the MNE has to further make a distribution decision. Indeed, upon the available amount of budget being scarce corresponding to achieving the concerned objective of the MNE, it has to further find the optimal portfolio of $EIFP_j$ $(\forall j)$ to maximize the degree of realization of this concerned objective. Such objective means that target return R_j^{target} of planning investment city j needs to be gleaned before T_j has elapsed. However, when available amount of budget is sufficient enough corresponding to achieving the concerned objective, the MNE necessitates obtaining the optimal portfolio of $EIFP_j$ ($\forall j$) to minimize the time required to glean the target returns of all planning investment cities. For convenience, we term the former the DSAS-MA (maximum achievement) model and the latter the DSAS-MM (minimum makespan) model. A DSAS-MM model will be considered in the following section, but any DSAS-MA model will be out of the scope here.

4. DSAS-MM Model

4.1. Assumptions

A1. The activities of production in a planning investment city (PIC) supply only the demands of this PIC.
A2. Any activity of production in a PIC starts only at that time when a customer arrives. Also, the lead time of satisfying a customer's demand is negligible.
A3. One production-line, at least, is invested in every PIC, as well as the same amount of capital cost is invested in all production-lines.
A4. The more cost invested in each production line of a PIC implies the higher quality of the commodity to be sold in this PIC. Whereas the ownership cost is exponential growth over increasing capital investment.
A5. The higher the quality of the commodity to be sold in a PIC, the larger demand rate of the commodity is there.
A6. The price of the commodity to be sold in any PIC has been determined.
A7. The demand rate in a PIC only depends on the quality standard and pricing of the commodity in this PIC.

Let $t(\mathbf{c})$ be the time required to enable all of the target returns of planning investment cities to be gleaned. The purpose on formulating DSAS-MM model is to find an optimal budget allocation policy $\mathbf{c}^*$ to minimize $t(\mathbf{c})$. In accordance with the scenario described in Section 3, the fundamental objective considered here is that every planning investment city j needs to glean its target return R_j^{target} when T_j has elapsed. In this paper we present a DSAS-MM model based on Assumption A1-A7 as below.

Suppose that infinite alternatives for scheduling each $EIFP_j$ are available. Each alternative refers to a specific quality standard for production. Let L_j be the number of the production-lines planned to invest in city j, and c_j the amount of capital investment for each production-line. Then we have that $EIFP_j$ is the product of L_j and c_j according to Assumption A2. Letting Z_j is the reward function, and then it follows that Z_j is the function of c_j based on A6 and A7. Furthermore, consider Z_j is a concave function and possesses an absolute maximum upon A4 and A5. Suppose c_j^* is the optimal amount of capital investment for the production line of city j, which maximize $Z_j(c_j)$. In addition, it is so intuitive that there is a minimal amount of capital investment for survival at beginning of any investment. Letting c_j^l is such an amount for investing in city j. Accordingly, DSAS-MM model will be written as follows:

$$\min_{\mathbf{c}} t(\mathbf{c}) = \max\left\{ t_j = \frac{R_j^{target}}{Z_j(c_j)}, j = 1,2,\cdots,J \right\} \quad (3)$$

Subject to

$$R_j^{\text{target}} = s_j(T_j) - EIFS_j - L_j c_j, \forall j \quad (4)$$

$$\sum_{j=1}^{J} L_j \cdot c_j \le B_0 \quad (5)$$

$$c_j^l \le c_j \le c_j^*,\ j = 1,2,\cdots,J \quad (6)$$

5. Piecewise approximation and Fractional Programming

If we take K_j grid points from interval $[c_j^l,\ c_j^*]$, noted by $r_{j(k)}, \forall k$, then $Z_j(c_j)$ will be rewritten as (12).

$$Z_j(c_j) \approx Z_j(r_j^0) + \sum_{k=1}^{K_j} \rho_{j(k)} \cdot c_{j(k)},\ \forall j \quad (7)$$

Where

$0 \le c_{j(k)} \le r_{j(k)} - r_{j(k-1)},\ r_{j(0)} = c_j^l,\ r_{j(K_j)} = c_j^*,$

$\rho_{j(k)} = \dfrac{Z_j(r_{j(k)}) - Z_j(r_{j(k-1)})}{r_{j(k)} - r_{j(k-1)}}$, as depicted in Figure 1.

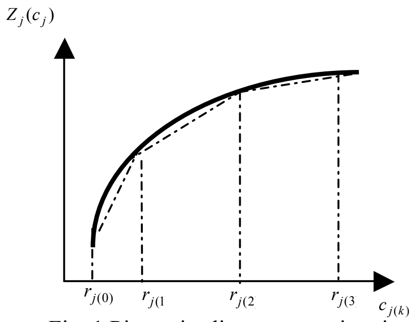

Fig. 1 Piecewise linear approximation

According to (7), Model 1can be rewritten as (8)-(13).

$$\min_{\mathbf{c}} t(\mathbf{c}) = \max\left\{ t_j = \frac{R_j^{\text{target}}}{\left[Z_j(r_j^0) + \sum_{k=1}^{K_j} \rho_{j(k)} \cdot c_{j(k)} \right]}, \forall j \right\} \quad (8)$$

Subject to

$$R_j^{\text{target}} = s_j(T_j) - EIFS_j - L_j r_{j(0)} - \sum_k L_j c_{j(k)},\ \forall j \quad (9)$$

$$\sum_{j=1}^{J} L_j \cdot \left[r_{j(0)} + \sum_{k=1}^{K_j} c_{j(k)} \right] \le B_0 \quad (10)$$

$$0 \le c_{j(k)} \le r_{j(k)} - r_{j(k-1)},\ \forall j,\ k \quad (11)$$

Also, Objective Function (13) will be rewritten as

$$\max_{\mathbf{c}} \frac{1}{t(\mathbf{c})} = \min\left\{ \frac{1}{t_j} = \frac{\left[Z_j(r_{j(0)}) + \sum_{k=1}^{K_j} \rho_{j(k)} \cdot c_{j(k)} \right]}{R_j^{\text{target}}}, \forall j \right\} \quad (12)$$

Moreover, if we let

$$x_{j(k)} = \frac{c_{j(k)}}{s_j(T_j) - EIFS_j - L_j\left\{ r_{j(0)} + \sum_k c_{j(k)} \right\}},$$

$$\lambda_j = \frac{1}{s_j(T_j) - EIFS_j - L_j\left\{ r_{j(0)} + \sum_k c_{j(k)} \right\}},$$

The model will be rewritten as

$$\text{Objective: } \max \frac{1}{t(\mathbf{c})} \quad (13)$$

Subject to

$$\frac{1}{t(\mathbf{c})} \le \frac{1}{t_j}, \forall j \quad (14)$$

$$\frac{1}{t_j} = Z_j(r_{j(0)})\lambda_j + \sum_{k=1}^{K_j} \rho_{j(k)} x_{j(k)}, \forall j \quad (15)$$

$$\left(s_j(T_j) - L_j r_{j(0)} - EIFS_j \right)\lambda_j - \sum_{k=1}^{K_j} L_j x_{j(k)} = 1, \forall j \quad (16)$$

$$\sum_{j=1}^{J} L_j \cdot \left[r_{j(0)} + \sum_{k=1}^{K_j} \frac{x_{j(k)}}{\lambda_j} \right] \le B_0 \quad (17)$$

$$x_{j(k)} - (r_{j(k)} - r_{j(k-1)}) \cdot \lambda_j \le 0, \quad \forall j, k \quad (18)$$

$$x_{j(k)} \ge 0, \quad \forall j,\ k \quad (19)$$

$$\lambda_j \ge 0, \quad \forall j \quad (20)$$

Because Constraint (17) possesses the fraction term, $\dfrac{x_{j(k)}}{\lambda_j}$, it still hard to resolve. In this paper we developed a weighted method described as follows:

Step 1: Use Constraint (21) instead of (17).
Step 2: Provide an initial weight, $w_j, \forall j$ so that $\sum_j w_j = 1$ and use OR software (e.g., LINGO) to solve the DSAS-MM model.
Step 3: Add Constraint (22) into the DSAS-MM model and view $\lambda_j, \forall j$ as a constant to resolve the model.
Step 4: Repeat Steps 1-3, until the optimal $t(\mathbf{c})$ is found.

$$\sum_{k=1}^{K_j} L_j x_{j(k)} + w_j[B_0 - \sum_{j=1}^{J} L_j r_{j(0)})] \le \lambda_j, \forall j \quad (21)$$

$$\sum_j w_j = 1 \quad (22)$$

6. Concluding Remark

A DSAS-MM model for multi-location investment is developed in this paper. The proposed model assume the enterprise utilizes the wholly owned market entry strategy and the decentralized synchronized (market) advancement strategy (DSAS) to invest the locations (cities) to want. DSAS refers to expanding business by decentralizing the available amount of capital budget into each planning investment location and investing them concurrently. Due to the nonlinear characteristics of the proposed DSAS-MM model, we propose a linear transform developed upon the piecewise-linear approximation, fraction programming and weighted method.

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