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A DEA benchmarking methodology for project planning and management of new product development under decentralized profit-center business model

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ABSTRACT

In today's highly competitive marketplace, technology-driven organizations widely adopt decentralized profit-center business model. In order to complete a series of new product development (NPD) activities on time and within budgetary constraints, the NPD managers need an objective benchmarking approach to gain accurate perception on the relations of resource allocations, profits, costs and times for each NPD activity. Thus, this study employs the data envelopment analysis (DEA) concept to put forward a benchmarking planning and management methodology to optimize the NPD activities within a profit center for achieving the goal of maximal profit and satisfying the resource constraints. By applying the real case of the electric motor scooter NPD project, this research demonstrates the method's real case application with superior results, comparing to other existing approaches.

1. Introduction

For reducing the operating cost and enhancing the global competitiveness, most companies enlarge their sizes for pursuing the economy of scale. Further, in order to make a large organization more flexible and agile in the constantly changing market place, there is a noticeable trend toward decentralized decision making. Decentralization is to distribute decision-making authorities to sub-divisions and holds the division managers responsible for the decision outcomes. The profit center business model belongs to one of the decentralized organization structures. Nonetheless, the decision making in a decentralized organization must maintain its consistency and accuracy with acceptable and rational principles and criteria. Nowadays, new product development (NPD) departments of many companies have been converted into profit centers. In order to reduce the number of engineering changes and to shorten the NPD time, a NPD project manager needs to implement concurrent engineering by establishing NPD guidelines and constraints. At the same time, all profit centers must comply with these NPD rules to achieve design for X. In addition, a manager of the profit center, given a NPD domain, needs to estimate the cost, resources, revenue and delivery time for each NPD activity based on previous experiences and circumstantial judgment. Although, there are a lot of decision-making supporting approaches proposed to assist NPD activity planning, these models assume that activity times are specific time distributions and utilize the linear regression to build the relationship between activity times and costs. These methods cannot fit the real applications for NPD. In order to complete a series of NPD activities on time and in budget, the profit-center managers need a scientific approach to find the efficient activities to form the efficient frontier. In light of the frontier, the NPD manger can evaluate and estimate the minimum activity time as well as optimize resource allocation. Thus, this study presents a DEA-based benchmarking methodology to optimize the NPD time and resource planning within a profit center for achieving the goal of maximal profit. Finally, this research uses the electric motor scooter design project to illustrate the efficacy of the methodology presented in the paper.

2. Literature review

Cost increases and schedule delays are common problems in engineering design projects. Chang [1] listed the common reasons for cost and schedule overruns. The analytical results assist project managers in tracing responsibilities and improving work processes. De Reyck and Herroelen [2] tackled a typical resource-constrained project scheduling problems with generalized precedence relations. The activities possess of different execution modes. Each mode possibly has a different impact on the duration and required resources. The objective function minimizes the project time. Because this model is a NP-hard problem, the research combines a local search methodology and a tabu search procedure to solve the

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Nomenclature

θ_t	the input oriented efficiency of the NPD activity t
pt_t	the assigned completion time of the present activity t
st_j	the time of the past similar NPD activity j
af_{et}	the given capacity of the facility e for the present activity t
if_{ej}	the input capacity of the facility e for the past similar NPD activity j
ah_{mt}	the given capacity of the human resource m for the present activity t
ih_{mj}	the input capacity of the human resource m for the past similar NPD activity j
fs_e	the reducing input quantity of the facility e for the feasibility evaluation of activity time under limited resources.
hs_m	the reducing input quantity of human resource m for the feasibility evaluation of activity time under limited resources.
λ_j	the weight of decision-making unit j
oaf_{et}	the optimal input quantity of the facility e for the NPD activity t
oah_{mt}	the optimal input quantity of the human resource m for the NPD activity t
φ_t	a coefficient of time adjustment for the present activity t
mfs_e	the reducing input quantity of the facility e for the minimum activity time estimation under limited resources.
mhs_m	the reducing input quantity of the human resource e for the minimum activity time estimation under limited resources.
$ctpv_t$	the cost-time performance value of the activity t
FC_e	the unit cost of the facility e
MC_m	the unit cost of the human resource m
ce_j	the output oriented efficiency of the contractor j
ci_k	the collaborative ability of the contractor k
oq_k	the quality of executing the NPD activity of the contractor k
ot_k	the activity time given by the contractor k
op_k	the price given by the contractor k
u_1,u_2, v_1,v_2	criteria weights
ov_t	the output value of the NPD activity t
tif_e	the total input quantity of the facility e
tih_m	the total input quantity of the human resource m
oap_t	the price of outsourcing the NPD activity t

problem. Wang [3] applied the simulated annealing (SA) approach and a genetic algorithm (GA) to develop NPD schedule repair with time-limit constraints. At first, GA can be used to repair a disrupted schedule and, then, the SA is applied to improve the schedule given by GA. Azaron et al. [4] presented a multi-objective model for solving resource allocation problem in a PERT network. This model assumes activity durations are exponential random variables and has four conflicting objective functions, including the cost of a project, the mean and the variance of a project completion time and the probability of meeting the deadline. Basso and Peccati [5] intended to solve a project finance problem with minimum and maximum activation levels. This problem is also shown to be NP-hard. Hence, a dynamic programming algorithm is proposed to determine the optimal project funding policy. Babu and Suresh [6] developed linear programming models to investigate the tradeoffs among time, cost and quality in project management. One of the three models optimizes one criterion by assigning the desired bounds on other criteria. Pillai et al. [7] proposed an integrated performance measurement framework for evaluating R&D project. This paper identifies the key factors in each phase of the project lifecycle and integrated them by developing a formula to derive an integrated performance index. Hence, this index can measure the overall performance of a project at any point. Dweiri and Kablan [8] utilized the MATLAB software to develop a fuzzy decision making model for the evaluation of project management internal efficiency (PMIE). The PMIE, combining the measures of project cost, time and quality, can serve as an indicator for the achievement level of project objectives to evaluate the performance of project teams. Barraza et al. [9] applied stochastic S curves and simulation approach to predict the project completion performance. This probabilistic approach assumes that the direct costs and durations of the project activities are normal distributions. By evaluating the final project performance, the project manager can determine the needs for corrective actions. Yang and Sum [10] employed the simulation method to simulate the performance of due date, resource allocation, project release and activity scheduling rules in a multi-project environment. The time intervals between project arrivals are generated from a uniform distribution. Fan and Yu [11] incorporated Bayesian belief networks (BBNs) in software project risk management and developed a BBN-based procedure using a feedback loop to predict potential risks, as well as identify the sources of risks.

Although many papers focus on NPD, none of them proposes a method to deal with the strategic NPD planning and management based on the latest NPD business model of decentralized profit centers. Hence, this research uses data envelopment analysis (DEA) to develop the benchmarking methodology to assist profit center managers in improving the effectiveness of NPD planning and management.

3. The DEA models based on NPD profit center setting

According to the professional clusters between NPD activities, a company divides the NPD processes into different domains. Each NPD domain forms an independent profit center. When an industrial design company receives a customer's order, the company sets up a NPD project and establishes the product specification based on the customer's requirements. According to the workload and input resources, the project manager allocates the revenue to each profit center. If a profit center can finish the given NPD tasks on time, this profit center obtains the allocated revenue. The revenue is the output value of executing these NPD activities. In order to achieving the objective of profit maximization, this research develops the DEA benchmarking models based on decentralized NPD profit-center model.

3.1. The analytical process for optimizing NPD activities

As illustrated in Fig. 1, the analytical process for optimizing NPD based on profit center business model is divided into two phases. Phase 1 evaluates the feasibility of meeting the NPD deadline. When the deadline can be achieved, Phase 2 begins to pursue the maximal profit of a profit center. First, the profit center manager analyzes the feasibility of executing the given NPD activities to meet the deadline by employing the model of feasibility evaluation of activity time under limited resources. If all activity times are feasible, the profit-center calculates the optimal resource allocations