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Research article

Financial Pinch Analysis: Minimum opportunity cost targeting algorithm

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ABSTRACT

To achieve the market competitiveness as well as sustainable products and processes, a firm invests in different environmental and conservation projects. Capital budgeting essentially entails the decision of funding a set of acceptable projects from a larger pool of available projects, subject to different funding constraints. This paper proposes a new algorithm, *the minimum opportunity cost targeting algorithm (MOCTA)*, to address the capital budgeting problems for selecting environmental management projects. This algorithm is based on the principles of Pinch Analysis, a well-established resource conservation methodology and can be directly applied to partially acceptable projects which can be formulated as a linear programming problem. The proposed algorithm, in coordination with the branch and bound technique, can further be applied to solve mixed integer linear programming (MILP) formulation of the problem, where projects should either be completely accepted or completely rejected. A hypothetical example demonstrates the applicability of the methodology through a complex search tree. The proposed methodologies are demonstrated through a case study of selecting energy conservation projects in the Indian Paper and Pulp industry.

1. Introduction

Optimal utilization of natural resources, as well as prevention of accumulation of pollutants in the atmosphere, are two most important factors to achieve sustainable management of environmental resources. Conservation of natural resources and pollution prevention call for the efficient use of resources, implementation of cleaner and greener processes, reduction of sources of pollution, and recycling of materials. To achieve the industrial sustainability through cleaner production, most important steps are to reduce the waste generation at the source, to recycle materials in a safe manner, to use renewable materials and energy, to operate the overall production system in most efficient ways, etc. However, these social and environmental aspects of sustainability cannot be achieved without appropriate allocation of capitals (Chen et al., 2013). With an eye on continuous generation of revenues, a firm looks to achieve sustainability through investing in projects that are both economically viable as well as environmentally beneficial. With the imposition of various taxes and regulatory norms, investments in different sustainability projects may lead to significant revenue generation. Appropriate valuation of the ecosystem plays a significant role in achieving this goal (Marre et al., 2016). To achieve the market competitiveness with a signature of sustainability, a firm invests in different environmental projects which give economic returns in the future (El-Halwagi, 2016). Clearly, the decision to invest has a huge impact on the firm in the long run and hence, the process undertaken is extremely critical (Dilger et al., 2017). Various factors such as execution procedure, various costs associated with the project, direct and indirect benefits, uncertainties associated with economic returns, etc. amongst other have to be considered before a decision is made. Finally, those projects have to be selected that return the capital invested along with the desired return in a consistent manner. These concerns and questions are to some extent addressed by the capital budgeting process that is undertaken by firms to identify and evaluate projects.

The importance of capital budgeting for the management of any firm was initially highlighted by Dean (1951). Before this, the decisions were made using non-discounting cash flow methods (Markovics, 2016). In today's context, industry executives consider capital budgeting extremely critical, because the right selection of projects enables them to maximize profit, to efficiently allocate

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Nomenclature

A	Accepted project
AR_{Fi}	Annual requirements of funding source i
B&B MOCTA	Branch and Bound based Minimum Opportunity Cost Targeting Algorithm
c_{DNj}	Unfunded amount of project j
C_{Fi}	Initial cash flow of funding source i
c_{ij}	Funds transferred from funding source i to project j
C_{Pj}	Initial investment required by project j
c_{Ui}	Unutilized funds of funding source i
CF_m	Cumulative net flow till $DROI_m$
CN_m	Cumulative NPV till $DROI_m$
CRN_k	Cumulative NPV till do-nothing resource k
CRF_{Fi}	Capital recovery factor of funding source i
CRF^*_{Fi}	Capital recovery factor of funding source i at MARR
CRF^*_{Pj}	Capital recovery factor of project j at MARR
d_i^{Pk}	Do-nothing cash flow (or resource flow) corresponding to project Pk
DROI	Discounted return on investment
$DROI_{Fi}$	DROI of funding source i
$DROI_m$	m^{th} distinct DROI when arranged in ascending order
$DROI_{Pj}$	DROI of project j
F_i	Net flow of project or fund i
F_m	Net cash flow corresponding to $DROI_m$
FPD	Financial Pinch Diagram
LP	Linear Programming
MARR	Minimum acceptable rate of return
MILP	Mixed Integer Linear Programming
MOCTA	Minimum Opportunity Cost Targeting Algorithm
MRPD	Material Resource Pinch Diagram
n_{Fi}	Life of funding source i
N_m	NPV corresponding to $DROI_m$
n_{Pj}	Life of project j
NPV	Net present value
NPV_{Fi}	NPV of the funding source i
NPV_{Pj}	NPV of a project j
P	Partially accepted project
Pi	Paper and Pulp energy conservation project i
R	Rejected project
R_{Pj}	Annual returns of project j
$RDROI_k$	DROI of do-nothing resource k
RF_j	Cash flow of do-nothing resource j
RN_j	NPV of do-nothing resource j
ROI	Return on Investment
x_i	Interest rate of funding source i
Z	Objective value
Z^*	Optimal objective value
z_L	Lower bound of the optimal objective value
z_U	Upper bound of the optimal objective value
β_j	Binary decision variable of project j

resources, to express business strategy, to continue the steady development of their corporations with a renewed competitive position in the market, and finally, to achieve overall sustainable development. Generally, a capital budgeting study has four important stages – identification of the projects, development or analysis of the projects, the process of selecting the projects, and performance appraisal of the projects (Burns and Walker, 2009). The overall objective is to optimize the return on investment using particular financial metric (Dean, 1951) such as net present value, internal rate of return, profitability index, accounting rate of return, and discounted payback period (Markovics, 2016), with or without incorporating embed sustainability issues (El-Halwagi, 2016). The net present value (NPV) is the preferred metric due to its consideration of time value of money, project life, cash flow during entire life, and computational simplicity. The profitability index is considered to be a very good metric in capital budgeting decision due to its applicability in capital rationing situations (Burns and Walker, 2009). Ryan and Ryan (2002) summarized the development in this field both in academia and in the industry.

Markowitz (1952) formulated the selection process of the project into a mathematical optimization problem and laid the foundation of many theories in this field. Although an over-arching theory encompassing all relevant aspects of the problem, like strategy, mental models, social interaction of all stakeholders, and quantitative preference criteria, is not yet developed (Kavadias and Loch, 2004). Incorporation of sustainability issues into the capital budgeting framework (El-Halwagi, 2016) is not yet practiced by the majority of the firms. The methods employed to select projects by the industry executives are mainly financial methods, business strategy methods, the bubble diagram, scoring models, checklists, risk-return diagrams, and process and product change matrix (Cooper et al., 2001). In most cases, various financial metrics can be used to assess solitary projects compared to the benchmarks defined by the firm's management. In practice, decision-making for this kind of problems is difficult and this lead to the development of various decision making models such as life cycle analysis (LCA) (Jiang et al., 2004), fuzzy analytic hierarchy process (FAHP) (Trianni et al., 2014), data envelopment analysis (DEA) (Han et al., 2015), analytic network process (ANP) (García-Melón et al., 2015), bi-level integer programming (Champion and Gabriel, 2015), and DEA with artificial neural network (DEA-ANN) (Han et al., 2016), among others. Similarly, rigorous methods have been developed to account for uncertainties in efficiency gains resulting from investments (Hong et al., 2015). Academia has tried to solve this problem by considering various aspects such as project risk, cost, flexible time horizon, and uncertainty of cash flows (Huang, 2007). These led to formulation of complex optimization models, which have been solved by goal programming (Badri et al., 2001), mixed integer linear programming (Jafarzadeh et al., 2015), and evolutionary algorithms, such as genetic algorithms (Ghorbani and Rabbani, 2009) and particle swarm optimization techniques (Huang et al., 2014). Recently, Bandyopadhyay et al. (2016) applied the principles of Pinch Analysis to address the problem of optimal selection of projects subject to budget constraints.

Pinch Analysis is half a century old technique, initially introduced to conserve energy in process plants (Hohmann, 1971). It became a popular method to improve energy efficiency in industrial processes (Linnhoff et al., 1982). It was initially introduced to conserve thermal energy in heat exchange network so as to reduce the requirement of external heating and cooling utilities. Graphical representations, in conjunction with simple algebraic solution procedures, not only helped in solving these energy conservation problems computationally efficiently, these methodologies also helped in improving overall conceptual understating of the process. Over the years, techniques of Pinch Analysis have been extended to address issues related to sustainable development.

Pinch Analysis was extended to consider the mass transfer network applications due to the similarities between heat and mass