Logistic Planning with Nonlinear Goal Programming Models in Spreadsheets

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ABSTRACT

This is a case study of a coal mining company to demonstrate how algebra principles and nonlinear goal programming can be applied for logistics planning using spreadsheet software. The paper asserts that mathematical programming techniques are not well-accepted by managers because the models are difficult to understand due to abstract notational conventions yet alternative commercial software is inflexible (and sometimes inaccurate). The relevant operations research literature was reviewed, highlighting techniques applicable for analyzing quantitative and qualitative logistics data. A practical supply-demand transportation logistics model was built which included determinist constraints and stochastic costing theories, while applying both linear and nonlinear calculus slope principles. The formulae were explained in algebraic standard form (citing corresponding spreadsheet functions). The logistics problem was optimized, illustrating how 6 mining sites could supply 4 countries with sufficient coal to meet different electricity demand levels, surpassing the break-even goal and projecting annual revenue of over $34 billion.

Keywords: Applied Logistics, Coal Mining, Deterministic Constraints, Linear Programming, Nonlinear Goal Programming, Spreadsheet Software, Stochastic Factors

INTRODUCTION

Several researchers have noted that mathematical linear programming and nonlinear operations research models are powerful but often impractical for logistics managers to apply due to their complexity (Mercer, 1977; Sharp & Dando, 1979; Worthington, 2009). MIT Management Professor John Little - well known for Little’s Law (1961) – complained: “managers don’t understand the models” (Little, 2004). By this he meant the interface is poor and the variables are difficult to apply to operations data. Another shortcoming with mathematical models is that they do not readily accommodate qualitative data such as human preferences or heuristics (Ueda, 2010). Paradoxically logistics researchers are calling for more qualitative data analysis along with other disciplinary methods such as experiments and case studies (Ellram, 1996; Mangan, Lalwani, & Gardner, 2004). More so, mathematical and statistical models can be confusing because “optimization is studied in many disciplines - each with its own terminology” (Bettonvil, del Castillo, & Kleijnen, 2009).

DOI: 10.4018/jal.2012100101
Logistics planning falls into the category of operations research where the models can be complex due to numerous goals, factors and conditions. Logistics managers often need to estimate multiple decision variables against the resource constraints to plan an optimal solution. Manuscripts in popular operations research journals rely on calculus theories (Zhang & Xu, 2010), multinomial systems of equations (Souza, Coelho, Ribas, Santos, & Merschmann, 2010), and matrix algebra (Kleijnen, Beers, & Nieuwenhuyse, 2010), which can be laborious to calculate without software. Commercial software can facilitate planning but often includes unspecified simulation distributions and masks assumptions that could produce unreliable estimates (without warning) if the model does not fit the operational data (Cochran, Cox, Keskinocak, Kharoufeh, & Smith, 2011). More so, commercial software applies a ‘black box’ one-size-fits-all philosophy. Theoretical disciplinary-specific logistical models are published in the literature but their formulae are difficult for managers to interpret due to the vector arithmetic and/or abstract calculus notational symbol system conventions (e.g., Leibniz, Newtonian, Euler, and Peano).

In a sense this leaves logistics managers facing a paradox of buying commercial software that is irrelevant or inflexible (and often expensive), yet powerful mathematical models being freely available in the operations research literature but they are too complex to understand for applying to production data. Simpler customizable models are needed. The approach here is to build logistical decision making models for a coal mining supply-demand case study, using common spreadsheet software, which makes the formulas and variables accessible as well as customizable.

LITERATURE REVIEW

There are numerous techniques in operations research to analyze coal supply logistical problems. A recent operations research-management science handbook documented 152 topics, including: Age Replacement, Ant Colony, Branch and Bound, Clustering, Consensus Building, Fuzzy Search, Genetic Algorithms, JIT, Linear Programming, Markov, MRP, Risk Analysis, Scenario Analysis, Percolation Theory, Simplex, Spanning Tree, Stakeholder Participation, Queuing, Wardrop Equilibria, Warrant Models, and many other techniques (Cochran et al., 2011). Some of these are procedures for qualitative data more so than techniques (e.g., consensus building), while the field of quantitative data approaches ranges from stochastic forecasting (using probability theory), deterministic linear programming (when constraints are known), to nonlinear goal or search heuristics where infinite or no solutions may be possible. The implications are that one or several of the available techniques may be necessary to solve a complex logistical dilemma.

In cases where fluctuating costs or prices are involved, financial portfolio selection principles are often applied (Xidonas & Psarras, 2009). Portfolio selection theory is grounded in Markowitz’s (1952) integration of economic and statistical principles for selecting the best portfolio investments (based on the mean-variance of beta risk and yield regression estimates). Average pricing is commonly applied for logistics planning because suppliers rarely have identical or constant prices. For example, Lin, Hoffman, and Duncan (2009) applied an extension to Markowitz’s mean-variance portfolio selection technique as criteria weights for purchasing higher quality stocks. Additionally, demand fluctuates and suppliers may partially fill orders rather than delay shipments.

Deterministic approaches such as integer or linear programming are often used for production planning situations where constraints such as the cost as well as the number of trucks/ships and operators are known (Shakeri & Logendran, 2007; Stecke & Toczyłowski, 1992; Zhang & Xu, 2010). In another study, Chen and Askin (2009) employed net present value with integer programming to the optimize the selection of projects. Mathematical programming techniques are often applied to
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