USING THE ANALYTIC HIERARCHY PROCESS FOR GROUP REVISION OF LINEAR PROGRAMMING SOLUTIONS IN CEMENT PRODUCTION AND DISTRIBUTION PLANNING

Chuvej Chansa-ngavej*
School of Management
Shinawatra University (SIU International)
Bangkok, Thailand
E-mail: chuvej@siu.ac.th

Jirachai Sakchanalaya
Department of Industrial Engineering
Chulalongkorn University
Bangkok,Thailand
E-mail: jirachas@scg.co.th

ABSTRACT

In practice, solutions of linear programming models often need to be further adjusted by the decision makers. This is because more often than not the original LP formulations fail to include such qualitative and intangible factors as implementation convenience, customer service level, and company operating guidelines. Also, most LP solutions often tell just the *"what"* and not the *"why"* of the recommendations. This paper applies the Analytic Hierarchy Process in a group decision making setting to make the LP solution adjustment process transparent and understandable to the decision makers involved. A case study of a large cement producer is used to demonstrate the practicality of the proposed procedure. Managers of the Logistics Division are interviewed and the criteria derived and grouped using the affinity diagram and the decision structure constructed by the AHP model. The first main criterion is **Distribution service level** with two sub-criteria: (1.1) *Capability of distribution management*, which consists of (a) Scheduling capability (b) Fleet management capability (c) Fleet controlling difficulty (d) Shipment volume suitability (e) Communication and coordination comfort and (1.2) *Readiness of facilities* which consists of (a) Truck fleet available (b) Parking area available (c) Truck ban constraint. The second main criterion is **Transportation Cost** constraints which consists of (2.1) *Minimum truck load capacity* and (2.2) *Task allocation to each transportation sub-contractors.* The results show that the use of AHP in the fine-tuning of LP solutions provide more consistent and clear decisions, improving the customer service level, and enabling more satisfying production and distribution planning.

Keywords: Qualitative and intangible factors, linear programming solutions, adjustment.

1. Introduction

With the exponential growth in computational power and information and communication technology in the last few decades, mathematical modeling has enjoyed vast applications among industrial practitioners. Despite, or perhaps because of, their widespread use, the issue of model reliability has never ceased to be of primary concern to practitioners. The questions related to this issue are how well the mathematical models portray the real world and how well their solutions fit in with the actually observed results (Shumway and Talpaz, 1977). At the same time, there are more needs for tools to explain the "why" of the results as mathematical programming becomes more computational (Geoffrion, 2003). For example,

* Corresponding author. The first author acknowledges the generous research support from Shinawatra University.

in the manufacturing and transportation route selection problem, it is not enough merely to provide the "what" in terms of the optimum configuration of manufacturing facility and distribution center location and transportation flows. There are demands from decision makers to understand "why" such facility locations and transportation flows are selected. A tool to provide such insight to decision makers is very much desirable and should be made part-and-parcel with the model solution.

In industrial practice, it is a known fact that solutions of linear programming (LP) models often need to be further adjusted by the decision makers. This is because in attempting to fit the models into the standard LP format, the original LP formulations often have to leave out such qualitative and intangible factors as implementation convenience, customer service level, and company operating guidelines. Most LP solutions often tell just the *what* and not the *why* of the recommendations. In past practices, each decision maker had to come up with improved solutions based on his/her own experience and intuition, without having an opportunity for open discussion.

The objective of this paper is to demonstrate the application of the Analytic Hierarchy Process in a group decision making setting to make the LP solution adjustment process transparent to the decision makers involved. A case study of cement production and distribution management in the Logistics Division of a large cement producer in Thailand is used to demonstrate the practicality of the suggested procedure. The decision is to select cement production and distribution centers together with the amount of cement to produce at each production and distribution center and the amount to distribute to each destination production while satisfying all the established criteria. To arrive at the solution, managers of the Logistics Division are interviewed and the criteria derived and grouped using the affinity diagram and the decision structure constructed by the AHP model. The relative importance of the evaluation criteria are then found by pairwise comparisons based on the subjective opinions of the group of decision makers using an AHP software. The overall procedure is therefore an integrated approach of LP-AHP with LP solved to optimality and AHP in a group decision setting.

2. Literature review

Ho (2008) reviewed 66 papers during 1997-2006 that applied AHP in conjunction with other techniques. The so-called integrated AHP papers covered AHP combined with mathematical programming (MP), quality function deployment, meta-heuristics, SWOT analysis, and data envelopment analysis. Five papers were reported using the AHP-MP combination, all of which use mixed integer linear programming (MILP) in the application domain of transportation route selection. In particular, Korpela and Lehmusvaara (1999), Korpela *et al.* (2001a), Korpela *et al.* (2001b), and Korpela *et al.* (2002) used AHP to establish first the importance weightings of the criteria, for use in the second step as coefficients in the MILP objective function. By contrast, in Tyagi and Das (1997) MILP was used first to generate a set of alternative heuristic solutions based on each of three criteria: cost, delivery time, and service rating, subject to the acceptable levels of the other two criteria. AHP was then applied to select the best solution with respect to the specified relative importance weights of the three criteria. Note that none of the above-mentioned papers use AHP-MP in a group decision making context.

Saaty *et al.* (2003) and Saaty *et al.* (2007) demonstrated how AHP can be used in two ways to extend LP resource allocation model to include the allocation of intangible resources. One way is to use AHP to establish the relative importance weightings for use as coefficients in the LP objective functions. Another approach is to incorporate the AHP relative importance weightings for intangible resources into the LP constraints together with the financial resource constraints. Saaty and Peniwati (2007) and Saaty and Shang (2007) proposed a framework for using AHP for group decision making, including its web-based implementation.

Using a mathematical programming model of production and distribution center network design and transportation flow determination as an example, Geoffrion (2003) outlined the steps that should be followed to help practitioners understand the “why”of the solutions: This involves the use of simple tradeoff relationships that are of great interest to the practitioners. As an example, the optimal number of distribution centers may be determined and total cost is shown to increase as the number of distribution centers deviate from the optimum number.

From the literature review, there is a vast research gap at the interface of LP and AHP, especially in the use LP in combination with the group decision making application of AHP. The present research is designed to fill in such a gap with specific applications to production and distribution planning of cement products. The case study of a leading cement producing and distribution firm in Thailand is reported. The contention is that the use of AHP in a group decision making context helps provide insight and improve the understanding of the “why” of the LP solutions for the managers involved. Moreover, the revised solutions are more practical for implementation and more acceptable to all concerned.

3. The LP model for cement production and distribution planning

The LP model has as its objective the minimization of unit cost which consists of (1) production cost, packing and distribution cost (2) transportation cost to distribution centers and material handling cost (if any) and (3) transportation cost from dispatching points to customers.

There are altogether about 2,000 decision variables which are the amount (in tons) of cement products to be transferred from the dispatching points to the destinations. The products involve bulk cement as well as cement in bags, three different product brands, three modes of transportation (ships, trucks, and trains), nine dispatching points including 5 production plants and four distribution centers), various destinations including 60 company warehouses and customers in the rural provincial areas.

The constraints consist of:

1. Production/supply capacity of the five production plants
2. Ships, trucks and trains freight capacity
3. Receiving-supplying capacity of the distribution centers
4. Customer demand
5. Others, for example customer-specified choice of production plant

The resulting LP model solutions are often found to contain results that are not compatible with the standard plant procedure and current planning. This is because the assumptions underlying the LP model in relation to unit cost consideration which includes both fixed cost and variable cost of production. Thus, an adjustment of the LP solutions is required. In the past, it is found that the fine tuning of the LP solutions are done individually without clear guidelines and lack transparency to the managers involved.

Based on past practice, the criteria used in the fine tuning of the LP solutions include such criteria as operational convenience, maintenance of service level, or operating policy. Such criteria are not suitable for inclusion in the LP model because they sometimes depend on the changing situation, or upto the subjective consideration of the relevant managers. The disadvantages of such individual practices are the lack of standard, the lack of transparency. More importantly, they do not promote insight or understanding among those managers involved about what is really going on in the decision making process..

4. The proposed group decision making AHP process for fine tuning of LP solutions

Because of the problems found in past fine tuning practices as mentioned in Section 3, the group decision making process using AHP is therefore proposed. The criteria for the fine tuning are established by using the affinity diagram (K-J technique), which is one of standard tool in the set of "new QC 7 tools" for total quality management (TQM) (Nayatani *et al.*, 1994). Basically, it is composed of a round of silent generation of ideas obtained by eliciting written responses on small pieces of sticky sheets of paper regarding what factors are considered important in the production and distribution planning. After that, the factors are placed on the board for all to see and for everyone to move them around so that the factors that should belong to the same categories are placed together in a group. In the end, when everyone is satisfied with the groupings, the results are put together and the criteria and sub-criteria are assigned appropriate names.

The criteria obtained are as follows:

Main Criterion 1
Service Level of the Cement Dispatching Point in the Management of Distribution Operation

Sub-criterion 1.1 *Capability of distribution management of the dispatching point*
which consists of five elements:
- (a) Scheduling capability
- (b) Fleet management capability
- (c) Fleet controlling difficulty
- (d) Shipment volume suitability
- (e) Communication and coordination comfort and

Sub-criterion 1.2 *Readiness of facilities*
which consists of three elements:
- (a) Truck fleet available
- (b) Parking area available
- (c) Truck ban constraint.

Main criterion 2
Transportation Cost constraints according to the transportation mode at the dispatching point

Sub-criterion 2.1 *Minimum truck load capacity* and
Sub-criterion 2.2 *Appropriate Task allocation to each transportation sub-contractors*.

The procedure for fine tuning the LP solutions are as shown in Figure 1.

Conclusion

A procedure of using AHP group decision making to fine tune the LP solutions is proposed in this paper. According to the procedure, the criteria are first developed in a group setting using a TQM tool called affinity diagram. The procedure has been applied to cement production and distribution planning for a leading cement producer in Thailand. It was found that the use of the combined LP-group AHP led to more insight and understanding and make it easier to reach consensus among the managers concerned.

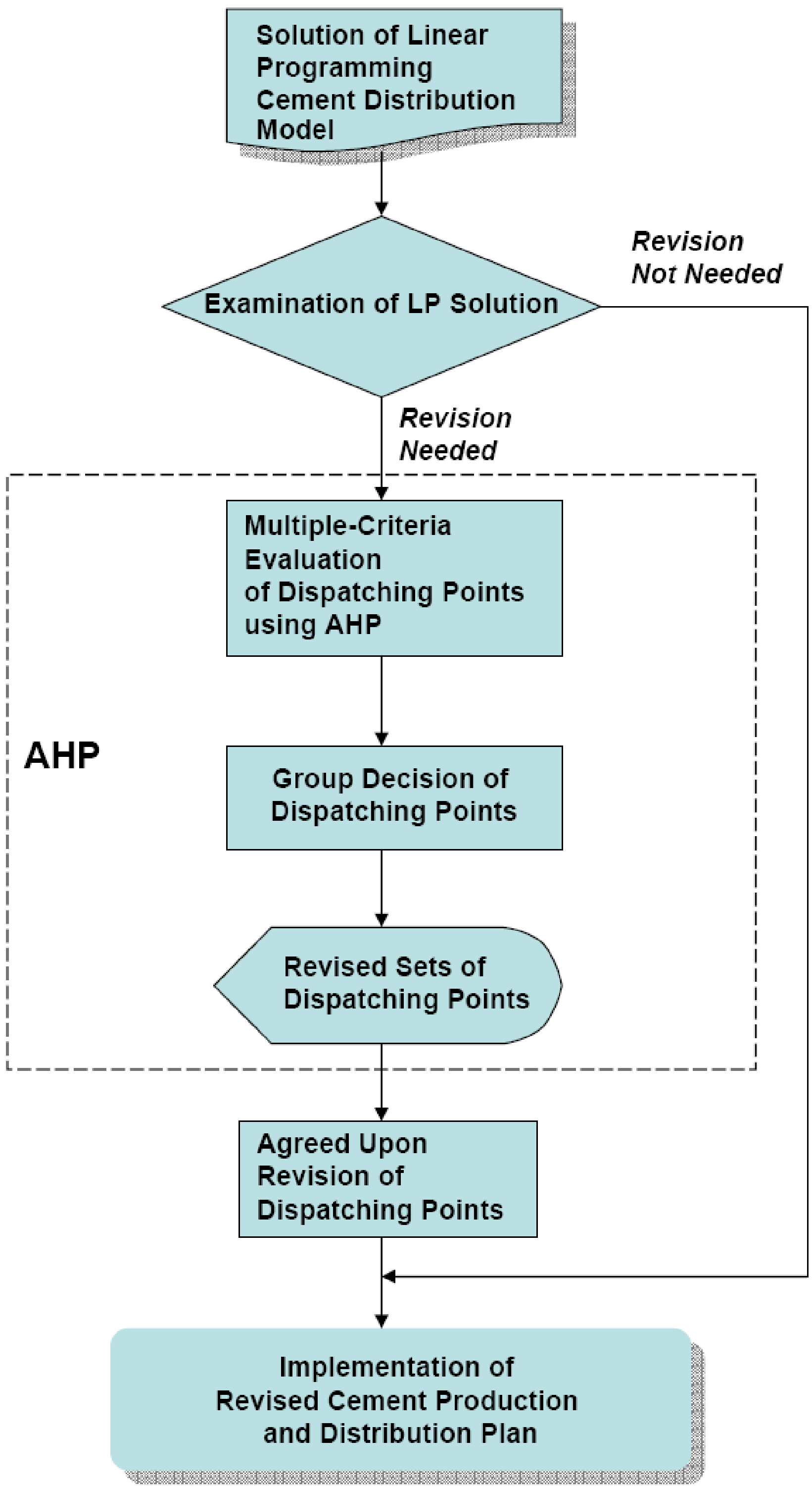

Figure 1. Procedure for using the Analytic Hierarchy Process for group revision of linear programming solutions in cement production and distribution planning.

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