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Professor MURUGESAN SELVAM, M.Com, MBA, Ph.D
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A REVIEW ON HEURISTIC APPROACHES TO SOLVE COORDINATED PRODUCTION - DISTRIBUTION PROBLEMS

Ajitha Angusamy
Faculty of Business, Multimedia University, Melaka, Malaysia
Email ID: ajitha.angusamy@mmu.edu.my

Mohamed K. Omar
Nottingham University Business School, Melaka, Malaysia
Email ID : mkhaledomar@gmail.com

and

Anantharaman R.N.*
Faculty of Business, Multimedia University, Melaka, Malaysia
Email ID : r.n.anantharaman@mmu.edu.my

Abstract

In the current competitive environment, companies need to be highly efficient in meeting customer demand at lower operational costs. As a result, companies are compelled to seek various ways to enhance their operations. Researchers realised that optimization of various departments separately would not guarantee overall optimization. This led the Researchers to focus on the effect of integrated approach and proven significant cost reduction on the overall operational costs. This paper provides a review on coordinated models in the literature and the role of heuristic approaches to solve such coordinated models. The review found that genetic algorithm plays a vital role in solving complex coordinated problems. The article also identifies the areas that are rarely addressed in coordinated models and genetic algorithms.

Keywords:*Coordinated Models, Optimization, Heuristics, Algorithms.*

JEL Code : *M31, M39.*

1. Introduction

In today's competitive environment, companies are challenged with characteristics such as the optimum time taken to design, manufacture and distribute the products. In order to face the challenges, companies need to be highly efficient in meeting the demand at lower operational costs. The concept of coordinated production and transportation model have proved a significant cost reduction for the industries that have used it. Most of the coordinated production and distribution problems in the literature, consider an overall production plan, inventory decisions and product flow through a facility over a single period of time in order to minimise the cost or maximise the profit.

In the past few decades, the coordinated production and transportation models that optimized the overall operational performance,

*** Corresponding Author**

have been an attractive area of research. Several mathematical models have been proposed for production-distribution problems in the literature and the complexity in solving such problems has also been investigated. Due to wide range of assumptions and conditions, the literature on the existing models and their solution approaches is very extensive. This paper focuses on studies related to production-distribution models that use heuristics method to obtain the solution.

2. Coordinated Production-Distribution Problem

The coordinated approach for production-distribution problems, consists of decisions that integrate various functions such as processing raw materials, inventory management, production planning, distribution of finished products to the warehouses and facilities location, into a single optimization model **(Fahimnia et al., 2013)**. One of the earliest coordinated models was proposed by **Geoffrion and Graves (1974)** and several coordinated models for various production-distribution environments were developed later. A brief summary of the coordinated models, studied in the literature, is presented in **Table 1**.

Models were developed for a wide range of industries, under different production environments. Models provided production planning and transportation decisions for solving the problem under review. The studies have proved that coordinated models are more efficient in several aspects than the uncoordinated models. However, coordinated functions may not be beneficial in all situations, as the integrated approach depends on the system parameters **(Chandra and Fisher 1994)** . The situations under which integrated efforts are more useful were provided by **Chandra and Fisher (1994)**.

The proposed models were developed by using mathematical programming of problems such as Linear Programming (LP), Mixed Integer Linear Programming (MILP), Mixed Integer Non-linear Programming, Network Flow Problems and Dynamic Programming. Most of the coordinated models were developed by using Mixed Integer Programming (MIP) and the objective function minimizes the total operational costs .

3. Why Heuristics?

In general, linear programming problems are easier to solve when compared to MIP. Various algorithms, with the latest developments in computers, have made even a large scale LP problems solvable in a reasonable time for implementation **(Hung and Hu 1998)**. Unlike LP problems, MIP problems are very difficult to solve. Due to the presence of integer variables, even a small MIP problem needs much computational effort to solve. Single level MIP problems are proved to be Non Deterministic Polynomial – time hard (NP hard) **(Bitran and Yanasse, 1982)**. In the case of multi-level problems, even finding a feasible solution has proved to be NP- complete **(Maes and Wassenhove, 1991)**. Hence most of the earlier studies proposed heuristics approach to solve MIP problems.

Heuristic approaches are proposed so as to find a near-optimal solution in a significantly less computation time. A mathematical programming procedure that is used to generate a solution for a complicated problem, is termed as Heuristic. Heuristics belongs to a class of optimum seeking mathematical programming methodology.

4. Heuristic Approaches

The general heuristics, called meta-heuristics, are more suitable for obtaining various combinatorial optimisation solutions **(Arostegui, 2006)**. The most popular meta-heuristics are Simulated Annealing, Tabu Search and Genetic

Algorithm. The basic concepts and introduction to meta-heuristics can be found in **Glover (1989, 1990)**, **Michalewicz (1994)**. General guidelines for meta-heuristic design are discussed in **Hertz and Widmer (2003)**.

4.1 Simulated Annealing

Simulated Annealing (SA), which was formally introduced by **Kirkpatrick et al. (1983)**, are often used to solve combinatorial optimisation problems. The characteristics of Simulated Annealing are discussed in **Eglese (1990)** and **Jans and Degraeve (2007)**. Studies that illustrate the efficiency of SA are **Kuik et al., (1993)**, **Marett and Wright (1996) Tian *et al.* (1996)**, **Drezner *et al.* (2002)**, **Ou Tang (2004)**. **Özdamar and Barbarosoglu (2000)** who suggested an integrated Lagrangean relaxation and simulated annealing method to solve a dynamic muti-level multi-item lot sizing problem. Authors found that the integrated approach is beneficial in providing satisfactory solution when compared with the solution obtained by Lagrangean relaxtion in **Tempelmeir** and **Derstroff (1996)**.

4.2 Tabu Search

Tabu Search (TS) is another searching technique that can be used as an alternative to SA. The earlier studies that used TS to solve capacitated lot problems, are Hindi (1995, 1996). The studies that compared TS with other heuristics and concluded that TS outperformed other heuristics are noxious facilities location problem by **Kincaid (1992)**, hydraulic turbine runner-balancing problem by **Sinclair (1993)**, fixed charged transportation problem by **Sun (1998)**, vehicle routing by **Gendreau et al.(1994)**, routing and distribution by **Rochat and Semet (1994)**, un-capacitated warehouse location by **Michel and Hentenryck (2004)**, p-median problems by **Rolland et al. (1996)** and **Voss (1996)**, un-capacitated facility location problem by **Ghosh (2003)**, budget constrained location problem by **Wang et al.(2003)**, single source capacitated locations problem by **Corinthal and Captivo (2003)** and **Chamberland (2004)**, supply chain scheduling by **Higgins et. al (2005)** and **Garcia and Lozano (2005)**, **Arosteguie (2006).**

Studies that used TS to solve production-distribution problems are **Keskin, and Üster (2007)**, **Bard and Nananukul (2010)**, **Armentano *et al.*, (2011)** and **Condotta et al. (2013)**. The heuristics proposed by **Armentano *et al.*, (2011)**, outperformed the algorithm developed by **Boudia and Pins (2009), Bard and Nananukul (2010)** in all instances.

4.3 Genetic Algorithms

In the recent years, Genetic Algorithms (GA) have attracted researchers. The basic concepts of GA were introduced by **Grinold and Marshall (1977)**. The general form of GA is described by **Goldberg (1989)**. The capability of GA, to obtain good quality solutions, are illustrated in **Goldberg (1989)**, **Shaw and Fleming (1996)**, **Lee et.al., (1997)**, **Herrman (1999)** and **De-Jong (2006)**. GA is a direct search algorithm which works by imitating principles of evolution and chromosomal processing in natural genetics **(Gupta and Bhunia, 2006)**. GA is a global search optimization technique which starts with an initial set of random solutions known as population. Every individual or solution in the population is called chromosome. The chromosomes in the population can be either represented by binary coded strings or real coded strings. It has been proven that GAs show much better performance in the case of solving large-size problems **(He & Hui, 2007a,2007b)**.

Several studies have proved genetic algorithms to be effective and useful approach for solving optimization problems. However, for many problems, the traditional simple genetic algorithm does not provide good quality solutions. Researchers proposed several methods of hybridization to overcome this problem. In the case of hybrid genetic algorithm, a local optimization is incorporated as an add-on extra to the simple genetic algorithm loop of recombination and selection. Due to the complementary properties of conventional heuristics and genetic algorithms, the hybrid approach often outperforms either method operation alone **(Gen & Cheng, 1997).**

GAs can be used to solve various problems such as lot-sizing and scheduling, scheduling and sequencing, facility-location problem, vehicle routing and scheduling, supply chain scheduling, production and distribution. The literature that addresses some of the above mentioned problems are summarized in **Table-2.** The studies illustrate that GA is capable of handling any kind of problem efficiently.

5. Discussions

The coordinated models reviewed, demonstrates a significant advance in the integrated analysis. The studies proved that coordination of production and distribution can bring significant cost reduction in the total cost. However, most of the models consist of only one objective function which aims at minimizing the total operational cost. Therefore, models with multi-objective functions and also maximization problems, need to be addressed in future studies. The literature also reveals that coordinated models are difficult to solve. Heuristic approach plays an important role in obtaining optimal or near optimal solutions for complex problems.

Meta-heuristics can be used to solve complex, combinatorial optimization problems. Very few studies used simulated annealing and tabu search to solve production-distribution problems. Among the meta-heuristics, GA is dominant in solving complex problems. Furthermore, GA, combined with other heuristics such as Lagrangean approach, greedy decoder and also with modified operators, neighbourhood search, has proved to be more beneficial than the traditional GA.

The application of real coded GA is scarce in literature. Since real coded representation makes hybridization easier **(Kaelo and Ali, 2007)**, there is still a need to develop more real coded hybrid GA in order to enhance the existing solution approaches.

6. Conclusion

The review of literature in the area of coordinated production-distribution problems that use heuristic approach to solve has been presented in this paper. The review of earlier research shows that coordinated models are more beneficial in terms of cost savings and operational efficiency. Most of the existing problems are modelled mathematically as MIP problems. The studies also reveal that complex problems can be solved for optimality or near optimality by using hybrid meta-heuristics. Among the meta-heuristics, hybrid GA is more dominant in solving complex problems. Future researches need to focus on problems with multi-objective functions and develop real coded hybrid GAs.

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Table -1 Review of Coordinated Models

Proposed Coordinated models	Author and Year
Production - Distribution	Benjamin (1989), Chandra and Fisher (1994), Zuo *et al.* (1991), Dhanenens-Flipo and Finke (1999), Jayaraman and Pirkul (2001), Ekşioğlu *et.al* (2006), Boudia *et.al* (2007), Chen (2004), Zhao and Stecke (2005), Chen and Vairaktaris (2005), Rizk et. al., (2006), Stecke and Zhao (2007), Boissière et.al., (2008), Aydinel et.al., (2008), Melo and Wolsey (2010), Yan et al. (2011), Amorim et al. (2012) Cóccola et al. (2013), Condotta et al. (2013), Fahimnia et al. (2011),
Supply-chain	Pyke and Cohen (1993), Erengüç *et. al.,* (1999), Jayaraman and Pirkul (2001), Spitter *et al* (2005), Ekşioğlu *et.al* (2006), Bilgen and Ozkarahan (2007), Boissière et.al.,(2008), Chiang et. al., (2009), Das and Sengupta (2009). Scholz-Reiter et al., (2010),
Production-Inventory - Transportation	Blumenfeld *et al.* (1985). Haq *et al.* (1991), Swenseth and Godfrey (2002), Bard and Nananukul (2010), Asgari et al. (2013)

Table – 2 Review of Models that use Genetic Algorithm

Author and Year	Problem Addressed
Kimms (1999)	Lot sizing and scheduling
Dellaert et.al.,(2000)	Multi-stage lot-sizing problem
Xie and Dong (2002)	General capacitated lot-sizing problem
Torabi et. al., (2006)	An economic lot and delivery scheduling problem
Kumar et. al., (2006)	Machine-loading problem
Gupta and Bhunia (2006)	Production-transportation problem
Li et. al., (2007)	Capacitated production planning problem
Chiadamrong and Kawtummachai (2008)	Warehouse and Distribution management problem
Borisovsky et. al., (2009)	Supply management problem
Fakhrzad and Khademi (2009)	Multi-stage production scheduling problem
Delavar et.al., (2010)	Coordinated scheduling of production and air transportation
Chung et.al., (2010)	Advanced planning in Multi-factory environment
Pasinideh et.al., (2011)	Non-linear programming problem for a economic order quantity for a two-level supply chain system.
Liu (2011)	Production-scheduling-transportation
Fahimnia et.al., (2011)	Production-distribution
Asgari et. al., (2013)	Production-inventory transportation