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A multi-objective supply chain optimisation using enhanced Bees Algorithm with adaptive neighbourhood search and site abandonment strategy

Baris Yuce [a,*], Ernesto Mastrocinque [b], Alfredo Lambiase [c], Michael S. Packianather [d], Duc Truong Pham [e]

[a] BRE Centre for Sustainable Constructions, School of Engineering, Cardiff University, Cardiff, UK
[b] School of Management, Royal Holloway, University of London, Egham, UK
[c] Department of Industrial Engineering, University of Salerno, Fisciano, Italy
[d] Institute of Mechanical and Manufacturing Engineering, School of Engineering, Cardiff University, Cardiff, UK
[e] School of Mechanical Engineering, University of Birmingham, Birmingham, UK

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ABSTRACT

In this paper, an enhanced version of the Bees Algorithm is proposed in dealing with multi-objective supply chain model to find the optimum configuration of a given supply chain problem in order to minimise the total cost and the total lead-time. The new Bees Algorithm includes an adaptive neighbourhood size change and site abandonment (ANSSA) strategy which is an enhancement to the basic Bees Algorithm. The supply chain case study utilised in this work is taken from literature and several experiments have been conducted in order to show the performances, the strength, the weaknesses of the proposed method and the results have been compared to those achieved by the basic Bees Algorithm and Ant Colony optimisation. The results show that the proposed ANSSA-based Bees Algorithm is able to achieve better Pareto solutions for the supply chain problem.

1. Introduction

Nowadays, the complexity of the business environments is rapidly growing [1]. This is due to several factors such as the expansion of the market, wide range of suppliers, increased competition and customers' demands on the performance of company, in particular the waiting time, cost and quality of the product [2]. Among these factors, if we consider the range of suppliers to the market, it is necessary to design an optimised supply chain model [3].

The supply chain is a complex network from suppliers to customers, which involves people, technologies, activities, information and resources. Its design and management has the purpose of obtaining the best global performances under specific operating criteria [4]. A typical supply chain is composed of the following elements: suppliers, manufacturing plants, warehouses, Distribution Centres (DCs), and customers/final markets.

The optimisation [5] of a supply chain is related to selecting the optimum resource options in order to satisfy the objective function/functions [6]. The single objective [7] based supply chain models are mostly aimed at finding the minimum total cost [8]. However, the modelling of a supply chain requires more than single-objective such as lead-time minimisation, inventory level minimisation, service level maximisation, environmental impact maximisation and so on [9]. Sometimes these objectives may cause conflicts such as increasing the service level usually causes a growth in costs. Therefore, the aim must be to find trade-off solutions [5] to satisfy the conflicting objectives.

In multi-objective optimisation [5] problems there is no single optimum solution, but there is a solution set which creates Pareto optimal solutions. Pareto optimal solutions are a set of trade-offs between different objectives and, are non-dominated solutions [5]; i.e. there is no other solution which would improve an objective without causing a worsening in at least one of the other objectives.

In the recent literature many optimisation approaches and algorithms have been developed and proposed in order to solve several problems in the field of logistics and transportation. Ribau et al. [10] utilised Genetic Algorithm (GA) to optimise the

* Correspondence to: BRE Centre for Sustainable Constructions, School of Engineering, Cardiff University, Queen's Buildings, The Parade, Cardiff, CF243AA, UK.
Tel.: +44 29 208 757 92.
E-mail address: YuceB@cardiff.ac.uk (B. Yuce).

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Nomenclature

ANSSA BA parameters

n	number of the sites
m	number of the sites selected for the for neighbourhood search
e	the number of top-rated (elite) sites
nep	the number of bees recruited for the best e sites
nsp	the number of bees recruited for the other $(m-e)$ selected sites
ngh	the neighbourhood size
sc	the shrinking constant
aband_site	the abandoned sites
keep_point	the number of repetitions for each site
rep_nshr	repetition number for the shrinking
rep_nenh	repetition number for the enhancement
rep_naban	repetition number for abandonment process

Supply chain parameters

i	activity index
j	resource option index
N	number of activities
D	set of delivery nodes
ξ	period of interest
N_i	number of resource option for the activity i
μ_i	the average demand per unit time at the activity i
a_k	the activities belonging to S_i
a_d	a delivery activity
S_i	Set of nodes that input to the node i
C_{ij}	the cost of the jth resource option for the activity i
y_{ij}	binary variable equal to 1 if the resource option j is selected to perform the activity i and 0 otherwise
LT_i	cumulative lead-time at node i
T_{ij}	the processing lead-time of the jth resource option for the node i
LT_k	the cumulative lead-time of node k
TC	total supply chain cost
TLT	total supply chain lead-time

official driving cycle for a hydrogen powered fuel cell hybrid bus. Ma et al. [11] proposed a mixed integer linear programming method to optimise the lane markings. In [12], GA-based optimised hierarchical fuzzy rule-based system was proposed to predict the traffic congestion. In [13], a GA based graph model was proposed to solve bi-level programming model developed for alternative traffic restriction problem. Bhattacharya et al. [14] proposed a kernel support vector mechanism based traffic flow estimation model to determine the states of the road traffic flow to generate an optimised schedule using a mixed integer programming [14].

Considering that there is no single algorithm which can find the best solution for all types of optimisation problems according to the no-free lunch theorem [15], in literature, several models have been proposed to solve supply chain design problems to get the Pareto optimal solutions. Most of these models are based on genetic algorithm and its enhanced versions [16–18]. In addition to the genetic algorithm-based supply chain models, several other methods have also been proposed especially based on the swarm-based optimisation methods [19–22]. A swarm-based optimisation model is proposed for a resource options selection problem in a bulldozer supply chain design in [21]. The model is based on Ant Colony optimisation technique to solve the multi-objective problem and to find the Pareto solution set where the aim is to find best combination of the resource options by minimising the total cost and the total lead-time. The same resource options selection problem has been solved by Mastrocinque et al. [23] proposing a multi-objective optimisation based on the Bees Algorithm [24]. The proposed approach showed encouraging results for solving the supply chain configuration problem.

The Bees Algorithm is based on the food foraging behaviour of a swarm of bees combining a random search with a neighbourhood search. The BA has been successfully applied on several optimisation problems [25–42] and other multi-objective optimisation problems, proving to be a valid approach to get the Pareto optimal set for multi-objective problems, compared with NGSA and NGSA. II [31,43,44].

In literature, improved versions of the basic Bees Algorithm have been proposed. Koc [45] proposed a combined neighbourhood size change and site abandonment (NSSA) strategy to improve the Bees Algorithm. However, Koc found that the convergence rate of a NSSA-based BA can be slow when the promising locations are far from the current best sites. To overcome this limitation, an adaptive neighbourhood size change and site abandonment (ANSSA) strategy is proposed which avoids local minima by changing the neighbourhood size adaptively [46,47].

In this work the authors propose an adaptive neighbourhood size change and site abandonment (ANSSA) strategy in order to solve the multi-objective optimisation problem of supply chain. The bulldozer supply chain problem solved in [21,23] was selected because of the complexity of the supply chain network and its general combinatorial nature that makes it suitable for various supply chain problems. The aim of the multi-objective optimisation is to find best combination of the resource options by minimising the total cost and the total lead-time.

The authors have already conducted a comparative study between the ANSSA-based BA, the basic BA and other common optimisation algorithms on a continuous type optimisation problem using benchmark functions [46,47]. The results have shown that the performance of ANNSA-based BA to be better when compared with other algorithms.

In this paper the ANSSA-based Bees Algorithm optimisation model is implemented on a resource options selection problem which has been taken from literature in order to minimise the total cost and the total lead-time of the supply chain. Several numerical experiments have been conducted in order to show the performance of the algorithm on Pareto solutions set and later the results were compared with those achieved by the basic Bees Algorithm and Ant Colony optimisation.

The contributions of the proposed ANNSA-based BA are twofold. The first contribution is in the field of the swarm intelligence where a new version of the Bees Algorithms is proposed. The second contribution is in the application area where a supply chain configuration problem, taken from the literature, is solved using the proposed algorithm.

This paper is organised as follows: the description of the basic Bees Algorithm (BA) and the new adaptive neighbourhood size change and site abandonment (ANSSA) strategy are given in Section 2, the multi-objective optimisation with the ANNSA-based Bees Algorithm together with the supply chain case study model is given in Section 3, the experimental procedure and results are given in Section 4, discussion is given in Section 5, and finally conclusions and future work are given in Section 6.