ARTIFICIAL BEE COLONY FOR INVENTORY ROUTING PROBLEM WITH BACKORDERING

N.H.Moin* and H.Z.A. Halim
Institute of Mathematical Sciences
University of Malaya
50603, Kuala Lumpur
Malaysia
noor_hasnah@um.edu.my, hudazuhrah@gmail.com

ABSTRACT

This paper addresses the inventory routing problem with backordering (IRPB) with a one-to-many distribution network, consisting of a single depot and multiple customers for a specified planning horizon. A fleet of homogeneous vehicles delivers a single product to fulfill the customers demand over the planning horizon. We assume that the depot has sufficient supply of items that can cover all the customers' demands for all periods. The backorder situation considered here is when the backorder decision either unavoidable (insufficient vehicle capacity) or more economical (savings in the coordinated transportation cost are higher than the backorder cost). The objective of IRPB is to minimize the overall cost such that transportation cost, inventory cost and backorder cost is optimal. We propose a metaheuristic method, Artificial Bee Colony (ABC) to solve the IRPB. The ABC algorithm is a swarm based heuristics which simulates the intelligent foraging behaviour of a honey bee swarm and sharing that information of the food sources with the bees in the nest. The bees are classified into three agents: the employed bee which carries the information about the food source, the onlooker bee watching the dance of the employed bees within the hive and making the decision to choose a food source based on the dances, and the scout bee, performing random search for the food sources. We modify the standard ABC algorithm by incorporating the inventory and backorder information and, a new inventory updating mechanism incorporating the forward and backward transfers. The modification also being made in the selection mechanism by the onlooker bees based on the waggle dance performed by the employed bees. We run the algorithm on a set of benchmark problems and the results are very encouraging.

Keywords: Backordering, Inventory, Artificial Bee Colony,

1 INTRODUCTION

Vendor managed inventory (VMI) is an innovative approach to remain competitive in the supply chain industry. In VMI, vendors manage the inventory at the customer's site, where they decide the quantity to be sent to customers. Backorder is defined as a delay order, where a customer's order cannot be fulfilled in certain period, and the customer is prepared to wait for some time. This can happen because of the unavailability of the product. Instead of lost sales, we can delay the delivery. To stay competitive, in VMI, managing inventory and backorder together can be beneficial, where delivery can be prioritized and more efficient routes can be arranged. Inventory routing problem with backlogging/ backordering (IRPB) is defined as a combined inventory management and vehicle routing problem (VRP) with backordering. There were many related research in solving the IRPB.

* Corresponding Author

In Barnes-Schuster and Bassok [1], the authors considered an IRPB network with a single depot with multi retailers, where the depot determines the replenishment quantity. Problem considered is infinite time horizon and stochastic demands IRPB. The problem addressed is a single depot with multi retailers, where the depot determines the replenishment quantity. The paper assumed that the order arrive at the depot and immediately delivered to retails. No inventory is held at the depot.

Reiman et al. [2], investigated the IRPB with stochastic demands. Their aim is to minimize the holding cost, backordering costs and transportation cost by proposing Monte Carlo simulation and heavy traffic simulation. The problem considered is a single depot and multiple retailers, serves by a single capacitated vehicle using direct deliveries (and predetermine routes); and products are assumed to be available at the depot.

Abdelmaguid and Dessouky [3] considered a multi period IRPB, where inventory holding, backlogging, and vehicle routing decisions are to be taken for a set of customers who receive units of a single item from a depot with infinite supply. The customers demand considered is deterministic and relatively small compared to the vehicle capacity, and the customers location are close such that a consolidated shipping strategy is appropriate. A Genetic Algorithm (GA) is proposed with a suitable GA representation, where a two dimensional matrix of the delivery schedule is designed. The authors solve the problem by decomposing it into vehicle routing problem and inventory problem for each time period. Both vehicle routing and inventory problems are link with deliveries quantities exchanges information (this information is carried in the chromosomes).

Abdelmaguid *et al.* [4] expanded the idea by introducing a constructive heuristic, referred as Estimated Transportation Cost Heuristics (ETCH) and is used to estimate single transportation cost value for each customer in each period. The problem is formulated and decomposed into two subproblems, where the inventory and backlogging decisions is compared with the estimated transportation cost, and the solution methods found were incorporated in the developed heuristic. To overcome some of the limitations of ETCH, an improvement heuristics where delivery amounts between periods are exchanged to allow for partial fulfillment of demands is introduced. The results obtained compared against the bounds found by CPLEX.

There are also other variants of IRP that have been studied. For a comprehensive review on IRP we refer the readers to Moin and Salhi [5], Andersson et al. [6] and recently Coelho et al. [7]. Moin and Salhi [5] emphasize on the road distribution, while Andersson et al. [6] focuses the problem in maritime IRP and finally Coelho et al. [7] complement the work by Andersson et al. by extending the IRP to Stochastic IRP for maritime IRP.

The remainder of the paper is organized as follows. In Section 2 describes the problem and presents its mathematical formulation. The Artificial Bee Colony is discussed in Section 3. Section 4 provides the computational results and in the last section we summarize our work.

2 PROBLEM DESCRIPTION AND FORMULATION

We consider a distribution system consisting a single depot denoted as 0, and N geographically dispersed customers, where each customer i, has a deterministic demand d_{it} in period t. The demand considered is relatively small compared to the vehicle capacity, and the customers are located closely to each other such that the consolidated shipping strategy is appropriate. A fix number of capacitated heterogeneous fleet of V vehicles housed at depot deliver a single product to the customers over the planning horizon, T. It is assumed that the vehicles must return to the depot, and no further assignment should be given to the same vehicle. And it is also assumed that renting additional vehicle is not an option.

Each customer i, has capacity up to C_i to manage its own inventory where each unit item incurs inventory carrying cost of h_i per period and shortage cost of π_i will be penalized per unit item per period if backorder occurs. It is assumed that sufficient amount of items to fulfill all customers' demand placed at depot for all the periods. Each trip of vehicle $v, v \in V$ between i and j has its transportation cost, which include a fixed usage cost, f_{vt} and also the travel cost per unit distance.

The problem allows for backordering but the stockout cost due to loss sales is not considered. Generally, the backordering decision can be divided into two. The first case is when there is insufficient vehicle capacity to deliver to the customers, given that no options to rent additional vehicle because of economy and technologies constraints. The second case is when the transportation cost saving is higher compared to the incurred shortage cost by a customer.

The aim of the study is to determine the best optimal routing by minimizing the overall transportation, inventory carrying and backlogging costs. We adopt the formulation given in Abdelmaguid et al.[4] as a basic IRPB. We will first introduce the notations that will be used throughout this paper.

Indices and sets

i, j	indices for customers, where 0 corresponds to the depot
t	index for periods
v	index for vehicle
N	set of customers
T	set of periods in the planning horizon
V	numbers of capacitated heterogeneous vehicle

Parameters

d_{it}	demand of customer i on period t
C_i	maximum capacity of each customer i
c_{ij}	transportation cost between customer i and customer j
f_{vt}	fixed vehicle cost of vehicle v at period t
h_i	holding cost at customer i
π_i	shortage cost (backorder penalty)
q_v	capacity of vehicle v

Decision variables

x_{ijt}^v	1 if vehicle v travels from customer i to customer j in period t 0 otherwise
y_{ijt}^v	vehicle load (amount transported) on vehicle v in period t
I_{it}	inventory at customer i at the end of period t
B_{it}	backorder decision at customer i at the end of period t

The formulation:

$$\min \sum_{t=1}^{T}\left[\sum_{j=1}^{N}\sum_{v=1}^{V} f_{vt}x_{0jt}^{v} + \sum_{i=0}^{N}\sum_{\substack{j=0\\ j\neq i}}^{N}\sum_{v=0}^{V} c_{ij}x_{ijt}^{v} + \sum_{i=1}^{N}(h_i I_{it} + \pi_i B_{it})\right] \quad \mathbf{(0)}$$

Subject to:

$$\sum_{\substack{j=0\\ j\neq i}}^{N} x_{ijt}^{v} \leq 1 \qquad i = 0,\dots,N;\ t = 1,\dots,T; v = 1,\dots,V \quad \mathbf{(1)}$$

$$\sum_{\substack{k=0\\ k\neq i}}^{N} x_{ikt}^{v} - \sum_{\substack{l=0\\ l\neq i}}^{N} x_{lit}^{v} = 0 \qquad i = 0,\dots,N;\ t = 1,\dots,T;\ v = 1,\dots,V \quad \mathbf{(2)}$$

$$y_{ijt}^{v} - q_v x_{ijt}^{v} \leq 0 \qquad i = 0,\dots,N; j = 0,\dots,N;\ i \neq j;\ t = 1,\dots,T;\ v = 1,\dots,V \quad \mathbf{(3)}$$

$$\sum_{\substack{l=0\\ l\neq i}}^{N} y_{lit}^{v} - \sum_{\substack{k=0\\ k\neq i}}^{N} y_{ikt}^{v} \geq 0 \qquad i = 0,\dots,N;\ t = 1,\dots,T;\ v = 1,\dots,V \quad \mathbf{(4)}$$

$$I_{it-1} - B_{it-1} - I_{it} + B_{it} + \sum_{v=1}^{V}\left(\sum_{\substack{l=0\\ l\neq i}}^{N} y_{lit}^{v} - \sum_{\substack{k=0\\ k\neq i}}^{N} y_{ikt}^{v}\right) = d_{it}$$

$$i = 1,\dots,N;\ t = 1,\dots,T \quad \mathbf{(5)}$$

$$I_{it} \leq C_i \qquad i = 1,\dots,N;\ t = 1,\dots,T \quad \mathbf{(6)}$$

$$I_{it} \geq 0 \qquad i = 1,\dots,N;\ t = 1,\dots,T \quad \mathbf{(7)}$$

$$B_{it} \geq 0 \qquad i = 1,\dots,N;\ t = 1,\dots,T \quad \mathbf{(8)}$$

$$y_{ijt}^{v} \geq 0 \text{ and } x_{ijt}^{v} = 0 \text{ or } 1 \qquad i = 0,\dots,N; j = 0,\dots,N;\ i \neq j;\ t = 1,\dots,T;\ v = 1,\dots,V \quad \mathbf{(9)}$$

The objective function (0) includes transportation cost and inventory carrying cost and shortage costs at the end of period inventory position. Constraint (1) is to make sure that a vehicle must not visit a location more than once in a period. Constraint (2) is to ensure route continuity. Constraint (3) serve for two purposes; first is to ensure that the amount transferred between two locations will always be zero whenever there is no vehicle moving between these locations, second is to ensure that the amount transported is less than or equal to the vehicle's capacity. Constraint (4) is to ensure that the efficient solutions will not contain subtours. Constraint (5) is the inventory balance equations for the customers. Constraint (6) is to limit the inventory level of the customers to the corresponding storage capacity. Constraints (7) - (9) are the non negativity constraints and the decision variable x.

3 ARTIFICIAL BEE COLONY

Recently, a new metaheuristics, Artificial Bee Colony (ABC) has received much attention as successful implementation of the ABC in real-parameter optimization. And recently the ABC algorithm has been successfully implemented to the combinatorial optimization which is known to be NP-hard. A comprehensive review on the success and their applications can be found in the review paper by Karaboga et al. [9].

ABC mimics the intelligent behavior of honey bee foraging. The intelligent behavior referred to the act of honey bee searching the food sources (known as nectar) and sharing that information of the food sources with the bees in the nest. The artificial bees were grouped into three: the employed bee, the onlookers and the scouts. Half of the artificial bees are the employed bees, while the other half is the onlooker bees.

Employed bee searching (exploiting) the food source, where these bees carry information about the food source (the distance, direction and the profitability) and then share it with the onlooker bee. The onlooker bee then selects and decides a beneficial food source by watching the dance of the employed bees in the dancing area within the hive; and then they will continue foraging from there. After employed bee finishes exploiting a food source, they will abandon it and becoming a scout bee. Scout bee is the bee that performs random search for the food sources, around the nest environment. The dancing area is the most important part of the hive, where the communications (information exchange) between bees related to the food sources are done. The communication between bees is through dancing (also known as waggle dance).

In ABC, the position of a food source represents a possible solution to the optimization problem, and the quality of the solution also known as the nectar amount of the food source is given by the fitness value of the solution. The population set contains a number of solutions (equal to the number of employed or onlookers bees); where the initial population consists of randomly generated solutions.

The ABC is a population based algorithm where the search process which includes the employed bees, the onlooker bees and the scout bees is repeated iteratively. The employed bee exploits the nectar within the area of the position (solution) in her memory depending on the local information and seeks a new nectar amount (new food position). If the new found nectar amount is higher than the previous one, the bee will memorize the new position and eliminates the old one. Otherwise the bee will keep the position of the previous position.

After all employed bees complete the search process; they will perform a dance and share the nectar amount and the position information of the food source they found, with the onlooker bees in the hive. The onlookers bees watch the dance and evaluate information received, and choose the best food source based on the probability of the nectar amount. As the onlookers and employed bees carry out the exploitation process in the search space, the scouts control the exploration process.

In this paper, we introduce an ABC algorithm for IRPB by modifying the steps of the ABC algorithm proposed in Szeto et al. [10] which was developed for Capacitated Vehicle Routing Problem (CVRP). The initial solution is represented in form of matrix. Example of the representation is given in Figure 1 until Figure 5. Here we considered 4 customers and 4 periods. Figure 1 shows the demand matrix. Figure 2 show the binary matrix, where 1 represent, that the customer is visited in that period. Figure 3 shows the corresponding delivery matrix. From Figure 3, we can obtain the Figure 4 and Figure 5 that are the inventory matrix and the backorder matrix. Note that the calculation of the outstanding demand of customer i at the beginning of period t is given by $\delta_{it} = \max(d_{it} - I_{it-1} + B_{it-1}, 0)$, with the assumption that $B = 0$ at period 0.

There are three phases in the ABC algorithm we developed. The first phase involves the employed bee exploiting a new food source and memorizing the distance, direction and the profitability of that food source, and compare with the old food source. Here, we added the inventory updating mechanism to give some information regarding the inventory level. The bee will keep the new food source found if it is better than the current one and discard otherwise. The information exchange between the employed bees and the onlooker bees is incorporated in the second phase. In this phase, the selection by the onlookers bees uses the stochastic universal sampling (SUS) to select the food source based on the waggle dance performed by the employed bees. SUS is found to be more efficient compared to the roulette wheel method adopted in Szeto et al. [10]. The final phase is when the food source can no longer be improved and the employed bee abandons the food source and it became scout bees and begins searching for a new food source. The summary of the algorithm ABC developed for IRPB is given in Figure 6.

		Period			
		1	2	3	4
Customer	1	36	32	14	33
	2	29	47	26	32
	3	41	37	44	38
	4	35	27	28	43

Figure 1: Demand matrix

		Period			
		1	2	3	4
Customer	1	1	1	0	1
	2	1	1	1	0
	3	1	1	1	1
	4	0	1	1	0

Figure 2: Binary matrix

		Period			
		1	2	3	4
Customer	1	36	46	0	33
	2	29	47	58	0
	3	41	37	44	38
	4	0	62	71	0

Figure 3: Delivery matrix

		Period			
		1	2	3	4
Customer	1	0	14	0	0
	2	0	0	32	0
	3	0	0	0	0
	4	0	0	43	0

Figure 4: Inventory matrix

		Period			
		1	2	3	4
Customer	1	0	0	0	0
	2	0	0	0	0
	3	0	0	0	0
	4	35	0	0	0

Figure 5: Backorder matrix

From Figure 6, in the initialization process, we generate n random solutions where $n = M/2$ where M is the total number of bees random solutions. All generated solutions are feasible. The initial solution indicate the food source z_i, $i = 1..n$. Then, for each food source we determine the delivery quantity for customer i in period t and then evaluate the objective function (fitness value). In addition, the initial backorder is also calculated using the heuristics called planned delivery, PLNDLV in Abdelmaguid et al. [4]. Note that each customer has an inventory capacity limit, C_i. Each solution (food source) is assigned an employed bee.

Exploitation of the food source by the onlookers bees utilize local search procedures to improve the solutions. We adopt 1-0 exchange and 2-opt* as inter route improvement procedures within the same period t. And finally when the exploration process reach the LIMIT, food source will be abandoned and replaced with a new one.

INITIALIZATION

Randomly generate a set of solutions as the initial food source z_i. Find the fitness value, $f(z_i)$ for each. Assign each food source with an employed bee.

PARAMETER

Set the value of $LIMIT$ and $MAXITER$. Set $l_i = 0$.

for iter=1:MAXITER
    for each employed bee z_i; $i = 1{:}n$
    new_z_i= INVENTORY_UPDATING (z_i).
        if $f(new\_z_i) < f(z_i)$
            $f(z_i) = f(new\_z_i)$.
            Reset $l_i = 0$.
        else
            $l_i = l_i + 1$
        end
    end

Phase I: Employed bee exploits the food source

    for each onlooker bee, ob_i; $i = 1{:}n$
    use SUS selection to choose a food source and begin exploiting it.
    new_ob_i = LOCAL_SEARCH (ob_i).
        if $f(new\_ob_i) < f(z_i)$
            $f(z_i) = f(new\_z_i)$.
            Reset $l_i = 0$.
        else
            $l_i = l_i + 1$
        end
    end

Phase II: Employed bee shares information with onlooker bee, begin exploits the selected food source

    for each employed bee z_i; $i = 1{:}n$
        if $l_i = LIMIT$
            Abandoned food source z_i.
            new_z_i=FIND_NEIGHBOR(z_i)
            $z_i = new\_z_i$.
            Reset $l_i = 0$.
        end
    end
end

Phase III: Employed bee abandons food source, become a scout bee, then begin search for new food source.

Figure 6: ABC algorithm for IRPB.

4 EXPERIMENTAL RESULTS AND DISCUSSION

4.1 Data set and Parameter Setting

We tested our algorithm on 30 datasets obtained from Abdelmaguid et al. [4]. The dataset is characterized by the number of customers N, period T, number of vehicles V and number of replicates. Each case has 5 different replicates. The dataset consisting at most 15 customers and 7 number of periods. The dataset can be classified into three categories with small $N = 5$, medium $N = 10$ and large $N = 15$, which each varies with period $T = 5$ and $T = 7$. The characteristics of the dataset are summarized in Table 1. The problems represent scenarios where each customer is located in a different major city. This scenario simulates real situations faced by the manufacturing companies in the current industries.

Note that the depot is located in the middle, surrounds by customers with locations within a square of 20 x 20 distance units. Capacity at each customer's site is 120 items and the fixed vehicle cost is 10 and the travel cost per unit distance used is 1.

For the ABC algorithm, we set the total number of bees to 50 bees with 25 employed bees and 25 onlookers bees. Maximum number of iterations is 250. Parameter LIMIT which controls the exploration process is set at $25 \times N$.

Table 1: Data Set

Characteristics	N=5	N=10	N=15
Fixed Vehicle Cost (f_{vt})	10	10	10
Travel Cost per Unit Distance	1	1	1
Vehicle Capacity (q_v)	500	1000	1500
Range of Holding Cost (h_i)	[0.06,0.14]	[0.05,0.16]	[0.05,0.14]
Range of Backorder Cost (π_i)	[4.11,6.19]	[3.75,6.12]	[3.88,6.29]

4.2 Results and Discussion

The proposed algorithm, ABC is coded using MATLAB 8.1 and the computational experiments were run on 8GB RAM computer with processor 3.1 GHz.. Each dataset were run 10 independent times and the best result is tabulated. We compare our ABC algorithm with the heuristics algorithm presented in Abdelmaguid et al. [4], together with the upper and lower bound found in AMPL-CPLEX [4]. Table 2 present the best results of ABC, results by Abdelmaguid et al. [4], lower bound (LB), upper bound (UB) and in the last column (%Δ) represents the percentage different between ABC and [4].

From table 2, we can see that ABC is able to obtain 4 better results compared to [4]. Percentage different shows that the farthest obtained by our algorithm produces 12.98% worse results than the heuristics method developed in [4]. Note that, for large problem with 15 customers ABC is better than the upper bound obtained by CPLEX. We are still modifying our algorithm by including certain local search in order to reduce the number of vehicles and the transportation cost.

We can see that the results found also show that the inventory cost in ABC is lower as compared to Abdelmaguid et al. [4], with a trade off of a higher transportation cost. The running time for small and medium case is within 80 seconds while running time for the large cases is not more than 200 seconds.

Table 2: Best Results, Lower and Upper Bound, and Percentage Different

PROBLEM	CPLEX		ABC				Abdelmaguid et al. [4]				%Δ
	UB	LB	TOTAL	INVENTORY	BACKORDER	TRANS	TOTAL	INVENTORY	BACKORDER	TRANS	
1-0551-1	205.84	205.84*	208.84	52.84	0	156	**205.84***	71.84	0	134	1.44
1-0551-2	150.74	150.74*	**150.74***	45.74	0	105	**150.74***	45.74	0	105	0.00
1-0551-3	186.60	186.60*	193.00	50.00	0	143	**186.6***	48.60	0	138	3.32
1-0551-4	200.80	200.80*	210.18	59.18	0	151	**204.30**	58.30	0	146	2.80
1-0551-5	184.80	184.80*	**184.80***	48.80	0	136	185.35	49.35	0	136	-0.30
1-0571-1	278.96	278.96*	**280.41**	88.41	0	192	281.81	70.81	0	211	-0.50
1-0571-2	268.68	268.68*	**272.94**	63.94	0	209	272.98	70.98	0	202	-0.01
1-0571-3	273.07	273.07*	277.15	77.15	0	200	**273.07***	75.07	0	198	1.47
1-0571-4	312.25	312.25*	**326.39**	86.39	0	240	349.49	80.49	0	269	-7.08
1-0571-5	310.98	310.98*	318.52	76.52	0	242	**314.04**	86.04	0	228	1.41
1-1051-1	327.09	306.82	339.69	128.69	0	211	**326.97**	108.97	0	218	3.74
1-1051-2	286.17	251.17	305.19	73.19	0	232	**276.41**	93.41	0	183	9.43
1-1051-3	300.69	295.90	316.69	63.69	0	253	**300.69**	90.69	0	210	5.05
1-1051-4	291.13	260.20	309.82	56.82	0	253	**280.13**	88.13	0	192	9.58
1-1051-5	269.47	218.90	266.42	86.42	0	180	**249.63**	69.63	0	180	6.30
1-1071-1	451.45	413.73	478.87	101.87	0	377	**451.84**	142.84	0	309	5.64
1-1071-2	454.86	374.32	433.31	101.31	0	332	**420.20**	132.20	0	288	3.03
1-1071-3	495.20	410.98	523.75	126.75	0	397	**467.65**	130.65	0	337	10.71
1-1071-4	489.67	428.21	508.43	130.43	0	378	**461.40**	142.40	0	319	9.25
1-1071-5	399.07	370.35	443.68	70.68	0	373	**397.96**	130.96	0	267	10.30
1-1551-1	458.73	337.92	430.16	49.16	0	381	**402.54**	153.54	0	249	6.42
1-1551-2	414.62	294.14	372.26	25.26	0	347	**349.76**	131.76	0	218	6.04
1-1551-3	430.06	319.32	415.82	38.82	0	377	**384.40**	130.40	0	254	7.56
1-1551-4	420.33	314.08	400.41	41.41	0	359	**367.88**	109.88	0	258	8.12
1-1551-5	425.91	315.85	414.82	56.82	0	358	**369.22**	121.22	0	248	10.99
1-1571-1	733.36	452.81	601.67	81.67	0	520	**523.57**	180.57	0	343	12.98
1-1571-2	654.56	454.07	586.14	41.14	0	545	**526.99**	194.99	0	332	10.09
1-1571-3	553.61	405.71	524.32	5.32	0	519	**483.02**	179.02	0	304	7.88
1-1571-4	649.16	469.47	595.51	62.51	0	533	**541.69**	196.69	0	345	9.04
1-1571-5	666.62	440.91	580.33	28.33	0	552	**512.48**	176.48	0	336	11.69

5 CONCLUSION

In this paper, we successfully proposed Artificial Bee Colony (ABC) for Inventory Routing Problem with Backordering (IRPB). ABC has 3 phases; the first phase is exploitation, where the employed bee exploits the food source, phase two is the information exchange, where the information regarding the food source is shared with the onlooker bees, and finally phase three controls the exploitation of the whole process, where employed bee will abandoned food source if it is no longer beneficial.

We implement a mechanism that handle both the inventory and backorder by proposing an inventory updating mechanism which includes the backward and forward transfers. There are two situations of backordering considered, first is when there is not enough vehicle capacity to do delivery and second is when it is more economical to backorder rather than to transport (due to transportation costs is higher than the backordering costs).

Results obtained are comparable when compared to the results in Abdelmaguid et al. [4] with 4 out of 30 problems produced better results. For further research, the inventory updating mechanism will be improved and a better local search will be embeded and investigated.

6 ACKNOWLEDGEMENT

This research is supported by Fundamental Grant FRGS (F041/2010B), Exploratory Research Grant ERGS ER-004-2013A and Postgraduate Research Fund (PG055-2013A).

7 REFERENCES

[1] D. Barnes-Schuster and Y. Bassok, "Direct shipping and the dynamic single-depot/multi-retailer inventory system," *European Journal of Operational Research*, vol. 101, pp. 509-518, 1997.

[2] M. I. Reiman, R. Rubio, and L. M. Wein, "Heavy traffic analysis of the dynamic stochastic inventory-routing problem," *Transportation Science*, vol. 33, pp. 361-380, 1999.

[3] T. F. Abdelmaguid and M. M. Dessouky, "A genetic algorithm approach to the integrated inventory-distribution problem," *International Journal of Production Research*, vol. 44, pp. 4445-4464, 2006.

[4] T. F. Abdelmaguid, M. M. Dessouky, and F. Ordóñez, "Heuristic approaches for the inventory-routing problem with backlogging," *Computers & Industrial Engineering*, vol. 56, pp. 1519-1534, 2009.

[5] N. H. Moin and S. Salhi, "Inventory routing problems: a logistical overview," *Journal of the Operational Research Society*, vol. 58, pp. 1185-1194, 2006.

[6] H. Andersson, A. Hoff, M. Christiansen, G. Hasle, and A. Løkketangen, "Industrial aspects and literature survey: Combined inventory management and routing," *Computers & Operations Research*, vol. 37, pp. 1515-1536, 2010.

[7] L. C. Coelho, J.-F. Cordeau, and G. Laporte, "Thirty years of inventory routing," *Transportation Science*, 2013.

[8] D. Karaboga, "An idea based on honey bee swarm for numerical optimization," Technical report-tr06, Erciyes university, engineering faculty, computer engineering department2005.

[9] D. Karaboga, B. Gorkemli, C. Ozturk, and N. Karaboga, "A comprehensive survey: artificial bee colony (ABC) algorithm and applications," *Artificial Intelligence Review*, pp. 1-37, 2012.

[10] W. Szeto, Y. Wu, and S. C. Ho, "An artificial bee colony algorithm for the capacitated vehicle routing problem," *European Journal of Operational Research*, vol. 215, pp. 126-135, 2011.