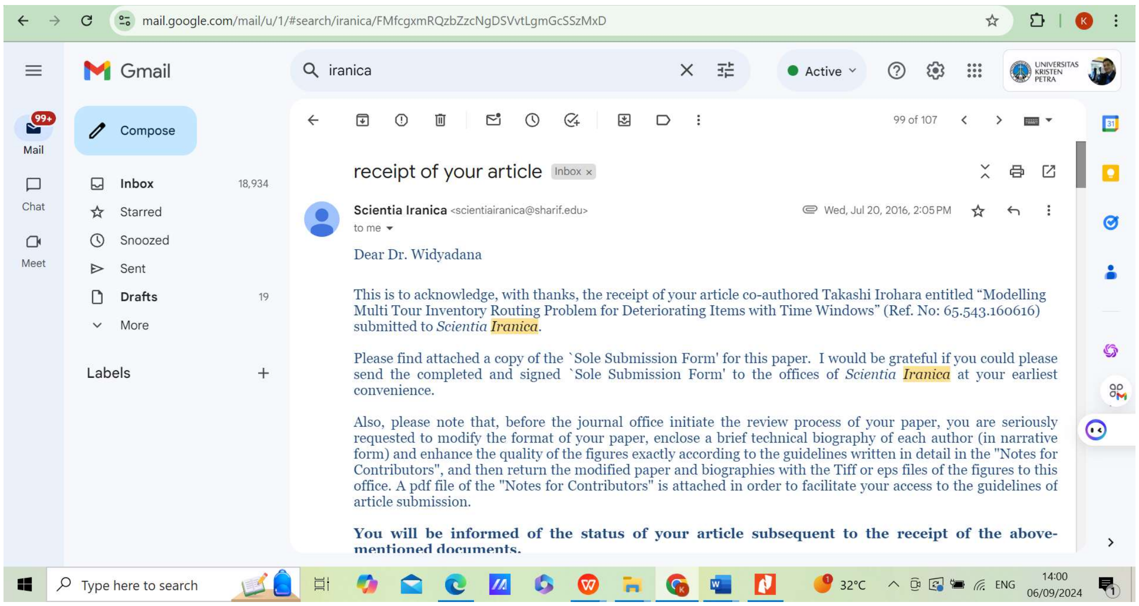
Tahapan pengiriman makalah

No	Tanggal	Tahapan
1	20 Juli 2016	Pengiriman makalah
2	10 April 2017	Review tahap 1
3	8 Januari 2018	Penerimaan makalah

Pengiriman Makalah


receipt of your article Inbox

Scientia Iranica <scientiairanica@sharif.edu> Wed, Jul 20, 2016, 2:05 PM

to me

Dear Dr. Widyadana

This is to acknowledge, with thanks, the receipt of your article co-authored Takashi Irohara entitled “Modelling Multi Tour Inventory Routing Problem for Deteriorating Items with Time Windows” (Ref. No: 65.543.160616) submitted to *Scientia Iranica*.

Please find attached a copy of the `Sole Submission Form' for this paper. I would be grateful if you could please send the completed and signed `Sole Submission Form' to the offices of *Scientia Iranica* at your earliest convenience.

Also, please note that, before the journal office initiate the review process of your paper, you are seriously requested to modify the format of your paper, enclose a brief technical biography of each author (in narrative form) and enhance the quality of the figures exactly according to the guidelines written in detail in the "Notes for Contributors", and then return the modified paper and biographies with the Tiff or eps files of the figures to this office. A pdf file of the "Notes for Contributors" is attached in order to facilitate your access to the guidelines of article submission.

You will be informed of the status of your article subsequent to the receipt of the above-mentioned documents.

Review Tahap 1

Dear Dr. Widyadana,

Please find attached the review comments on your article entitled, “Modelling Multi Tour Inventory Routing Problem for Deteriorating Items with Time Windows” (Ref. No: 65.543.160616), which was submitted to Scientia Iranica for possible publication.

It would be appreciated if you could kindly examine the review comments and accomplish the followings:

1. If applicable, please implement the review recommendations and provide an itemized list of the alterations made.

2. In the revised manuscript, please highlight the places where the contents have been revised according to the review comments.

3. If the review comments are inapplicable, please forward a response to the review suggestions.

Please send/upload the file of the revised paper and the itemized list of the alternations made in a period of <u>at most one month</u> from the receipt of this letter. The paper will be ignored from the list of submitted papers, if it is not received within this period.

Your cooperation and consideration are fully appreciated and we are looking forward to hearing from you regarding this matter in the near future.

Sincerely yours,

A. Vafai, Professor

S. T. A. Niaki, Professor

Editors-in-Chief

PS. Please acknowledge receipt of this e-mail.

Reviewer 1

Ref. No: 65.543.160616

"Comments to the Authors"

The Inventory research considering Routing Problem is interesting and worthy of the research. The paper has the potential to attract many readers. A minor revisions are listed below:

1. The writing of the paper need improvement. Please ask a native English speaker or others to

check the English writing. A few corrections are listed below:

(i) I the first paragraph,In recent decades, there are intensive researches on deteriorating

inventory. However, only few researchers focus onthe inventory routing problem for deteriorating item. There are many items such as foods, electronic products that deteriorate with time, and many other products in the market also have perishable characteristic.

(ii)This paper is divided into five sections. Use sections instead of chapters

2. The equations in the pdf files have bugs, I cannot read them.

3. More references on deteriorating item models should be included. Some are:

2013, Revisiting a fuzzy rough economic order quantity model for deteriorating items

considering quantity discount and prepayment, Mathematics and Computer Modelling, Vol 57,

Issue 5-6, pp. 1466-1479.

2013. Pricing and replenishment strategy for a multi-market deteriorating product with time-

varying and price-sensitive demand, Journal of Industrial and Management Optimization

(JIMO), Vol. 9, NO.4, October pp. 769-787

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and incentive-dependent sale, Mathematical and Computer Modelling, Vol. 57, pp. 536-550.

2013, An inventory model with variable demand, component cost and selling price for

deteriorating items, Economic Modelling, Vol. 30, pp. 306-310.

Reviewer Comments Directed to Author(s)

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Reviewer 2

Ref. No: 65.543.160616

"Comments to the Authors"

The authors developed an Inventory routing problem for a deteriorating item. None of the

mathematical equations of the paper is readable. As a result it is not possible to make any

comment about the mathematical formulation of the model. Moreover standard of the English of

the manuscript is very poor. English should be checked by an expert of English language or

professional proof reader. Mathematical expressions should be written in such software that it

will be readable for evaluation.

Revisi

Modelling Multi Tour Inventory Routing Problem for Deteriorating Items with Time Windows

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Abstract

There is intensive research on deteriorating inventory however only a few researchers focuses on the inventory routing problem for deteriorating item. There are many items such foods, electronic deteriorate in time, and some products also have the perishable characteristic. The other important variable that should be considered is the time windows constraint. Time is crucial for deteriorating and perishable items. An organization tries to provide fresh items on time, so she set the time constraints. Only a few papers discuss the inventory routing problem for deteriorating items from our intensive literature research. In this paper, an inventory routing problem with time windows for deteriorating items is developed. Particle Swarm Optimization (PSO) is used to solve the problem since PSO can solve problems in a reasonable period with near optimal solutions. We use two numerical examples to illustrate the model. In a sensitivity analysis, key parameters change that effect costs are shown. Our results show that the deteriorating rate in inventory has bigger effects than deteriorating rate in the vehicle, so this research has a significant contribution and managers can give more effort to reduce deteriorating in inventory than the deteriorating rate in vehicles.

Keywords: Inventory, IRP, Time Windows, Deteriorating items, PSO

1. Introduction

Many companies have to face products distribution problem from the manufacturer or vendor to many retailers. The objective of the companies is how to optimize the products transportation cost and then inventory holding cost as well. This problem is called as an inventory routing problem (IRP). The IRP problem has been introduced for more than 30 years ago, and many variations of models and solutions have been studied [1]. The model variations include IRP with continuous move [2], vehicle multi-tours [3], stochastic demand [4] and time windows [5].

The time windows are a constraint to be fulfilled where vehicles must arrive at the retailers within the time windows defined by the earliest and latest times. There are two types of time windows which are hard time windows and soft time windows. For the hard time windows, the vehicle must arrive on time during the earliest and latest time, and for the soft time windows, vehicles can come before the most initial time or after the most recent time with penalty cost as a consequence.

The cyclic inventory routing problem is a variant of IRP where customer demand rates are stable, and the planning horizon is infinite [6]. Similar to the other IRP problem, in this issue, the objective function is to minimize total transportation and inventory cost for the long term. Banos [7] solved vehicle routing problems with time windows using a combination of evolutionary algorithm and simulated annealing. Shen [8] developed an IRP model with multiple customer, time period and transportation mode. The model was applied in the crude oil transportation problem. Qin [9] proposed a local search for solving a periodic inventory routing problem where replenishment period, delivery quantity and vehicle routing remains the same for every replenishment time. Raa and Aghezzaf [10] proposed solid modeling and solution approach for solving cyclic IRP by considering driving time restrictions. Osvald and Stirn [11] developed a vehicle routing problem with perishable food. They assumed food has limited life span and divide into three periods. In the first period, the food quality is stable, in the second-period quality decrease and in the last period the product is unacceptable. Chen et al. [12] developed vehicle routing problem with perishable products. They considered that value of the product decayed in particular value compare to its original price. They did not consider product decay in term of product's volume. Amorim and Alamada-Lobo [13] developed a routing problem model by considering two objectives which are distribution cost and freshness of food. They concluded that time windows have high impacts on the freshness level of product.

According to the authors' extensive literature research, only a few papers discuss the inventory routing problem for deteriorating items. Deteriorating items are defined as decay, evaporation, obsolescence, and loss of quality marginal value of a commodity that results in decreasing usefulness from its original condition. Things like vegetables and fuels are two examples of deteriorating items. There is intensive research on deteriorating items such as a deteriorating inventory model with a permissible delay of payment [14], deteriorating inventory items by considering quality, inspection and maintenance, varying demand and production rates [15] and deteriorating items with preventive maintenance and rework [16]. Some researchers developed EOQ models for deteriorating items by considering two important variables which are pricing and replenishment policy simultaneously such as Sarkar et al. [17], Chung et al. [18], Yang et al. [19]. They concluded that solve pricing and replenishment policy simultaneously result in higher total profit than only considering one of them, especially for price dependent items. Therefore deteriorating inventory item models should not only consider replenishment policy but should find other relevant costs or strategies. Baker et al. [20] mentioned about some research in deteriorating inventory models, but they did not discuss any investigation on the deteriorating inventory model by considering transportation cost. Taleizadeh et al. [21] developed a deteriorating inventory model considering quantity discount, prepayment and transportation costs. However, the shipping cost is only from one vendor to one buyer. This paper introduces inventory routing problem for deteriorating items where the model does not only consider inventory cost but also transportation cost and the items started to deteriorate when the items are loaded onto the truck. The shipping cost is seen from one depot to retailers and return to the depot. Time is an important parameter to be considered for deteriorating items, so the model is also considered time windows. Since the model is an NP-hard model, a particle swarm optimization method (PSO) is used to solve the problem. PSO is a good way to solve vehicle routing problems such as discussed by [22], [23], [24], and [25]. This paper is divided into five chapters. The first chapter discusses research motivation and research gap. An inventory deteriorating item model is developed in Chapter 2, and Chapter 3 shows the PSO method for solving the model. A numerical example is presented in Chapter 4 to get the best PSO parameters, and a sensitivity analysis is conducted to get some insights of the model. We derive conclusions in Chapter 5.

2. Mathematical Model

In this problem, a depot with unlimited capacity serves some retailers with different and constant demand rate. As a vendor managed inventory (VMI) scheme, the depot can control inventory in his warehouse and inventory in all retailers store. Since the items are deteriorating items, items quantity to be delivered to retailers should consider the amount of deteriorated items in vehicles and retailer's warehouse. The IRP problem using cyclic IRP where the planning horizon is infinite. However, retailers set specific time windows for items delivered. When vehicles arrive at the retailer's warehouse before the earliest time window, the retailers will charge the extra cost to the depot. In the other case, when a vehicle arrives after the latest time window, the retailer has to pay overtime for unloading workers. The overtime payment will be charged to the depot. When an optimal cycle time and routing are set for every vehicle, the same decisions are applied for every cycle time. One vehicle can be used to deliver in consecutive days, and there is more than one vehicle can be operated. The entire paper using assumptions, parameters and decision variables as below:

Assumptions

1. Vehicle have to return to the depot in 24 hours
2. One retailer only be served by one vehicle
3. Each vehicle can have more than one trip in one cycle time
4. Vehicle capacity is fixed and homogeneous
5. Vehicle speed is constant
6. Items are deteriorated when vehicles depart from the depot with the constant deteriorating rate.
7. Deteriorating rate in vehicles is higher than the deteriorating rate in the warehouse.
8. Shortage is not allowed

Parameters

i	: Retailers $1,2, \dots, I$
R	: Depot
v	: vehicles 1, 2, … *V*
d_i	: Demand rate/units/time at retailer i
$Q_i^{'}$	: Total demand at retailer i
s_{ij}	: Distance between location i to *j* where $\{i,j\} \in S^{+} = S \cup \{r\}$
ve_v	: Average speed of vehicle v
t_{ij}	: Transportation time between location i to *j* where $\{i,j\} \in S^{+}$, where $t_{ij} = s_{ij}/ve_v$
γ	: Deteriorating cost (€/unit)
δ_v	: Transportation cost for vehicle v (€/km)

ve_v : Average speed of vehicle v

φ_i : Handling cost at retailer i (€)

ψ_v : Operational cost of vehicle *v* (€/unit time)

η_i : Holding cost for retailer i (€/unit/unit time)

P_e : Earliest penalty cost

P_l : Latest penalty cost

k_v : Maximum capacity of vehicle v

E_t : Earliest time window

L_t : Latest time window

T^v : Cycle time of vehicle *v*

θ_1 : Deteriorating rate during delivery process

θ_2 : Deteriorating rate at retailer's warehouse

t_0 : Time to start of vehicle from *DC*

t_{1i} : Time of vehicle arrive at retailer i

t_{2i} : Time when inventory stock is zero at retailer *i*

I_i : Average inventory at retailer i

T^v_{min} : Minimum cycle time of vehicle *v*

T^v_{max} : Maximum cycle time of vehicle *v*

Decision variables

x_{ij}^{v} : $\begin{cases} 1, \text{if there is delivery from retailer } i \text{ to } retailer\ j \text{ using vehicle } v \\ 0, \text{otherwise} \end{cases}$

y^{v} : $\begin{cases} 1, \text{if vehicle } v \text{ is used} \\ 0, \text{otherwise} \end{cases}$

T^{v}_{EOQ} : The optimal cycle time of vehicle v

A^{i}_{v} : Time of vehicle *v* arrive at retailer *i*

z_{ij}^{v} : Volume of items loaded by vehicle *v* from retailer *i* to retailer *j*

L_{rr}^{nv} : Total vehicle capacity at sub-tour n in multi-tour v start from depot r back to depot r

Since there is no production in retailers, the inventory level in each retailer decrease by constant customer demand and deteriorating rate. The inventory level for deteriorating items at a particular time is:

$$\frac{dI(t)}{dt} + \theta_2 I(t) = -\, d_i \quad (1)$$

Through some calculation processes and simplifications, one has:

$$I(t) = \left(e^{\theta_2 t} - 1\right)\frac{d_i}{\theta_2} \quad (2)$$

The order quantity at retailer *i* depend on demand and deteriorating rate during a cycle time. The order quantity for retailer *i* is:

$$Q_i = \left(e^{\theta_2 T} - 1\right)\frac{d_i}{\theta_2} \quad (3)$$

Item quantity during the transportation time is decreasing with a constant deteriorating rate. So items amount at a particular time during transportation can be modeled as:

$$\frac{dI(t)}{dt} + \theta_1 I(t) = 0 \quad (4)$$

Through some simplifications one has:

$$I(t) = \frac{Q'}{e^{\theta_1 t}} \quad (5)$$

When t_1 is a transportation time and quantity of item needed at each retailer *Q*, then quantity of items that has been brought by each vehicle (*Q'*) is

$$Q_i^{'} = Q_i e^{\theta t_{1i}} \quad (6)$$

From (3) and (6) can be derived the total quantities that have been delivered by each vehicle to each retailer as:

$$Q_i^{'} = \frac{d_i\left(e^{\theta_2 T} - 1\right)e^{\theta_1 t_{1i}}}{\theta_2} \quad (7)$$

Fig. 1 shows the total quantity loaded by each vehicle. The total amount is depending on transportation time, replenishment time, deteriorating rate and demand rate.

Put Figure 1 here

Using Fig. 1, the total quantity that is delivered by each vehicle for a single tour can be modeled as:

$$L_{rr} = \sum_{i \in ST_n} \frac{\left(e^{\theta_2 T} - 1\right)e^{\theta_1 t_{1i}} d_i}{\theta_2} \quad (8)$$

The total cost of the problem consists of transportation cost, handling cost, holding cost, deteriorating cost and penalty time cost Transportation cost/unit time can be modeled as:

$$C_T = \frac{1}{T^v}\left(\sum_{i \epsilon S^+}\sum_{j \epsilon S^+}\left(\delta_v\, t_{ij} x_{ij}^v\right)\right) \qquad (9)$$

Handling cost/unit time can be formulated as:

$$C_H = \sum_{i \epsilon S}\left(\frac{\varphi_i}{T^v}\right)\left(\sum_{j \epsilon S^+} x_{ij}^v\right) \qquad (10)$$

The total quantity delivered by each vehicle at each retailer minus aggregate demand is equal to total deteriorating items at each retailer. The total deteriorating items at each retailer can be modeled as:

$$D_i = \frac{\left(e^{\theta_2 T^v} - 1\right) e^{\theta_1 t_{1i}} d_i}{\theta_2} - d_i T^v \qquad (11)$$

The total deteriorating items cost/unit time can be modeled as:

$$C_D = \sum_{i \epsilon S} \left(\frac{\gamma_i D_i}{T^v}\right) \sum_{j \epsilon S^+} x_{ij}^v \ (12)$$

The total inventory cost/unit time can be formulated as follows:

$$C_s = \sum_{i \epsilon S} \left(\frac{\eta_i d_i}{T^v {\theta_2}^2}\left(-1 - \theta_2 T^v + e^{\theta_2 T^v}\right)\right)\left(\sum_{j \epsilon S^+} x_{ij}^v\right) (13)$$

When a vehicle arrives before the earliest time windows or after the latest time windows, penalty costs are charged by the retailer to the vendor. The penalty costs per unit time at retailer *i* can be modeled as:

$$CP_i = \frac{1}{T^v}\left(\sum_{i \in S} P_e max(E_t - A_i^v, 0) + \sum_{i \in S} P_L max(A_i^v - L_t, 0)\right) (14)$$

The objective function and the constraints of the model can be modeled as follows:

$IRP_{IP}: Minimize$

$$\begin{aligned} Z = \sum_{v \in m} \Bigg[& \frac{1}{T^v}\left(\sum_{i \epsilon S} \sum_{j \epsilon S^+} \left(\delta_v \, ve_v t_{ij} x_{ij}^v\right)\right) \\ & + \sum_{i \epsilon S}\left(\left(\frac{\varphi_i}{T^v} + \frac{\eta_i d_i}{T^v {\theta_2}^2}\left(-1 - \theta_2 T^v + e^{\theta_2 T^v}\right) + \left(\frac{\gamma D_i}{T^v}\right)\right)\right)\left(\sum_{j \epsilon S^+} x_{ij}^v\right) \\ & + \frac{1}{T^v}\left(\sum_{i \in S} P_e max(E_t - A_i^v, 0) + \sum_{i \in S} P_L max(A_i^v - L_t, 0)\right)\Bigg] \end{aligned}$$

Subject to:

$$\textstyle\sum_{v \in V} \sum_{i \in S^+} x_{ij}^v = 1 \qquad j \in S \qquad (16)$$

$$\sum_{i\in S^+} x_{ij}^v - \sum_{k\in S^+} x_{jk}^v = 0 \quad j \in S^+, v \in V \tag{17}$$

$$\sum_{i\epsilon S}\sum_{j\epsilon S^+} t_{ij}^v x_{ij}^v - T^v \leq 0 \quad v \in V \tag{18}$$

$$\sum_{v\in V}\sum_{i\in S^+} z_{ij}^v - \sum_{v\in V}\sum_{k\in S^+} z_{jk}^v = \frac{d_j\left(e^{\theta_2 T^v} - 1\right)e^{\theta_1 t_{ij}} x_{ij}^v}{\theta_2} \quad i,j \in S \tag{19}$$

$$x_{rj}^v - y^v \leq 0 \quad v \in V, j \in S \tag{20}$$

$$z_{rj}^v \leq k(v) \quad v \in V, j \in S \tag{21}$$

$$A_i^v + t_{ij} X_{ij}^v \leq A_j^v \quad v \in V, i,j \in S^+ \tag{22}$$

$$A_d^v \leq 24 \quad v \in V \tag{23}$$

$$x_{ij}^v \in \{0,1\}, z_{ij}^v \geq 0, y^v \in \{0,1\}, T^v \geq 0 \; for\ all\ v \in V, i,j \in S^+$$

The objective function is represented by equation (15). The objective function consists of transportation cost, handling the cost, inventory holding costs, deteriorating cost and earliest and latest penalty cost. It is derived from the summation of the equation (9-14). Equation (16) assures that one retailer is served by one and only one vehicle. A first routing equation that ensures that once a vehicle enters a retailer, it will leave the retailer is shown in equation (17). Equation (18) state that the total transportation time of one vehicle cannot be higher than the cycle time. Equation (19) guarantees that volume of the items load in one vehicle is equal to total demand during one cycle, deteriorated items in a retailer's warehouse during one period and deteriorated items during transportation time. When there is a delivery from the depot, the same vehicle must be used. This condition is shown in Equation (20). Equation (21) assures that total demand and deteriorated items loaded in one vehicle cannot bigger than vehicle's capacity. Equation (22) ensures that time of a vehicle arrive at retailers must be larger than vehicle comes at previous retailers and transportation time between retailers. A vehicle should return to the depot before a day so that it can be used in the next day is shown in equation (23). Since the model is a non-linear model and it is an NP-hard model, PSO algorithm is used to solve the model.

3. Particle Swarm Optimization for solving IRPDITW

This chapter describes a PSO algorithm to address an inventory routing problem for deteriorating items with time windows (IRPDITW). In this chapter, a PSO algorithm is proposed to solve inventory routing problem for deteriorating items with time windows (IRPDITW). This section is divided into three parts. The first part discusses the PSO framework; the second shows the decoding method and the final section discusses the routing for one day.

3.1. PSO framework

Particle swarm optimization is a population-based computation technique where each particle moves according to its best position and the best position of the other particle. It is like a flock of birds collectively foraging for food, where the fitness function represents the food location. Detail of the PSO algorithm for solving multi tour inventory routing problem for deteriorating items is presented as Algorithm 1.

Algorithm 1.

1. Initialize particle by setting particles (*pr*), some iterations (α) and some initial parameters. Set $\overrightarrow{v_0} = 0$, personal best (Pbest) $\overrightarrow{xl_{ps}} = \overrightarrow{x_{ps}}$ and iteration *i*=1.
2. For *i*=1,...,*p* decode $\overrightarrow{x_{ps}}$ to a set vehicle route R_i.
3. For *i*= 1...,*p*.calculate the performance measurement of R_i as *Zi*

Calculate optimal economic period using (24). The solution can be found by using Bisection method.

$$Minimize: Z_i = R_i\left(\frac{\sum_{i\in S}\sum_{j\in S} + \delta_v\, ve_v t_{ij}}{T_{EOQ}(C_v)} + \sum_{i\in S}\left(\frac{\varphi}{T_{EOQ}(C_v)} + \eta\bar{I}_i + \frac{\gamma\left(L_r^{iv} - d_i T_{EOQ}(C_v)\right)}{T_{EOQ}(C_v)}\right) + \frac{1}{T_{EOQ}(C_v)}\sum_{i\in S} P_e max(E_t - A_i^v, 0) + \sum_{i\in S} P_L max(A_i^v - L_t, 0)\right) \quad v \in V$$

subject to

$$T_{min}^v \le T_{EOQ}^v \le T_{max}^v \quad v \in V \quad (25)$$

4. Update Pbest by setting $\overrightarrow{xl_{ps}} = \overrightarrow{x_{ps}}$ if $Z_{x_{ps}} < Z_{xl_{ps}}$

5. Update Gbest by setting $\overrightarrow{xg_s} = \overrightarrow{xl_{ps}}$ if $Z_{xl_{ps}} < Z_{xg_s}$

6. Update the velocity and the position of each particle

$$\overrightarrow{v_{ps}}(i+1) = w(i) \times \overrightarrow{v_{ps}}(i) + u[0,1] \times c1(i) \times \left(\overrightarrow{xg_s} - \overrightarrow{x_{ps}}(i)\right) + u[0,1] \times c2(i) \times \left(\overrightarrow{xl_{ps}} - \overrightarrow{x_{ps}}(i)\right) \quad (26)$$

Update of the moment inertia using fitness distance ratio (FDR), and it can be can be shown as:

$$w(i) = w(F) + \left(\frac{i-F}{1-F}\right)(w(1) - w(F)) \quad (27)$$

Calculate the new position using (28)

$$\overrightarrow{x_{ps}}(i+1) = \overrightarrow{x_{ps}}(i) + \overrightarrow{v_{ps}}(i+1) \quad (28)$$

7. If the generation meets the stopping criteria, stop. Otherwise, add generation by one and return to step 2.

8. Set Gbest of the last solution as the best solution for multi-route inventory routing problem for deteriorating items.

3.2. The decoding method

A particle is represented by three parts. The first part is the number of retailers, the second part is a constant value from 0 to 1, and the third part is the sequence number of each retailer. The sequencing procedure using Algorithm 2.

Algorithm 2. Decoding method

1. Generate random numbers from 0 to 1 for the x_{ps} values.
2. Sort in ascending order the value of x_{ps} and set the sequence of the retailers
3. Particle representation for nine retailers can be represented in Table 1.

Table 1. Particle representation

Retailers	1	2	3	4	5	6	7	8	9
x_{ps}	0.47	0.61	0.29	0.26	0.43	0.66	0.23	0.95	0.9
Sequence	5	6	3	2	4	7	1	9	8

Once a global route has been established, the next step is allocating the route to vehicles by one day schedule considering vehicles capacity and time constraint. Since items are deteriorating, a quantity that should be brought by each vehicle consists of retailer demand and the amount of deteriorated items during delivery time and stock period in the warehouse.

3.3.The routing schedule in one day

Routing is set to get the balance of quantity in one day to be delivered and the distance. The routing method is thoroughly described in Algorithm 3. We calculate it using weights as shown in equation (27).

Algorithm 3. Routing method

1. For all i, calculate we_i using equation (29)

$$we_i = d_i\big(t_{(i-1,i)}\big) \qquad i \in S \quad (29)$$

2. Calculate $W = \sum_{i\in S} we_i$
3. Set i=1,ws_0=0, j = 1
4. Set ws_i= we_i If $we_i > W$, go to 7
5. Set $i=i+1$
6. Calculate ws_i=ws_{i-1}+ we_i, if $ws_i<W$ go to 5 otherwise go to 7
7. Calculate $|ws_{i-1} - W|\ and |ws_i - W|$. If $|ws_{i-1} - W| < |ws_i - W|$, allocate 1 to i-1 into route j, otherwise allocate 1 to i into route j
8. Set i=0, ws_0=0, $j = j+1$ and go to 5.
9. If all retailers have been allocated then finish

The next step is setting how many days the routing for the determined cycle time should be assigned to one vehicle. The solution is done by using Algorithm 4.

Algorithm 4. Routing allocation in one day

1. Set sr=1, k=1
2. Calculate $T_{min} = \sum_k T_k$
3. Calculate $T_{max} = \frac{K_v}{\sum_{k\in ST_n} \frac{\left(e^{\theta_2 T}-1\right) e^{\theta_1 t_{1k}} d_k}{\theta_2}}$, if $T_{min} > T_{max}$ go to 5
4. Set $k=k+1$ and go to 2

5. Put 1 to *k-1* into sub routing *sr*. If all retailers in routing have been allocated or the *Tmin* violating 24 hours for routing time limitation for one day then go to 6, otherwise, go to 1.
6. Calculate the fitness function
7. Set *K* as number of vehicles and *k* = 1
8. Set discrete random variable from 1 to some retailers (*n*=U(1..N)).
9. Allocate the first *n* retailers to vehicle *k*
10. If *k*<*K*, then *k*=*k+1* and go to 9, otherwise go to 11
11. Calculate the fitness function. If $K_v < \sum_{k \in ST_n} \frac{(e^{\theta_2 T}-1)e^{\theta_1 t_{1k}} d_k}{\theta_2}$ then fitness function = fitness function + infeasible penalty cost, where infeasible penalty cost is a big value.
12. Choose days allocating vehicles with the best fitness function

4. Numerical Example and sensitivity analysis

A numerical example is conducted to show how the model works and to get the best PSO solution and a sensitivity analysis is carried out to get management insight of the model.

4.1. A numerical example

A set data from Aghezzaf (2006) is used for the first example, where 15 retailers are supplied from one depot. Table 2 shows demand rate at each retailer where each retailer has different demand rate. The other parameters used in this numerical example are vehicle capacity equal to 100 units, average vehicle speed 50 km/hour, fixed operating cost €50/hour, transportation time €1/km, inventory holding cost €0.1/unit/hour and fixed handling cost is equal to €50. There are two vehicles available.

Table 2. Demand rate at retailers

Retailer	Demand rate (units/hour)
1	0.109
2	0.326
3	0.322
4	0.478

5	0.134
6	0.429
7	0.381
8	0.503
9	0.187
10	0.123
11	0.953
12	0.638
13	0.247
14	0.188
15	0.441

The best solution is derived when Pbest weight = 0.5 and Gbest weight = 2 with a total cost per unit time is equal to € 92.2715 with route schedules for every vehicle in every day as shown in Table 3.

Table 3. The route schedules for every vehicle

Vehicle 1 **T Optimal = 120 hours (5days)**		**Vehicle 2** **T Optimal = 192 hours (8 days)**	
Day	**Route**	**Day**	**Route**
1	D – 13 – D	**1**	D – 14 – 3 - D
2	D – 15 – 12 - D	**2**	D – 1 – D
3	D – 9 - D	**3**	D – 5 – 6 - D
4	D – 4 – 11- D	**4**	D – 2 – D
5	D – 8 – D	**5**	D – 7 – 10 – D

4.2. Sensitivity analysis

Sensitivity analysis is conducted by changing one particular parameter and keep the other parameters with the same value. Different values of the deteriorating rate of the vehicle, deteriorating rate at the warehouse, latest time windows and inventory cost are used to analysis the effect of those parameters and give some management insight. The deteriorating rate at vehicle and warehouse are necessary to be analyzed since we want to know which effect is more significant to the other. The latest time windows need to be analyzed to show the significance of time windows to the decision. We only analyzed the latest time windows since most solutions show the problem tends to be late delivery than previous delivery. The inventory cost is examined since in many research inventory cost significantly affects the total cost of the inventory problem model. The sensitivity analysis is conducted by decreasing and increasing the parameter value to 20% and 40%. The sensitivity analysis results are shown in Table 4 -Table 7.

Table 4. The total cost per unit time for varies value of latest time windows

Trial	**Total cost per unit time (€)**				
	-40%	**-20%**	**0%**	**20%**	**40%**
1	99.6382	99.4641	100.8938	89.7916	90.5262
2	102.079	95.7855	92.5685	91.8985	90.8656
3	106.4597	99.1407	95.2522	93.7587	95.7397
4	106.3438	99.0277	90.0606	92.9678	91.1201
5	100.6295	101.9542	89.1333	97	90.0207
Average	103.03	99.0744	93.5817	93.0374	91.6545

Table 5. The total cost per unit time for varies value of deteriorating rate at vehicle

Trial	**Total cost per unit time (€)**				
	-40%	**-20%**	**0%**	**20%**	**40%**
1	89.7673	89.103	100.8938	89.7579	89.6748
2	90.7791	96.7518	92.5685	94.0219	89.9219
3	97.7465	96	95.2522	99.7857	96.0674
4	90.4186	89.8167	90.0606	90.8412	100.7251
5	93.2059	93.2948	89.1333	95.8621	95.036
Average	92.3835	92.9922	93.5817	94.0538	94.2850

Table 6. The total cost per unit time for varies value of deteriorating rate at warehouse

Trial	Total cost per unit time (€)				
	-40%	**-20%**	**0%**	**20%**	**40%**
1	90.3121	92.3688	100.8938	97.9547	97.0158
2	89.9552	94.8818	92.5685	96.9384	96.9922
3	93.3972	87.3266	95.2522	102.6957	99.4056
4	97.6252	93.9552	90.0606	95.7184	98.6285
5	91.2684	96.3813	89.1333	92.2641	95.8131
Average	92.5116	92.9827	93.5817	97.1143	97.5710

Table 7. The total cost per unit time for varies value of inventory cost

Trial	Total cost per unit time (€)				
	-40%	**-20%**	**0%**	**20%**	**40%**
1	77.0046	84.8719	100.8938	105.6132	107.2956
2	82.7451	83.9341	92.5685	103.0243	111.3618
3	79.0822	81.2	95.2522	105.3589	117.0833
4	72.5536	86.2717	90.0606	100.6852	106.1367
5	78.4133	90.9494	89.1333	100.5856	112.1578
Average	72.5536	81.2000	89.1333	100.5856	106.1367

From Table 4-7 we can figure out a sensitivity analysis for the four parameters as shown in Fig. 2.

Put Figure 2 here

Fig. 2 shows that the total cost per unit time is significantly sensitive to varies the value of inventory cost and the total cost increase as the inventory cost increase. This result is consistent with the other research in inventory modeling. The total cost per unit time has an opposite trend with latest time windows. Total cost decrease as the most recent time windows increase. However, the effect of varying latest time windows to the total cost is smaller than inventory cost. In practice, it is better to give higher effort to reduce inventory cost than asking for retailers to increase their latest time windows. Even though the effect of deteriorating rates to the total cost are smaller to the effect of latest time windows and inventory cost, deteriorating rates affect the total cost. The total cost increase as deteriorating rates increase. These results are consistent with some previous research on deteriorating inventory items. The effect of deteriorating rate in inventory to the total cost is larger than the deteriorating rate in the vehicle. This finding shows the manager has to put more effort to reduce the deteriorating rate in inventory than the deteriorating rate in the vehicle to reduce the total cost. The effort to reduce the deteriorating rate in the warehouse is also easier than reducing the deteriorating rate in the vehicle. The effect of varying environmental temperature is also more comfortable to be handled in a warehouse than during transportation time. Temperature stability is easier to be controlled in the warehouse than during shipping time. The result also supports the purpose of this research for considering the deteriorating rate in inventory and vehicle instead of considering deteriorating items in the vehicle as shown by previous research before.

5. Conclusion

In this research, we try to discuss deteriorating rate in the cyclic inventory routing problem. From our intensive literature study, there is no research which has examined deteriorating items in the cyclic inventory problem. We have hypotheses that deteriorating rate affects inventory total cost of any items that have deteriorating characteristic. A mathematical model is developed to solve the problem. Since the model is an NP-hard problem, a Particle Swarm Optimization (PSO) drawn up to address the problem. A numerical example is conducted to show how the model work Sensitivity analysis has been done by changing the parameter of one variable and keep the same values of the other parameters. The changing parameters are latest time windows, the deteriorating rate in the vehicle, deteriorating rate in warehouse and inventory holding cost. The sensitivity analysis shows consistent results as results of previous inventory deteriorating models and gives some management insights. The holding cost gives the biggest effect on the total cost comparable to the other parameters. So, it is better for companies to give the highest effort for reducing inventory holding cost to get the smaller total cost. Even though the effect of deteriorating rates is not as big as inventory holding cost, deteriorating rate affects the total cost. Deteriorating rate in inventory results in a higher effect on the total cost than deteriorating rate in vehicles. So the contribution of this research by considering both deteriorating rates in inventory and vehicle instead of only considering the deteriorating rate in a vehicle alone is significant. The model can be developed by considering perishable items and price dependent time.

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Response to reviewer Comments

Our responses to the Reviewers' comments:

Journal: Scientia Iranica

Title: Modelling Multi Tour Inventory Routing Problem for Deteriorating Items with Time

Windows

First of all, we would like to thank the reviewers for spending their time on reviewing our

manuscript and for their constructive comments. We have revised the manuscript according to

their recommendations. In the following, we have commented how the recommendations of the

reviewers have been considered in rewriting the paper.

Our responses to Reviewer #1:

The writing of the paper need improvement. Please ask a native English speaker or

others to check the English writing. A few corrections are listed below:

(i) I the first paragraph,In recent decades, there are intensive researches on

deteriorating inventory. However, only few researchers focus on the inventory routing

problem for deteriorating item. There are many items such as foods, electronic products

that

deteriorate with time, and many other products in the market also have perishable characteristic.

Our response:

The writing has been improved. The improvements are shown in blue words/sentences.

(ii)This paper is divided into five sections. Use sections instead of chapters

Our response:

We have changed chapters with sections

1. The equations in the pdf files have bugs, I cannot read them.

Our response:

I am sorry the equatons in pdf file have bugs. We export words to pdt using a different tool, so the equatiosn can be read.

2. More references on deteriorating item models should be included. Some are:

2013, Revisiting a fuzzy rough economic order quantity model for deteriorating items considering quantity discount and prepayment, Mathematics and Computer Modelling, Vol 57, Issue 5-6, pp. 1466-1479.

2013. Pricing and replenishment strategy for a multi-market deteriorating product with time-varying and price-sensitive demand, Journal of Industrial and Management Optimization (JIMO), Vol. 9, NO.4, October pp. 769-787

2013, Retailer's replenishment policy for deteriorating item in response to future cost increase and incentive-dependent sale, Mathematical and Computer Modelling, Vol. 57,
pp. 536-550.

2013, An inventory model with variable demand, component cost and selling price for deteriorating items, Economic Modelling, Vol. 30, pp. 306-310.

Our response:

Thank you for your valuable input, some related papers has been added.

Our responses to Reviewer #2:

Reviewer 2

Ref. No: 65.543.160616

"Comments to the Authors"

The authors developed an Inventory routing problem for a deteriorating item. None of the mathematical equations of the paper is readable. As a result it is not possible to make any comment about the mathematical formulation of the model. Moreover standard of the English of the manuscript is very poor. English should be checked by an expert of English language or professional proof reader. Mathematical expressions should be written in such software that it will be readable for evaluation.

Our response:

I am sorry that the equations can not be read. We use a different tool to exports from words to pdf so they can be read clearly now.

The English of the manuscript has been revised. We highlight the improvement in blue sentences.

Short Biography

Gede Agus Widyadana is a lecturer at Industrial Engineering Department, Faculty of Industrial Technology, Petra Christian University, Surabaya, Indonesia. His research interests include inventory management, supply chain management, and operation research. He has published in several journals such as OMEGA, International Journal of Production Economics, International Journal of Systems Science, International Journal of Production Economics and Applied Mathematics and Modelling

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Penerimaan makalah

Dear Dr. Widyadana,

Please find attached copies of the relevant copyright documents for your paper submitted to *Scientia Iranica* entitled, “Modelling Multi Tour Inventory Routing Problem for Deteriorating Items with Time Windows” (Ref. No: 65.543.160616).

We would be most grateful if you could please complete and sign the attached documents and send them, together with the computer file of the final version of your article in either Word format or "TEX/LATEX", and the graphic files of the figures, as mentioned below, to this office within one week of the receipt of this email. Please note that the receipt of the original copies of the signed documents is essential for this office.

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Sincerely yours,

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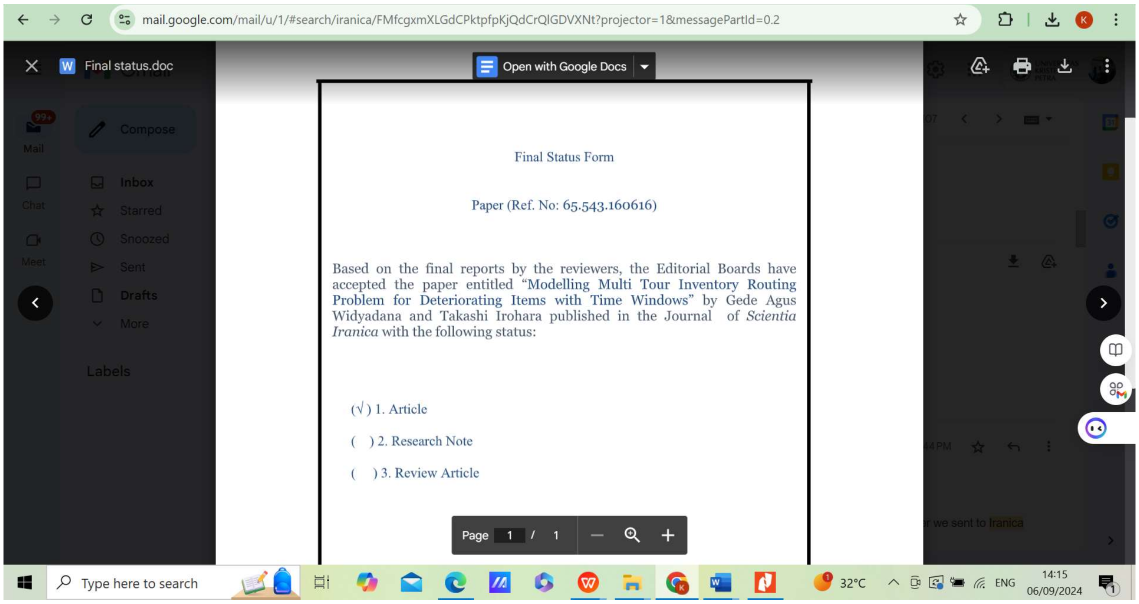
Editors-in-Chief



Final Status Form

Paper (Ref. No: 65.543.160616)

Based on the final reports by the reviewers, the Editorial Boards have accepted the paper entitled "**Modelling Multi Tour Inventory Routing Problem for Deteriorating Items with Time Windows**" by Gede Agus Widyadana and Takashi Irohara published in the Journal of *Scientia Iranica* with the following status:

(√) 1. Article

( ) 2. Research Note

( ) 3. Review Article