MÜHENDİSLİK BİLİMLERİ ve TASARIM DERGİSİ
JOURNAL OF ENGINEERING SCIENCES AND DESIGN
e-ISSN: 1308-6693
YAYINCI PUBLISHER

Düzeltme / *Corrigendum*

Mühendislik Bilimleri ve Tasarım Dergisi
11(1), 426 - 432, 2023
e-ISSN: 1308-6693

Journal of Engineering Sciences and Design
Reference-DOI: 10.21923/jesd.999165

Düzeltme **Corrigendum**

A NOVEL BI-OBJECTIVE MODEL FOR A MULTI-PERIOD MULTI-PRODUCT CLOSED-LOOP SUPPLY CHAIN

Nadi Serhan AYDIN*

Department of Industrial Engineering, Istinye University, Istanbul, Turkey

Keywords

Closed-loop supply chain, Multi-objective model, Mixed-integer model, Goal attainment method, Sensitivity analysis.

Abstract

Closed-loop supply chain (CLSC) is a kind of supply chain which contains forward and backward flows of commodities within a logistics network. In the decision-making process of CLSC, locational, inventory control and transportation issues are addressed to deal with strategic, tactical and operational decisions. This paper utilizes a novel bi-objective mixed-integer linear programming (MILP) model to formulate a multi-period multi-product CLSC design problem considering aggregate cost minimization and service level maximization at the same time. To tackle the bi-objectiveness of the model, goal attainment method (GAM) is applied which is then executed by Gurobi Python API to test the applicability of the suggested model for three different scales (small, medium and large). It is demonstrated that the proposed methodology can find the optimal solutions for different problems in a maximum of 500 seconds. Finally, a set of sensitivity analyses is carried out on the main parameters in order to test the behaviors of the objective functions and suggest managerial insights as well as decision aids. The results reveal that the model is highly dependent on the demand parameter, that is, an increase in demand is closely related to an increase in the aggregate cost and a simultaneous downward trend in the service level.

ÇOK PERİYOTLU ÇOK ÜRÜNLÜ KAPALI DÖNGÜ TEDARİK ZİNCİRİ İÇİN YENİ BİR ÇİFT-AMAÇLI MODEL

Anahtar Kelimeler

Kapalı-döngü tedarik ağı, Çok amaçlı model, Karmaşık-tamsayılı model, Hedefe ulaşma yöntemi, Duyarlılık analizi.

Öz

Kapalı döngü tedarik zinciri (KDTZ), bir lojistik ağ içinde ürünlerin ileri ve geri akışlarını içeren bir tür tedarik zinciridir. KDTZ'nin karar verme sürecinde, stratejik, taktik ve operasyonel kararlarla başa çıkmak için lokasyon, envanter kontrolü ve taşıma konuları ele alınmaktadır. Bu araştırma, aynı anda hem toplam maliyet minimizasyonu hem de hizmet seviyesi maksimizasyonu dikkate alınarak çok periyotlu ve çok ürünlü bir CLSC tasarım problemini formüle etmek için yeni bir çift-amaçlı karma tamsayılı doğrusal programlama (KTDP) modelini kullanmaktadır. Modelin iki yönlülüğünü sağlamak adına hedefe ulaşma yöntemi (GAM) kullanılmış ve daha sonra Gurobi Python API kullanılararak önerilen modelin üç farklı ölçekteki (küçük, orta ve büyük) problemler üzerinde uygulanabilirliği test edilmiştir. Önerilen metodolojinin farklı problemler için en uygun çözümleri maksimum 500 saniyede bulabildiği gösterilmiştir. Son olarak, amaç fonksiyonlarının davranışlarını değerlendirmek ve yönetimsel öngörüler ve karar destek çıkarımları sağlamak için anahtar parametreler üzerinde bir dizi duyarlılık analizi yapılmaktadır. onuçlar modelin talep parametresine yüksek oranda bağlı olduğunu göstermektedir. Öyle ki, talepteki bir artış toplam talepteki artışla ve aynı anda servis seviyesinde görülen aşağı yönlü trendle yakında ilişkilidir.

Alıntı / Cite

* İlgili yazar / Corresponding author: serhan.aydin@istinye.edu.tr, +90-850-283-6000

Aydin, N. S. (2023). A Novel Bi-Objective Model For A Multi-Period Multi-Product Closed-Loop Supply Chain, Journal of Engineering Sciences and Design, Corrigendum, 11(1), 426-432.

Yazar Kimliği / Author ID (ORCID Number)	Makale Süreci / Article Process	
Nadi Serhan Aydin, 0000-0002-1453-0016	**Başvuru Tarihi / Submission Date**	23.09.2021
	Revizyon Tarihi / Revision Date	22.10.2021
	Kabul Tarihi / Accepted Date	11.02.2022
	Yayım Tarihi / Published Date	20.03.2022
	Düzeltme Tarihi / Corrigendum Date	23.02.2023
	Onay Tarihi / Approved Date	10.03.2023
	Yayım Tarihi / Published Date	27.03.2023

1. Corrigendum

Upon feedbacks from some critical readers of the present article titled “A Novel Bi-Objective Model For A Multi-Period Multi-Product Closed-Loop Supply Chain”, the authors regrets to notice that some of the mathematical model constraints needed correction, which also required some modifications to the model variables as well as inclusion of new ones. The reader can find the corrections below.

1.1. Abstract

Due to the changes we’ve made in the model, we need to update the runtime-related statement in the abstract that reads “a maximum of 500 seconds.” to “less than a second”.

1.2. Mathematical model

1.2.1. Parameters

We make changes to, and add, the following model parameters:

GI_{kd}: Unit holding cost of product k at distribution center d for one time period,

GB_{kc}: Unit shortage cost of product k for customer c for one time period,

$IV0_{kd}$: Initial inventory level of product k at distribution center d at the beginning of planning period,

$BL0_{kdc}$: Initial backlog level of product k at distribution center d for customer c at the beginning of planning period

M: A sufficiently large number.

1.2.2. Variables

We need to modify the definitions of the following two variables as given below:

IV_{kdt}: Level of inventory for product k in distribution center d at the end of period t,

BL_{kdct}: Change in backlogged demand for customer c for product k in distribution center d in period t.

We also introduce the following three variables to make our objective function values more accurate:

BLP_{kdct}: Positive change in backlogged demand for customer c for product k in distribution center d in period t (newly backlogged items).

BLN_{kdct}: Negative change in backlogged demand (amount of backlogs fulfilled) for customer c for product k in distribution center d in period t.

CBL_{kct}: Level of backlogged demand for customer c for product k at the end of period t.

The cumulative backlog variable will be incorporated into objective one, whereas the positive change in backlog variable will help us keep track of the newly backlogged items objective two.

1.2.3. Objective functions

In the first objective function given by Eq. (1), we change the term related to backlog cost to the following to reflect the latest changes in variables. Use of cumulative backlogs instead of just periodic backlogs ensures that backlogs are penalized repeatedly as long as they are maintained.

$$\sum_{k\in K}\sum_{c\in C}\sum_{t\in T} GB_{kc}\, CBL_{kct} \tag{1}$$

Our second objective function given by Eq. (2), service level should have been defined as the proportion of demand that is fulfilled "on time" after considering any shortages (or, backorders) in distribution centers. Accordingly, Eq. (2) should be modified as:

$$\max SL \;=\; 1-\frac{\sum_{d\in D}\sum_{c\in C}\sum_{k\in K}\sum_{t\in T} BLP_{kdct}}{\sum_{k\in K}\sum_{t\in T}\sum_{c\in C} DM_{ckt}} \tag{2}$$

to more accurately reflect the backlogged proportion of the periodic demand. Since we now monitor net changes in backlogs in each period, the inclusion of the net increase in backlogs in Eq. (2), instead of just backlogs earlier, gives a more accurate figure of the proportion of demand backlogged in each period.

1.2.4. Constraints

We now introduce a missing constraint as Constraint (5) that takes care of the establishment decisions related to the distribution centers and the numberings for Constraints (5)-(11) should be updated accordingly as Constraints (6)-(12).

$$\sum_{c\in C}\sum_{k\in K}\sum_{t\in T} YB_{dckt} \le MZA_d \qquad \forall\, d \in D, \tag{5}$$

In Constraint (12), we need an equality instead of $\leq$ to ensure no inventory at plants. Accordingly, Constraint (12) can be better expressed by stating that "it ensures that the amount of products sent from a manufacturing facility to distribution centers in a certain period equals the amount produced in that facility."

$$\sum_{d\in D} YA_{kpdt} = X_{kpt} \qquad \forall p \in P, k \in K, t \in T, \tag{12}$$

We need to remove the existing Constraint (12) below, because Constraints (17)-(18) already capture the balance in the physical flow of goods. Backorders should not be included in Constraints (17)-(18) below, as suggested by one reader, because they do not represent physical flows and their net impact is already captured in YB through a deviation from the demand. So, we have to remove,

$$\sum_{c\in C} YB_{kdct} \le \sum_{p\in P} YA_{kpdt} \qquad \forall d \in D, k \in K, t \in T, \tag{12}$$

In Constraint (16), we now update the backorder term to incorporate the index c for customers and ensure that the total amount of products transported from distribution facilities to a customer during each time period plus the net backorder in that period (can be positive or negative) is equal to the demand by that customer. Constraint (17) needs to be added to define BL_{kdct}.

$$\sum_{d\in D}(YB_{kdct} + BL_{kdct}) = DM_{ckt} \qquad \forall c \in C, k \in K, t \in T. \tag{16}$$

$$\sum_{d\in D} BL_{kdct} = \sum_{d\in D}(BLP_{kdct} - BLN_{kdct}) \qquad \forall c \in C, k \in K, t \in T. \tag{17}$$

We must also emphasize that we don't restrict the total amount transfers for a specific product from distribution centers to a customer over the planning period to be equal to total demand from that customer (i.e., eventual backlogs are allowed at a cost).

We once again emphasize that backorders are not included in Constraints (18)-(19) below as they are not physical flows and their effects on YB have already been reflected through Constraint (16). The new Constraint (20), on the other hand, defines the cumulative backlog for customer c and product k by the end of period t.

$$IV0_{kd} + \sum_{p \in P} YA_{kpdt} - \sum_{c \in C} YB_{kdct} = IV_{kdt} \quad \forall k \in K, d \in D, t \in \{1\}, \tag{18}$$

$$IV_{kd(t-1)} + \sum_{p \in P} YA_{kpdt} - \sum_{c \in C} YB_{kdct} = IV_{kdt} \quad \forall k \in K, d \in D, t \in \{2,3,\dots,\bar{t}\}, \tag{19}$$

$$CBL_{kct} = \sum_{t'=1}^{t} BL_{kdct'} = \sum_{t'=1}^{t} (BLP_{kdct'} - BLN_{kdct'}) \quad \forall c \in C, k \in K, t \in T, \tag{20}$$

Finally, we have to include our new variables in restrictions (21) and (22):

$$BLP_{kdct}, BLN_{kdct}, CBL_{kct} \in \mathbb{R}^{+}, \;\; BL_{kdct} \in \mathbb{R} \qquad \forall d \in D, k \in K, c \in C, t \in T. \tag{22}$$

1.3. The solution method: GAM

In using the GAM method, where $f_1(x) = AC$ and $f_2(x) = SL$ as given in Eqs. (1) and (2), respectively, we have to modify the GAM constraints in a way that optimal value the variable φ is calculated in a more consistent way. Specifically, since SL assumes percentage values whereas AC absolute ones, to improve GAM algorithm, we needed to modify the unscaled GAM model for the objective functions to reflect the percentage deviations from supreme values by introducing $g_1(x) = f_1(x)/u_1^* - 1$ and $g_2(x) = u_2^* - f_2(x)$. Eventually, the single-objective model that results from GAM is now represented as follows:

$$\min Z_{GAM} = \varphi \tag{23}$$

$$g_1(x) - w_1\varphi \leq 0 \tag{24}$$

$$g_2(x) - w_2\varphi \leq 0 \tag{25}$$

where φ is a free scalar variable, subject to constraints (3)-(22). We should have also made it clear that the choice of (w_1, w_2)=(0.6, 0.4) is arbitrary.

1.4. Experimental results

We implement the modified model on a Intel(R) Xeon(R) CPU @ 2.20GHz processor. Another error was the presentation of parameters in Table 2 as random values from uniform distribution, which resulted from an earlier implementation of the model using GAMS software that accepts ranges for parameters. The correct table should be as below.

Table 2. Input parameters of the mathematical model.

Parameter	Value	Parameter	Value	Parameter	Value
DM	120	IVO	300	FA	15
CA	1500	BLO	0	FB	3.5
CB	350	δ	300	FC	3.5
CC	550	TA	7	FD	3.5
CD	550	TB	7	FE	3.5
CE	550	TC	7	DA	30
LA	150000	TD	7	DB	30
LB	150000	TE	7	DC	30
LC	150000	TF	7	DD	30
LD	150000	α	0.15	DE	30
GI	1.5	β	0.3	DF	30
GB	2500				

Due to the changes we've made to the model, the computational results, including the runtimes, as well as sensitivity results also had to be updated (see Tables 3, 4 and Figures 2, 3, 4, 5). We also did not emphasize that the results presented in tables and figures (except for Figure 2) were actually for Problem 1.

Table 3. Computational results obtained for the proposed methodology

Problem	Z_{GAM}	u_1^* (*10⁶)	u_2^*	AggregateCost	ServiceLevel	Runtime (s)
#1	0.011	2.90	0.833	2.92	0.8289	0.011
#2	0.005	24.61	0.708	24.68	0.7065	0.122
#3	0.002	105.97	0.667	106.12	0.6657	0.659

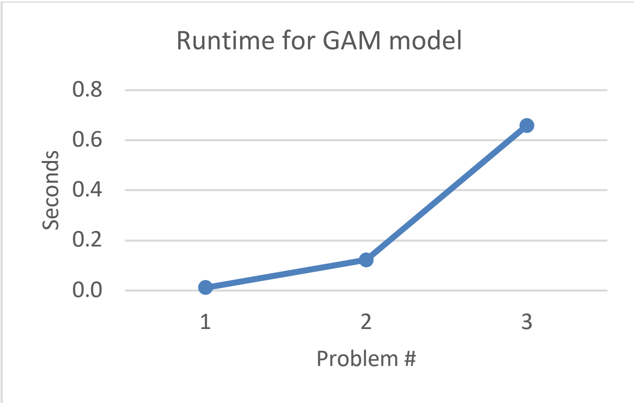

Fig. 2. Run time comparison of different problems

Table 4. Results of the sensitivity analyses

DM_{ckt}	−20%	−10%	0%	+10%	+20%
AC (*10⁶)	2.44	2.68	2.92	3.18	3.54
SL	0.994	0.920	0.829	0.754	0.691
α_{kct}	−20%	−10%	0%	+10%	+20%
AC (*10⁶)	2.87	2.89	2.92	2.95	2.98
SL	0.833	0.832	0.829	0.826	0.824
β_{kit}	−20%	−10%	0%	+10%	+20%
AC (*10⁶)	2.916	2.920	2.924	2.928	2.931
SL	0.830	0.829	0.829	0.829	0.828

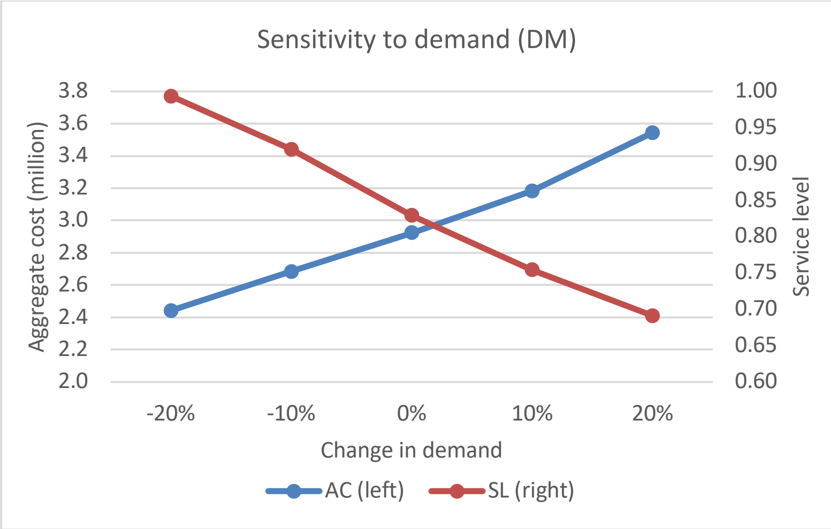

Figure 3. Sensitivity analysis for DM_{ckt}.

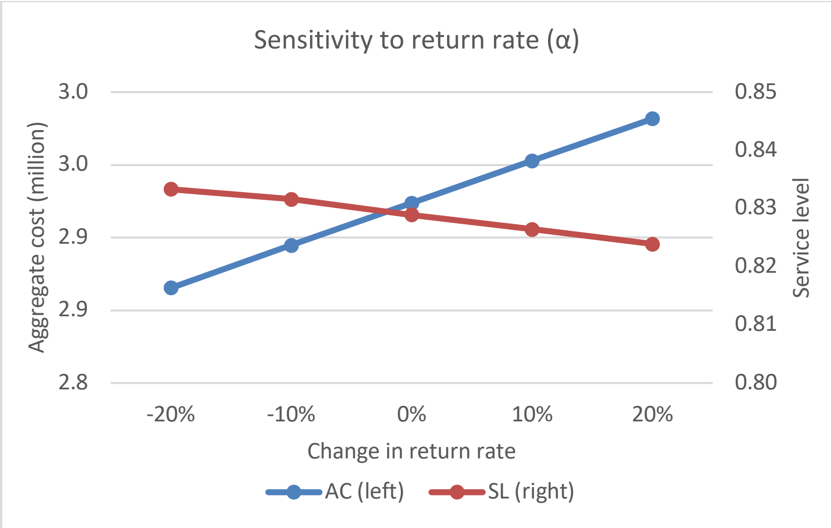

Figure 4. Sensitivity analysis for α_{kct}.

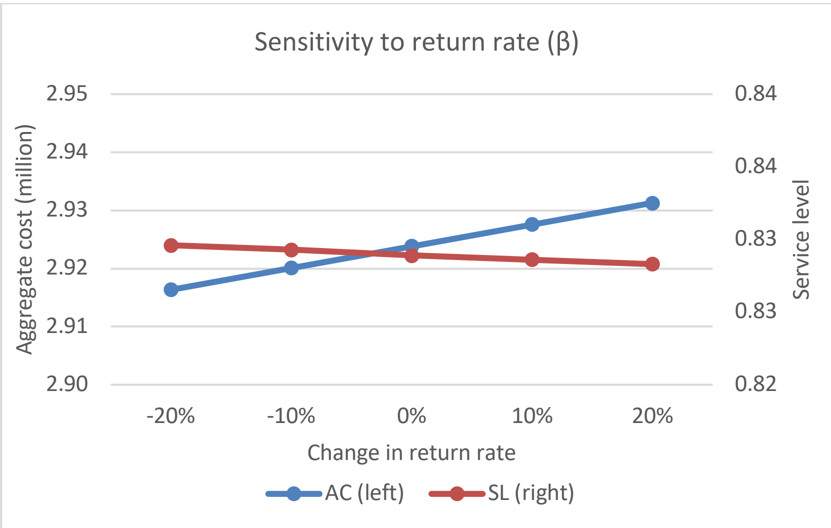

Figure 5. Sensitivity analysis for β_{kit}.

2. Editorial Review

The corrigendum is approved for publishing.

Conflict of Interest

No conflict of interest was declared by the authors.

References

No new references were used.