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An Imperialist Competitive Algorithm for 1-D Cutting Stock Problem

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Abstract Minimizing trim-loss is an important matter in many industries such as steel and paper. Sometimes making small changes in cutting pattern can createconsiderable benefits in different areas such as production costs. In recent studies this matter has been looked into from a different point of view. In our approach trim-loss concentration has been introduced as a solution to trim-loss problem based on simulated annealing (SA) algorithms using a new kind ofvirtual cost. Trim-loss concentration problem and credibility of the virtual cost theory has been studied in this paper, as well as reviewing literature onresolving cutting-stock problem. Furthermore, a solution based on Imperialist Competitive Algorithm (ICA) has been presented that reduces the wastage as well asconcentrating them on the minimum number of stocks. The benchmark data has been randomly generated using CUTGEN 1 application.In most of the experimental results, ICA proved to produce more accurate results compared to other algorithms.

Keywords Optimization, Cutting Problem, One Dimensional Cutting Stock, Cutting Stock Concentration, Imperialist Competitive Algorithm

1. Introduction

The Cutting Stock Problem (CSP) is used in many industries, such as steel, paper, plastic, glass and wood[1-3].In one dimensional cutting Stock problems, a part or some parts of the material (stock) might not be reused, when a piece is cut out of a bigger part. It happens due to applying various patterns freely. Recently, cutting problem has attracted the attention of many researchers all over the world[4-7]. Choosing a cutting pattern and its consequences is put forward by cutting problems. Sometimes cutting problems are too complicated, and it is not easy to find an optimized response for them. In such a case, even the smallest improvement in cutting pattern, may lead to a considerable economizing in raw material, which are used over and over in mass quantity.Most standard problems that are related to one dimensional cutting problem are known as NP-complete problems. However it is possible in many cases to model them by mathematical programming and find a solution via accurate or approximate methods. The goal of this research is applying an algorithm that is ordered for cutting problems in order to change them into other ordered pieces, in a way that having the minimum wastage.On the basis of H. Dyckoff's typology, the one dimensional problem can be explained as 1/V/D/R whenever sufficient materials are available. "1" stands for one dimensionality of the problem. "V" means that all required items should be produc ed by a selection of big consuming pieces; in other words, although some parts of stocks (big pieces) are only used, all orders will be produced. "D" means that there are several big consuming pieces in different sizes. And "R" represents the number of items, considering the limited variety.

Dyckoff classifies the solution of the one dimensional problems into two classes: Item-Oriented and Pattern-Oriented methods. In item-oriented method, every ordered piece (item) is cut out of the big piece independently. Then another cutting will be executed on the rest of the big piece. It continues up to a point, in which no cutting is possible anymore. After that the next big piece will be prepared for cutting. In pattern-oriented method, firstly the length of ordered stocks is combined in cutting pattern. The number of cuts is determined on the basis of predetermined cutting pattern for affording the order in order to find the answer. Existing limitations in this method are prepared according to an algorithm by P. C. Gilmore and R. E. Gomory[12 - 15]. The item-oriented method is applied to solve the understudy problem, because the pattern-oriented method is applicable in a condition that all items have the same length or several standard lengths, and the item-oriented method is applied whenever the length of items are different.

The first related formula to CSP was suggested by Kantorovich in 1939. It was published in English language in 1960[15], although several studies and researches had practically been conducted about 45 years before this event

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and different solutions are suggested for solving CSP problem up to now. However various innovative solutions are suggested in real world in order to solve the CSP problems, applying them is not helpful in similar problems due to the special characteristics of such problems [16].

Minimizing the cutting wastage can be considered as the main purpose of CSP, some other goals can be defined for it though. 15 effective factors on being profitable were listed by Stainton in 1977. This list contains some factors that cannot be measured easily (e.g. the staff spirit and viewpoint, or obtained profit by computerized analyses)[17]. Practically, the cost of using a special cutting model and changing the cutting patterns are important ordinary factors as well as cutting wastage.

In 2007, Fusson et al. modeled the cutting problem in a way that a deadline had to be determined for each small piece; according to them, each item deadline and the whole order deadline had to be considered [18].

The peripheral aspects (e.g. the required energy) can be considered by an appropriate formulation and making the smallest improvement in cutting pattern[19]. It leads to a big thriftiness in stocks, which are consumed quickly and repeatedly in huge mass. Fruitlessness and costliness of manual methods, which are applied by cutting contractors, reminds the necessity of cutting automation[20, 9]. Furthermore, the potential of suggested methods can be distinguished easily, due to the impossibility of comparing the different solutions together over and over[11]. There are several algorithms and methods to calculate the one dimensional cutting wastages, considering various factors. It is suggested that minimizing the wastage is the most important factor in different methods.

Principally there are three different classes for solving the CSP: 1- Algorithmic methods, 2- Innovative methods, 3- Metahuristic methods.

Algorithmic methods guarantee an optimal response, despite of calculating complications. But they are time consuming, especially in big problems. That is why the complete algorithmic methods were rarely used in the past.

Innovative methods get to the answer quickly, but not an optimum answer necessarily. Obtained responses via the innovative methods can be considered as ideal ones, as long as they are close to the optimum answers. Innovative methods usually are designed for special problems. Mentioned method depends on special conditions drastically, so it is not applied as a general method[16].

The solution process in metahuristic methods usually is guided in lower levels, and contrary to traditional metahuristic methods, they are not limited to local optimum conditions. Some articles like[21-23] can be considered as appropriate samples for solving the optimizing problems via metahuristic methods.

The amount of wastage dispersion, which is a qualitative parameter, is explained quantitatively in the second part of this article by discussing some criteria for measuring the one dimensional cutting wastage. In the third part, a related model will be explained and the optimizing parameter will be discussed. A method based on ICA will be offered in the fourth part in order to reduce the wastage in the cutting stock problem. In the fifth part, the problem will be discussed and solved in a bigger view. And results and consequences are offered in the sixth part.

2. The Criteria to Measure the Wastage Dispersion

In research model, the target functions are posed either as minimizing the pattern numbers or minimizing the raw subgroups in one dimensional cutting problem. But both of these functions are following the same goal at the final step, i.e. minimizing the cutting wastage amount. On the other hand, two goals are following in cutting wastage concentration problem simultaneously. The first goal is reducing the cutting wastage, exactly the same as cutting problem, and the second one is concentrating the cutting wastage on the minimized consumed stocks. The second goal is considered as an important issue especially in some industries with expensive materials.

Virtual cost (VC) is a parameter that is applied in order to solve the one dimensional cutting wastage concentration problem[29]. Mentioned parameter expresses the quality of wastage in concentration viewpoint on minimizing the big consuming pieces. In other words, it is tried to show the wastage concentration properly in this parameter in order to change the best quality level of wastage concentration into the quantity.

This parameter can help us to search among the resulted optimum answers in one dimensional cutting problem to find the best one in cutting wastage dispersion viewpoint. Suppose that the cost of each stock differs from another. These costs are considered as virtual costs as increasing whole numbers. These virtual costs are attributed to each big stock, which is consuming in cutting process, and is multiplied in the amount of wastage in each stock. The least cost is allocated to the stock with the most wastage.

2.1. Total Virtual Cost (TVC)

The amount of virtual cost in each stock[(VCj)j] should be multiplied in the amount of wastage in each stock[(Wj)], then the resulted amount in each stock should be added together in order to calculate the total virtual cost (TVC). Formula (1) is used to figure out the application of total virtual cost in different wastages:

$$TVC = \sum_{J=1}^{M} W_j \times VC_j \quad (1)$$

2.2. How to Use the Total Virtual Cost

Since the total virtual cost is a cost and we want to use it as criteria for wastage dispersion, it should be minimized. In other words, it is always tried to use some stocks with higher virtual cost for cutting process in order to reduce the increasing of virtual costs as much as possible. The process of calculating the total virtual cost is depicted in Figure 1:

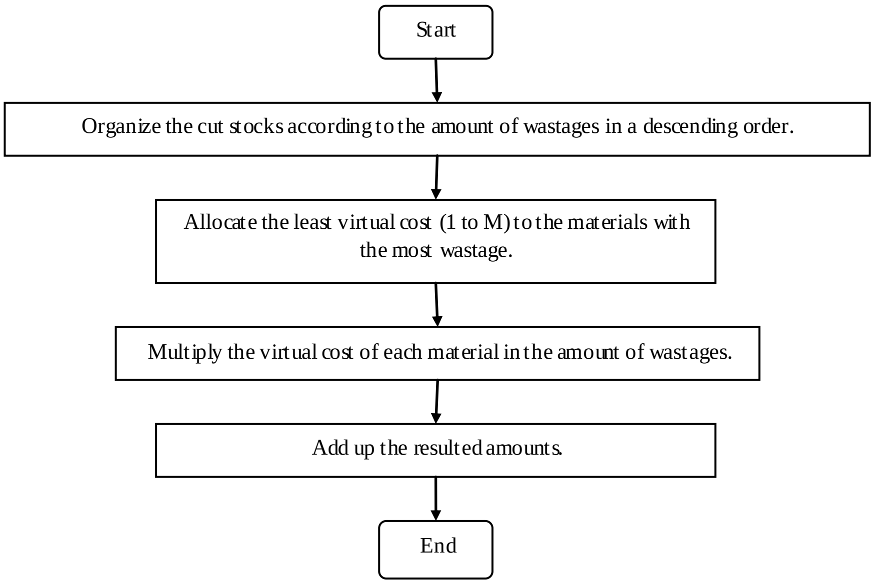


Figure 1. A Chart to Calculate the Total Virtual Cost

Therefore, if the cutting is fulfilled to reduce the total virtual cost, the cutting process will be done in a way that less wastage will appear on the stocks with lower virtual cost. Example 1: Suppose that the length of a stock equals 20 m. and cutting is ordered as follow:

Table 1. The amount of length and number of orders in example 1

Number of Orders	Length (Meter)
7	3
12	2

Two answers with the same amount of wastage will be concluded by choosing two different cutting patterns in this example.

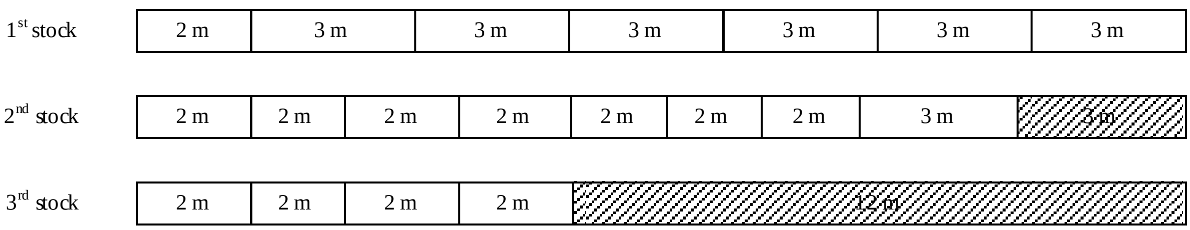


Figure 2. Result of solving the example 1 by the first optimum pattern, total wastage = 15 m

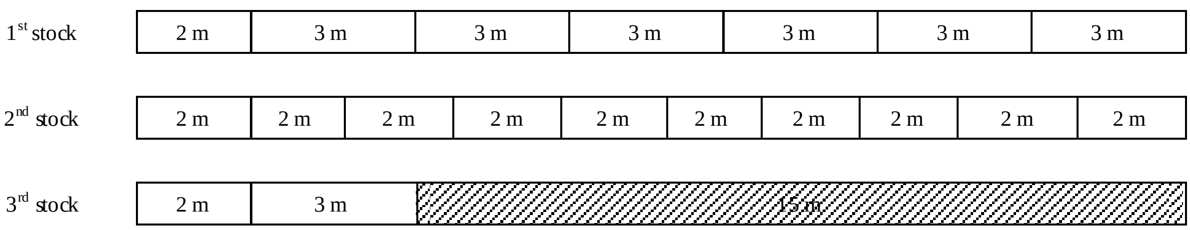


Figure 3. Result of solving the example 1 by the second optimum pattern, total wastage = 15 m

The amount of total virtual cost is calculated for both optimum answers in following table:

Table 2. The calculating of total virtual cost amounts in both optimum answers in one dimensional CSP

The 1st optimum answer				
	The stock no.	1	2	3
	The wastage amount (M)	0	0	15
	Virtual cost	3	2	1
	Total wastage (Meter)	15		
	Total virtual cost	15		

The 2nd optimum answer				
	The stock no.	1	2	3
	The wastage amount (M)	0	3	12
	Virtual cost	3	2	1
	Total wastage (Meter)	15		
	Total virtual cost	18		

It can be observed that the total virtual cost for the first optimum answer was less than the second one. And the wastage concentration in the first answer was better than the second answer as well. The longer length of wastages on the third stock is the exact meaning of wastage concentration.

3. The Problem Modeling

3.1. Compiling the Existing Parameters in the Problem

The required parameters for compiling the mathematical model to solve the cutting wastage concentration problem, considering the virtual cost and calculate the minimum amount of total virtual cost are as follow:

n_k = the number of ordered pieces (small piece), as long as l_k

N = the total number of ordered pieces with different lengths

l_i = the length of i^{th} ordered piece, i = 1, 2, …, N (this piece can be at the same size of other pieces.)

M = the number of big pieces (consumed stocks).

L_j = the length of j^{th} consumed stock, j = 1, 2, …, M.

W_j = the wastage of j^{th}stock.

$$X_{ij} = \begin{cases} 1 & \text{If the } i^{th} \text{ piece is cut out of the } j^{th} \text{stock} \\ 0 & \text{Otherwise} \end{cases} \quad (2)$$

Considering the mentioned parameters and formula (2), the amount of cutting wastage can be calculated on the basis of general definition of cutting wastage (resulted wastage in a stock equals the stock length subtracted by the total length of cut pieces out of the same stock) via the formula (3):

$$w_j = L_j - \left(\sum_{i=1}^{N} l_i . x_{ij}\right) \quad (3)$$

In this formula, the amount of wastage in the j^{th} raw material is calculated by considering the cut pieces of the same stock.

The total wastage amount (w) can be obtained via adding the wastages of each stock (w_j) according to formula 4:

$$\sum_{j=1}^{M} w_j = W \quad (4)$$

3.2. Schematic Model of Minimizing the Dispersion in One Dimensional Cutting Stock Problem

If we consider the cutting problem as an item-based problem, the primary amount can be offered by defining the total virtual cost as the target function in order to get to the minimum amount of total virtual cost and a cutting pattern with the best wastage concentration consequently.

3.3. The Target Function

In this model, considering the defined parameters, the target function is defined according to the total virtual cost as follows [29]:

$$\min TVC = \sum_{j=1}^{M}\left(VC_j \times \left(L_j - \left(\sum_{i=1}^{N} x_{ij} \times l_i\right)\right)\right) \quad (5)$$

In this target function, the amount of $\left(L_j - \left(\sum_{i=1}^{N} x_{ij} \times li\right.\right.$ equals the wastage amount of j^{th}stock (wj), multiplied by $VC_j$and finally adding up the total amount of$VC_j \times w_j$. It is called TVC and we are trying to minimize it.

3.4. The Model Restrictions

The restrictions in this model can be divided into two different groups: firstly, the restrictions in the length of big pieces; and secondly, the restrictions in the number of small pieces cuttings.

3.4.1. Restrictions in the First Group

This group of restrictions, whose numbers equal the number of big pieces, controls this point that the length of cut pieces out of a stock does not exceed the length of the same stock. According to the relation (6), this group is defined as follow:

$$\sum_{i=1}^{N} l_i \times x_{ij} \leq L_j \quad j = 1, 2, \ldots, M \quad (6)$$

3.4.2. Restrictions in the Second Group

This group of restrictions, whose numbers equal the number of items, controls this point that each small piece should be cut out of one stock only. According to the relation (7), this group is defined as follow:

$$\sum_{j=1}^{M} x_{ij} = 1 \quad i = 1, 2, \ldots, N \quad (7)$$

3.5. Evaluating the Optimization of Total Virtual Cost

Firstly, two rules are discussed in order to evaluate the optimization in cutting wastage concentration model. These two rules should be considered in cutting the pieces. 1- Whenever one of the small pieces is cut out of a big piece, the existing wastage on the big piece decreases as long as the small piece length and whenever one of the small pieces is not cut out of a big piece, the existing wastage on the big piece increases as long as the small piece length. 2- All small pieces in the order list should be cut out of the existing big piece.

Suppose that one of the small pieces is not cut out of the big piece. According to the first rule, it causes more wastage on the same stock. But according to the second rule, that small piece should be cut in the cutting process and be cut out of another stock. It leads to a point, in which according to the first rule the wastage of another big piece is decreased. Thus it can be mentioned that while changing the sequence of small pieces cutting, generally increasing or decreasing of the wastage in one of the big pieces lead to increasing or decreasing in another big piece. The amount of such an increasing or decreasing equals the length of replaced small piece (i.e. the general rule of cutting wastage concentration). In fact it can be pointed out as this word that increasing or decreasing of the wastage in one piece is in contrary to another piece. Considering this fact, which is known as the general rule of cutting wastage concentration, the optimum operation of the total virtual cost in concentrating the cutting wastage can be proved.

Suppose that in a one dimensional cutting process, the virtual cost 2 is allocated to the k^{th} stock, the virtual cost 1 is allocated to the k'^{th} stock, and TVC is calculated according to these amounts. By replacing the i^{th} piece as long as l_i in cutting process, when the wastage of k^{th} stock is increased l_i unit, the total virtual cost will increase $2 \times l_i$. According to the general rule of cutting wastage concentration, the increasing of cutting stock in k^{th} stock leads to the decreasing on the k'^{th} stock as big as l_i unit. Thus the virtual cost will be decreased as big as $1 \times l_i$. It can be observed that when the cutting wastage in unchangeable in both mentioned conditions, the virtual cost in the second condition will be increased as big as l_i. By contemplating on the application of total virtual cost, it can be observed that whenever the cut stocks are organized according to the wastage in a descendant way, the best wastage concentration will be obtained, if the wastage appears on the first stocks (with less VC). It means that the items should be cut out of the stocks with more VC (i.e. last stocks) instead of the stocks with less VC (i.e. first stocks). Therefore the stocks with less VC contain more wastages and it reduces the TVC.

Following scheme depicts the process of optimizing evaluation. In this diagram, it is supposed that the stocks are organized according to their wastage amount in a descendant way. And virtual cost is allocated to the stock as a whole number from 1 to M (i.e. the virtual cost in j^{th} stock equals j). It is also supposed that: M > K > 1.

If the ΔTVC changes are negative, it will be decreasing. Example 2: Suppose that big pieces are as long as 2 meters and the item order is as follow:

Table 3. The length amounts and the number of orders in ex. 2

The Number of Orders	Length (Meter)
2	6
10	2
3	4

The model is entered in Lingo software, after solving it: $x_{7_1}, x_{8_1}, x_{9_1}, x_{10_1}, x_{11_2}, x_{12_2}, x_{13_2}, x_{14_3}, x_{15\_3}, x_{1\_4}, x_{2\_4}, x_{3\_4}, x_{4\_4}, x_{5\_4}, x_{6\_4}$ equaled 1 and other x_{ij} amounts equaled zero. According to the amounts above, the cutting pattern was obtained as follow:

Table 4. The obtained cut pattern by the problem solving via Lingo (Ex. 2)

	The cut length out of each stock (Meter)						Each Stock
Stock 1	2	2	2	2			2
Stock 2	4	4	4				0
Stock 3	6	6					0
Stock 4	2	2	2	2	2	2	0

It can be observed that all wastages are concentrated on the first stock. But if one of the cut 2 m pieces out of stock 4, had been cut out of stock 1, there were the same 4 m of wastages, and the problem was not being optimized in CSP viewpoint. This time the wastage was appeared on stock 2, though. Example 3: Suppose that big pieces are as long as 12 meters and the item order is as follow:

Table 5. the length amounts and the number of orders in ex. 3

The Number of Orders	Length (Meter)
2	4.5
10	2.5
3	0.5

The model is entered in Lingo software, after solving it: $x_{1\_3}, x_{3\_3}, x_{4\_3}, x_{5\_3}, x_{2\_2}, x_{6\_2}, x_{4\_2}, x_{8\_2}, x_{9\_1}, x_{10\_1}, x_{11\_1}, x_{12\_1}, x_{13\_1}, x_{14\_1}, x_{15\_1}$ equaled 1 and other x_{ij} amounts equaled zero. According to the amounts above, the cutting pattern was obtained as follow:

Table 6. The obtained cut pattern by the problem solving via Lingo (Ex. 3)

	The cut length out of each stock (Meter)						Each Stock
Stock 1	0.5	0.5	2.5	2.5	2.5	2.5	0.5
Stock 2	2.5	2.5	4.5				0
Stock 3	2.5	2.5	4.5				0

It can be observed that all wastages are concentrated on the first stock.

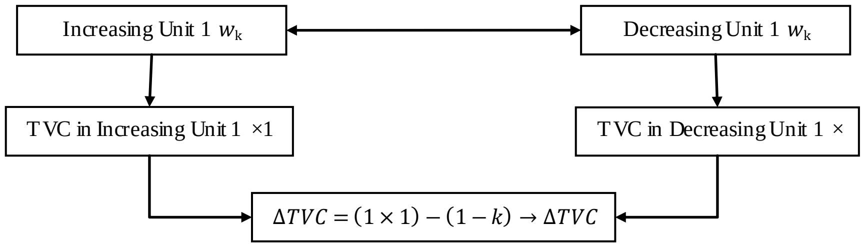


Figure 4. The Scheme of Optimizing Evaluation in Total Virtual Cost

3.6. The Calculating Problems in this Model

The discussed model is expected to get the minimum amount of cutting wastage concentration and its size is too big. It should be mentioned that cutting problems usually are raised in big sizes and considering increasing amount of variants 0 and 1, and increasing the restrictions consequently, solving this model at a big size is too time consuming and sometimes impossible. This model was planned to show the application of the cutting wastage dispersion problem only. It can be used to find an innovative method in order to solve the one dimensional cutting wastage dispersion problem by obtained ideas.

Dependence of the model on the number of big pieces is another difficulty of this model. The exact number of required big pieces cannot be calculated before cutting. An upper bound can be supposed for the number of big pieces though. The extra big pieces can keep unused in cutting process in discussed model, but using the upper bound increases the dimensions of the problem groundlessly.

The cutting process can be simulated once by a method in order to solve this problem. The approximate number of required big pieces in this model can be calculated via this simulation. A method on the basis of the metahuristic algorithms is needed to improve the searching condition of concentration in cutting wastage dispersion problems and use the discussed model to approach an answer close to an optimum amount in the logical time.

4. The Process of Optimizing Method by ICA

4.1. The ICA and its History

The ICA is a method which has been used in many different optimizing problems since its introduction. At first, this method was introduced by Atashpaz et al. (2007) to solve the PID controlling problem[24].this algorithm is based on this logic that beside the natural aspect, the human evolution possess the social and political aspects as well. It has been the origin of the ICA phenomenon. Nowadays various activities are fulfilling to expand this algorithm usage according to the imperialismphenomenon in the world. In different researches, this algorithm has offered an optimized answer for many complicated engineering problems.

4.2. The Target Function

As it pointed out earlier, the target function in this article is discussed as minimizing the TVC amount in relation (5). First of all, an array as long as N, containing the ordered items is formed. Another array is considered containing the length of stocks as long as M. The exact amount of M cannot be determined at first. So some changes are needed in algorithm FFD to determine the amount of M in order to get to the number of required stocks. According to such changes, when an item cannot be cut out of available stocks, one unit is added to M, and this process continues up to the end of cutting all items.

The stocks will be organized according to their wastage amount after cutting all pieces and clarifying the amount of wastage in each stock. Finally the virtual costs will be allocated to the stocks. TVC is calculated in this way.

4.3. Producing the Primary Acceptable Answer

In order to get to the primary answer, algorithm FFD executes for the current sequence after organizing the length of pieces in a descendant way. Since bigger pieces are cut out of bigger stocks first in this method, this answer looks qualified enough and it can be considered as an ideal primary answer.

On the basis of this algorithm, if the length of i^{th} piece is smaller than the rest of j^{th} stock, it should be cut out of the j^{th} stock ($x_{ij} = 1$). Otherwise if possible, it should be cut out of the next stock (i.e. stock $j^{th} + 1$).

The sequence of items is very important in using this method. Sometimes the wastage dispersion style (and sometimes the amount of sequences in cutting the items on the wastage dispersion) changes with such a sequence.

4.4. The Steps in Solving the Problem

ICA has been used to solve many problems [24-27]. It was tried to improve the ICA method to solve the cutting stock problem. At first, the orders table, standard length of big pieces, the number of countries, the number of algorithm repetitions, related ratios to absorption factor, imperialist competitive and revolution are determined and put into related variants. Figure 4 depicts the chart of solving the problem.

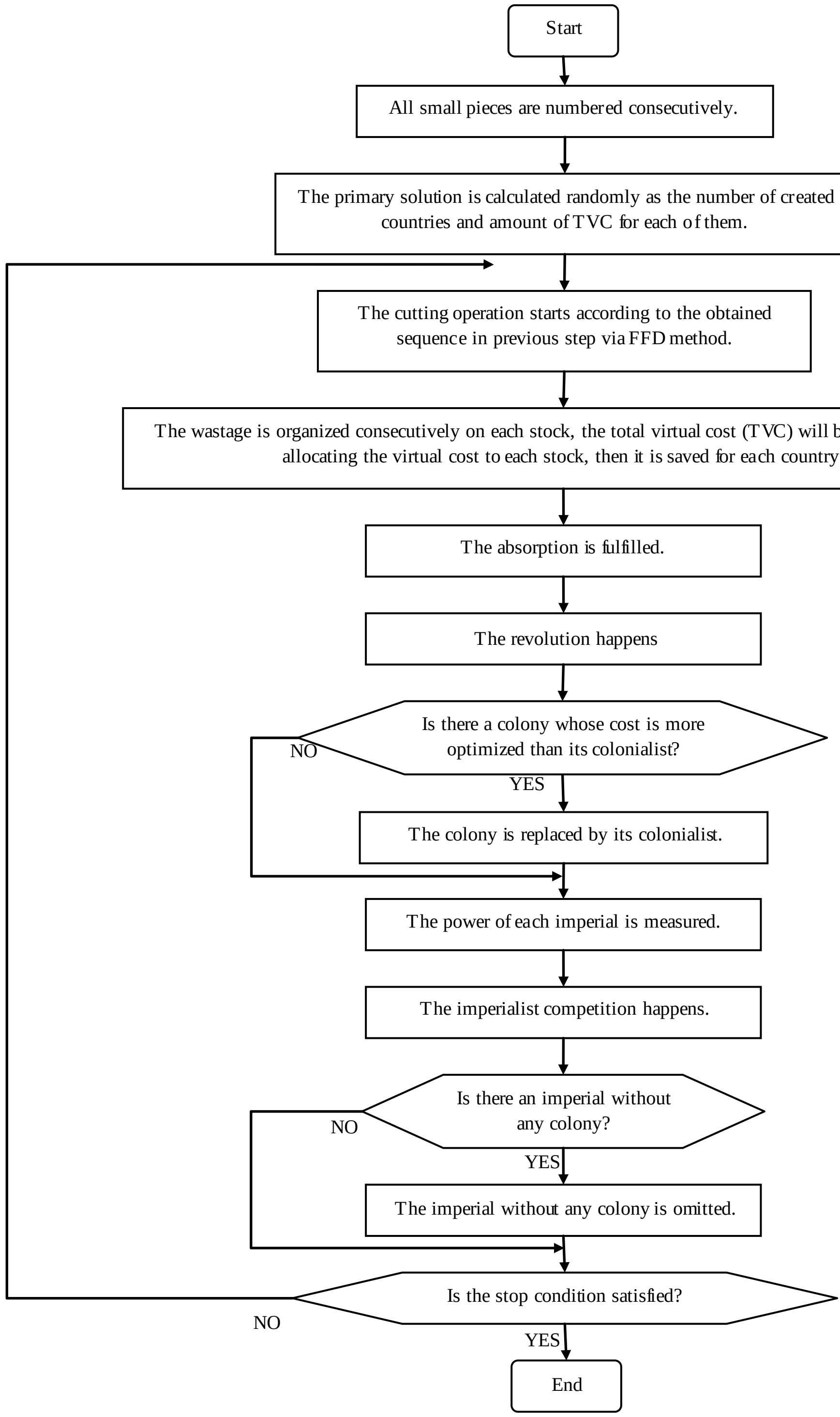


Figure 5. The chart of solving the one dimensional cutting stock problem via ICA

4.5. How to Stop the Algorithm

The explained solution can be stopped under three circumstances: 1- When the wastage amount and total virtual cost equal zero, there will be no reason to continue the algorithm in this case. 2- Whenever the amount of wastage and total virtual cost are not the same. The amount of wastage will be concentrated on one big piece in this case, and it can be considered as the best wastage concentration. 3- When the number of evolved generations gets to a predetermined number in algorithm. The best possible answer on the memory is considered in this case, and it will be introduced as the best problem answer.

5. Problem Solving and Results

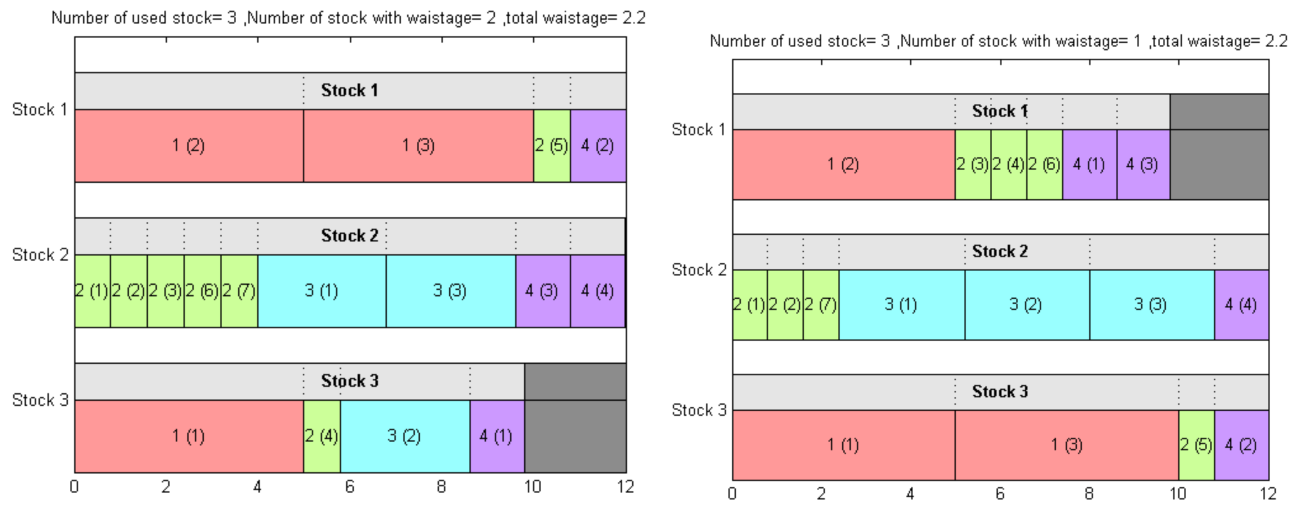
At the first comparison, the application of ICA is compared to genetic, Tabu search and simulated annealing(SA) algorithmsfor a model in example 4 in smaller size. Suppose that big pieces are as long as 12 meters and ordered items are as following table:

Table 7. the length amounts and the number of orders in ex. 4

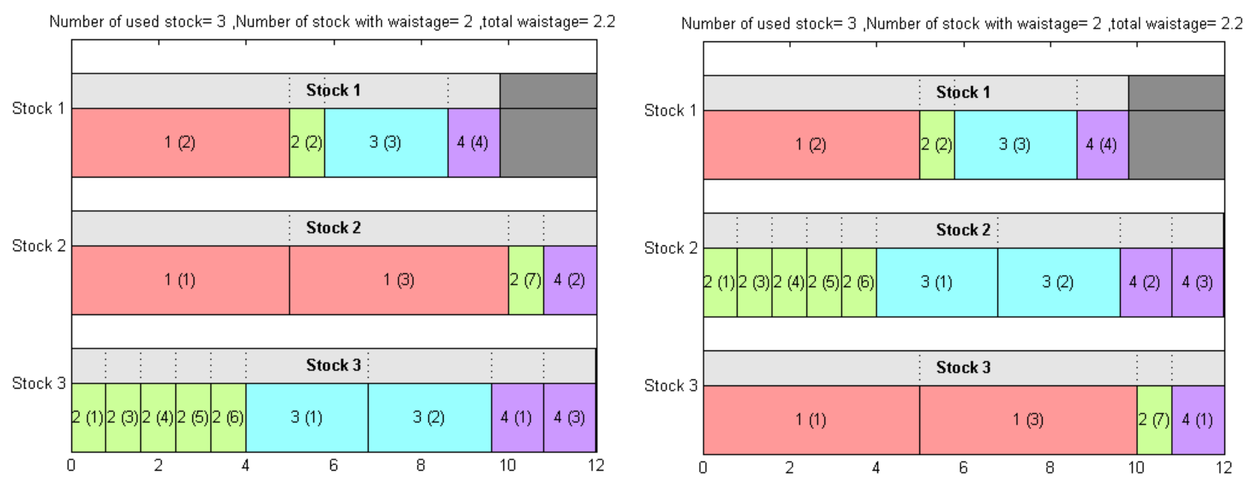
No	Order number	Length (Meter)
1	3	5
2	7	0.8
3	3	2.8
4	4	1.2

Figure 6 is resulted from solving the model by four mentioned algorithms.

As it can be observed in Figure 6 (1-4), for the wastage minimizing model with wastage concentration, the ICA produces the least dispersion and performs better that other algorithms, such as genetic algorithm (Figure 6-2), Tabu search algorithm (Figure 6-3) and SA (Figure 6-4). Totally 20 problems were made randomly in various dimensions in three different classes by CUTGEN1 software [28] in order to evaluate the quality of obtained answer accurately. Table 8 represents their related information.



6-1: Solving by ICA6-2: Solving by genetic algorithm



6-3: Solving by Tabu search6-4: Solving by SA

Figure 6. Results of solving Ex. 4 via different algorithms (M)

Table 8. Applied classes in CUTGEN1 software for making the problem

	Each class Dimension	Number of orders	The length of each consuming stock	Minimum threshold in each piece	Maximum threshold in each piece	Total number average of pieces	Applied version	The number of made problems
Class 1 (C1)	Small	10	1000	0.01	0.2	5	1994	10
Class 2 (C2)	Medium	20	1000	0.01	0.2	5	1994	5
Class 3 (C3)	Large	40	1000	0.01	0.2	5	1994	5

These problems are solved according to the wastage optimizing pattern to minimize the stock with wastage under the similar circumstances for SA (SA) algorithm and ICA via MATLAB software. The samples of solved problems by ICA possessed better wastage dispersion comparing to other solved problems by SA. The results are shown in tables (9-11). Statistical results (figures 7-9) represent that ICA has found more appropriate answers than SA in 95 percent of cases.

Table 9. Obtained results out of made problems in sample C1 by MATLAB software

No	Class	The number of ordered pieces	The length of each stock	Consumed stocks in ICA	Wastage in ICA	Wastage dispersion in ICA	The best cost in ICA	Consumed stocks in SA	Wastage in SA	Wastage dispersion in SA	The best cost in SA
1	C1	10	1000	6	205	6	4,1655	7	1205	7	6,69
2	C1	10	1000	5	137	4	3,8222	5	137	4	4,8771
3	C1	10	1000	5	874	4	4,0373	5	874	4	4,134
4	C1	10	1000	6	822	5	4,1347	6	822	5	4,1655
5	C1	10	1000	7	696	6	4,3087	7	696	7	4,5983
6	C1	10	1000	8	867	7	4,6995	8	867	8	4,7672
7	C1	10	1000	6	677	6	4,2733	6	677	6	4,7051
8	C1	10	1000	5	317	5	3,8553	5	317	5	4,6615
9	C1	10	1000	4	112	2	4,1621	4	112	4	4,8612
10	C1	10	1000	7	990	7	4,2854	7	990	7	4,4464

The output of ICA and SA algorithm for class 1 is compared in Figure 7. As it can be observed, the best answers belong to ICA.

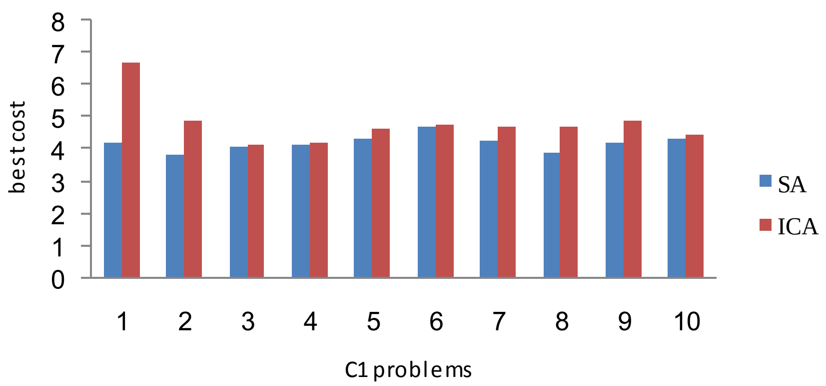


Figure 7. Related results of solving the C1 problems

Table 10. Obtained results out of made problems in sample C2 by MATLAB software

No	Class	The number of ordered pieces	The length of each stock	Consumed stocks in ICA	Wastage in ICA	Wastage dispersion in ICA	The best cost in ICA	Consumed stocks in SA	Wastage in SA	Wastage dispersion in SA	The best cost in SA
11	C2	18	1000	12	602	12	4,902	13	1602	13	5,0693
12	C2	19	1000	11	1027	7	6,6835	11	1027	10	7,3306
13	C2	20	1000	16	1359	13	8,9147	16	1359	16	11,6849
14	C2	19	1000	10	648	9	4,7448	10	648	9	4,9003
15	C2	19	1000	12	412	12	4,856	13	1412	13	6,4264

As it can be observed in Figure 8, comparing to SA, the best answers in all problems in C2 belong to ICA, too.

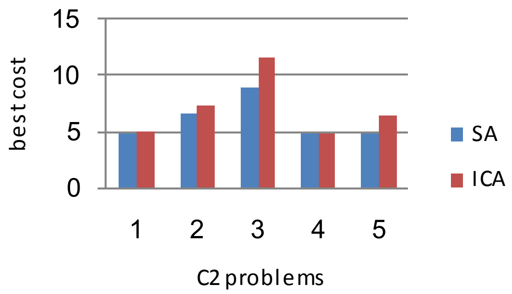


Figure 8. Related results of solving the C2 problems

The difference among the answers will increase by enlarging the dimensions. Table 11 and Figure 9 can prove this claim.

Table 11. Obtained results out of made problems in sample C3 by MATLAB software

No	Class	The number of ordered pieces	The length of each stock	Consumed stocks in ICA	Wastage in ICA	Wastage dispersion in ICA	The best cost in ICA	Consumed stocks in SA	Wastage in SA	Wastage dispersion in SA	The best cost in SA
16	C3	38	1000	21	577	19	4,9453	22	1577	22	18,3003
17	C3	38	1000	24	360	24	4,8459	25	1360	25	21,9907
18	C3	38	1000	20	321	18	4,8332	21	1321	21	18,1659
19	C3	40	1000	22	538	20	4,9325	23	1538	23	23,8063
20	C3	40	1000	20	643	20	4.9339	21	1643	21	20,6844

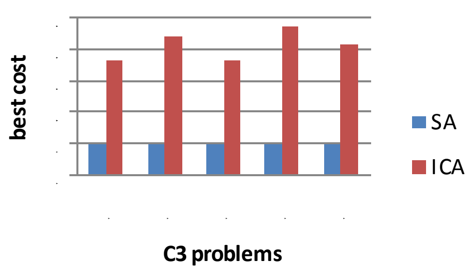


Figure 9. Related results of solving the C3 problems

6. Discussions and Future Works

In this article, the extra costs were used in order to reduce the wastage dispersion and total wastage consequently among the answers of one dimensional cutting problem. A kind of virtual cost for cutting is obtained by applying the extra cost in cutting problem, which can be used as a criterion for comparing the resulted answers in order to get to better wastage dispersion. Finally, a solution was offered to solve the one dimensional cutting problem by applying ICA method and the wastage dispersion model. Comparing the resulted answers by ICA and SA methods, it was cleared that ICA is more efficient qualitatively (especially in bigger sizes that are closer to the real world models).

As a suggestion for future works, it can be expressed that minimizing the cutting wastage to minimize the stock dispersion has been studied on the basis of evaluated items only. Evaluating this problem in a pattern-based condition not only can quicken the model responding, but it also is a proper background for researchers. Furthermore, applying some other algorithms, such as cuckoo search, can evaluate the model in an efficiency aspect by modern algorithms.

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