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New Approaches in Meta-heuristics to Schedule Purposeful Inspections of Workshops in Manufacturing Supply Chains

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A B S T R A C T

Nowadays, with the growth of technology and the industrialization of societies, work-related accidents, and consequently the threat of human capital and material resources are among the problems of the countries of the world. The most important legal solution in most countries to control occupational accidents and illnesses is to conduct periodic site visits and identify hazardous sites. To the best of our knowledge, no study from the supply chain point of view has been reported to model and address this kind of problem. Thus, this paper is to select the best route that reduces the time elapsed between the workshops and the visit time of the inspectors by using two-tier supply chain simulation coupled with the vehicle routing problem (VRP) to give them more opportunity to visit more workshops. In this study, by considering the number of workshops, the limitation of the number of the existing inspectors and the priority of inspecting the workshops, a bi-objective mathematical model is presented. The main aims are to maximize the number of visited workshops and minimize travel times and workshops visit times. In this study, three meta-heuristics (i.e., SA, SEO and RDA) and two hybrid algorithms are used to address the model. Then, the quality of the meta-heuristics and hybrid algorithms are evaluated and compared by using four metrics. The SEO algorithm provides the best performance; however, in a long time, the hybrid GASA algorithm provides the worst performance. Finally, a real-case study is used to validate the presented model.

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1. INTRODUCTION AND LITERATURE REVIEW

Nowadays, one of the most considerable challenges in the world, especially in developing countries, is occupational accidents [1]. According to the statistics published by the International Labour Organization[1], there are about 2.3 million fatalities annually owing to job-related risks that put enormous costs on states' economies. To identify potential hazards in high-risk industrial and mineral units, as well as to plan and supervise properly the implementation of the labor code approvals designed to prevent work-related accidents, it seems necessary to visit from workshops. Periodic inspection from workshops is very useful for identifying high-risk areas, controlling accidents and occupational diseases that lead to the discovery of potential hazards as well as reducing work-related accidents [2]. Therefore, designing a comprehensive, dynamic and efficient inspection system to create safe and secure work environments can be the main pillar of the reduction of occupational accidents.

In this regard, a comprehensive plan can help inspectors get the most out of workshops in the shortest amount of time. Although there are some studies in the literature considering special cases in a supply chain along with a vehicle routing problem (VRP), an approach is proposed to plan to inspect workshops by considering the maximization of the number of inspection and minimization of the time spent on this process to enhance occupational safety for preventing accidents in

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[1] https://www.ilo.org/global/langen/index.htm.

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workshop. Moreover, we propose hybrid algorithms to utilize the benefit of the intensification and diversification phases of the algorithms.

In this paper, we assume a two-tier supply chain where in the first level, there is a node (office) that inspectors are in it. In the second level, there are many workshops that inspectors should visit them. For this purpose, we consider a bi-objective mathematical model that maximizes visits to the workshops and minimizes the time taken to go to workshops and visit them. Besides, it considers prioritization in the timetable for visiting workshops. We apply meta-heuristic and hybrid algorithms to solve the model. Besides, we use four metrics to compare the performance of the algorithms. By presenting a case study, we consider the application of the proposed model in practice. Figure 1 depicts the schematic representation of the concept.

Arquillos et al. [3] recommended that the severity of accidents was related to variables and they concluded that a small company is not always necessarily safer than a large company in the face of fatal accidents. Besides, it was shown that periodic inspections increase immunity and almost half of the contractors have no commitment to a safe work environment [4–6]. Hajakbari and Minaei-Bidgoli [7] considered that priority was given to weighting the variables with variables for periodic inspection. Zhou and Ding [8] proposed an Internet-of-Things-based safety barrier warning system to achieve a safer construction.

Furthermore, to combine the flow of information or products between suppliers to customers, Supply Chain Management (SCM) deals with different concepts [9]. At the right place and right time with the optimal cost, services and products are received in the SCM [10, 11]. A VRP is one of the most well-known hybrid optimization problems that is extremely complex to solve on a large size [12]. Ke [13] extended the well-known capacitated VRP. The contribution of this paper was to minimiz the time in which vehicles had to be visited. Another issue developed in a previous study was

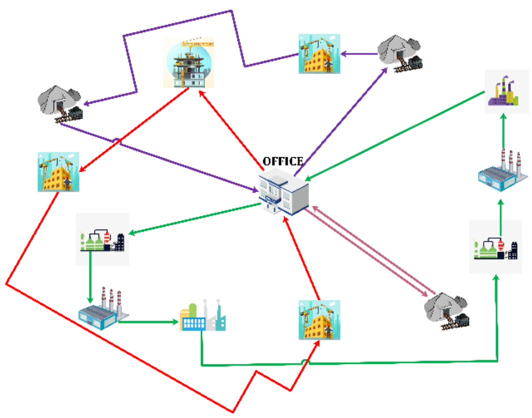


Figure 1. Schematic representation of the concept

shipping hazardous substances suggested by Bula et al. [14], in which in addition to considering a restriction of a time window, the shipping path is allocated to each fleet.

The rest of this paper is organized as follows. In Section 2, we not only explain a framework for the problem and describe the objective of this issue, but also presente the details of the mathematical model. Meta-heuristics and hybrid algorithms with their steps in detail are considered in Section 3. Section 4 shows evaluation and comparison among approaches by different criteria with the experimental computation. In Section 5, a case study is used to validate the model. Finally, Section 6 presents the conclusion and future studies.

2. PROBLEM STATEMENT

2. 1. Assumptions The main assumptions are as follows:

- All workshops can be visited in the first period. In the second period, all workshops except the construction workshops are completed because the first period of the reporting deadline was completed. In the second period all workshops except construction and mines. Priority visits continue through the fourth period.
- The reporting priority workshop in the second period can be visited in the first period and submitted in the second period. However, the workshop that is the priority of the visit in the third period cannot be visited in the fourth period so visiting the workshops is permitted before the reporting time but after submitting the report the workshop is removed from the list of the visiting options.
- Each inspector is required to make a minimum number of visits during the schedule.
- The beginning and end of visits are during office hours.
- Inspectors are required to visit at least one predetermined number of workshops during scheduling.
- The duration of visiting from each workshop is fixed.
- The parameter of experience coefficient has been added to this model, which means that the duration of each inspector's visit to the workshop varies according to the experience of the inspectors.
- The time interval between workshops is clear and constant.
- Just one inspector visits each workshop.

2. 2. Indices Let $G = (S, A)$ be a graph, where $S = \{i | i = 0, \dots, n\}$ is the node set and S_0 is the central office. $A = \{(S_i, S_j): S_i, S_{i'} \in S\}$ is the arc set, where each arc $(S_i, S_{i'})$is associated with a non-negative distance, $d_{ii'}$. Besides, S-{0} is divided to i_1, i_2, i_3, i_4, and i_5 that are construction workshops, workshops on metal industry and casting, workshops on gas, petrochemical and chemical industries, mines, and other workshops in the field of protection, respectively. Also, J and T are inspector set and period set, respectively. Besides t_1, t_2, t_3, t_4 exhibit the set of days in a period. The parameters and variables used in this model are presented as follows:

w_i	Significance factor of the *i*-th workshop
$d_{ii'}$	Time distance between the *i*-th and the *i'*-th workshop
$time_i$	Visit duration of the *i*-th workshop
α_j	Experience factor of the *j*-th inspector
B	Minimum number of inspections per month by each inspector
a	Business start time
b	End of the business day
$C_1, \dots, C_4$	Minimum number of visits to each different workshops
$x_{ii'jt}$	1, if the *j*-th inspector is dispatched from the *i*-th node to the *i'*-th node in period *t* to visit; and 0, otherwise
s_{ij}	Arrival time of the *j*-th inspector at the *i*-th workshop
F_{ij}	Exit time of the *j*-th inspector from the *i*-th workshop.

2. 3. Model

$$\text{Max } Z_1 = \sum_i \sum_{\substack{i' \\ i' \neq i}} \sum_j \sum_t w_i * x_{ii'jt}$$

$$\text{Min } Z_2 = \sum_i \sum_{\substack{i' \\ i' \neq i}} \sum_j \sum_t (d_{ii'} + time_{i'}) * x_{ii'jt}$$

s.t.

$$\sum_{\substack{i \\ i \neq i'}} \sum_j x_{ii'jt} \leq 1, \forall\, t_1, i' \in i_1, i_2, i_3, i_4, i_5 \quad (1)$$

$$\sum_{\substack{i \\ i \neq i'}} \sum_j x_{ii'jt} \leq 1, \forall\, t_2, i' \in i_2, i_3, i_4, i_5 \quad (2)$$

$$\sum_{\substack{i \\ i \neq i'}} \sum_j x_{ii'jt} \leq 1, \forall\, t_3, i' \in i_3, i_4, i_5 \quad (3)$$

$$\sum_{\substack{i \\ i \neq i'}} \sum_j x_{ii'jt} \leq 1, \forall\, t_4, i' \in i_4, i_5 \quad (4)$$

$$\sum_{\substack{i \\ i \neq i'}} x_{ii'jt} - \sum_{\substack{i \\ i \neq i'}} x_{i'ijt} = 0, \quad \forall\, i' \in S, j, t \quad (5)$$

$$\sum_{i,i' \epsilon q} x_{ii'jt} \leq |q| - 1 \quad \forall\, |q| \geq 2, q \subset \{0,1,2,\dots,n\}, j, t \quad (6)$$

$$\sum_i \sum_{\substack{i' \\ i' \neq i}} \sum_t x_{ii'jt} \geq B \quad \forall\, j \quad (7)$$

$$S_{ij} \geq a \quad \forall\, i, j \quad (8)$$

$$F_{ij} \leq b \quad \forall\, i, j \quad (9)$$

$$S_{ij} \leq M * \sum_{\substack{i' \\ i' \neq i}} \sum_j x_{i'ijt}, \quad \forall\, i \in S - \{0\}, j, t \quad (10)$$

$$S_{i'j} + M(1 - x_{ii'jt}) - a - d_{ii'} \geq 0 \quad \forall\, i, i'(i \neq i'), i = 0, i' \in S - \{0\}, j, t \quad (11)$$

$$S_{i'j} - M(1 - x_{ii'jt}) - a - d_{ii'} \leq 0 \quad \forall\, i, i'(i \neq i'), i = 0, i' \in S - \{0\}, j, t \quad (12)$$

$$S_{i'j} + M(1 - x_{ii'jt}) - F_i - d_{ii'} \geq 0 \quad \forall\, i, i' \in S - \{0\}\ (i \neq i'), j, t \quad (13)$$

$$S_{i'j} - M(1 - x_{ii'jt}) - F_i - d_{ii'} \leq 0 \quad \forall\, i, i' \in S - \{0\}\ (i \neq i'), j, t \quad (14)$$

$$F_{i'j} - S_{i'j} - time_{i'} * \alpha_j + M(1 - x_{ii'jt}) \geq 0 \quad \forall\, i' \in S - \{0\}, i \in S, j, t \quad (15)$$

$$F_{i'j} - S_{i'j} - time_{i'} * \alpha_j - M(1 - x_{ii'jt}) \leq 0 \quad \forall\, i' \in S - \{0\}, i \in S, j, t \quad (16)$$

$$\sum_{\substack{i \\ i \neq i'}} \sum_j \sum_t x_{ii'jt} \geq C_1 \quad \forall\, i' \in i_1 \quad (17)$$

$$\sum_{\substack{i \\ i \neq i'}} \sum_j \sum_t x_{ii'jt} \geq C_2 \quad \forall\, i' \in i_2 \quad (18)$$

$$\sum_{\substack{i \\ i \neq i'}} \sum_j \sum_t x_{ii'jt} \geq C_3 \quad \forall\, i' \in i_3 \quad (19)$$

$$\sum_{\substack{i \\ i \neq i'}} \sum_j \sum_t x_{ii'jt} \geq C_4 \quad \forall\, i' \in i_4 \quad (20)$$

The first objective function is to increase the total number of visits to all workshops. If some workshops are prioritized for visiting reasons, you can encourage the model to visit that workshop by increasing the important factor of the workshop. The second objective function minimizes all the routing functions of the means of transportation. Also in this model, we seek to minimize travel time.

Constraints (1) - (4) are part of the routing constraints, stating that each workshop can be visited by maximum one inspector in the desired period (no need to visit the workshop). Constraint (5) is one of the routing constraints; enter and exit an arc node (it must exit when an inspector enters a workshop). Constraint (6) is the routing constraint; prevents the creation of sub tours. Constraint (7) illustrates that every inspector is required to make a B visit each schedule. Constraints (8) and (9) indicate the beginning and finish times of visits during office hours. Constraint (10) states that when the inspector moves from workshop *i'* to workshop *i*, the time to reach workshop *i* can take a value. Constraints (11) and (12) specify the time of arrival of the inspector to the workshop *i* after leaving the office. Constraints (13-14) show the time the inspector arrives at the workshop *i'* after completing a visit to workshop *i*. Constraints (15) and (16) calculate the time when the inspector *j* 's visit to the workshop ends. Constraints (17) – (20) indicate the minimum number of inspections per period of each type of workshop.

3. PROPOSED HEURISTIC AND HYBRID META-HEURISTIC ALGORITHMS

3. 1. Proposed Meta-heuristics Algorithm

In this model, we utilize four algorithms. These algorithms include Simulated Annealing (SA) [15] Social Engineering Optimizer (SEO) [16], Red Deer Algorithm (RDA) [17], and Genetic-Keshtel (GAKA) algorithms. Hajiaghaei Keshteli and Aminnayeri [18] first developed the KA algorithm, SA and SEO are a single solution. On the other hand, RDA, hybrid GAKA and GASA are population solution.

3. 2. Encoding Plan To depict the "Random-key" method, an array in length of the number of workshops plus the number of inspectors minus one is shaped using uniform distribution $U(0,1)$. Then, these numbers are sorted and the number of workshops associated to each inspector is determined. Figure 2 shows an example of this array for the algorithms.
The results are as follows:
$Inspector\ 2 = \{b_3 \longrightarrow b_7 \rightarrow b_2\}$
$Inspector\ 1 = \{b_8 \rightarrow b_1\}$
$Inspector\ 3 = \{b_6 \rightarrow b_5 \rightarrow b_4\}$

3. 3. Data Generation In this section, three different categories including seven test problems are utilized to test and to evaluate the system. Coordination of the model is shown in Tables 1 and 2.

3. 4. Parameter Tuning The reason for the non-effective behavior of the algorithm is untuned algorithm parameters. The Taguchi method avoids this problem [19]. Control and noise factor are approaches which are examined in double primary groups. The equation of the signal-to-noise proportion is defined by:

$$S/N = -10log\left(\frac{\sum_{i=1}^{n} Y_i^2}{n}\right) \quad (21)$$

0.79	0.39	0.87	0.12	0.28	0.92	0.20	0.54	0.63	0.71
3	7	2	10	8	1	9	6	5	4

Figure 2. Chromosome

TABLE 1. Categories of the issue

Category	Instance	Issue size (I, J, T)
Small	SP1	(40,2, 4)
	SP2	(80,2, 4)
Medium	MP3	(300,2, 8)
	MP4	(400,3, 8)
	MP5	(500,3, 8)
Large	LP6	(1000,3, 15)
	LP7	(1258,3,24)

TABLE 2. Coordinates of the model

Parameter	Values	Unit
w_i	Uniform ~ (0,1)	-
$d_{ii'}$	Case study	Minute
$time_i$	Case study	Minute
α_j	Uniform ~ (0,1)	-
B	60	-
a	08:00	Time
b	16:00	Time
$C_1, \ldots, C_4$	32-3-24-1	Workshop

The objectives' measure in each presented experiment is divers so the relative percentage deviation (RPD) manner is applied.

$$RPD = \frac{Alg_{sol} - Min_{sol}}{Min_{sol}} \quad (22)$$

In this equation, in each repetition, a specific value is gained for the objective which is called Alg_{sol} , also, the best output of experiments obtained in the given instance is Min_{sol} . Calculating the mean of RPD and converting objective values is the next step. Then, S/N ratios are obtained from the mean values of RPD, being the mean per experiment at each level. The Taguchi procedure suggests L9 for SA, SEO, GAKA, L16 for RDA, and L18 for GASA relying upon the factors as well as their levels. Table 3 illustrates the parameters which are tuned.

TABLE 3. Tuned values of optimizers

Optimizer	Parameters
SA	Sub-it=25; R=0.995; T0=1300; Tm= Reversion
SEO	α =0.25; β =0.07; N =50;
RDA	n-pop=200; Nmale=35; Pα=0.8; Pβ =0.4; Pγ =0.7
GAKA	n-pop=20; PN1=0.3; PC=0.65; Nswirl =5
GASA	n-pop=30; CP=60%; MP=0.4;Sub-it=20; R=0.995; T0=1200

4. COMPARISON OF ALGORITHMS

Four metrics are proposed to evaluate the problem of the proposed algorithm. These metrics include Spread of Non-dominance Solution (SNS), Diversification Metric (DM), Percentage of Domination (POD), and Data Envelopment Analysis (DEA). It should be noted that the higher values obtained from metrics are causing more output quality [20, 21].

The best results of each proposed metrics are stored after that each algorithm is run for 30 times. Then, the efficiency and performance of all metrics are measured and evaluated with each other. The comparison of these standard criteria is according to Pareto solutions. The Diversification Index (DI) has been achieved from the proposed metrics after normalization [17] showing the deviation which is related to each algorithm metrics. In each size of the issue, the scale of the best solution related to each method is changed, called normalized. We benefit from an ANalysis of VAriance (ANOVA) to investigate the results. Based on the ANOVA analysis, the outcomes gained from all algorithms indicate the SEO algorithm has better performance. Also, the GASA algorithm illustrates the worst outcomes among them.

Moreover, another index that has been utilized to the extent of the efficiency and performance of an algorithm is the Intensification of the Index (II), which will be elaborated in the following relation including four parameters combined into a parameter:

$$II = w_{DM} \, . DM_{sol}^{DI} + w_{SNS} \, . SNS_{sol}^{DI} + w_{POD} \, . POD_{sol}^{DI} + w_{DEA} \, . DEA_{sol}^{DI}$$

Each algorithm possesses DI parameter that has been placed in this equation including $DM_{sol}^{DI}; SNS_{sol}^{DI}; POD_{sol}^{DI}$ and DEA_{sol}^{DI}. Also, each metrics has a different weight for assessment shown with w_{DM} , w_{SNS} , w_{POD} and w_{DEA} . In this paper, the amount of 1, 0.5, 1.5 and 0.5 was proposed for each metric (SNS, DM, POD and DEA), respectively. In this part, the more the amount of II, the more is desirable. The GAP with the help of the best solutions evaluates the amount of deviation and was introduced to explain the algorithms' efficiency.

$$GAP = \frac{II_{max} - II_{sol}}{II_{max} - II_{min}} \tag{23}$$

As mentioned before, we run 30 times for each algorithm, so the amount which is achieved by each optimizer after each run is named II_{sol}, and also, the best and the worst amounts of II are named II_{max} and II_{min}, respectively. In this equation, it is obvious that the less GPA, the better is the algorithm. Besides, Figure 3 not only does determine the best methods but also depicts the interaction between problem size and GAP. Also, this figure shows SEO has superior efficiency. As shown in this figure, except in two cases (SP1 and MP3), the SEO algorithm has superior performance among all algorithms. SEO needs more time to touch the best solution, although it possesses superior outcomes. In total, among all algorithms, SEO and GASA have the best and the worst performance, respectively.

The non-dominated outputs are shown in Figure 4, which are obtained via all algorithms in the MP4 case. This figure demonstrates that 11 points were considered as the number of solutions named the Pareto front. The SEO outputs prevail to the other suggested algorithm's outputs.

5. CASE STUDY

In this section, an industrial example is applied to validate the presented model. These data stem from the

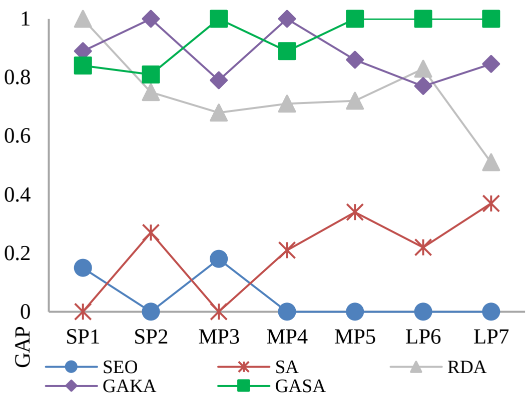


Figure 3. Comparing the GAP among suggested meta-heuristics and hybrid mta-heuristics

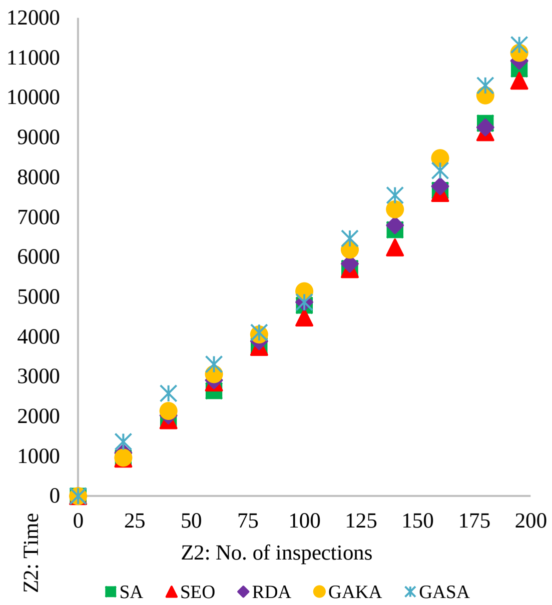


Figure 4. Pareto front for LP7

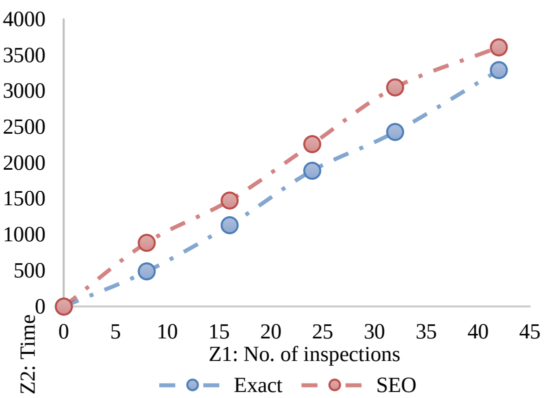
Iranian Labor organization (Savadkooh and North Savadkooh office). These two cities have two industrial parks and one industrial zone. They also have 1258 small and medium enterprices known as workshop units, listed separately in Table 4.

This office has three inspectors, that their duties are inspection from workshops to audit and prevent possible accidents. The other parameters are shown in Table 2. As mentioned before, the VRP is one of the NP-hard problems; so, we apply meta-heuristics and hybrid algorithms to obtain the solution in a reasonable time. At first, as shown in Figure 5a, although SP1 as an small example can be solved with an exact method by GAMS software; however, the solution time is too long and should be interrupted. Also, the model is solved by the SEO algorithm to compare between the algorithm and exact method. As to be expected, SEO is able to handle the model markedly in a shorter time compared with the exact method. Moreover, LP7 adapting to the case study is solved by SEO due to the best efficiency proved in the previous section, compared to the other mentioned algorithms. Figure 5b indicates the result of the Pareto front computed by the SEO algorithm.

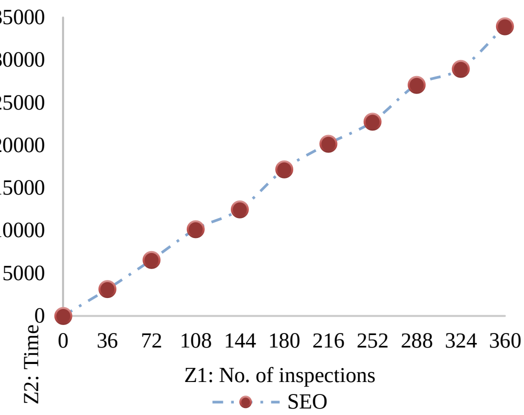
Table 5 describes the last Pareto point in Figure 5b. The number of visits per inspector is reported separately per day. Also, the last row of the table shows the spending time when the inspector is involved in reaching the target workshop and inspecting it for a total of twelve days per minute.

TABLE 4. All of the available workshops

Workshop type	No. of workshops
Construction workshops	219
Workshops on metal industry and casting	12
Workshops on gas, petrochemical and chemical industries	57
Mines	3
Other workshops	967



(a)



(b)

Figure 5. (a) Pareto outline for SP2 with exact and SEO algorithm; (b) Pareto outline of SEO algorithm for LP7

TABLE 5. Number of visits per inspector per day

Day	INS 1*	INS 2	INS 3	Day	INS 1	INS 2	INS 3
1	4	6	6	13	4	5	7
2	4	5	6	14	3	5	6
3	3	6	5	15	2	5	6
4	5	6	5	16	4	6	9
5	4	4	5	17	3	6	6
6	4	6	8	18	6	6	5
7	4	6	5	19	4	3	5
8	4	6	6	20	3	5	5
9	4	5	5	21	3	5	8
10	5	3	5	22	2	4	5
11	4	5	6	23	5	5	6
12	4	6	7	24	3	4	7
Time	5732	5662	5579		5748	5681	5578

* Number of visits for the first inspector

Workshops are scheduled to visit over a period of one month, including 24 working days by 3 inspectors. The maximum time available for three inspectors is 34560 minutes on the planning horizon. 32-3-24-1 is the top priority for visiting construction workshops, workshops on the metal industry and casting, workshops on gas, petrochemical and chemical industries, and mines, respectively. The SEO algorithm suggests that the maximum of 360 workshops can be visited in the planning horizon within 33980 minutes. Finally, there are also 10 Pareto points proposed above for this problem.

It should be noted that in the model there are parameters, named as the factor of experience for each inspector, the lowest value for the first inspector and the highest value for the third inspector. So the timing of the inspector's visit will be different. Considering this point, we can see that the less the number of first inspectors in comparision to the other two inspectors, the time taken to do so is much more greater.

6. CONCLUSION AND FUTURE STUDIES

To decrease occupational accidents, we proposed a scheduled plan for inspection from workshops. In this study, from another angle, the issue of routing within the supply chain framework has been addressed. The application of routing in this paper is to visit workshops which were introduced and modeled. The objective functions not only maximize the number of visited workshops but also minimize travel times and workshops visit times. The model is formulated as MILP alongside with some assumptions that help to reach a real study. To figure out the best outputs for the proposed model, several hybrid and meta-heuristic algorithms containing SEO, SA, RDA, GAKA, and GASA, have been utilized. To compare the result of solution approaches, we needed to tune factors of algorithm which were different and various so the Taguchi method was used. Then, four metrics alongside with the GAP index were introduced and applied to compute and measure the best suitable algorithm. The proposed SEO demonstrated the best outputs and stability among suggested meta-heuristic and hybrid algorithms. The outcomes depicted when inspectors wanted to gain better efficiency of managing the plan from the daily operations, they could count on the model stemmed from the supply chain. This model was a practical appliance for the decision-makers in making operational decisions. This technical planning calculates the number of workshops assigned to each inspector and the occupied time of inspectors as shown in the case study to maximize the number of visits.

For future studies, extending the mathematical model by applying uncertainty and stochastic in the parameters is suggested. Also, new hybrid and evolutionary algorithms were utilized for evaluating and comparing the outputs of the model. Some real constraints, such as social and environmental aspects of Greenhouse Gas (GHG) emission can be added to the suggested model for the subsequent expansion of this model.

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Persian Abstract

چکیده

امروزه با رشد فناوری و صنعتی شدن جوامع، حوادث ناشی از کار و به تبع آن تهدید سرمایه انسانی و منابع مادی از جمله مشکلات کشورهای جهان است. مهمترین راه‌حل قانونی در اکثر کشورها برای کنترل حوادث و بیماری‌های شغلی، انجام بازدیدهای دوره‌ای از کارگاه‌ها و شناسایی مکان‌های خطرناک است. در این مقاله، با استفاده از شبیه‌سازی زنجیره تأمین دو سطحی همراه با مسئله مسیریابی وسیله حمل و نقل بهترین مسیر را که موجب کاهش زمان صرف شده جهت رفتن به کارگاه‌ها و زمان بازدید بازرسان از کارگاه‌ها می‌شود، انتخاب کرد تا فرصت بیشتری برای بازدید از کارگاه‌ها فراهم شود. در این مطالعه، با در نظر گرفتن تعداد کارگاه‌ها، محدودیت تعداد بازرسان موجود و اولویت بازرسی از کارگاه‌ها، یک مدل ریاضی دو هدفه ارائه می‌شود. هدف اول به حداکثر رساندن تعداد کارگاه‌های بازدید شده و هدف دوم به حداقل رساندن زمان سفر و زمان بازدید از کارگاه‌ها است. در این مطالعه از سه روش فراابتکاری شامل SA، SEO، RDA، و دو روش ترکیبی برای حل مدل استفاده شد، سپس به ارزیابی و مقایسه کیفیت الگوریتم‌های فراابتکاری و ترکیبی بوسیله چهار متریک پرداخته شد. الگوریتم SEO بهترین عمکرد اما در زمان بالاتر و الگوریتیم ترکیبی GASA بدترین عمکلکرد را ارائه دادند. سزانجام مطالعه موردی برای اعتبارسنجی مدل پیشنهاد شده ارائه گردیده است.