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A heuristic algorithm for workforce scheduling with synchronization constraints and ergonomic aspects at cross-dock platforms

Parmis SHAHMALEKI *[1], Alpaslan FIĞLALI[2]

Abstract

This research studied a practical scheduling problem arising in the repackaging phase of cross-dock platforms. Packaging/repackaging is one of the significant concerns in cross-dock internal operations, where most of the tasks have been done by a number limited of teams. The problem also contains many practical constraints such as synchronization between teams and ergonomic aspects, as well as several managerial constraints. These conditions make internal workforce scheduling a complex and important issue for cross-docks. Implementation of the decision support system for planning and manpower scheduling in the repackaging phase of a cross-dock is encouraged us for this research. We try to model a real-world problem from automotive industry. Due to the non-deterministic polynomial time hardness (NP-hard) of the problem, finding a good solution is difficult. Therefore a novel greedy construction heuristic algorithm is proposed. We apply this heuristic method for real problem instances. Although the current process of planning and scheduling is manually and time consuming, our proposed algorithm generates good results for real problem instances in reasonable times.

Keywords: Staff scheduling, Synchronization constraints, Ergonomics, Greedy construction heuristic, Cross-dock

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1. INTRODUCTION

The automotive industry is one of the most competitive sectors in the world. Car manufacturers try to globalize their activities in order to benefit from economies of scale and maintain competitiveness. For this reason, most of them try to establish their facilities in different countries due to reducing their costs regarding the logistics and manufacturing operations. So international logistic flows significantly increase in this industry [1]. In these logistic patterns, for improving efficiency and lowering costs, reducing inventory in warehousing at every step of operations is a central concern [2].Thereby, using cross-docking platform is one of the main strategies that help carmakers to cope with their global challenges.

Cross-docking, which has applications in different sectors such as manufacturing, retail companies and logistic service providers, plays an important role in the large distribution network that has a huge variety of shipments like the automotive industry[3,4].

Cross-docking tries to reduce warehouses to trans-shipment centers where the storage of products is limited or nonexistent and its leading functions are receiving and shipping items[2].In other words, a cross-dock is an intermediate node in the supply chain that reduces the cost of storing and inventory.

In general, in a cross-dock, the working environment can be divided into three different areas. These 3 zones are inbound area, internal (treatment) area and outbound area. In Figure1 the general flow shop and operations of cross-dock has been shown. In the cross-dock, at the inbound area, large incoming loads from different suppliers are unloaded, unpacked, disaggregated, and placed. Successively, items based on the customer demands are sorted. Whenever the repackaging is needed items are transported to an intermediate area for deconsolidation, sorting, repackaging and consolidation operations, otherwise they are sent directly to the outbound zone. In this area, once the items are consolidated, the containers are built up and finally loaded onto outbound vehicles and sent to customers.

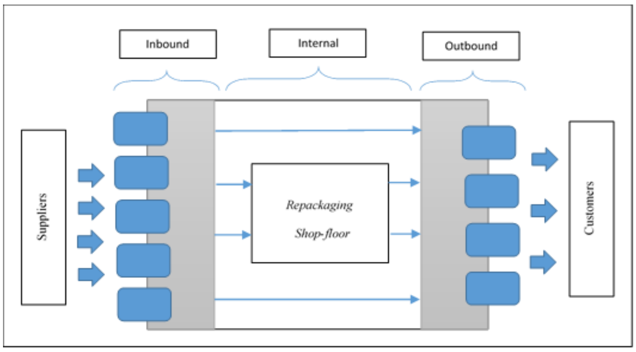

Figure 1. Cross-dock layout

This study focuses on the intermediate work area and especially on the repackaging phase.

Generally main research subjects concerning cross docking are considered as either strategical, tactical or operational level problems[1]. Using this classification, since the cross-dock platform that we consider is already active and the tactical issues are out of our scope, the problem that we address here is considered to be an operational problem. Most of the activities in the intermediate work area are heavy physical activities and done by workers, so the workforce is one of the main factors that affect the productivity of the whole system. In the repackaging stage of cross-dock, there is a limited number of worker teams that process tasks, so the efficient management of such teams in the context of manpower allocation and scheduling becomes a priority.

A simplified description of the manpower allocation problem for the repackaging phase in a cross-dock is as follows: different tasks in the shop floor demand varying number of teams. A planning center dispatches teams to satisfy this demand by considering the specified features of this real-world problem.

Furthermore, due to the customer service strategy of this cross-dock, finishing high priority tasks as early as possible is desirable in the planning period for the managers. It is noteworthy that the planning horizon is short and daily schedules are needed. Therefore, our main goal in this research is to create a daily schedule for tasks and workers in such a way that the number of processed tasks will be maximized by taking into account the distinctive features of this real world problem.

One important feature of the considered manpower allocation is cooperation or synchronization between teams. Some of the tasks demand more than one team to be processed so cooperation will be required. Cooperation or synchronization means a temporary combination of teams joined together for a specific task [5]. These teams should start the processing of that specific task simultaneously.

Forasmuch as humans have different characteristics that distinguish them from other inanimate parts of the systems, contemplating these features lead to a more precise and realistic assessment [6].So another important feature of our problem is the ergonomic aspect. As defined by International Ergonomics Association, “ergonomics” addresses the ways and methods to optimize the worker’s well-being and overall system performance via improving the interaction between humans and other elements of the system [7].

The literature frequently emphasized the significant impact of scheduling and sequencing decisions on system performance. Besides, the human factor and ergonomics literature demonstrated the important role of the sequencing of human tasks on human performance and well-being. So the interaction between scheduling and ergonomics may affect system performance positively. In their research, Carnehan et al.[8] showed that by increasing the human performance via improving workers’ ergonomic criteria such as reducing stress, fatigue and work injury risk, the overall performance of the system enhanced consequently. However, typically in most scheduling problems, the effects of these human characteristics on their performance are ignored and several assumptions are used to simplify human behavior[9].

Several factors can impact human performance directly or indirectly. Some of these factors are fatigue, stress, boredom, cumulative workload, skill learning etc.[10].

Workload can be divided into physical workload and mental workload. Workload can be measured in different dimensions. Various workload assessment measures are used to assess the perceived demand of the task processed by the worker. Targeted working activities of these methods, as well as their desired level of details, provide differences in the application of them. The most frequently used ergonomic measurement methods are NLE(NOISH Lifting Equation)[11], JSI (Job Strain Index)[12], RULA (Rapid Upper Limb Assessment)[13], REBA(Rapid Entire Body Assessment)[14], EAWS(Ergonomic Assessment Worksheet)[15] and OCRA(Occupational Repetitive Actions)[16].

In this research, the focus is on physical ergonomic risks.

The works under study, which are done manually by the workforce in the repackaging section, are of the type of activities with low load and high frequency. In such situations, The International Organization for Standardization standard 11228e3 and the European Standard 1005-5 recommended using OCRA method to evaluate the risk exposure during repetitive work[17,18].So the OCRA method has been used to evaluate ergonomic scores of tasks.

To limit exposure to ergonomic risk factors and to increase safety and motivation in understudied section, two issues have been considered. First, heavy tasks (tasks with high Ergonomic Score) should not be done consecutively by a team. Second, leveling workload among teams is desired. The first issue is considered as a hard constraint in the planning process that means it should not be violated at all but for the latter issue, tolerance is acceptable so, it is applied as a soft constraint.

The main contribution of this paper, which is based on a real-world oriented case study, is twofold. These are describing a new manpower allocation and task scheduling problem that often occurred in the interval section of cross docks and proposing a novel greedy construction heuristic to find reasonable schedules in a reasonable time. It is necessary to mention that the proposed solution algorithm alters the planning process from a subjective process to an objective one.

The rest of this paper is structured as follows. In section 2, the literature related to our work has been reviewed. We describe the model with details in section 3, and also we presented the proposed algorithm. In section 4, the computational results are provided. Finally, in section 5, we conclude our paper and suggest possible opportunities for future research.

2. LITERATURE REVIEW

The purpose of the problem is to assign a set of tasks to teams and schedule them over a planning period by considering the ergonomic fairness and synchronization features. So related literature review has been done in three directions: Synchronization workforce scheduling, ergonomics in workforce scheduling and recent publications related to the OCRA method.

Synchronization has been studied in some researches, but most of them are related to vehicle routing problems. The studies focusing on personnel scheduling and using the synchronization concept are summarized below:

Li et al.[19], for the first time, introduced the manpower allocation problem with job teaming constraints and time windows. There is a set of tasks located at different locations, and each task needs a team of workers. The objectives are to minimize a weighted sum of the total number of workers, the total traveling distances of all workers, and their total waiting time. Two heuristic algorithms are proposed which are shown to be effective for real instances in Port of Singapore.

Dohn et al.[5], introduced (m-MAPTWTC) problem. At this research, they try to assign tasks to a limited number of teams in the way that the number of assigned tasks is maximized. The studied manpower allocation problem is consisting of cooperation between teams and time windows restrictions for tasks and teams. In their model, the number of teams is limited, and the objective function is to maximize the number of assigned tasks. They introduce a branch and price approach and solve the realistic test instances from a European airport.

Ho and Leung [20]addressed a manpower scheduling problem that is motivated by airline catering operations. In their model, tight job time windows and job-skills compatibility constraints are exist. They try to form appropriate teams and assign teams to flights. The objective function is to cover the required services for as many flights as possible. The authors propose a Tabu search heuristic and a simulated annealing heuristic approach to solve the problem. The results show the effectiveness of their solving approach.

Lim et al. [21]proposed a mathematical model for the manpower allocation problem which occurs in workforce dispatching and planning in ports. In this problem, there are servicemen who are dispatched from a central point and assign to tasks in different location in the yard. In addition, there are time windows for tasks. This problem has multiple objectives. Objectives are to minimize traveling distances, traveling time, waiting times, and the number of required servicemen. Two algorithms, Tabu embedded simulated annealing and squeaky wheel optimization with local search, are proposed for solving real world data. The results confirm the effectiveness of the proposed approaches.

Luo et al.[22]considered the manpower routing problem with synchronization constraints (MRPSC). To find an exact solution, a branch and price and cut (BPC) algorithm was proposed. Experimental results show the effectiveness of this approach.

Cai et al.[23]investigated the manpower allocation problem with time windows for tasks and job teaming constraints (MAPTWTC). They propose a tree data structure for representing solutions. A novel Tabu search algorithm with new search operators based on the tree data structure is proposed.

Nasir and Kuo[24]suggested a decision support framework for creating simultaneous schedule and route plans for caregivers and home delivery vehicles with considering synchronization between staff and vehicle's visits, multiple visits to patients, multiple routes of vehicles and pickup/delivery visits related precedence for vehicles. An MILP model was proposed and due to the complexity of the problem a hybrid genetic algorithm was developed.

The studies focusing on personnel scheduling and using the ergonomic considerations with fairness are summarized below:

Lodree, Jr. et al.[10] demonstrated the lack of collaboration between scheduling theory and human factor engineering. They proposed a framework for interdisciplinary connection between workforce assignment and scheduling with human factor engineering.

Hochdorffer et al.[25] presented a mathematical model for generating job rotation schedules. By considering the workers' qualifications, the workplace ergonomic, and workforce assignment, the complexity of the problem increases. Authors propose a linear programming based heuristic. Testing this method on real data from the assembly line of an automotive producer in Germany shows the effectivity of the approach.

Otto and Battaia [26] focused on assembly line balancing, rotation scheduling and physical ergonomic risks in their survey article. They provided a comprehensive review of articles that investigate the physical ergonomic risks for job rotation scheduling in line balancing concept. Also, they provide helpful insights and research directions for operation researchers, ergonomists, and production managers.

Yoon et al.[27] developed a mathematical model for generating job rotation schedules by considering the reduction of cumulative workload in the automotive assembly line in Korea. Here the cumulative workload is related to successive use of the same body region. They try to reduce the variance of daily workload between workers and prevent repeated high workload exposure on the same body region. They use rapid entire body assessment (REBA) for calculating workload. Their proposed model shows good results in the ergonomic aspect, in spite of an increase in computational time.

Paulsen et al.[28] examined the inter-rater reliability of two physical exposure assessment methods of the upper extremity, the Strain Index (SI) and Occupational Repetitive Actions (OCRA) Checklist.

Rosecrance et al.[17] Conducted and compared SI (Strain Index) and OCRA checklist method for evaluating ergonomic risk of cheese processing tasks in a factory in Italy. Seven ergonomists assessed task-level physical exposures to the upper limb of workers performing 21 cheese-manufacturing tasks.

Tiacci and Mimmi [18] used the OCRA index as a method for ergonomic risk assessment for proposing an approach to design asynchronous assembly lines in compliance with ergonomic aspect at a company related to agricultural equipment. They suggested a genetic algorithm to tackle with this problem.

Reis et al.[29] analyzed the risks associated with repetitive movements of the upper limbs of workers performing meat processing tasks. The study was conducted in a slaughterhouse in Brazil. They used the OCRA checklist method.

Lasota et al.[30] used the OCRA checklist method for assessing risk measurement in the packaging operation in a factory in Poland, and their results showed the efficiency of this method for manual packaging activities

To the best of our knowledge and as can be seen from the literature review, no problem with the features discussed in this study has been investigated before.

3. PROBLEM STATEMENT OF THE STUDY

Internal operations of a cross-dock are deconsolidation, sorting, repackaging, and consolidation. This research focuses on the intermediate work area and especially on the repackaging phase. At this phase, packaging of parts is done by teams of workers and equipment. The transported parts are packed in pallets and successively in containers.

The preparation and repackage of goods is driven by international customers' orders. A schedule or daily work plan for a day is produced a day before with consideration of the rolling horizon. The domain of scheduling is 8-hour shifts.

The whole assignment and scheduling procedure consist of two main steps:

In the first step of planning and scheduling, the tasks are prioritized based on specified predetermined criteria. The higher priority means greater importance and represents the partial importance of the tasks. These given priorities act as task weights in objective function in the proposed model.

In the second step, since the number of teams is limited, some tasks can be left unassigned. We try to assign a sequential order of tasks to teams to maximize the total number of assigned tasks by considering time, ergonomic, and synchronization constraints. As a subordinate objective, during the scheduling, tasks with higher priority should be tried to schedule earlier, because depending on this cross-dock's customer service policy this approach makes advantages on service levels and in relations with international customers.

The objective function in this step is maximizing the weighted sum of selected jobs for the planning horizon.

3.1. Problem Definition

The problem is described as follows: There are N tasks to be done by M teams. A team is formed by a group of workers where the number of workers in each team is fixed and workers have the same skills and experience. Teams are homogenous and identical. Number of teams is limited. Each team can process one packing task at a time. Each task is required to be processed by one or more teams, depending on its difficulty. In some situations, all teams must collaborate to process one task. These teams should start a task at the same time, in other words there should be synchronization between teams.

The number of tasks varies daily but for the planning period (typically an 8-hour shift) it is determined. Each task has a predetermined priority (weight), deterministic processing time, due date, required number of teams and heaviness which is determined by the ergonomic score of the task.

On the other hand, as some of these tasks are ergonomically heavy, they must not be done consecutively by a team.

Transportation time is negligible compared to processing time. Therefore, the walking times for workers and transportation times for forklifts are neglected. Preemption is not allowed, which means that once a task is started, it must be finished even if a higher priority task arrives. The objective of the problem is to minimize the total weighted completion time ($\sum w_j C_j$) of the jobs. The weight (w_j) shows the relative importance of each job (j) and the C_j is the completion time of the job$j$.

3.2. Workload Assessment

In this research, we focus on physical ergonomic risks, and we have used the OCRA method. OCRA[16] is an observational technique that allows quick evaluation of the exposure of upper limbs in repetitive works. A higher value of the OCRA index indicates higher ergonomic risks.

The OCRA checklist method has been used in different fields, for example, in poultry slaughterhouse[29], in animal facility operators[31] and packing line operators[30].

There are two kinds of OCRA method: the OCRA index and the OCRA checklist. The OCRA checklist is a simplified version of the OCRA index [32].

We used the OCRA checklist method for assessing risk measurement for "multitask" jobs in repackaging section.

We use a five-level color system for facilitating interpretation of the overall risk scores. This system reflects the ergonomic risks in categories. Green, yellow, light red, red, and purple indicates acceptable, very low, medium-low, medium, and high risk levels, respectively [30, 33]. The OCRA checklist score is shown in Table 1.

Table 1
The OCRA checklist score

Checklist Score	Exposure Level
<= 7.5	No exposure
7.6-11.0	Very low exposure
11.1-14.0	Light exposure
14.1-22.5	Medium exposure
>=22.5	High exposure

The heaviness of each task is calculated, via the OCRA method. As can be seen from the table above, if the ergonomic score of a task is above 22, it is considered a heavy (risky) task. Besides, for each team, the cumulative ergonomic score (CES) is calculated by multiplying the OCRA score and processing time of the tasks performed by that team. As a second objective function, we try to distribute ergonomic loads fairly among the teams. This objective function is minimization and calculated as the sum of the differences from the average. 0 means all teams are evenly loaded.

3.3. Proposed Algorithm

The main goal of this research is to find a practical solution approach for real instances of the workforce scheduling problem presented in the previous section. The current approach in the cross-dock is manual, subjective, and time-consuming. We propose a greedy construction heuristic algorithm by considering all practical and ergonomic constraints.

The proposed algorithm is applied to a problem instance as follows:

A list of gaps, that is idle time interval, is determined for each team. Starting from the first task of the $Unassigned$ tasks set,each task is scheduled at the earliest possible time, by considering the ergonomic and technological constraints. If possible gaps are found, the task is scheduled, relevant gaps are updated immediately, and the task is placed in the Assigned tasks set. But if the feasible gaps aren't found, then the task remains in the Unassigned tasks set.

The main flow of the algorithm is given below:

1-In the first step, tasks are sorted in decreasing order by their priorities. Sort available tasks in descending order based on their priority points that determined previously.

2-The tasks are taken from the sorted list one by one and a schedule is constructed incrementally.

3-All current intervals are searched to see if there is a sufficiently long interval for processing task$j$. Then, a set from all feasible intervals is formed.

4-Depending on the number of required teams for a task, the feasible combination of intervals is chosen and put in a $suitTj$ set. (All possible groups are collected into a $suitTj$ set.)

5-Among the feasible combinations in set $suitTj$, the one that gives the earliest start time for the task, is selected.

6-If there is no feasible interval or combination of intervals, the algorithm continues and takes the next task in the list.

7- The Algorithm continues until all possible tasks are assigned or the time is over.

The notations given below are used in the algorithm:

Mtotal number of teams

N total number of tasks

TS planning period (typically an 8-hour shift)

Indexes

i ,i' Teams i ,i' $\in$ M

j ,j' Jobs j ,j' $\in$ N

$schedule$ is a $M * N$ matrix that is used to show the schedule

NRT_j refers the number of required teams to process task j.

st_j starting time of task j.

d_j is a duration of task j

In order to explain this algorithm in detail, let $gapT_i$ and $suitT_j$be the sets of gaps for team i and suitable overlapping groups of gaps for task$j$, respectively.

The algorithm can be described in detail as follows:

Step1: Initialize two main sets, $Assigned\ tasks\ set = \{\}$and $Unassigned\ tasks = \{1,2, \dots, N\}, N$is the total number of tasks.

Step 2: for each team i, initialize$gapT_i$ to $[0, TS]$,where TS is an available shift time and $suitT_j = \{\}$.

Step 3: for $p = 1$ to the total number of tasks until the termination criteria (all tasks are assigned or reaching maximum available time) are fulfilled do the following:

Step 3-1: consider the task j at position k in $Unassigned\ tasks\ set$

Step 3-2: determine intervals $[l, u]$ so that task j can be assigned to time slot.

Feasible intervals for task j have to be fulfilled by the time and the ergonomic criteria:

1. $u - l \geq d_j$, d_j is a duration of task j
2. If task j is heavy then tasks at position $schedule(i, u+1)$ and position $schedule(i, l-1)$ should be light tasks.In other words, if a task j is heavy, the tasks assigned before and after that task should be light. But if a task is light, it doesn't matter if the tasks before and after that task are heavy or light.

Step 3-3: Feasible Interval gaps for each team are arranged based on the starting time (lower bound) from earliest to the latest. (It is obvious that there is no overlap between these intervals).

Step 3-4: based on the NRT_j for a task, the feasible combination of intervals are determined and put in a $suitT_j$ set. In other words, $suitT_j$ is a set of possible groups of gaps that task j can be assigned. If $NRTj$ is 1, the $suitT_j$ consists of only feasible gaps, but when the $NRTj$ is more than 1, $suitT_j$ consists of feasible groups of gaps. It is noteworthy that the number of gaps in each group equals to the number of required team for this task. All teams in a group have a common time interval that is at least as long as the duration of the task.

Therefore, step 3-4 can be stated as follows: determine intervals $[l, u] = [l_{ik}, u_{ik}] \cap [l_{i'}, u_{i'}] \dots \cap [l_{i''}, u_{i''}]$ so that $u - l \geq d_j$

Step 3-5:Among the intervals determined in step 3-4, select interval or a group of intervals with minimum $[0, TS]$. If there is more than one option with minimum, assign the task to the team or teams with smallest cumulative ergonomic score.

Step 3-6: Remove interval $[stj, stj + dj]$ from related gaps.

In order to clarify the step 3-4 of the proposed algorithm, assume that $NRT_j = 1$, in this case, for each team, the feasible interval with the earliest starting time (lower bound) is selected and moved to $suitT_j$set. But if $1 < RNB_j \leq M$, then all possible combinations of feasible gaps are selected.

A compound is feasible if the overlap of all considered intervals is equal to or greater than the processing time of task j, in other words,

$$\min \underbrace{(u_{i,k}, u_{i'k'},, \dots, u_{i''k''})}_{the\ number\ is\ equal\ to RNB_j} - \max(l_{i,k}, l_{i'k'}, \dots, l_{i''k''}) \geq d_j$$

If a compound is feasible then it be placed in $(suitT_j)$ set of task j.

An acceleration mechanism may be useful in some cases.

If for an interval of a team a feasible combination is found then the search on next intervals of this team will be stopped and the search continues from the intervals of the next team. In other words, since we are trying to find the earliest starting time for each task, we will stop looking at the next intervals of the same team as soon as we find the first possible interval. Therefore useless searching will not be done.

If in searching the upper bound of considered interval is smaller than the lower bound of the interval then searching in intervals of this team will stop because the intervals in each team sorted based on their lower bound.

The intervals of each team is sorted based on lower bound (starting times) from earliest to the latest. In a case, where a task required more than one team, in searching process between teams to find suitable combination of intervals, if the upper bound of an interval of team i is smaller than a lower bound of an interval of team i'so the searching is stopped on the intervals of teami' and searching process continues from next team's intervals.

The flowchart of the main steps of the proposed algorithm is shown in Figure 2.

As an illustration, let us consider a small instance with 12 tasks and three teams. Priorities (weights), Processing times, number of required teams, and ergonomic scores are given in Table 2.

The consecutive steps of the algorithm are shown in Table 3. k is a counter. The Gantt chart of the obtained solution is depicted in Figure 3.

After executing the algorithm, the tasks that remain in unassigned set, will be shifted to the next period, and obviously their priority will be changed.

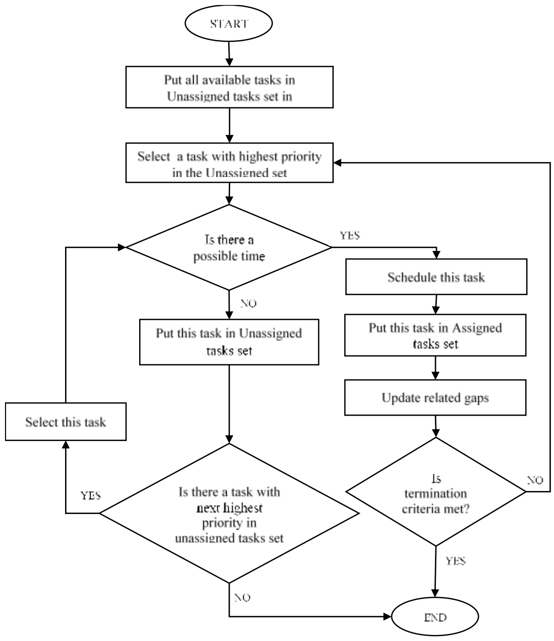

Figure 2 Flowchart of the algorithm

4. RESULTS AND DISCUSSION

Since this study's problem has not been investigated in the literature before, there is no exact or approximate solution method developed for its solution.

The method currently used in the cross-dock, where the study was conducted, is somehow inspired by dispatching rules.Dispatching rules are kinds of construction heuristic methods that are widely used in practical scheduling problems.Examples of common dispatching rules are FIFO (First In First Out), SPT (Shortest Processing Time), EDD (Earliest DueDate) [34][35]. There are also different dispatching rules explicitly developed for the problems defined in the literature [36][37].

Since there is no definitive dispatching rule that can be used directly regarding the unique features of this problem, we developed and coded the highest priority first (HPF)based dispatching rule for simulating the current method in the cross-dock. The advantage of the HPF is to serve to minimize the “total weighted completion time” objective function but its disadvantage is disregarding the ergonomic fairness.

The proposed algorithm and HPF heuristic were coded in MATLAB 2014a and the results were compared with the schedules implemented by the cross-dock. These algorithms were implemented in a personal laptop with Core i5 processor, 2.40 GHz CPU, 4 GB RAM, and Microsoft Windows 10 64-bit operating system.

The number of teams was three, and the number of jobs was between 40 and 60. To measure the efficiency of the proposed algorithm, real problems were solved using the proposed algorithm and HPF heuristic and the results were compared with the real schedules.

It takes approximately 2 hours for an employee to make a daily schedule, and a schedule is created in line with the employee's experience, in case the person responsible for scheduling is absent due to sickness, leave, etc., the schedule can be very inefficient. Since the CPU time of the heuristic method we recommend is limited to seconds, it mainly provides ease of application. In addition, when 15 charts belonging to different days are compared, it is seen that an average of 6% improvement is achieved in the total completion time of the works and 7% in the balanced distribution of the workload in terms of ergonomic scores. The most important advantage of the model is that important works are completed earlier. Also, despite the HPF heuristic CPU time being relatively smaller than the proposed heuristic, the solution values are drastically worse. The comparison of all algorithms and performance improvement of the proposed heuristic can be seen at Table 4. Based on the results, the proposed algorithm is superior to the current conventional method and HPF heuristic in terms of quality. Since the solution time of the proposed algorithm is much less than the time to solve the existing method, using this algorithm is economical in terms of time.

Table 2
Data for the example

Task *j*	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Weight(priority)	10000	9000	7000	5500	1000	750	200	80	20	15	10	5
Processing time	10	5	15	5	5	5	10	5	15	7	5	15
Number of required team	2	1	3	1	1	3	2	2	2	1	2	1
Ergonomic Score	25	25	10	25	10	20	25	25	25	15	15	15

Table 3
Steps of the algorithm

k	Task	$[l,u]$	st	Team 1		Team 2		Team 3	
				Idle Gaps	CES*	Idle Gaps	CES	Idle Gaps	CES
1	1	[0,10]	0	GapT1[10,120]	25	GapT2[10,120]	25	GapT3[0,120]	0
2	2	[0,5]	0	GapT1[10,120]	25	GapT2[10,120]	25	GapT3[5,120]	25
3	3	[10,25]	10	GapT1[25,120]	35	GapT2[25,120]	35	GapT3[5,10]∪[25,120]	35
4	4	[25,30]	25	GapT1[30,120]	60	GapT2[25,120]	35	GapT3[5,10]∪[25,120]	35
5	5	[5,10]	5	GapT1[30,120]	60	GapT2[25,120]	35	GapT3[25,120]	45
6	6	[30,35]	30	GapT1[35,120]	80	GapT2[25,30]∪[35,120]	55	GapT3[25,30]∪[35,120]	65
7	7	[35,45]	35	GapT1[35,120]	80	GapT2[25,30]∪[45,120]	80	GapT3[25,30]∪[45,120]	90
8	8	[25,30]	25	GapT1[35,120]	80	GapT2[45,120]	105	GapT3[45,120]	115
9	10	[35,42]	35	GapT1[42,120]	95	GapT2[45,120]	105	GapT3[45,120]	115
10	11	[45,50]	45	GapT1[42,45]∪[50,120]	110	GapT2[50,120]	120	GapT3[45,120]	115
11	9	[50,65]	50	GapT1[42,45]∪[65,120]	135	GapT2[65,120]	145	GapT3[45,120]	115
12	12	[45,60]	45	GapT1[42,45]∪[65,120]	135	GapT2[65,120]	145	GapT3[60,120]	130

*CES is the abbreviation of Cumulative Ergonomic Score

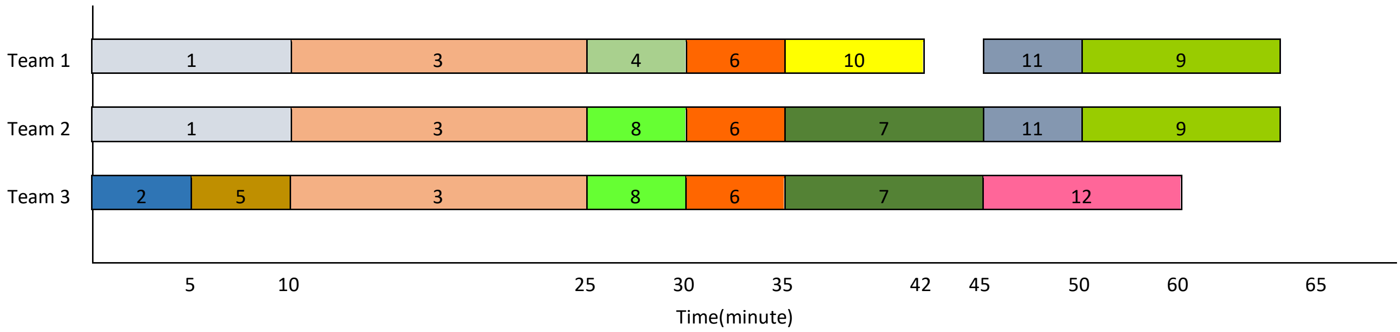

Figure 3 The Gantt chart of the obtained solution

Table 4.
Comparison of the solution methods

Instance	Proposed Heuristic			HPF Heuristic			Manual Method		% improvement: Proposed Heuristic vs. Manual Method		% improvement: Proposed Heuristic vs. HPF	
	$\sum wjcj$	CES	CPU time (Sec)	$\sum wjcj$	CES	CPU time (Sec)	$\sum wjcj$	CES	$\sum wjcj$	Workload Distribution	$\sum wjcj$	Workload Distribution
1	690752	313.33	0.32	777734	962.00	0.09	777872	341.67	16.02	8.29	16.33	67.43
2	742267	1302.00	0.35	787240	1624.00	0.14	807887	1418.00	4.58	8.18	5.71	19.83
3	1418647	858.00	0.19	1418653	858.00	0.10	1616997	858.00	0.71	0.00	0.71	0.00
4	1721428	1084.00	0.21	1733178	1236.00	0.15	1805598	1114.33	1.63	2.72	1.83	12.30
5	753777	684.00	0.21	763623	2702.00	0.21	798905	718.00	6.19	4.74	6.53	74.69
6	794155	550.00	0.19	971740	2446.67	0.10	803709	595.00	11.14	7.56	18.27	77.52
7	1968954	290.00	0.27	2390292	1874.67	0.12	2162847	300.33	12.99	3.44	17.63	84.53
8	1121493	905.33	0.28	1122900	1689.33	0.09	1232756	1005.67	9.02	9.98	9.03	46.41
9	966846	855.33	0.20	1064701	2160.00	0.08	1010923	964.00	6.22	11.27	9.19	60.40
10	1395727	652.00	0.21	1590251	1520.00	0.13	1437489	708.00	9.22	7.91	12.23	57.11
11	1256580	1149.33	0.18	1264311	1458.67	0.09	1269109	1211.67	1.00	5.14	1.40	21.21
12	1753390	1768.67	0.20	1796118	1918.00	0.12	1910249	1892.00	1.95	6.52	2.38	7.79
13	881664	844.67	0.23	882114	1261.33	0.11	898537	913.33	1.88	7.52	0.05	33.03
14	2011394	414.00	0.32	2013991	750.67	0.12	2149915	446.00	0.57	7.17	0.63	44.85
15	1655576	484.67	0.20	1791964	1587.33	0.10	1754871	580.67	10.05	16.53	10.40	69.47
								Average	**6.21**	**7.13**	**7.49**	**45.10**

On the other hand, due to the higher quality of the solutions produced, it is also appropriate to use the obtained schedule when it is evaluated in terms of accuracy. In addition, an exact and systematic method like the OCRA was used for evaluating risk factors of each task,which brings more accuracy in practice. This algorithm also tries to distribute workloads evenly among teams.

5. CONCLUSIONS

The distribution center links overseas industrial sites with domestic suppliers. In terms of guaranteeing a high service quality and rate, distribution, operation planning, and scheduling play an important role. In the under researched distribution center, tasks scheduling and workforce assignment in the repackaging section, are the key activities. Due to current manual process for scheduling in this section, finding an alternative algorithm has been identified as an improvement opportunity.

In this paper, the workforce scheduling problem at the repackaging section under real conditions is discussed. In this problem, some works require cooperation between more than one team simultaneously and heavy tasks shouldn't be performed consecutively. The goal is to find the best work schedule and workforce allocation to maximize the number of jobs performed in a work shift with a limited number of work teams.

Due to the high complexity of the problem, a greedy heuristic algorithm that provides appropriate schedules in a shorter time was suggested.After coding this algorithm with MATLAB and comparing its results with the available information, the efficiency of this algorithm was measured. The results show that acceptable answers are obtained in a shorter time. Therefore, it is recommended to implement this algorithm in the distribution center.

In future research, a more accurate model of the problem can be considered. Also, according to the dynamic conditions of the data, more efficient and accurate solution methods can be researched. In addition, solving the problem with multi-objective approach can be considered as one of the directions of future research.

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Authors' Contribution

All authors have contributed to the theory of the manuscript and the writing of the manuscript equally.

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The authors declare that this document does not require an ethics committee approval or any special permission.

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