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COMPARING HEURISTIC METHODS' PERFORMANCE FOR PURE FLOW SHOP SCHEDULING UNDER CERTAIN AND UNCERTAIN DEMAND

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Abstract
The main aim of this research is to compare the results of the study of demand's plan and standardized time based on three heuristic scheduling methods such as Campbell Dudek Smith (CDS), Palmer, and Dannenbring. This paper minimizes the makespan under certain and uncertain demand for domestic boxes at the leading glass company industry in Indonesia. The investigation is run in a department called Preparation Box (later simply called PRP) which experiences tardiness while meeting the requirement of domestic demand. The effect of tardiness leads to unfulfilled domestic demand and hampers the production department delivers goods to the customer on time. PRP needs to consider demand planning for the next period under the certain and uncertain demand plot using the forecasting and Monte Carlo simulation technique. This research also utilizes a work sampling method to calculate the standardized time, which is calculated by considering the performance rating and allowance factor. This paper contributes to showing a comparison between three heuristic scheduling methods performances regarding a real-life problem. This paper concludes that the Dannenbring method is suitable for large domestic boxes under certain demand while Palmer and Dannenbring methods are suitable for large domestic boxes under uncertain demand. The CDS method is suitable to prepare small domestic boxes for both certain and uncertain demand.

Keywords
Forecasting, Monte Carlo simulation, standardized time, heuristic scheduling methods.

Introduction

Production scheduling is assigning resources to complete the work and plays an important role from a practical point of view [1]. It is logical that the competition between manufacturers is going to be incisive [2]. Obviously, in the manufacturing company, especially in the glass industry the expense should be minimized. In particular, the expense of rework has been consuming a large portion of the cost [3] because it does not only affect the additional processing but also increase the penalty cost due to tardiness. Needless to say, a rework operation is not equal to the higher rate productivity, even though this includes the value-adding time. On one hand, a higher rate of production means the involvement of extra manpower which yields high productivity [4]. On the other hand, over-processing does not necessarily mean a higher rate of productivity regarding the same amount of final product. Delivering the product on time plays an important role as an element of services intangibility [5].

As the leader of the glass industry in Indonesia, the company has to maintain the production, reach a new marketplace, increase the company's profit, and improve the company to pursue customer's needs. Hence, the company must do continuous improvement in all aspects to gain the achievement as the first national glass company in Indonesia and can compete with other companies. There are many aspects that the company can improve, one of the aspects is time punctuation. The company itself has full control to maintain their company from processing raw materials until finished goods, and even prepare their packaging for the finished goods.

In general, the company produces domestic boxes and export boxes under a pure flow shop manufacturing system. This paper deepens processing and analyzing data only in domestic boxes due to their dominance in company production. In 2017 alone, the total box demand for domestic and export are 97,655 and 46,261 units respectively. Previous studies tried to overcome the tardiness by pointing out the transportation problem [6] considering stochastic travel times [7]. A study utilized heuristics algorithms to solve the location-routing problem [8]. Based on observations, it was found that the tardiness of the finished goods is not caused by the transportation design, but the inappropriate process in preparing packaging boxes. Any tardiness will increase holding costs and penalties [9] therefore eventually result in waste [10].

Data sources from the study were divided into two sources, namely primary and secondary data sources. Primary data sources are data obtained from the researchers' observations in the form of processing time for each large and small domestic box packaging unit. Secondary data sources are data obtained directly from the company, such as the demand.

The example of tardiness in January 2017 is given in Table 1 and Fig 1. It can be seen that there were several numbers of tardiness in January 2017 which is highlighted by the red color. Large boxes size "A" had been demanded of 1589 boxes but the Department Preparation Box (simply later called PRP) only fulfilled 1554 boxes, so it caused the shortage of 35 boxes. The number of tardiness happens because of changes in demand and improper scheduling.

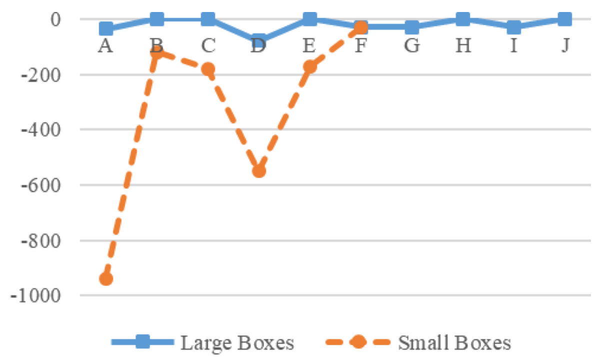

Fig. 1. Tardiness visualization in January 2017.

Table 1
Number of Tardiness in January 2017.

No.	Size	Type	January			Throughout the Year		
			Demand	Fulfilled	Difference	Trend	Seasonal	Random
1	A	Large Boxes	1589	1554	−35	Uptrend	Yes	Yes
2	B	Large Boxes	0	0	0	Uptrend	Yes	Yes
3	C	Large Boxes	44	44	0	Uptrend	Yes	Yes
4	D	Large Boxes	627	549	−78	Uptrend	Yes	Yes
5	E	Large Boxes	294	294	0	Uptrend	Yes	Yes
6	F	Large Boxes	720	690	−30	Uptrend	Yes	Yes
7	G	Large Boxes	354	324	−30	Uptrend	Yes	Yes
8	H	Large Boxes	226	226	0	Downtrend	Yes	Yes
9	I	Large Boxes	241	211	−30	Uptrend	Yes	Yes
10	J	Large Boxes	129	129	0	Uptrend	Yes	Yes
11	A	Small Boxes	3590	2686	−904	Downtrend	Yes	Yes
12	B	Small Boxes	425	305	−120	Uptrend	Yes	Yes
13	C	Small Boxes	575	395	−180	Downtrend	Yes	Yes
14	D	Small Boxes	670	197	−473	Uptrend	Yes	Yes
15	E	Small Boxes	1220	1049	−171	Downtrend	Yes	Yes
16	F	Small Boxes	25	25	0	Uptrend	Yes	Yes

Figure 2 tells the example of time series and trend analysis plot for large box size "A". Overall, the demand data pattern has a seasonal pattern that occurs in a particular month, which were 2214, 2804, 3046, and 3994 units in February, June, September 2017, and March 2018 respectively. The demand data pattern also has an uptrend which is indicated by the movement of the lines fits in a linear regression trend that increases over time. In addition, there is a random element in the demand pattern, which causes the graph to look up and down, as from January to February 2017 there was an increase in demand by 625 units, but from February to March 2017 there was a decrease in demand by 582 units.

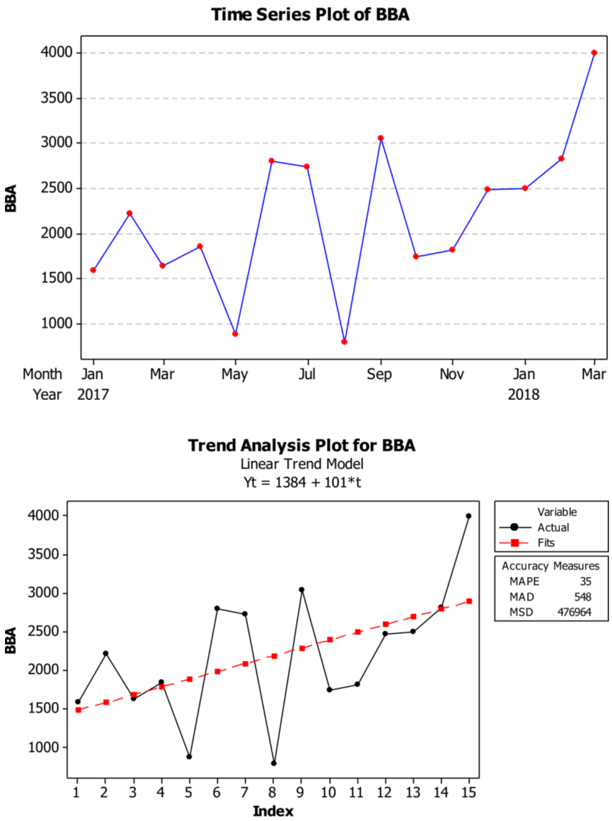

Fig. 2. Time series and trend analysis plot for large box size "A".

All large and small boxes demand data patterns are illustrated in the time series plot graph and trend linear regression. Then the demand data pattern is analyzed and summarized in Table 1. All of the demand data patterns show the seasonal and randomness for 15 months of historical data. As for the trend, many demand data pattern is showing an uptrend while few others showing a downtrend.

Consequently, PRP has to examine some methods, such as forecasting, Monte Carlo simulation, work sampling, and heuristic scheduling methods to solve this problem. Forecasting is an art and knowledge to predict events in the future [11]. Many forecasting methods can be used such as Naïve, Simple Moving Average, Weighted Moving Average, Single Exponential Smoothing, Double Exponential Smoothing, Triple Exponential Smoothing, and Linear Regression [12]. Monte Carlo simulation is a model to estimate the deterministic parameters based on random sampling [13]. Monte Carlo simulation also can be defined as a technique to select the random number from a probability distribution [13]. Work sampling is usually used to calculate the individual time which does many operations [14]. Work sampling has some beneficial aspects such as identifying distribution time of work, work analysis, and reduce repetitive and irregular activities. Scheduling is basically assigning the tasks that need to be completed for the project to be finished in a timely manner [15]. Scheduling is closely related to complexity theory which means objectives and cases are NP-Hard problems [16] so it can be solved by the heuristic method. A previous study proved that the Palmer and Campbell Dudek Smith (CDS) heuristic methods show the minimum value of average of makespan and average utilization of machine [17]. Meanwhile, another study presented Dannenbring established a rapid access technique to syndicate the advantages of the Palmers slope index and the CDS [18]. This paper demonstrates three heuristic methods such as CDS, Palmer, and Dannenbring altogether.

Related works

Some special conditions are needed to do forecasting calculations. The proposed constant of α is at range 0 to 0.3 if the demand plot does not have trend and constant of α and β are bigger than 0.75 if the demand plot says otherwise [19]. The previous forecasting models are built to accomplish several goals. A study built the time series forecasting model to predict the release times of jobs [20]. The prospect trend of plantation area and production was examined by using time series data from 1980 until 2013 and was utilized five different forecasting methods (linear trend, quadratic trend, exponential growth, s-curve, and moving average) [21]. The result shows production represents an increasing trend both in area and production.

Data uncertainty has driven many studies to develop ways to encounter a real-life problem [22]. A Heuristic Estimation Method (HEM) was suggested to predict the completion time of an ongoing mega project [23]. The Monte Carlo simulation was applied to identify the category of efficient and inefficient green cars for the environment [24]. Another research realizes that there are many uncertainties and unintentional from the surface of soils, so simulation Monte Carlo can help the research to maintain the uncertainty of soil surface and soil slip [25]. A previous study implemented a Monte Carlo simulation technique for perceiving the impact of risk and uncertainty in prediction and forecasting the company's profitability [26]. A recent study developed Genetic Algorithm and Monte Carlo simulation to overcome the scheduling problem under uncertainty demand [27]. Another contributive study determined the probability distributions for the required number of labor-hours for each activity and quantify the delay risk using Monte Carlo simulation [28]. One thing that should be remembered that the Monte Carlo simulation requires random numbers. The most common arithmetic operation for generating (0,1) random numbers is the multiplicative congruential method [13]. Given the parameters $u0$, b, c, and m, a pseudorandom number Rn can be generated from the Eq. (1) and (2) [13]

$$u_n = (bu_{n-1} + c)mod(m), \qquad n = 1, 2, 3, ... \quad (1)$$

$$R_n = \frac{u_n}{m}, \qquad n = 1, 2, 3, ... \quad (2)$$

where n – sample size, R – random number.

The order fulfillment process is one of the core business processes that comes with a wide range of activities involved, and is carried out by people from different functional units [29]. Therefore, this paper also utilizes a work sampling method that has great relevance to precisely quantify and benchmark labor productivity, which in turn enables in evaluating productivity losses and identifying its causes [14]. Furthermore, work sampling can provide empirical data about the productivity level in construction nowadays, especially electricity installation in Norway [30].

A simple algorithm for large sequencing and scheduling problems had long been introduced without the use of a computer, CDS algorithm can approximate the nearest solution up to $m - 1$ sequences [31]. An improved scheduling algorithm has been suggested by giving priority to items according to the longest processing time [32]. Another study has compared four heuristic scheduling methods and find that Palmer and CDS have the best result to minimize makespan [17]. Recent research uses the latest method of heuristics method on scheduling one machine with different processing time and due date assuming the work cannot be reprocessed to minimize tardiness [9]. Previous research also raised the issue of scheduling in a flexible job shop [16], hybrid flow shop, and parallel flow shop [1] manufacturing systems while this study used a pure flow shop system.

Research methodology

The research was conducted in sequence on the method of data processing, where the research started from identifying the problem as a preliminary step and the background development of the problem. After constructing the background of the problem, the study proceeds to the stage of problem formulation and the making of the theoretical foundation.

After that, proceed to both primary and secondary data collection stage and processed in such a way using forecasting method, Monte Carlo simulation, and job sampling method to generate input for the heuristic scheduling methods. After that, the calculation of the heuristic scheduling methods is performed to produce the output according to the demand.

The study proceeds to the stages of analysis and discussion, which will be explained in its entirety back to conclusions and suggestions. The following is the problem-solving framework shown in the flow diagram of Fig. 3.

Result and discussion

In this section, the best forecasting technique is chosen under certain and uncertain demand. Next, the standardized time is presented to obtain the time processing as input for the scheduling stage. Later, three heuristics scheduling methods are applied in minimizing the makespan and the tardiness simultaneously.

Forecasting

Secondary data collection or demand from January 2017 to March 2018 is calculated by using several forecasting techniques and Monte Carlo simulation techniques. Forecasting is used by considering the plot of demand shows the trend and seasonal pattern. However, Monte Carlo simulation is used by considering the plot of demand shows uncertainty or random pattern. Thus, the proposed technique for certain and uncertain demand is forecasting and Monte Carlo simulation, respectively.

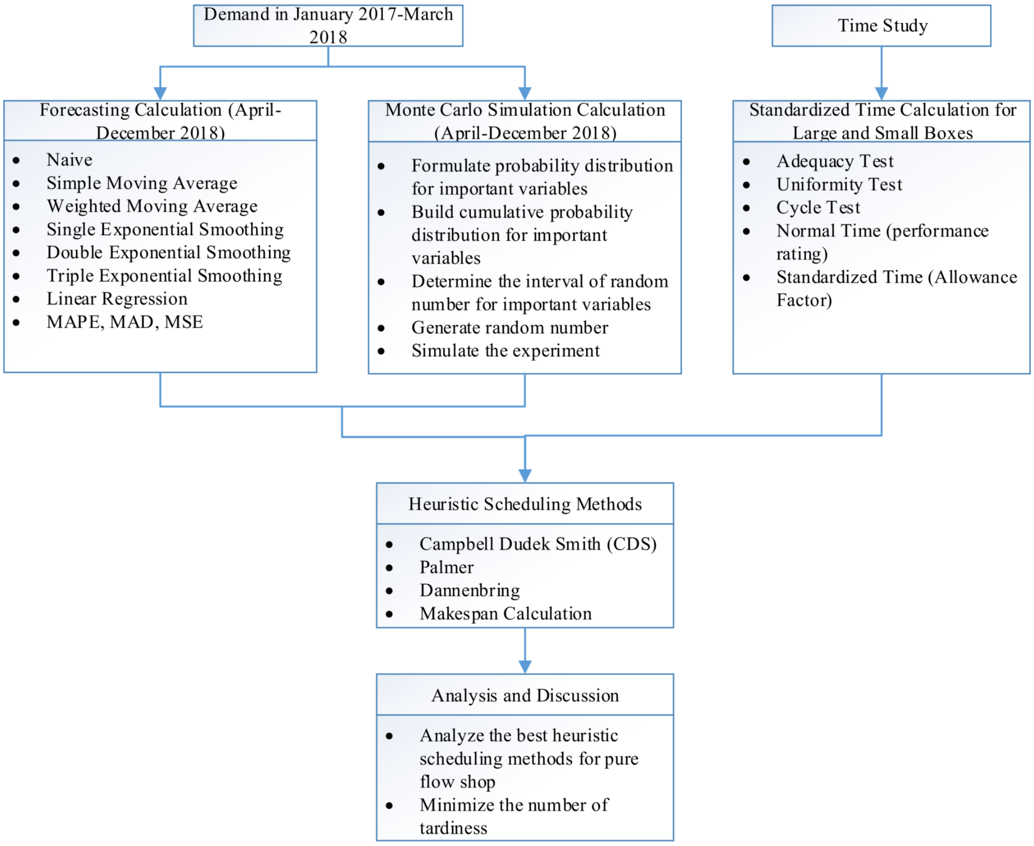

Fig. 3. Research flow chart.

As mentioned earlier, the plot of demand shows a trend and seasonal graphics. The result of the trial and error of forecasting technique is determined by the least Mean Absolute Percentage Error (MAPE), Mean Absolute Deviation (MAD), and Mean Squared Deviation (MSD). In some cases, MAPE, MAD, and MSD values do not show the same best forecasting method. Under these conditions, we chose the best method shown by most indicators. In Fig. 4, we only display the MAD value as a good and consistent indicator in the selection of the best forecasting method for large box size A, as an example. We run 35 forecasting methods including Naive, Simple Moving Average, Weighted Moving Average, Single Exponential Smoothing, Double Exponential Smoothing, Triple Exponential Smoothing, and Linear Regression. Thus, regarding the least of error accuracy and demand plot, Triple Exponential Smoothing has been chosen as the best forecasting technique with and $\alpha = 0.7$, $\beta = 0.8$, $\gamma = 0.9$ for all items, except large box size "I". The large box size "I" can be predicted well using the values of $\alpha = 0.6$, $\beta = 0.7$, $\gamma = 0.8$.

The final result of demand prediction is shown in Table 2. The prediction result presents the original properties of the demand, which has a trend, seasonal, and erratic. The largest demand is expected to fall to size "A" for both large and small boxes.

Towards overcoming the erratic demand, Monte Carlo simulation is applied. Monte Carlo simulation is done by generating random numbers to match with interval random numbers as shown in Table 3. The initial step is to sort the demand for each packaging box starting from the least amount to the most in January 2017 to March 2018. Then determine the frequency of the same demand occurs. It is known that there is no equal demand every month for large box size "A", so a number is given for each demand in these 15 months. After that, the probability distribution function is made for each demand. The next stage is to calculate the cumulative distribution of each demand by summing each probability cumulatively to the end. The determination of random number intervals for each demand refers to the cumulative probability. For example, the first demand has a cumulative probability of 0.07, meaning that the random number interval has a range between 1–7. Then, the second demand has a cumulative probability of 0.13, meaning that the random number interval has a range between 8–13, and so on until the last demand.

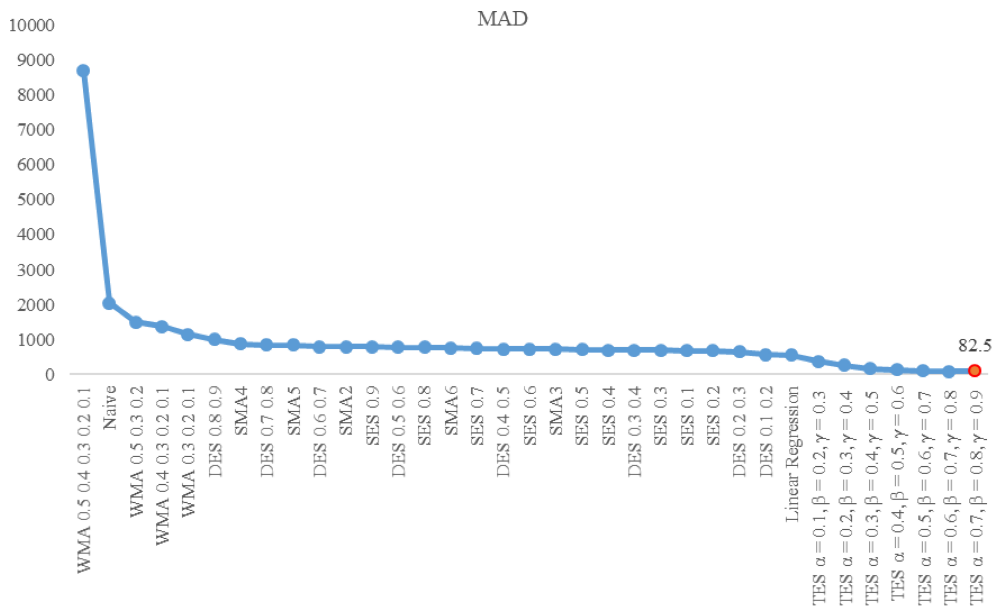

Fig. 4. Mean absolute deviation value for large box size “A”.

Table 2
Demand prediction using triple exponential smoothing.

Month	Large boxes										Small boxes					
	A	B	C	D	E	F	G	H	I	J	A	B	C	D	E	F
Apr-18	1933	79	44	764	350	795	406	178	30	136	3232	466	598	723	1043	26
May-18	2412	73	46	407	69	73	374	49	43	81	2983	234	20	141	453	102
Jun-18	1753	96	46	375	124	269	298	48	26	7	2235	135	25	20	58	76
Jul-18	2027	47	40	659	281	627	493	28	77	51	3413	209	208	409	395	92
Aug-18	982	24	62	480	328	359	647	34	64	31	1372	211	434	463	240	56
Sep-18	3149	41	34	533	101	64	189	30	88	84	3617	354	424	209	484	77
Oct-18	3063	108	74	546	233	450	430	122	34	467	741	222	189	151	324	103
Nov-18	890	103	74	731	47	137	995	49	86	111	466	412	296	365	494	62
Dec-18	3400	93	34	1043	139	462	650	78	61	43	2249	322	133	292	517	62

Table 3
Random number interval for large box size “A”.

Demand	Frequency	Probability	Cumulative probability	Class intervals	
				Lower	Upper
795	1	1/15 = 0.07	0.07	1	7
881	1	1/15 = 0.07	0.13	8	13
1589	1	1/15 = 0.07	0.20	14	20
1632	1	1/15 = 0.07	0.27	21	27
1744	1	1/15 = 0.07	0.33	28	33
1814	1	1/15 = 0.07	0.40	34	40
1852	1	1/15 = 0.07	0.47	41	47
2214	1	1/15 = 0.07	0.53	48	53
2479	1	1/15 = 0.07	0.60	54	60
2501	1	1/15 = 0.07	0.67	61	67
2729	1	1/15 = 0.07	0.73	68	73
2804	1	1/15 = 0.07	0.80	74	80
2819	1	1/15 = 0.07	0.87	81	87
3046	1	1/15 = 0.07	0.93	88	93
3994	1	1/15 = 0.07	1.00	94	99
Total	15	1			

Table 4
Demand prediction using Monte Carlo simulation.

Month	Large boxes										Small boxes					
	A	B	C	D	E	F	G	H	I	J	A	B	C	D	E	F
Apr-18	2819	135	0	934	294	482	842	4	163	50	3138	390	130	0	320	0
May-18	795	94	24	344	210	70	918	56	58	153	3880	553	290	396	420	25
Jun-18	2214	36	46	481	294	340	642	54	125	157	3880	335	235	20	530	100
Jul-18	1632	0	34	481	64	450	842	54	50	80	3604	390	205	235	320	0
Aug-18	881	82	24	594	297	260	320	44	33	153	500	440	185	0	420	55
Sep-18	1589	90	46	482	297	129	599	52	150	82	3348	425	425	350	1220	100
Oct-18	1744	0	74	368	297	450	352	4	221	153	2095	553	20	448	395	0
Nov-18	1852	0	0	426	294	60	396	226	0	82	3590	305	450	145	320	0
Dec-18	3046	136	40	670	266	450	642	68	130	50	3880	335	340	448	320	25

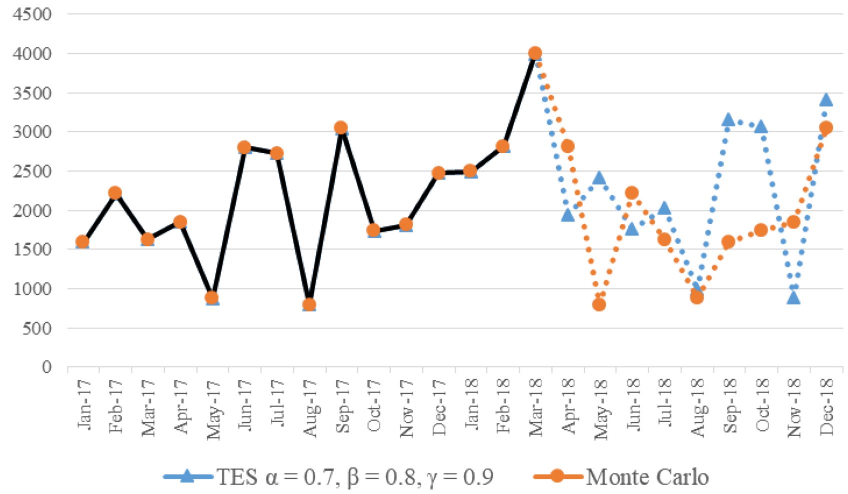

Fig. 5. Forecasting demand using triple exponential smoothing and Monte Carlo simulation.

The final step is the simulation of an experimental series by selecting any number from 100 random numbers of 9 to represent the predicted demand for April 2018 to December 2018. After obtaining random numbers, then the random numbers are adjusted to the table of random numbers and demand intervals. Hence, the result shown in Table 4 represents the future demand from April 2018 to December 2018. Figure 5 illustrates the difference between TES and Monte Carlo simulation for large box size "A", as an example. They are showing the divergent result as a consequence of applying different techniques. It turns out, that certainty and uncertainty demand vary the forecasting result.

Standardized time

Standardized time is produced from observation time during workers' preparation activities. Standardized time is processed through adequacy test, uniformity test, cycle calculation, and normal calculation with considering the performance and allowance factors as Tables 5 and 6 show.

Table 5 tells the amount of performance rating for large boxes and small boxes, 0.02 and 0.09 respectively. Meanwhile, Table 6 gives the number of allowance factors for large boxes and small boxes, 67%, and 58% respectively. Table 6 is divided into two major parts of the allowance, namely constant and variable allowances. Constant allowances are the factor that must be experienced by every worker, namely personal needs, such as going to the toilet or taking a drink and general fatigue, such as aches in the limbs. Other allowances, namely variable allowances are other special factors experienced by workers during work, such as workplace conditions, workplace boredom, noise levels, and others. Furthermore, the quality of work depends on the health and safety working conditions [33]. To improve the quality of the work, one must solve the difficulties of work, and the difficulties of self-development [34].

Table 5
Performance rating.

Category	Large boxes			Small boxes		
	Class	Symbol	Score	Class	Symbol	Score
Skill	Good	C1	+0.06	Good	C1	+0.06
Effort	Fair	E1	−0.04	Average	D	0.00
Condition	Good	C	+0.02	Good	C	+0.02
Consistency	Fair	E	−0.02	Good	C	+0.01
Total			0.02			0.09

Table 6
Allowance factors [%].

		Large boxes	Small boxes
A. Constant allowances			
1	Personal Allowance	5	5
2	Basic Fatigue Allowance	4	4
B. Variable allowances			
1	Standing Allowance	2	2
2	Awkward Position	2	2
3	Use of Force (50 lbs.)	13	4
4	Light (Well Below)	2	2
5	Atmospheric conditions	30	30
6	Close Attention (Fairly)	0	0
7	Noise Level (Int-very loud)	5	5
8	Mental Strain (Fairly)	1	1
9	Monotony (Medium)	1	1
10	Tediousness (Tedious)	2	2
Total		67	58

The following are the reasons for granting allowances to the large and small boxes preparation activities:

1) Standing allowances. This allowance is used for the job because workers standing during working time.
2) Abnormal position allowance. Sometimes in the process of preparing large and small boxes, workers have to bow for some time. This causes the work position is not appropriate or awkward.
3) Use of force or muscular energy. Workers must be able to lift a large box and a small box that weighs 20–25 kg (around 50 lbs) and 10–15 kg (around 25 lbs), respectively.
4) Bad light. The level of lighting in the working area is not good, because the location only relies on lighting from the sun and a few lights, so the lighting is categorized as well below or less.
5) Atmospheric conditions. Atmospheric conditions in the field are not very good, because of its location adjacent to the glass burning furnace. So the area is quite hot.
6) Close attention. The PRP department workers are only assigned to prepare large and small boxes, so they do not need special attention when working.
7) Noise level. As previously explained, the location is close to the glass furnace, so that the conditions are quite noisy.
8) Mental strain. Workers do not experience difficulties when doing their job. Otherwise, the workers look to enjoy the job from the beginning to the end.
9) Monotony. Work performed by workers is always the same and repetitive, the only difference is the types of boxes. Therefore, this paper states the monotonous level of work at an intermediate level.
10) Tediousness. Work performed by workers is always the same and repetitive, so workers cannot avoid being bored while working.

After giving weight to the job allowances, the process continues to the calculation of the standard time for each large and small boxes. This standard time is used as the input for the heuristics scheduling methods.

Heuristics scheduling

Jobs (future demand) and machines (standardized time) are inputs for heuristic scheduling methods, such as CDS, Palmer, and Dannenbring. First of all, the result of jobs and machines is combined into one matrix as for the example given in Table 7.

Table 7
Matrix scheduling for small boxes with forecasting and standardized time as inputs.

Demand	Job i (small boxes)	Processing time [s]			
		1	2	3	4
3232	A	2.47	23.32	39.71	80.38
466	B	7.00	24.73	39.15	88.63
598	C	7.25	34.65	39.26	101.61
723	D	5.72	36.76	46.67	95.37
1043	E	6.19	41.96	40.11	116.67
26	F	7.23	48.83	42.50	158.18

The row of each demand time row of each processing time will result in the exact time that workers spend to prepare small boxes. For example, workers spend 7996 seconds to do the first activity, 7538 seconds to do the second activity, 128345 seconds to do the third activity, and 259779 seconds to do the fourth activity while preparing 3232 small A boxes. This matrix scheduling is applied to all of the demands and activities from April 2018 until December 2018. Afterward, all of matrices scheduling is ready to through other processes, such as CDS, Palmer, and Dannenbring tabulation to get job sequences and minimum makespan. CDS sequences jobs of each month by prioritizing the fastest processing time of job i. Palmer sequences jobs of each month by prioritizing the biggest slope index for every job i. Dannenbring sequences jobs of each month by combining CDS and Palmer methods into *pi1* and *pi2* for every job i.

The result of all tabulations is job sequences of each month that have the minimum makespan. Job sequences and the minimum makespan for heuristic scheduling in 9 periods are summarized in Tables 8 and 9. As can be seen, the objective is to minimize makespan. Makespan is the maximum amount when all jobs are processed together [35]. There are some reasons why the researchers use makespan as an indicator to sequence the jobs.

- All domestic boxes come to storage in wet conditions. The physics of boxes will shrink when it dry, this condition will cause edge boxes to buckle. So, the boxes have to be prepared quickly and filled with glasses.
- In the field, the production department wants all domestic boxes ready fast because they do not want too many glasses to accumulate in the packing station.
- To minimize idle time because all jobs are started from zero time.

Two main points can be analyzed according to Tables 8 and 9. First, for the demand of large boxes, the proposed heuristic scheduling is Dannenbring for certain demand and Palmer or Dannenbring for uncertain demand. Palmer and Dannenbring are suggested to schedule the preparation of large boxes because of their domination giving the best result of optimum makespan since April until December 2018, while CDS only gives the good result of optimal makespan in July, August, and September 2018. Second, for the demand for small boxes, the proposed

Table 8
Job sequences and makespan with forecasting and standardized time as inputs.

Selected scheduling techniques	Boxes' type	Month	Sequences	Minimum makespan [hr]
CDS	Large Boxes	Apr-18	I-C-B-J-H-E-D-G-F-A	144.61
Dannenbring	Large Boxes	May-18	A-G-D-J-F-E-B-H-I-C	170.12
Palmer	Large Boxes	May-18	A-G-D-J-B-F-E-H-I-C	170.12
Dannenbring	Large Boxes	Jun-18	A-D-G-F-E-B-H-C-I-J	151.96
Dannenbring	Large Boxes	Jul-18	A-F-D-G-E-I-J-B-C-H	218.07
CDS	Large Boxes	Aug-18	B-J-H-C-I-E-F-D-A-G	144.54
Dannenbring	Large Boxes	Sep-18	A-D-G-I-J-E-F-B-H-C	222.04
Dannenbring	Large Boxes	Oct-18	A-J-F-D-G-E-H-B-C-I	282.52
Dannenbring	Large Boxes	Nov-18	G-A-D-F-J-I-B-C-H-E	136.87
Dannenbring	Large Boxes	Dec-18	A-D-G-F-E-H-B-I-J-C	301.24
CDS	Small Boxes	Apr-18	F-B-D-C-E-A	141.67
			F-B-C-D-E-A	141.67
CDS	Small Boxes	May-18	C-F-D-B-E-A	110.51
CDS	Small Boxes	Jun-18	D-C-E-F-B-A	78.15
CDS	Small Boxes	Jul-18	F-B-C-D-E-A	129.47
CDS	Small Boxes	Aug-18	F-B-E-D-C-A	71.43
CDS	Small Boxes		F-B-E-C-D-A	71.43
CDS	Small Boxes	Sep-18	F-D-B-E-C-A	138.40
CDS	Small Boxes		F-D-B-C-E-A	138.40
CDS	Small Boxes	Oct-18	F-D-C-B-A-E	47.93
CDS	Small Boxes		F-D-C-B-E-A	47.93
CDS	Small Boxes	Nov-18	F-C-D-B-A-E	50.00
CDS	Small Boxes	Dec-18	F-C-D-B-E-A	90.02

Table 9
Job sequences and makespan with Monte Carlo simulation and standardized time as inputs.

Selected scheduling techniques	Boxes' type	Month	Sequences	Minimum makespan [hr]
Palmer	Large Boxes	Apr-18	A-D-G-F-E-I-B-J-H-C	286.33
Palmer	Large Boxes	May-18	A-G-D-E-J-B-F-I-H-C	134.49
Dannenbring	Large Boxes	Jun-18	A-G-D-F-E-J-I-H-C-B	222.15
Palmer	Large Boxes	Jun-18	A-G-D-F-E-J-I-H-C-B	222.15
CDS	Large Boxes	Jul-18	B-C-I-H-E-J-D-F-A-G	180.94
CDS	Large Boxes	Aug-18	C-I-B-H-J-F-E-A-G-D	129.06
CDS	Large Boxes	Sep-18	C-B-H-J-F-I-E-D-A-G	164.03
Dannenbring	Large Boxes	Oct-18	A-F-G-D-E-I-J-C-H-B	187.10
Palmer	Large Boxes	Oct-18	A-F-G-D-E-I-J-C-H-B	187.10
Dannenbring	Large Boxes	Nov-18	A-G-D-E-H-J-F-B-C-I	168.31
Dannenbring	Large Boxes	Dec-18	A-G-D-F-E-I-B-H-J-C	277.29
CDS	Small Boxes	Apr-18	D-F-C-E-B-A	114.31
CDS	Small Boxes	May-18	F-C-D-E-B-A	149.24
CDS	Small Boxes	Jun-18	D-F-C-B-E-A	143.10
CDS	Small Boxes	Jul-18	F-D-C-E-B-A	133.94
CDS			F-C-D-E-B-A	133.94
CDS	Small Boxes	Aug-18	D-F-C-E-B-A	43.67
CDS	Small Boxes	Sep-18	F-D-B-C-E-A	152.09
CDS	Small Boxes	Oct-18	F-C-E-D-B-A	90.65
CDS	Small Boxes	Nov-18	F-D-E-B-C-A	133.82
CDS			F-D-B-E-C-A	133.82
CDS	Small Boxes	Dec-18	F-B-E-C-D-A	147.10

heuristic scheduling is CDS. It is no doubt that both certain and uncertain demand produce the same result to use CDS as the proposed scheduling for PRP. Palmer and Dannenbring produce makespan time longer than CDS does.

The impact of minimum makespan is minimized of tardiness. The workers prepare the boxes for 30 days (480 hours), named available time capacity. Both large and small preparation boxes are done by many workers simultaneously. Tables 10 and 11 are given below.

Overall, there is no tardiness after using heuristic scheduling Palmer or Dannenbring for large boxes and CDS for small boxes. For example, Table 10 – April 2018 shows total makespan for large boxes is 144.61 hours and total makespan for small boxes is 141.67 hours. Therefore, the real makespan they spend in April 2018 is 144.61 hours. This work hour is faster than time available capacity of 480 hours. This means that there is a zero tardiness in April 2018.

Table 10
Number of tardiness with forecasting and standardized input.

Month	Type	Makespan [hr]	Type	Makespan [hr]	Max. makespan	Time available cap. [hr]	Number of tardiness
Apr-18	Large Boxes	144.61	Small Boxes	141.67	144.61	480	0
May-18	Large Boxes	170.12	Small Boxes	110.51	170.12	480	0
Jun-18	Large Boxes	151.96	Small Boxes	78.15	151.96	480	0
Jul-18	Large Boxes	218.07	Small Boxes	129.47	218.07	480	0
Aug-18	Large Boxes	144.54	Small Boxes	71.43	144.54	480	0
Sep-18	Large Boxes	222.04	Small Boxes	138.4	222.04	480	0
Oct-18	Large Boxes	282.52	Small Boxes	47.93	282.52	480	0
Nov-18	Large Boxes	136.87	Small Boxes	50.00	136.87	480	0
Dec-18	Large Boxes	301.24	Small Boxes	90.02	301.24	480	0

Table 11
Number of tardiness with Monte Carlo simulation and standardized input.

Month	Type	Makespan [hr]	Type	Makespan [hr]	Max. makespan	Time available cap. [hr]	Number of tardiness
Apr-18	Large Boxes	286.33	Small Boxes	114.31	286.33	480	0
May-18	Large Boxes	134.49	Small Boxes	149.24	149.24	480	0
Jun-18	Large Boxes	222.15	Small Boxes	143.10	222.15	480	0
Jul-18	Large Boxes	180.94	Small Boxes	133.94	180.94	480	0
Aug-18	Large Boxes	129.06	Small Boxes	43.67	129.06	480	0
Sep-18	Large Boxes	164.03	Small Boxes	152.09	164.03	480	0
Oct-18	Large Boxes	187.1	Small Boxes	90.65	187.10	480	0
Nov-18	Large Boxes	168.31	Small Boxes	133.82	168.31	480	0
Dec-18	Large Boxes	277.29	Small Boxes	147.10	277.29	480	0

Conclusion

After analyzing and doing the discussion based on the real condition of preparing domestic boxes in PRP, the forecasting must be applied when PRP wants to predict future demand by considering trend and seasonal pattern of demand (certain). The best method which produce minimum error accuracy is Triple Exponential Smoothing with $\alpha = 0.6$, $\beta = 0.7$, $\gamma = 0.8$ and $\alpha = 0.7$, $\beta = 0.8$, $\gamma = 0.9$. However, Monte Carlo simulation is applied when PRP wants to predict future demand by considering a random plot or called uncertainty. PRP needs to calculate standardized time based on performance rating and allowance factors to define workers' skill, effort, condition, consistency, and many allowances [36]. Either Palmer or Dannenbring has been proposed as a heuristic scheduling method that obtains minimum makespan while preparing large boxes are, while CDS is proposed for small boxes. The proposed heuristic scheduling methods have succeeded in minimizing both makespan and the number of tardiness. These proposed heuristic scheduling methods obtain zero tardiness.

Further research may consider the new type of boxes which influence the processing and final result, such as data collection, data processing, and methods.

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