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Workload Balancing for Stability Test Using a Mixed Integer Programming Model

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Abstract

This research studies a monthly task assignment for staff and testing equipment of a stability testing process in a pharmaceutical company. A stability testing process begins with collecting drug to the system, preparing chemical, glassware and equipment, testing drugs on equipment and writing reports. There are three types of a stability test where each drug requires different type of stability test, and some drugs require multiple types. Each testing process requires different types of testing equipment, which requires different set-up time and processing time. Currently, task assignments are determined based upon division manager's experience which leads to unbalanced workload. To solve this problem, a mixed integer linear programming model (MILP) is proposed to find the optimal solution, which focuses on minimizing the difference between maximum and minimum workload of staff, overtime, and penalty cost of postponement. The result of this model shows that the unbalanced workload among staff is reduced. Moreover, by test postponement, overtime does not occur.

Keywords
Task assignment, Stability test, Pharmaceutical products, Workload balancing and MILP.

1. Introduction
A testing process is essential to control product quality as it helps prevent poor-quality products and increases product reliability. Efficient quality control ensures customers' satisfaction. The pharmaceutical industry is one of industries that regularly requires testing. Due to the rising of consumers' health consciousness, pharmaceutical products have become one of the most effective factors in the livelihood of people in terms of treatment and prevention of diseases to maintain a healthy life. After the drug production process is completed, a stability test plays a crucial part in providing evidence on how quality of drug substances varies under a variety of environmental factors to establish a re-test period or a shelf life for the drug. This test requires specialists and advanced testing machines to test and validate product quality to meet the needs and expectations of people in obtaining standard safety treatment.
Drug stability test is a part of the testing department, which is mainly responsible for testing the stability of finished products. It must be conducted in accordance with the ICH topic Q1A(R2) guideline for a stability test. In this paper, we are interested in three main types of drug testing. First, "Assay" is an investigative or analytic procedure for identifying or measuring the present of compounds, amount, or functional activity of pharmaceutical products. Second, "Impurity" is a step of determining and isolating the number of inorganic impurities, organic impurities, and residual solvents. Third, "Dissolution" is a step of measuring the release and extent of the pharmaceutical products substances.

Each drug requires different types of stability test. To develop a stability test, pharmacists, scientists, and testing machines are required. However, each type of test requires different types of machines with different set-up time and

processing time. A flowchart of stability testing process is shown in Figure 1. In the current work process, an order of tests is not concerned. If a drug requires more than one test type, any type can be done first. However, before drug substance testing, pharmacists or scientists need to prepare chemicals, glassware, and equipment while pharmacists may set up the machine during the same time. After these two processes are done, drug substances are automatically tested on the machine. Each machine is used to test one drug at a time. Finally, a test report is written by scientists. Figure 1. shows a flowchart of a stability testing process.

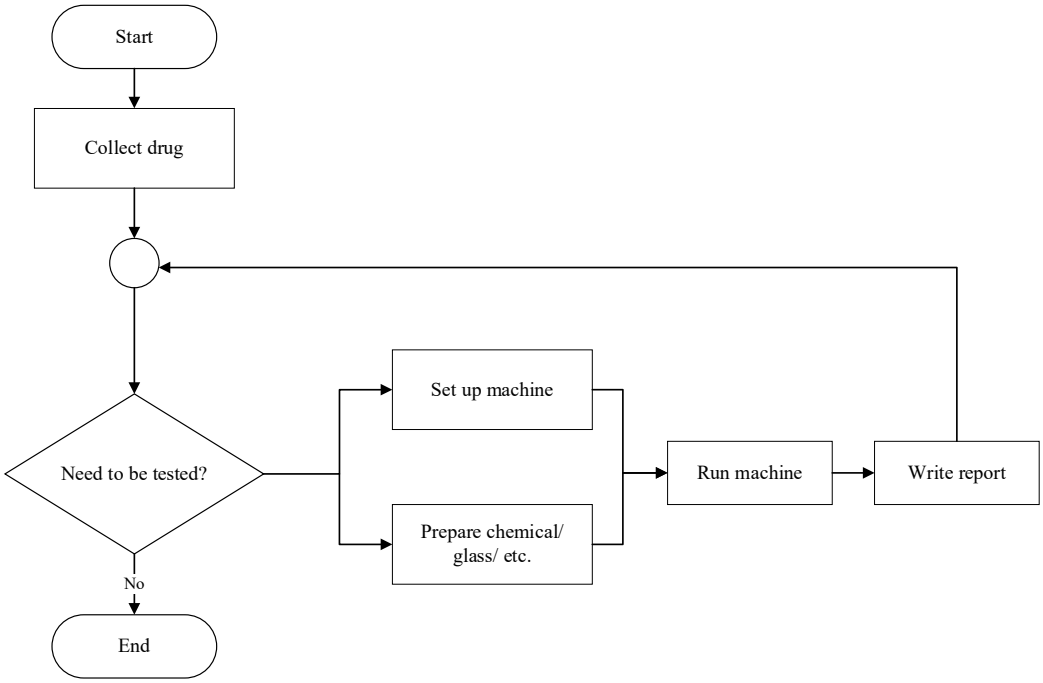


Figure 1. Flowchart of stability testing process

Because of resource limitation, stability test planning is a crucial process. Bunkerd et al. (2021) developed a methodology to determine a proper number of staff and testing equipment for an annual stability testing process. They developed a capacity plan to determine an amount of drugs to be tested in each month to minimize the production cost. However, Bunkerd et al. (2021) did not provide a methodology to assign jobs to resources (staff/machines). As a result, an unbalanced workload among the staff occurs. This paper focuses on developing a methodology to determine a monthly task assignment to minimize unbalanced workload, overtime of staff, and penalty cost due to postponement. A mixed integer programming (MIP) model is proposed to solve this problem.

2. Literature Review

Work processes in organizations consist of a series of tasks which require different machines and worker expertise. Properly assigning tasks to workers based on evaluation of their suitability and resource constraints is known as the "Assignment problem" (Wayne 2004). Generalized Assignment Problem (GAP) focuses on assigning a set of tasks to a set of agents according to their abilities and experiences with the objective of minimizing the total cost. Task assignment is one possible way to increase efficiency. The challenge is to determine task assignments that meet all requirements and result in the best performance. The poor design may lead to efficiency reduction and unfinished work. Many task assignment models were proposed to reallocate resources with various objective functions (Kandemir and Handley 2014). The unbalanced workload between employees and workstations, which can cause job dissatisfaction, is one of the concerned objectives.

Task assignment was studied in various applications. Cetin et al. (2020) and Huka et al. (2021) studied personnel task assignment problems. They developed a multi-objective mathematical model to assign the number of transactions to employees in a bank by considering this problem as GAP. This problem was solved by Linear Physical Programming (LPP). GAMS was used as a solver for all the test problems. Huka et al. (2021) formulated a linear programming

model for personnel allocation and workload assignment in prefabricated housebuilding element production lines to develop the maximum capacity utilization. Alakaş et al. (2022) studied a problem of assigning a case file to lawyers by calculating the workloads of lawsuits to be filed in courts with purpose to ensure that workloads were equally distributed. A goal programming model was established to achieve the goal. Schaus et al. (2009) studied a daily assignment of newborn infant patient to nurses with the objective of balancing nurse workload. Because of a large size problem, constraint programming (CP) model was developed to find solution of this problem. Shen et al. (2022) constructed a task assignment model to balance U-shaped assembly line, minimize the number of operators and balance operator workload. M-COMSOAL and COMAOSAL algorithm were proposed to find solutions.

Workload balance is one of the objectives considered by many previous works in task assignment problems. Different criteria were used to represent workload balance. Rajakumar et al. (2004) addressed the workload balancing problem to provide an equal distribution of load on parallel machines, which considered the minimization of the maximum workload or the completion time of the bottleneck machine. The relative percentage of imbalance (RPI) was used to evaluate the performance of three workflow balancing strategies including random, shortest processing time and longest processing time. Rajakumar et al. (2007) proposed a genetic algorithm (GA) to compare with the three workflow balancing strategies from their previous study. The result showed that GA performed better than those strategies. Ouazene et al. (2014) formulated a new mixed integer model to minimize the workload unbalance on identical parallel machines, which minimized the difference between workload of the bottleneck machine and workload of the fastest machine. Ammons et al. (1985) proposed a bicriterion loading model to minimize the total number of machines visited by jobs and determine an assignment with the best workload balance among workstations by minimizing the difference between the maximum and minimum processing times assigned to the machines. A heuristic solution methodology was proposed to solve the problem.

Since many drugs are required to do stability test, and resources (staff and machines) are an important issue. Hadid et al. (2022) and Bunkerd et al. (2021) developed methodologies to determine a proper number of staff and testing equipment. Hadid et al. (2022) proposed a multi-objective model to determine the number of staff (pharmacists, nurses, technicians etc.), assign tasks and schedule staff in outpatient chemotherapy process. Bunkerd et al. (2021) proposed a mathematical model to determine the proper number of staff and testing equipment that would be sufficient for the testing process over a year. They targeted minimizing the production cost. This paper studies the same process as Bunkerd's. The number of resources determined by Bunkerd's model is used as an input for our model. Then, we focus on task assignments.

3. Problem Description

In each month, a certain number of drugs requires testing. Each drug requires different types of stability test. Normally, drugs should be tested by the end of the required month. However, if it is unable to be tested, there will be a penalty cost for late drug testing. Drugs will be stored in inventory and tested in the following months. The maximum postponement is four months. For example, drugs that are required to be tested in January, can be postpone to February, March and April.

As mentioned, there are three types of stability test. In the current process, all types of stability test require similar steps. The testing process includes five steps as follows:

1. Collecting drug
2. Preparing chemical, glass and equipment
3. Setting up machine
4. Testing on machine
5. Writing report

In each step, the responsibilities of resources have been defined. Only a pharmacist can handle machine set up processes. Each drug may require different types of machines for the same process.

A small problem having 2 drugs are used to illustrate the problem and an example of solution is shown. This small example includes drugs X01 and X02. Drug X01 requires all three types of stability test and drug X02 requires only an assay test. Machines used for each type of stability test are listed in Table 1. A pharmacist and 2 scientists are workforce in this problem.

Table 1. Machines used for stability test in each type

Product	Type of test	Machine
X01	Assay	M1
	Impurity	M3
	Dissolution	M2
X02	Assay	M4

Based on the current work process, there are many possibilities of work scheduling. Figure 2. shows an example of work scheduling for staff and machines. The sequence of testing drug X01 is assay, impurity and dissolution, respectively. Scientist 1 and pharmacist are required for testing drug X01 while scientist 2 and pharmacist are responsible for testing drug X02. As you can see from Figure 2, setting up machine and preparing chemical, glass and equipment can be done parallelly. Therefore, the pharmacist may start from setting up machines M1, M3, M2 and M4 respectively. Processing time of pharmacist is distributed into each machine and shown in pharmacist's row. Meanwhile, scientist 1 starts from collecting drug X01 (blue), preparing chemical, glass, and equipment (orange) for assay, impurity and dissolution of X01 and then writing the report (yellow). Scientist 2 starts from collecting drug X02 (blue), preparing chemical, glass, and equipment (orange) for assay of X02 and finally, writing the report (yellow). Machines automatically run after previous processes are completed (green).

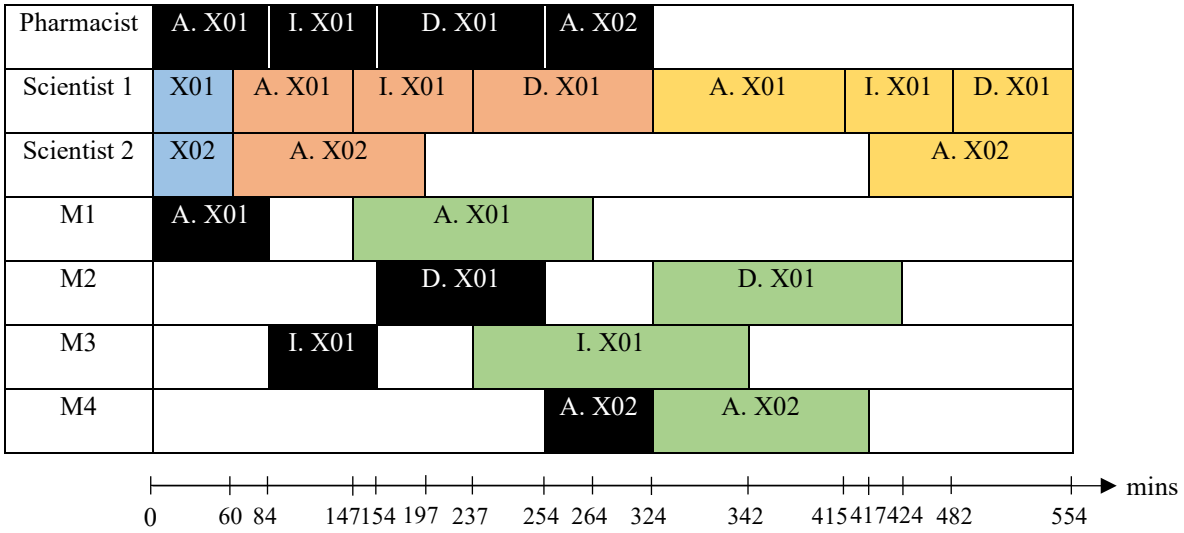


Figure 2. Example of scheduling table for testing X01 and X02

4. Methods

From the problem description, the final solution for this problem is task scheduling for all resources. However, we propose a two-stage methodology to solve this problem. The first stage is to assign tasks to resources and the second stage is to schedule those assigned tasks. In this paper, we focus on only the first stage which is assigning tasks to balance workload, minimize overtime and penalty cost of drug test postponement. Note that the number of resources is obtained from the previous work (Bunkerd et al. 2021). To simplify the problem, we classify the testing process into 7 sub-processes based on resource requirements. We propose a mathematical model to assign sub-processes to resources based on the total processing times of all stability test types that each drug requires. For example, since drug X01 requires assay, impurity and dissolution tests, the processing time for collecting drug of these three test types are combined. Moreover, because collecting drug and preparing chemical, glass, and equipment require the same type of resource, processing time of these 2 steps are included in the processing time of sub-process 1. In other words, the

processing time of all blue and orange jobs for each drug from Figure 2 are included in the processing time of sub-process 1. Details of the sub-processes and resources are in Table 2.

Table 2. Detail of sub-processes and resources using in the proposed model

Steps	Sub-Processes	Resources
1. Collecting drug 2. Preparing chemical, glass and equipment	1. Collecting drug, preparing chemical, glass and equipment	pharmacists or scientists
3. Setting up machine	2. Setting up machines	pharmacists
4. Testing on machine	3. Running M1	Machine M1
	4. Running M2	Machine M2
	5. Running M3	Machine M3
	6. Running M4	Machine M4
5. Writing report	7. Writing report	scientists

In a case study problem, there are 113 product types that require stability test per year. In term of resources, there are two types of staff: a pharmacist, 12 scientists and four types of machines: 11 M1, one M2, one M3 and one M4. Each drug requires one person for sub-processes 1, 2, and 7, where each sub-process does not require the same person. Sub-processes 3 to 6 are done by machines M1 to M4, respectively. If drug is tested in a month, all sub-processes must be done within the same month.

Notations:

$\boldsymbol{I}$	Set of drugs
J	Set of months
K	Set of sub-processes
P	Set of pharmacists
C	Set of scientists
H	Set of machines M1
S	Set of machines M2
G	Set of machines M3
D	Set of machines M4

Parameters:

$demand_{ij}$	Drug i scheduled to be tested in month j (lots)
$begin\_inv_i$	Drug i required to be tested from the previous planning period (lots)
$fixed\_time_{ik}$	Fixed time required to test drug i in sub-process k (minutes)
$varia\_time_{ik}$	Variable time required to test drug i in sub-process k (minutes/lot)
cap_ph_j	Capacity of a pharmacist in month j (lots/month)
cap_sc_j	Capacity of a scientist in month j (lots/month)
cap_H_j	Capacity of a machine M1 in month j (lots/month)
cap_S_j	Capacity of a machine M2 in month j (lots/month)
cap_G_j	Capacity of a machine M3 in month j (lots/month)
cap_D_j	Capacity of a machine M4 in month j (lots/month)
$pcost_i$	Late test penalty cost of drug i ($/lot/month)
$required_{ik}$	Required resource to test of drug i in sub-process k
M	Huge number

Decision Variables:

$tested_{ij}$	Number of drug i tested in month j (lots)

$tested\_ph_{ijpk}$	Number of drug i tested in month j by pharmacist p in sub-process k (lots)
$tested\_sc_{ijck}$	Number of drug i tested in month j by scientist c in sub-process k (lots)
inv_{ij}	Number of drug i that cannot be tested within its require month j (lots)
ph_{ijpk}	1 if drug i is tested in month j by pharmacist p in sub-process k, 0 otherwise
Sc_{ijck}	1 if drug i is tested in month j by scientist c in sub-process k, 0 otherwise
H_{ijh}	1 if drug i is tested in month j by machine M1 h, 0 otherwise
S_{ijs}	1 if drug i is tested in month j by machine M2 s, 0 otherwise
G_{ijg}	1 if drug i is tested in month j by machine M3 g, 0 otherwise
D_{ijd}	1 if drug i is tested in month j by machine M4 d, 0 otherwise
$Maxwl\_ph_j$	Maximum workload of all pharmacists in month j (minutes)
$Minwl\_ph_j$	Minimum workload of all pharmacists in month j (minutes)
$Maxwl\_sc_j$	Maximum workload of all scientists in month j (minutes)
$Minwl\_sc_j$	Minimum workload of all scientists in month j (minutes)
OT_ph_{pj}	Amount of overtime of pharmacist p in month j (minutes)
$Idle\_ph_{pj}$	Amount of idle time of pharmacist p in month j (minutes)
OT_sc_{cj}	Amount of overtime workload of scientist c in month j (minutes)
$Idel\_sc_{cj}$	Amount of idle time of scientist c in month j (minutes)

Mathematical Model:

$$Minimize\ z = \sum_{j\in J} Maxwl\_ph_j - Minwl\_ph_j + \sum_{j\in J} Maxwl\_sc_j - Minwl\_sc_j + \sum_{p\in P}\sum_{j\in J} OT\_ph_{pj} + \sum_{c\in C}\sum_{j\in J} OT\_sc_{cj} + \sum_{i\in I}\sum_{j\in J} inv\_cost_i * inv_{ij} \quad (1.1)$$

The objective function (1.1) is to minimize the difference of maximum and minimum workload, overtime workload of pharmacists and scientists and the total penalty cost of postponement.

$$begin\_inv_i + demand_{i1} - tested_{i1} = Inv_{i1} \quad \forall i \in I \quad (1.2)$$
$$Inv_{ij-1} + demand_{ij} - tested_{ij} = Inv_{ij} \quad \forall i \in I, j \in \{2, \dots, 12\} \quad (1.3)$$
$$Inv_{i12} = 0 \quad \forall i \in I \quad (1.4)$$

Constraints (1.2) and (1.3) find the number of drugs that cannot be tested in the require month and kept in the inventory. Constraints (1.4) specifies that all drugs must be tested by the end of the year.

$$\sum_{p\in P} Ph_{ijp1} + \sum_{c\in C} Sc_{ijc1} \le required_{i1} \quad \forall i \in I, \forall j \in J \quad (1.5)$$

Constraint (1.5) limits the number of pharmacists or scientists that test each drug in sub-process 1 not to be more than one person in each month.

$$\sum_{p\in P} ph_{ijp2} \le required_{i2} \quad \forall i \in I, \forall j \in J \quad (1.6)$$
$$\sum_{p\in P} ph_{ijp2} \le \sum_{p\in P} ph_{ijp1} + \sum_{c\in C} sc_{ijc1} \quad \forall i \in I, \forall j \in J \quad (1.7)$$
$$\sum_{p\in P} ph_{ijp2} \ge \sum_{p\in P} ph_{ijp1} + \sum_{c\in C} sc_{ijc1} + required_{i2} - 1 \quad \forall i \in I, \forall j \in J \quad (1.8)$$

In sub-process 2, machine setup process, only pharmacist can handle this sub-process. One pharmacist is required for this sub-process as in constraints (1.6). If sub-process 1 is done, sub-process 2 must be done if required as in constraints (1.7) and (1.8).

$$\sum_{h\in H} H_{ijh} \le required_{i3} \quad \forall i \in I, \forall j \in J \quad (1.9)$$
$$\sum_{h\in H} H_{ijh} \le \sum_{p\in P} ph_{ijp1} + \sum_{c\in C} sc_{ijc1} \quad \forall i \in I, \forall j \in J \quad (1.10)$$
$$\sum_{h\in H} H_{ijh} \ge \sum_{p\in P} ph_{ijp1} + \sum_{c\in C} sc_{ijc1} + required_{i3} - 1 \quad \forall i \in I, \forall j \in J \quad (1.11)$$

Constraints (1.9) limit number of machines M1 required for testing drug to be less than or equal to one machine in each month. If sub-process 1 is done, sub-process 3 must be done if required as in constraints (1.10) and (1.11).

$$\sum_{s\in S} S_{ijs} \le required_{i4} \qquad \forall i \in I, \forall j \in J \qquad (1.12)$$
$$\sum_{s\in S} S_{ijs} \le \sum_{p\in P} ph_{ijp1} + \sum_{c\in C} sc_{ijc1} \qquad \forall i \in I, \forall j \in J \qquad (1.13)$$
$$\sum_{s\in S} S_{ijs} \ge \sum_{p\in P} ph_{ijp1} + \sum_{c\in C} sc_{ijc1} + required_{i4} - 1 \qquad \forall i \in I, \forall j \in J \qquad (1.14)$$

Constraints (1.12)-(1.14) are similar to constraints (1.9)-(1.11) but they are applied for M2.

$$\sum_{g\in G} G_{ijg} \le required_{i5} \qquad \forall i \in I, \forall j \in J \qquad (1.15)$$
$$\sum_{g\in G} G_{ijg} \le \sum_{p\in P} ph_{ijp1} + \sum_{c\in C} sc_{ijc1} \qquad \forall i \in I, \forall j \in J \qquad (1.16)$$
$$\sum_{g\in G} G_{ijg} \ge \sum_{p\in P} ph_{ijp1} + \sum_{c\in C} sc_{ijc1} + required_{i5} - 1 \qquad \forall i \in I, \forall j \in J \qquad (1.17)$$

Constraints (1.15)-(1.17) are similar to constraints (1.9)-(1.11) but they are applied for M3.

$$\sum_{d\in D} D_{ijd} \le required_{i6} \qquad \forall i \in I, \forall j \in J \qquad (1.18)$$
$$\sum_{d\in D} D_{ijd} \le \sum_{p\in P} ph_{ijp1} + \sum_{c\in C} sc_{ijc1} \qquad \forall i \in I, \forall j \in J \qquad (1.19)$$
$$\sum_{d\in D} D_{ijd} \ge \sum_{p\in P} ph_{ijp1} + \sum_{c\in C} sc_{ijc1} + required_{i6} - 1 \qquad \forall i \in I, \forall j \in J \qquad (1.20)$$

Constraints (1.18)-(1.20) are similar to constraints (1.9)-(1.11) but they are applied for M4.

$$\sum_{c\in C} sc_{ijc7} \le required_{i7} \qquad \forall i \in I, \forall j \in J \qquad (1.21)$$
$$\sum_{c\in C} sc_{ijc7} \le \sum_{p\in P} ph_{ijp1} + \sum_{c\in C} sc_{ijc1} \qquad \forall i \in I, \forall j \in J \qquad (1.22)$$
$$\sum_{c\in C} sc_{ijc7} \ge \sum_{p\in P} ph_{ijp1} + \sum_{c\in C} sc_{ijc1} + required_{i7} - 1 \qquad \forall i \in I, \forall j \in J \qquad (1.23)$$

Constraints (1.21)-(1.23) are similar to constraints (1.9)-(1.11) but they are applied for sub-process 7.

$$tested\_ph_{ijp1} \le M * ph_{ijp1} \qquad \forall i \in I, \forall j \in J, \forall p \in P \qquad (1.24)$$
$$tested\_sc_{ijc1} \le M * sc_{ijc1} \qquad \forall i \in I, \forall j \in J, \forall c \in C \qquad (1.25)$$
$$\sum_{p\in P} tested\_ph_{ijp1} + \sum_{c\in C} tested\_sc_{ijc1} = tested_{ij} \qquad \forall i \in I, \forall j \in J \qquad (1.26)$$

Constraints (1.24) and (1.26) are used to specify the number of drug tested in each month.

$$Maxwl\_ph_j \ge \sum_{i\in I} fixed\_time_{i1} * ph_{ijp1} + \sum_{i\in I} tested\_ph_{ijp1} * varia\_time_{i1} + \sum_{i\in I} fixed\_time_{i2} * ph_{ijp2} \qquad \forall j \in J, \forall p \in P \qquad (1.27)$$
$$Minwl\_ph_j \le \sum_{i\in I} fixed\_time_{i1} * ph_{ijp1} + \sum_{i\in I} tested\_ph_{ijp1} * varia\_time_{i1} + \sum_{i\in I} fixed\_time_{i2} * ph_{ijp2} \qquad \forall j \in J, \forall p \in P \qquad (1.28)$$

Constraints (1.27) and (1.28) determine the maximum and the minimum workload of all pharmacists in each month.

$$Maxwl\_sc_j \ge \sum_{i\in I} fixed\_time_{i1} * sc_{ijc1} + \sum_{i\in I} tested\_sc_{ijc1} * varia\_time_{i1} + \sum_{i\in I} fixed\_time_{i7} * sc_{ijc7} \qquad \forall j \in J, \forall c \in C \qquad (1.29)$$
$$Minwl\_sc_j \le \sum_{i\in I} fixed\_time_{i1} * sc_{ijc1} + \sum_{i\in I} tested\_sc_{ijc1} * varia\_time_{i1} + \sum_{i\in I} fixed\_time_{i7} * sc_{ijc7} \qquad \forall j \in J, \forall c \in C \qquad (1.30)$$

Constraints (1.29) and (1.30) determine the maximum and the minimum workload of all scientists in each month.

$$\sum_{i\in I} fixed\_time_{i1} * ph_{ijp1} + \sum_{i\in I} tested\_ph_{ijp1} * varia\_time_{i1} + \sum_{i\in I} fixed\_time_{i2} * ph_{ijp2} = cap\_ph_j + OT\_ph_{pj} - Idel\_ph_{pj} \qquad \forall j \in J, \forall p \in P \qquad (1.31)$$

Constraints (1.31) are used to calculate overtime and idle for each pharmacist in each month.

$$\sum_{i\in I} fixed\_time_{i1} * sc_{ijc1} + \sum_{i\in I} tested\_sc_{ijc1} * varia\_time_{i1} + \sum_{i\in I} fixed\_time_{i7} * sc_{ijc7} = cap\_sc_j + OT\_sc_{cj} - Idel\_sc_{cj} \qquad \forall j \in J, \forall c \in C \qquad (1.32)$$

Constraints (1.32) are used to calculate overtime and idle for each scientist in each month.

$$\sum_{i\in I} fixed\_time_{i3} * H_{ijh} \leq cap\_H_j \qquad \forall h \in H, \forall j \in J \qquad (1.33)$$
$$\sum_{i\in I} fixed\_time_{i4} * S_{ijs} \leq cap\_S_j \qquad \forall s \in S, \forall j \in J \qquad (1.34)$$
$$\sum_{i\in I} fixed\_time_{i5} * G_{ijg} \leq cap\_G_j \qquad \forall g \in G, \forall j \in J \qquad (1.35)$$
$$\sum_{i\in I} fixed\_time_{i6} * D_{ijd} \leq cap\_D_j \qquad \forall d \in D, \forall j \in J \qquad (1.36)$$

Constraints (1.33)-(1.36) limit workload on each machine to be less than its capacity.

5. Results and Discussion

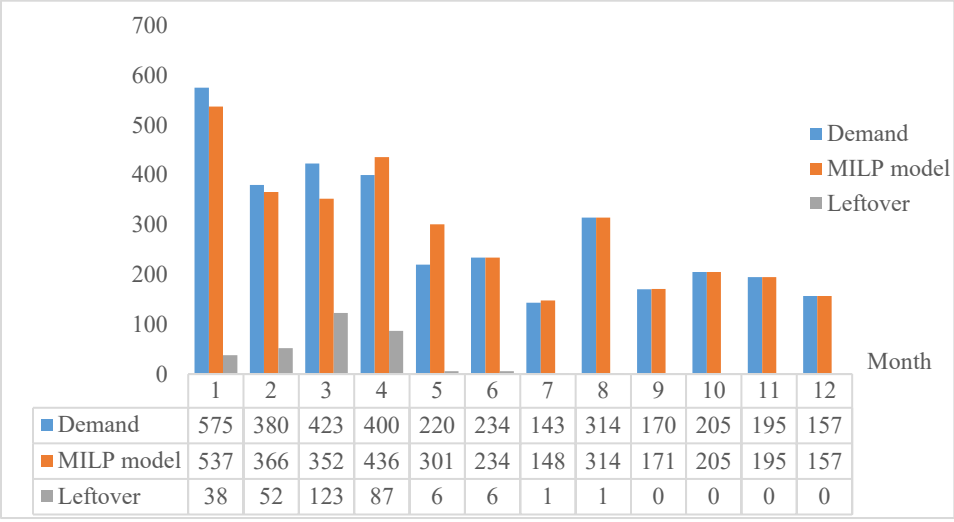
Currently, a division manager assigns tasks based on his experience, which leads to unbalanced workload. We propose a MILP model for this problem. The model is solved by IBM ILOG CPLEX Optimization Studio. The result from the mathematical model shows staff workload in each month as in Table 3.

Table 3. Workload of staffs in each month (mins)

Workload		Month											
		1	2	3	4	5	6	7	8	9	10	11	12
Pharmacist	Max/Min	4808	5032	5425	5526	4692	5535	4978	5516	5105	5339	5450	5618
Scientist	Max	5479	4438	4812	4938	4975	3747	2925	4198	2802	3180	3461	3217
	Min	5361	4260	4419	4806	4111	3532	2754	4074	2721	3124	3373	2935
	Difference	118	178	393	132	864	215	171	124	81	56	88	282

Since the input data contains only one pharmacist, max/min workloads of the pharmacist are the same value. The highest difference in workload of scientists occurred in the fifth month at 864 minutes.

Figure 3 displays the number of drugs that can be tested in each month by a MILP model compared with demand. Due to the high demand at the beginning of the year, some products cannot be tested completely in the required month. Therefore, it is necessary to postpone the test to the following months. The maximum number of postponements is four months. In addition, it is found that the number of leftovers gradually decreases until it reaches zero in the ninth month. Noted that lot splitting is not found in the optimal solution.



	1	2	3	4	5	6	7	8	9	10	11	12
Demand	575	380	423	400	220	234	143	314	170	205	195	157
MILP model	537	366	352	436	301	234	148	314	171	205	195	157
Leftover	38	52	123	87	6	6	1	1	0	0	0	0

Figure 3. Demand, products should be tested by MILP and leftover (lots) in each month

Once the tasks have been assigned to the resources by proposed solution, resources are equally assigned tasks. As a result, the idle time was similar, and no overtime incur in each month. Table 4. shows the average idle time of

pharmacist and scientist in each month. The result shows pharmacist has no more than 30% idle time while scientist tends to more availability in the last six months, with idle time up to 51% in the ninth month due to the demand for drugs to be tested decreases.

Table 4. Average idle time of pharmacist and scientists in each month

Idle time (%)	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Pharmacist	13%	1%	10%	2%	21%	11%	20%	26%	9%	5%	7%	12%
Scientist	4%	13%	20%	13%	25%	35%	49%	26%	51%	44%	40%	46%

In this research, we used the number of resources from Bunkerd's study as an input for our model. The total number of resources was determined at the beginning of the year to be sufficient for the amount of demand and didn't change within a year. Therefore, idle time occurs. The manager may reorganize the capacity planning during the year because the resources are not used efficiently. There is only one pharmacist in the division, therefore may not be able to adjust. In term of scientist, capacity usage has decreased the last six months so, it is not necessary for all scientists to the test. The manager should assign idle scientists to perform other tasks instead.

6. Conclusion and Future Work

In this paper, a monthly task assignment of a stability test is studied. The stability testing process of pharmaceutical products begins with collecting drug to the system, preparing chemical, glass and equipment, testing on machines and writing the report. The objective of this paper is to propose a monthly task assignment model to minimize the unbalanced workload, overtime working of staff and the total penalty cost due to test postponement. A mixed integer linear programming model is developed to solve the problem from a real setting. The optimal solution for assigning tasks can be obtained. Due to demand variation in each month, all tests cannot be performed in the required month. Test postponement can help reduce overtime and balance workload. We observe that lot splitting does not occur due to fixed processing time to operate tasks.

In this paper, we combine the processing time of each drug required on each resource and develop a model to assign tasks to resources by considering resource capacity. To implement the solution, a sequence of tasks on each machine must be considered. Task scheduling should be studied in the future.

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