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Improving Utilization of On-Site Physical Examination: An Electronic Factory Study

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Abstract. Many large organizations have offered annual on-site physical examinations to facilitate their employees and to maintain a consistent daily workforce. Unlike a hospital, this temporary physical examination site raises concerns for a healthcare provider as medical staff and resources must be prepared for an unplanned number of patients in a new environment. This study was carried out on the physical examination of an electronic factory that operates 24 hours a day. Based on the preliminary data, blood sample collection is a critical process as it requires fasting and must be completed before the beginning of each shift, whereas other physical examination procedures can be done during breaks or the following date. As a result, we adopted lean management and proposed operational improvements, such as appointing patients, bypassing stations, and balancing medical staff. Using a discrete-time event simulation, the comparison suggests that a suitable combination of appointing patients daily and bypassing some stations can improve the utilization of stations at the same service levels.

Keywords. On-Site Physical Examination; Health Service Case Study; Simulation

1. Introduction

As people pay more attention to their health, a regular physical examination has become an integral part of discovering any abnormal conditions or risk factors [1]. Hence, many large organizations have offered an annual on-site physical examination to their employees not only as a benefit but also to maintain a consistent daily workforce.

1.1. On-Site Physical Examination.

Despite omit in guidelines for adult prevention, public desire for a comprehensive annual physical examination is high across the world. Oboler et al [2] surveyed adults in the United States revealed that the majority of participants believed that the physical examination is essential and demanded lifestyle discussion or laboratory testing. This public opinion and desire to remain healthy make the medical profession changes its position to carefully reconsidering the health promotion of the examination as many organizations have embraced this annual routine. Some organizations have begun to offer

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on-site physical examination as a means to reduce examination costs and measure individual health information while representing goodwill to their employees [3].

In general, an on-site physical examination targets all employees with similar procedures as in a hospital, including physical measurement, vital sign, blood sample collection, urine and stool specimen collection, chest x-ray, health risk assessment questionnaire, and doctor consultation [4]. Other additional examination procedures may base on gender, age, and health risks of each employee, such as electrocardiogram (EKG), Papanicolaou test (PAP). Unlike a regular physical examination at a hospital that has sufficient resources and standard procedures, operating an on-site physical examination challenges a health care provider as medical staff and resources must be prepared for an unplanned number of patients in a new environment. On the one hand, insufficient resources could lead to complaints from long waiting queues. On the other hand, low utilization of such valuable resources could significantly affect the bottom line and interrupt operation hours, similar to general problem in a case study factory.

1.2. Problems Analysis at Case Study Factory

By implementing RFID card, the arrival time of each employee at every physical examination station could be collected. The health care provider could analyze data and observed fluctuation and inconsistency of utilization in each station comparing between factory operating hour and non-operating hour, as shown in Figure 1.

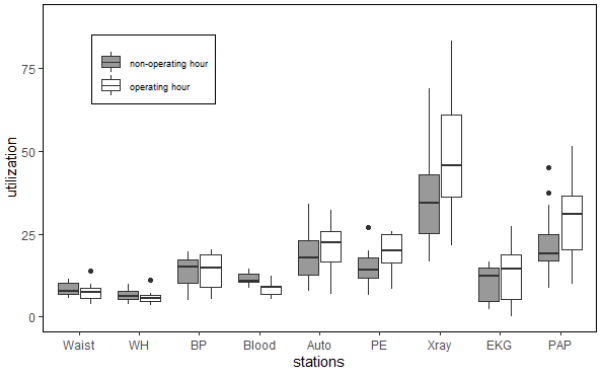

Figure 1. Low and fluctuated utilization across stations

Except for an x-ray station, the average utilizations were less than 50% as the physical examination stations were crowded in the morning before the beginning of the morning shift. In the afternoon, however, the majority of medical staff was idle. The figure also shows that the utilization of stations during operating hours and non-operating hours are more or less the same. This fluctuation of utilization indicates that some employees were at the physical consultation stations instead of working in their respective positions during their operating hours, as shown in Figure 2

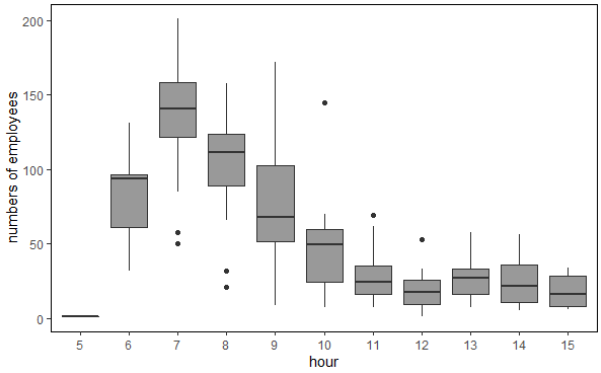

Figure 2. Distribution of employees completed their check up

Figure 2 shows the numbers of employees who finished doctor consultation--the last procedure in physical examination. It can be seen that majority of employees completed the procedure between 07:00-09:00, which is operating hours. Factory managers had noticed operation interruption and complained about the issue through the HR department. The preliminary analysis reveals that the blood sample collection is the critical procedures as it requires fasting and must be completed before the beginning of each shift. In contrast, other physical examination procedures can be done during breaks or the following date. As a result, the health care provider addresses the problem by organizing operational flow and repositioning medical staff in each station based on current number of employees. These proposed solutions became the subject of our study focusing on the operational flow of employees and a suitable number of medical staff. In this case, we applied lean management and simulation model to evaluate the effectiveness of the proposed solutions

2. Related Researches

2.1. Lean Application in Healthcare

Originated from Toyota Production System, lean management is a production philosophy that aims to create value for customers. In general, the philosophy consists of identifying value-creation processes and, then, eliminating non-valued added activities through continuous improvement as well as ensuring an individual flow of products at consumers' desiring rate [5]. After its successful applications in manufacturing and supply chain management, many service industries have begun to adopt lean management, including hospitals [6] for example, Virginia Mason Hospital which experienced financial situation [7]. After several years of lean management application, the hospital reviewed existing programs and eliminated unnecessary programs, such as additional hyperbaric chamber and endoscopy suites. Its continuous and relentless efforts to improve and redesign processes led to less staff required and fewer works, resulting in significant cost reduction without laying off employees.

2.2. Simulation in Health System

Fueled by the availability of data and general acceptant, a computer simulation model has gradually become one of the powerful methods to analyze and understand health systems [8]. Armed with animated media and health-care-oriented framework [9], a simulation model has the potential to virtually replicate the relationship between agents and resources. It also graphically communicates what-if scenarios to general audiences and key stakeholders before actual implementation, which are essential properties for modification of medical processes and allocation of essential resources [10]. Furthermore, many researchers [11-12] described a framework and mechanism in which simulation models can be developed and applied to improve the accessibility of patients, the demand management, and resource allocation in hospitals. As a result, the simulation model in health care is a fertile research area. For example, Wang *et al*. [13] modeled and resolved the long waiting time in emergency services using discrete-event simulation by enabling software systems. The simulation model coupled with design of experiment can be applied to determine a suitable configuration similar to case studies [14-15] that embedded data into computer simulation models to improve utilization and to evaluate layouts. It is important to note that the sequence of health care activities may be views as the job-shop scheduling [16]. An interested reader can consult the recent review of the healthcare scheduling in optimization context [17] for the insights that are helpful for developing policies for the simulation model.

After discussing the background of physical examination and reviewing related research, Section 3 discusses the environment of a case study factory that leads to proposed policies to improve off-site medical resource utilization as well as the experimental setting. Before suggesting a suitable combination of policies in Section 5, Section 4 introduces a discrete simulation model, and compare applies alternative settings as well as different operational policies.

3. Environment and Policies

Located in an eastern province of Thailand, the case study factory is a major electronic assembly factory that employs more than 6,500 employees. Employees operate two shifts per day with a 60-minute dining break and a 30-minute break each shift. These breaks are overlapped to avoid congestion in the hallway and cafeteria. In general, each employee rotates among four-day shifts and four-night shifts with two days off between rotation. Nevertheless, the number of employees in each shift may vary based on production targets. The factory had outsourced a health care provider a 12-day physical examination for all employees, excluding executives. The agreement specifics numbers of medical staff, equipment, and employees as well as operating hours of stations, particularly 05:45-16:00.

3.1. Operational Constraints

The factory divided employees across departments into six groups, shown as in Table 1.

Table 1. Working timeslot of each employee group

	1	2	3	4	5	6	7	8	9	10	11	12
	TH	F	SA	SU	M	T	W	TH	F	SA	SU	M
G1	D	D	D	O	O	N	N	N	N	O	O	D
G2	D	D	O	O	N	N	N	N	O	O	D	D
G3	N	O	O	D	D	D	D	O	O	N	N	N
G4	O	O	D	D	D	D	O	O	N	N	N	N
G5	O	N	N	N	N	O	O	D	D	D	D	O
G6	N	N	N	N	O	O	D	D	D	D	O	O

The factory also scheduled the physical examination for the day-shift groups who work between 07:00-18:30, denoted by 'D', whereas the night-shift groups who work between 19:00-06:30, denoted by 'N', must wait for the shift rotation. For example, employees in Group G1 can be examined on days 1, 2, 3, and 12. Nevertheless, the factory was unable to appoint an individual employee on a specific date as managers agreed that the approach could disrupt production. As a result, additional medical staff and equipment were requested, and some employees had to visit the factory during their day-off, denoted by 'O'.

In terms of stations, the factory and the health care provider divided physical examination stations into two groups based on a number of participants.

- **Compulsory stations** are referred to as stations that perform medical procedures that every employee is eligible without an additional fee regardless of gender, age, or tasks. In general, an employee visits these stations in tandem with an identical sequence similar to a hospital starting from registration to weight-and-height (WH) measurement, waist measurement, blood pressure (BP) measurement, blood sample collection, and eye examination with autorefraction (Auto) before consulting and examination with physician (PE).
- **Optional stations** are referred to as stations that some selected employees may visit based on specific criteria. This includes optional procedures or laboratory testing. For example, pelvic ultrasound is required for female employees, whereas EKG test is available for employees aged above 35 years old without an additional fee. Employees visit these optional stations, differently.

All physical stations were arranged along a hallway, as shown in Figure 3.

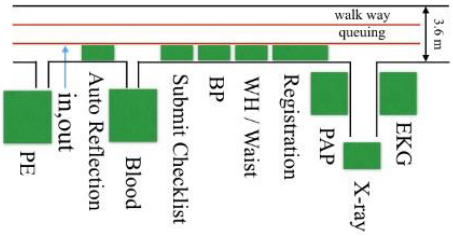

Figure 3. Layout of physical examination stations

In Figure 3, employees start their physical examination at the registration station located near the corner of a hallway where an RFID card is issued. Employees, then, visit all compulsory stations following the sequence until arriving at PE station. Upon completion, an employee can visit x-ray, PAP, and EKG stations based on his or her eligibility or individual plan. It is interesting to note that x-ray, EKG, and PAP are separated and located on the other side of the registration station as the former connects

to the hallway and leads to an x-ray vehicle outside the building. In contrast, EKG and PAP stations are optional stations and experience lower number of employee visits

3.2. Proposed Policies

Based on the literature, preliminary analysis, and operational environment, we proposed three interdependent policies as follows

- **Appointing Employees Daily:** Despite recommending as an essential process to smooth the utilization of medical resources, a concept of individual appointment was rejected on the ground of interrupting factory production. This condition resulted in fluctuation in the number of employees participating the medical examination. Notably, the first two days experienced 900 and 927 employees respectively more than the average of 470; however, the numbers of employees who participated in the last two days was significantly lower than other days at 183 and 210 employees, respectively. Hence, we proposed three levels as follows:
  E0 represents the current situation where no specific date appointment is allowed.
  E1 is referred to a what-if situation where day-shift employees have the appointment before the shift started as they had fast in the morning.
  E2 is a modification of level **E1** where appointed period is extended to noon similar to hospital schedule.
- **Bypassing Stations:** The idea of bypassing stations is a generation of observations during the physical examination. As the shift begins, some employees skipped some compulsory stations or delayed their visits to optional stations. In addition, a health care provider occasionally redirected employees to available compulsory stations and complete the blood sample collection procedure sooner. Hence, we proposed three sequences, as shown in Figure 4.

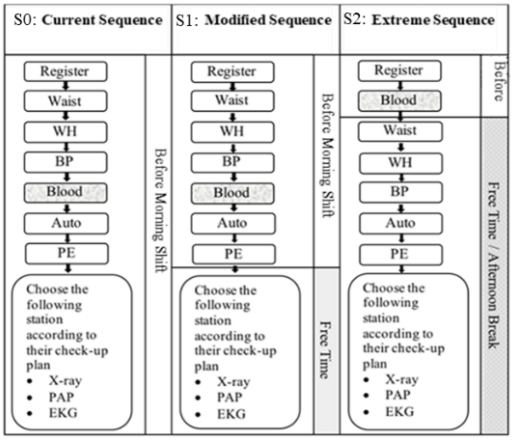

Figure 4. Comparison of operation flow between stations

S0 is referred to the current sequence similar to the physical examination in a hospital where no station can be skipped nor employee can be re-routed.

S1 presents a modification where some compulsory stations, namely x-ray, PAP, and EKG, are postponed if employees have insufficient time before the shift. Employees can visit these stations during their breaks.

S2 is an extreme case of **S1** where employees visit the blood sample station right after registration. They can visit remaining compulsory and optional stations if they have sufficient time before the shift or wait until breaks.

- **Balancing Number of Staffs:** Because employees tended to visit stations sequentially, some stations were busy in the morning, yet they are idle in the afternoon. The adjusted numbers of medical staff could alleviate congestion and improve overall utilization. By adopting the lean-management production balancing concept, the medical skills required of each station have to be classified to identify the bottleneck station and the possible allocation. Using the overall actual utilization of the median station as theoretical and targeted utilization shown in Equation 1, the suitable numbers of medical staff in each station can be determined by rounding up a number to the nearest integers while considering the available staff with Equation 2.

$$\rho = \text{median}\left(\frac{t_s \cdot r_s \cdot N}{n_s}\right) \quad (1)$$

$$\hat{n}_s = \frac{t_s \cdot r_s \cdot N}{\rho} \quad (2)$$

where,

N = total number of employees

t_s = mean processing time of station S

r_s = ratio of designated employees in station S

n_s = current number of staffs at station S

ρ = theoretical median utilization of a station

$\hat{n}_s$ = suggested number of staffs at station S

Based on these equations with $\rho = 12.92$, the proposed number of medical staff in each station can be determined as shown in Table 2.

Table 2. Number of current and proposed medical staffs

Station (S)	n_s	$\hat{n}_s$	r_s	t_s
Waist	3	2	1.0000	18.47
WH	4	2	1.0000	18.09
BP	6	6	1.0000	71.96
Blood	17	12	1.0000	138.70
Auto	3	5	1.0000	49.42
PE	6	7	1.0000	77.53
x-ray	1	4	1.0000	40.11
PAP	6	10	0.3875	149.80
EKG	6	4	0.4162	105.50

These numbers of medical staff lead to the following alternatives:

P0 is referred to as the current allocation of medical staffs

P1 is referred to as the adjusted medical staffs based on theoretical utilization according to Table

4. SIMULATION MODEL AND RESULTS

The proposed policies and data were embedded into a simulation model implemented on Rockwell Arena [18] version 14.6

4.1. Validation and Accuracy of Model

Before the comparison of the policies, it is important to validate a simulation model. Using the Kolmogorov-Smirnov distribution test, the distribution of interarrival time was statistically matched to its empirical distribution, and the normal distribution was found the most suitable distribution for processing times. As for the outputs, the comparisons between the actual utilization and the generated one are grouped by operating hours and non-operating hours, as shown in Table 3

Table 3. comparison between actual and generated utilization

	operating hours			non-operating hours		
	actual	**generated**	**%error**	**actual**	**generated**	**%error**
Waist	7.53	6.72	10.86	8.26	8.56	3.67
WH	5.89	4.39	25.47	6.64	5.64	15.12
BP	13.86	15.25	9.99	13.50	18.41	36.37
Blood	8.54	8.43	1.26	11.54	13.96	21.01
Auto	20.45	21.84	6.82	18.08	22.96	27.03
PE	19.43	19.26	0.90	14.66	14.93	1.85
x-ray	52.73	51.71	1.93	35.87	48.89	36.29
EKG	12.94	11.62	10.21	9.48	9.20	2.92
PAP	30.38	30.31	0.24	22.65	23.55	3.95

In general, the average percentage error during operating hours and non-operating hours is less than 12% and should represent the on-side physical examination at the case study factory. However, the output validation of each station using its utilization exhibits inaccuracy as the utilizations of the actual data are limited and there is high fluctuation during non-operating hours.

4.2. Results and Statistical Analysis

Based on the possibility of implementation, we proposed ten scenarios that cover individual policies as well as their combination. The average utilization and average total time of the scenarios are shown in Table 4

Table 4. Proposed scenarios and utilization, and total time

Configuration				Average Utilization		Average Total time
Scenario	Appointing	Bypassing	Balancing	Operating hours	Non-Operating. hours	
A0	E0	S0	P0	18.96±0.40	20.07±0.47	69.22±3.31
A1	E1	S0	P0	19.87±0.33	17.85±0.32	137.20±4.27
A2	E2	S0	P0	20.25±0.47	18.14±0.42	60.15±3.23
A3	E0	S1	P0	23.15±0.38	14.72±0.44	67.96±2.77
A4	E0	S2	P0	27.00±0.33	9.65±0.47	81.46±4.83
A5	E0	S0	P1	14.51±0.31	14.78±0.41	12.96±0.46
A6	E0	S2	P1	23.49±0.36	3.17±0.23	35.48±1.42
A7	E2	S1	P0	23.11±0.35	14.18±0.46	61.84±2.15
A8	E2	S1	P1	19.28±0.41	8.41±0.24	22.32±0.75
A9	E2	S2	P1	23.94±0.40	2.32±0.18	28.31±0.81

Scenario A0 serves as the base case for the current operation, whereas Scenarios A1–A5 represent the effects of a single individual policy. Without the assistance of the case study factory, Scenario A6 denotes the best effort of the health provider by routing employees to reduce the congestion and re-allocating medical staffs to improve the utilization at each station. Scenarios A7 and A8 are similar to the physical examination at a hospital without and with medical staff adjustment, respectively. Scenario A9 depicts an ideal scenario where both the health provider and the case study factory collaborate to improve utilization.

The results suggest that the appointment could improve overall utilization. However, the requirement for employees to complete all stations before the beginning of the shift could lead to congestion and long waiting time at the PE station, especially Scenario A1 in which the appointment period is only 75 minutes or during 05:45-07:00. In Scenarios A3-A4, the bypassing station policies can reduce the fluctuation of medical resources enable employees to spend less total time in stations. This finding highlights the importance of a flow manager or senior nurse who oversees total operations as well as the communication between stations. Nevertheless, bypassing all stations excepted the registration and blood sample collection stations could lead to an extended total time in system as physician consultation is required to complete health information of an employee. Adjusting medical staff alone in Scenarios A5 surprisingly leads to lower utilization since employees must wait along with the crowd as the congestion moves along sequential stations. However, the combination of adjusting medical staff together with bypassing stations such as in Scenarios A6, A8, and A9 could significantly reduce the total time in stations and cause less work disturbance during operating hours as there is no bottleneck.

The comparison of policies also reveals that a suitable combination of appointing employee daily and bypassing some stations could improve utilization of stations. However, reducing the average total time requires balancing numbers of medical staff.

5. CONCLUSION

Despite of its transportation and cost benefits, the on-site physical examination program has faced planning and executing challenges and conditions, such as lack of daily appointment, inflexible operating hours of employees, spatial and area constraints, and inflexibility or lack of skills of medical staff. As illustrated in the case study factory, these challenges and conditions could lead to the production disruption as the blood sample collection requires fasting and must be completed before the beginning of each shift. The health care providers also experienced the low utilization during the last few days and during non-operating hours. Having analyzed processing time collected by RFID, we applied lean management and proposed three interdependent policies: appointing patients, bypassing stations, and balancing medical staff. These policies and associated were embedded into a computer simulation to compare and suggest the following recommendation:

- The health care provider should explain and quantify the effect of each challenge and conditions. The ideal result requires the collaboration and compromise.
- The appointing schedule should consider of time constraint and number of employees participated.
- A flow nurse who oversees number of waiting participated employees at each station is essential to overall utilization.

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