CHAPTER 2
LITERATURE REVIEW AND BASIC THEORY

2.1. Literature Review

2.1.1. Shift Scheduling

Shift scheduling problems have become common problems in every sector of business. Therefore, there are many methods developed to solve this problem. For example, Rekik et al. (2010) tried to solve shift scheduling problem with multiple breaks and break windows. The problem occurred at continuous 24 hours day work with 9 hours' work per shift. Rekik et al. extended models of Aykin, Bechtold and Jacobs on implicit model with new concept of fractional breaks and work stretch duration restrictions with forward and backward constraints. The idea on fractional breaks was giving 3 sub breaks with 15 minutes minimum and 90 minutes maximum. Then, compare the performance between model of Aykin and model of Bechtold and Jacobs. The result showed that extended Aykin model performs better on very large problems. In other hand, extended model of Bechtold and Jacobs performed better on highly flexible environments.

2.1.2. Day-Off Scheduling

Alfares (2001) had solved (5, 7) day-off scheduling problem by implementing dual linear programming. The (5, 7) day-off scheduling problem meant that the workers are assigned to work for 5 days with 7 days' workweek cycle and 2 consecutive days off. The solution of dual linear programming model was used to determine minimum of manpower size and assign the workers for their day-off patterns in order to get minimum total labor cost. Although the labor cost occurred for specific day-off patterns was different among one and another, this model also accommodate it for finding the minimum total labor cost.

Another case Alfares (2002) had solved about (14, 21) day-off scheduling problem. This problem assigned workers to work 14 consecutive days and break 7 consecutive days-off with 21 days' workweek cycle. This schedule was applied on major oil company. The objective in this case was to minimize workforce size and reduce transportation cost by minimizing number of active day-off patterns (number of patterns to which some employees are actually assigned). The

method used in this case was utilizing dual solution and primary-dual relationship without involving linear or integer programming.

Alfares (2006) also had solved (3, 7) day-off scheduling problem. This schedule assigned employees to work 3 days and 4 day-off with 7 days' work cycle. The objective of this case was minimizing total workforce cost. The proposed method used in this case was integer programming with workforce size as the constraint compared to traditional integer programming. It was showed that implementing traditional integer programming could not solve more than 57% of the test problems by Excel Solver. But, the additional constraint considered on integer programming has made it possible to solve all test problems.

In other hand, Elshafei and Alfares (2008) had solved single shift day-off scheduling problem with sequence dependent labor cost by generating dynamic programming algorithm. The algorithm they used was applied on evening and night shift assignment of security personnel in university with maximum work stretch, maximum number of workdays per week, and minimum number of consecutive off days per week as the constraints. Security in university got maximum 3 work days with minimum 2 consecutive days off per week. The solution achieved was chosen based on total cost and CPU execution time which were affected by number of workforce, cost vector, demand pattern, and other conditions.

2.1.3. Cyclic/Tour Scheduling

Brusco and Jacobs (2000) had solved continuous tour scheduling problem with break windows, overlapping start-time bands, and start-time intervals by implementing GSCF (generalized set-covering formulations) and implicit programming. GSCF was used for representing decision variables explicitly in form of integer number. Implicit model was focused on assignment given from start of shift to end of shift including meal break period. Meal break period has been set between the fourth and sixth hours of nine hours shift. Starting time for each employee were varying one and another with 3 hours interval between starting time. The employees were assigned to work for 5 days and rest for 2 days. The result showed that implicit model provides accurate and flexible tools on evaluating trade-off between policies considered in this case.

Laporte and Pesant (2004) proposed on developing Constraint Programming (CP) for multi-shift rotating schedules with the advantages on its flexibility,

robustness and speed required. They declared that CP can handle a complex and non-linear constraints which mostly appeared in scheduling problem. The working cycle in this case was 5 weeks with three types of shift, i.e. day, evening, and night shift. The shift stretch for each worker was 2 or 3 for lower limit and 6 to 9 for upper limit. Model used in this case could be applied on any sequences of work stretch. This algorithm has been tried to apply on several cases such as Airport, Alcan, Edmonton police, Quebec transportation, Montreal police, St. Louis Police and other unspecified problems. It was showed that this algorithm is flexible enough to be applied in any cases.

Brunner, Bard, and Kolisch (2009) developed new approach, flexible shift scheduling for scheduling physician in university hospital, Munich, Germany by minimize the overtime based on cost coefficients. Flexible shift scheduling was an approach that the shift construction is built period by period over the day implicitly. The physician in this university hospital was assigned to work for 7 hours minimum and can be extended up to 13 hours maximum with an hour break. According to work contract, physician had to work for 42 hours to 54 hours per week. The model created to solve this case was by generating Mixed-Integer Programming. The result showed that new schedule does not require overtime on most cases. If the demand on hospital was tend to steady, the alternative solution for cost saving was by downsizing number of physician.

Shift schedule problem also appears on Vancouver 2010 Olympic Games for scheduling RCMP (Royal Canadian Mounted Police) officers in cyclic six days work pattern (Kaluzny and Hill, 2011). The objective on this case was to minimize unmet demand. The shift in cyclic six day work pattern was previously determined. Officer worked for 8, 10, or 12 continuous hours per shift. Officers were also grouped into three watches per venue. Each watches should worked for 4 continuous work days and 2 continuous off days. Moreover, that work pattern was repeated over again after having those off days. The constraints in this case were required number of personnel each day, shift length, start time, and rest period. To solve this case, Kaluzny and Hill were generating Integer Linear Programming model and split & stitch method for reducing formulation size. The model created helped to get the valid schedule for regular work and minimize overtime work. Then, the solutions achieved were interactive which allowed the planner to adjust the schedule by few modifications.

Another literature showed about developing shift pattern with between-days break-time constraint to determine optimal cycle period for Front Office staffs roster in Disaster Oasis Training Center, YAKKUM, Surakarta, Central Java (Yuniartha, 2012). Front Office in Disaster Oasis Training Center was operated for 24 hours with 3 types of shift; morning, evening, and night shift. Currently, there are 3 staffs of front office. As number of staffs equal to the number of shifts, and each of staff should had one day-off once a week, those staffs must had overtime to overcome the staff shortage. In addition, each staff should worked for 5 consecutive days and rest for 1 day. Currently, between-days break-time for staff is 8 hours which influencing on staff performance, such as coming late on next shift. Therefore, adequate between-days break-time for staff should be given. The idea to fix that problem was by changing minimum between-days break-time into 15 hours based on remaining hours in one day (24 hours) after work for one shift (9 hours at maximum per shift). Then the methods used to solve this case were determining work stretch, overtime pattern, and shift pattern in one work cycle. The result of new shift pattern had better distribution of work and rest period compared to previous shift pattern.

2.1.4. Gap Analysis

Gap analysis used to show the contribution of this research by comparing the previous researches with this research based on several aspects which can be seen on Table 2.1. The gap analysis shows that there is previous research considering multiple breaks and other researches considering work pattern and shift type but there is no research has considered combination between those two components. Therefore, contribution of this research is application of tour scheduling which is combining between work pattern and shift type and application of break scheduling for multiple breaks in one shift.

Table 2.1. Gap Analysis

No.	Author (Year)	Scheduling Classification	Shift Type	Work Pattern	Break Time	Method	Objective
1	Alfares (2001)	Day-Off Scheduling	N/A	5 days' work - 2 days off	N/A	Dual Linear Programming	Minimize workforce size
2	Alfares (2002)	Day-Off Scheduling	N/A	14 days' work - 7 days off	N/A	Dual LP Solution and Primary-Dual Relationship	Minimize number of workers and transportation cost
3	Alfares (2006)	Day-Off Scheduling	N/A	3 days' work - 4 days off	N/A	Integer Programming	Minimize total cost of workforce
4	Brunner, Bard, and Kolisch (2009)	Tour Scheduling	Min 7 hours – max 13 hours	42 hours to 54 hours per week	1 hour break	Mixed-Integer Program	Minimize overtime
5	Brusco and Jacobs (2000)	Tour Scheduling	9 hours per shift	5 days' work - 2 days off	Between fourth and sixth hours of shift	GSCF and Implicit Programming	Minimize total workforce size
6	Elshafei and Alfares (2008)	Day-Off Scheduling	Not considered in calculation	3 days' work – min 2 days off	N/A	Dynamic Programming	Minimize total labor cost
7	Kaluzny and Hill (2011)	Cyclic Scheduling	8, 10, or 12 hours per shift	4 days' work - 2 days off	N/A	Split and Stitch, and ILP	Minimize unmet demand
8	Laporte and Pesant (2004)	Cyclic Scheduling	Day, Evening, and Night shift	General	N/A	Constraint Programming	Develop new algorithm with flexibility, robustness, and speed required
9	Rekik, Cordeau, and Soumis (2010)	Shift Scheduling	9 hours per shift	N/A	3 sub breaks (min 15 minutes, max 90 minutes)	Forward and Backward, Implicit Model	Minimize workforce size

Table 2.1. (Continued)

No.	Author (Year)	Scheduling Classification	Shift Type	Work Pattern	Break Time	Method	Objective
10	Yuniartha (2012)	Cyclic Scheduling	Morning, Evening, and Night shift	5 days' work-1 day off	N/A	Develop shift pattern	Give adequate between-days break-time
11	Hapsari (2015)	Tour Scheduling and Break Scheduling	Day, and Night shift	4 to 6 days' work-1 to 2 days off	2 breaks (min 40 minutes)	Develop break schedule and work pattern	Fulfill the regulations

* N/A = not available

2.2. Basic Theory

2.2.1. EICC Code of Conduct

As this company and one of its supply chains are joining EICC (Electronic Industry Citizenship Coalition), this company has to follow EICC Code of Conduct. Based on EICC (2014), code regarding with shift worker are stated on section A (3) as follow:

Working Hours: Studies of business practices clearly link worker strain to reduced productivity, increased turnover and increased injury and illness. Workweeks are not to exceed the maximum set by local law. Further, a workweek should not be more than 60 hours per week, including overtime, except in emergency or unusual situations. Workers shall be allowed at least one day off per seven-day week.

2.2.2. Apple Supplier Code of Conduct

As Apple is one of the customers, the company should follow the regulation from Apple which known as Apple Supplier Code of Conduct. Apple (2013) code regarding with labor and human right is stated as follow:

Working Hours: A workweek shall be restricted to 60 hours, including overtime, and workers shall take at least one day off every seven days except in emergencies or unusual situations. Supplier shall follow all applicable laws and regulations with respect to working hours and days of rest, and all overtime must be voluntary.

2.2.3. Thailand's Labour Protection Act

As the subject of this research is located in Thailand, this company also should follows regulation from Thailand's Ministry of Labor which stated in Labour Protection Act. Labour Standard Development Bureau (2008) is stated on section 9 as follow:

The provision of Section 23 of the Labour Protection Act B.E. 2541 shall be repealed and substituted by the following:

"Section 23   An Employer shall notify a normal working time to an employee, by specifying the commencing and ending time of work in each day of the employee, which shall not exceed the working time for each type of work as prescribed in Ministerial Regulations and not exceed eight hours per day. Where the working

hours of any day less than eight hours, the Employer and the employee may agree to make up the remaining working hours in other normal working days, but not exceed nine hours per day and the total working hours per week shall not be exceed forty-eight hours. Except for the work which may be harmful to health and safety of the employees as prescribed in the Ministerial Regulations for which the normal working hours shall not exceed seven hours per day and the total working hours per week shall not exceed forty-two hours.

Where the Employer and the employee agree to make up the remaining hours in other normal working days under paragraph one and the total working hours exceed eight hours per day, the Employer shall pay remuneration to the daily employee and the hourly employee at a rate of not less than one and a half times of the hourly rate on a working day for a number of exceeding working hours, or to the employee who receives wages on a piece rate basis at a rate of not less than one and a half times of the piece rate of wages of a working day for a number of piece work done in the exceeding working hours.

Where the Employer may not notify the commencing and ending time of daily work due to the nature or condition of work, the Employer and the employee shall agree to specify the working hours in each day of not exceeding eight hours and the total working hours per week shall not exceed forty-eight hours."

Ministry of Labour (1998) is stated on section 24 as follow:

An Employer shall not require an Employee to work overtime on a Working Day unless the Employee's prior consent is obtained on each occasion.

Whereas the description or nature of work requires it to be performed continuously and stoppage may cause damage to the work, or it is emergency work, or other work as prescribed in the Ministerial Regulations, an Employer may require an Employee to work overtime as necessary.

Ministry of Labour (1998) is stated on section 25 as follow:

An Employer shall not require an Employee to work on a Holiday unless the description or nature of work requires it to be performed continuously and stoppage may cause damage to the work, or it is emergency work. In that case, an Employer may require an Employee to work on a Holiday as necessary.

An Employer may require an Employee to work on a Holiday in a hotel business, an entertainment establishment, transport work, a food shop, a beverage shop, a

club, an association, a medical establishment or any other businesses as prescribed in the Ministerial Regulations.

For the purposes of production, sale and service, an Employer may require an Employee to work on a Holiday as necessary, other than as prescribed under paragraph one and paragraph two, provided that the Employee's prior consent is obtained on each occasion.

Ministry of Labour (1998) is stated on section 26 as follow:

The hours of Overtime Work under Section 24 paragraph one and the hours of Holiday work under Section 25 paragraph two and paragraph three in total shall not together exceed the number of hours prescribed in the Ministerial Regulations.

Ministry of Labour (1998) is stated on Ministerial Regulation No.3 as follow:

By virtue of Section 6 and Section 26 of the Labour Protection Act B.E. 2541 (1998), the Minister of Labour and Social Welfare hereby issues the following Ministerial Regulations:

Overtime working hours under paragraph one of Section 24 and working hours on Holidays under paragraphs two and three of Section 25 shall, in aggregate, not exceed 36 hours per week in aggregate.

Working hours on Holidays shall include overtime working hours on holidays.

Ministry of Labour (1998) is stated on section 27 as follow:

On a Working Day, an Employer shall arrange a rest period during work for an Employee of not less than one hour per day after the Employee has been working for not more than five consecutive hours. An Employer and Employee may agree in advance that each rest period may be less than one hour but the total rest period per day shall not be less than one hour.

Whereas an Employer and Employee agree to specify rest periods during work other than paragraph one, the agreement shall be applicable only if it is more favorable to the Employee.

A rest period during work shall not be counted as working time except where the total rest period is more than two hours per day, where the amount of time exceeding two hours shall be counted as normal working time.

Whereas any Overtime Work after normal working time is more than two hours, the Employer shall arrange for the Employee to take a rest period of not less than twenty minutes before the Employee commences the Overtime Work.

The provisions in paragraph one and paragraph four shall not apply where an Employee is required to do work of a continuous nature or character with the consent of the Employee, or in case of the emergency work.

Ministry of Labour (1998) is stated on section 28 as follow:

An Employer shall provide a weekly holiday of not less than one day per week for an Employee, and the interval between weekly holidays shall be not more than six days the Employer and the Employee may agree in advance to fix any day as a weekly holiday.

2.2.4. Work Stretch and Rest Period

Some literatures considering work stretch and rest period are explained as follow:

Keller (2009) saw that the workers should have enough rest periods before switching their shift from day to night shift and vice versa. Therefore, Keller had done research that explained rest period from night to day shift should be 2x24 hours and rest period from day shift to night shift should be 1x24 hours.

In other hand, Tucker et al. (1999) found that allowing workers have 2 days off after work for 12 hours shift in 4 days before change their shift will prevent fatigue. Tucker et al. also suggest for not having 3 consecutive night shifts because working for 4 consecutive days with 12 hours shift, especially night shift will give negative impacts to workers health, wellbeing, and safety.

Organization which represents workers throughout U.S. and Canada, Unite the Union (2013) also published handbook about health and safety issues on shift work and night work. Unite The Union explained that maximum working hours per week is 72 hours with 6x12 hours shift and one day off. In general, worker should not allow working for more than 5 to 7 days per week and should have one day off per week. Actually, employee can work 78 hours per week at maximum with having 11 hours rest period between shifts. Employees also should have 2 days off before switching their shift from day to night shift and vice versa.