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MIXED INTEGER LINEAR PROGRAMMING MODEL FOR WORKLOAD LEVELING ON OFFSHORE PLATFORM OF PETROLEUM COMPANY

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for the Degree of Master of Science Program in Computer Science and Information

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ในวิทยานิพนธ์นี้ผู้วิจัยได้ทำการศึกษาปัญหาการปรับระดับภาระงานอัตโนมัติ ที่เกิดขึ้นในแผนกซ่อมบำรุงและตรวจสอบ บนแท่นกลางทะเลของบริษัทน้ำมันในประเทศไทย อุปกรณ์ และพนักงานบนแท่นที่มีประสิทธิภาพเป็นปัจจัยที่มีความสำคัญที่สุดต่อสินค้าและบริการที่มีคุณภาพ ดังนั้น ในแต่ละปีทางแผนกจะได้รับใบงานการซ่อมบำรุงและตรวจสอบมากมาย สืบเนื่องมาจากวัสดุและอุปกรณ์ที่ใช้ในงานจำนวนมากบนแท่นกลางทะเล การปรับระดับภาระงานจึงมีความจำเป็นในการแจกจ่ายงานทั้งหมด สำหรับจำนวนคนงานและจำนวนที่พักที่มีอยู่อย่างจำกัดบนแท่นกลางทะเล จากปัญหาดังที่กล่าวมาแล้วข้างต้นจึงมีการนำเทคนิคตัวแบบกำหนดการเชิงเส้นจำนวนเต็มผสม โดยใช้วิธีขยายและจำกัดเขตมาใช้ในการแก้ปัญหา ตัวแบบมุ่งเน้นปรับระดับและลดจำนวนของพนักงานที่ทำงานบนแท่น โดยคำนึงถึงทุกความต้องการของงาน ผู้วิจัยใช้ซอฟต์แวร์ต้นฉบับเปิด GUSEK เพื่อจัดสรรทรัพยากรให้มีประสิทธิภาพสูงสุด ผู้วิจัยหาผลเฉลยที่ใกล้เคียงที่สุดด้วยการลดจำนวนรอบในการหาผลเฉลยโดยใช้ mipgap ซึ่งใช้เวลาน้อยกว่าเมื่อเทียบกับการหาผลเฉลยจากกำหนดการเชิงเส้นจำนวนเต็มผสมต้นฉบับ ผลการวิจัยแสดงให้เห็นว่าผู้วิจัยใช้จำนวนคนที่น้อยกว่าและค่อนข้างจะคงที่มากกว่าเมื่อเทียบกับข้อมูลที่ต้นฉบับได้รับมาจากแผนใบงานประจำปีของบริษัท

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MALINEE WONGRUEAN: MIXED INTEGER LINEAR PROGRAMMING MODEL FOR WORKLOAD LEVELING ON OFFSHORE PLATFORM OF PETROLEUM COMPANY.

THESIS ADVISOR: PROFESSOR CHIDCHANOK LURSINSAP, Ph.D., THESIS CO-ADVISOR : SIRIPUN SANGUANSINTUKUL, Ph.D, 50 pp.

The problem of automatic workload leveling and optimizing occurring in the maintenance and inspection section on offshore platform of a major petroleum company in Thailand is studied. Efficient equipment and offshore personnel are the most significant factors in providing more efficient products and services. Therefore, each year the department receives a tremendous number of maintenance and inspection work orders regarding a large number of equipments on offshore platforms. Workload leveling is needed in order to distribute all works for limited number of personnel and accommodations on offshore platform. Mixed integer linear programming (MILP) technique using branch and cut method is utilized for this problem. The model aims to balance and minimize the number of personnel working offshore while maintaining all work requirements. Researchers use the open source optimization software GUSEK to determine the optimal resource allocation. We determine the nearly optimal solution by reducing the number of iterations using the mipgap which is considerably faster than the original MILP. The results indicate that less number of personnel are employed and personnel are more leveling when compared with the original data from yearly work order plan of the company.

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Finally, I would like to thank all of my friends, and particularly, my parent and my family for everything they give to me. I would love to consecrate this work to all people that I have mentioned above.

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CHAPTER I

INTRODUCTION

The current global economy is highly competitive. Organizations with better management, will survive and get enormous profit in return. Hence, the optimization plays an important role in the successful business. Optimization problems are widely seen in everyday life from small problems solving by hand up to complex combinatorial problems in NP hard class. It pertains to everyday decision making and helps us to make a reasonable decision.

1.1 Problem Identification and Motivation

Gas and oil companies concerning drilling and offshore crude oil production operations are in high risk, both in economic loss and polluted environment. Hence, safety is an important issued to be emphasized. It will be a disaster and substantial economic loss if the offshore safety regulations are neglected [1],[2]. Therefore, a periodic equipment maintenance and inspection are needed in order to assure that all equipments are still in good conditions and ready for the operations. Efficient equipments and offshore personnel are the most significant input factors necessary in providing a more efficient product. Therefore, the routine scheduling of maintenance and inspection for offshore equipment is a major priority. The Computer Maintenance Management System (CMMS) was proposed as the main system [3] of Operation Maintenance Inspection (OMI) in order to improve the management of any periodic maintenance and inspection work order but the problem still occurs due to a tremendous number of work orders. It generates a lot of periodic maintenance and inspection jobs (work orders) under limited resources and environmental constraints such as personnel, time, tools, weather and port status. Thus, the resource allocation problems have been arising due to the limited number of accommodations at Quarter Platform (QP) and living barge combined with scarce qualified personnel who can work on specific required jobs. After that reformulated model is propose, multi-skilled personnel are taken into account for the improvement, in order to decrease the number of personnel needed, as well as completing all of the assigned work orders. The proposed solution is using a Mixed Integer Linear Programming (MILP) model with branch and cut methodology. The model can balance and decrease the number of required personnel while completing all of the work orders on time.

The petroleum company must provide all work orders with required personnel who have to go to work offshore according to the following restrictions:

- The COS training (Sea survival training): COS training deals with how to handle the problem when some accidents occur while being on the transfer chopper or working offshore.
- Onshore accommodation: providing the travel arrangements for the workers from their residence to the chopper base region and any accommodations while waiting for offshore transfer.
- Helicopter transportation: all personnel are transferred from shore to offshore by chopper (round trip).
- Offshore accommodations: preparing the accommodations such as catering, vacant rooms / bed at Quarter Platform (QP) or living barge. This is the main reason for minimizing the amount of offshore personnel.
- Working rate: the offshore pay rate is much higher than onshore rate.

All those steps are costly and must be minimized. The balancing work order assignments at offshore platforms under different types of constraints can be considered as one of the combinatorial problems. At this time, equipments and individuals (each personnel) are ignored.

There are two main types of platform in oil field operations: complex and remote. The complex offshore platform consists of five operating platforms connected by bridges where the personnel can easily walk. But for the remote platforms, the personnel can only go there by boat or chopper. It is a fact that there is a large risk to go out on boat or chopper during the typhoon season which begins from October to December of each year. Therefore, a station set is needed in order to separate the work order types. According to a lot of equipment, the numerous periodic maintenance and inspection work orders are generated. Thus, the petroleum optimization problem arises to which the planning engineer allocates personnel with different positions (skills) for working on the given work orders base on specific job plan.

Moreover, the special skills and expertise of personnel are needed such as sea survival training, working under confine space training, requirement skill of specific job, etc. If personnel have the ability to work in different types of work, it not only decreases the number of personnel, but it also could be advantageous when some skilled personnel are absent, resigned or shorthanded, especially in an unexpected or emergency situation. The quicker the problem is recovered, the smaller the impact is. Thus, the offshore personnel should be multi-skilled so that they can deal with different situations.

1.2 Research Objectives

The challenge in this research is to fit limited personnel under the scarce accommodations while assigning enough personnel for working on offshore platform. The contributions of this thesis are to introduce the model to explain how it can be solved for the optimal result and to evaluate the benefits that result from applying this model to the offshore assignment. The central focus of this research is to find a simple but efficient methodology to minimize and balance the number of personnel who need to perform maintenance and inspections offshore while satisfying all the restrictive resource constraints. The use of the mathematical programming modeling language was applied to solve such a problem. Thus, MILP model is proposed to find the optimal solution from the workload leveling problems and the multi-skilled personnel allocation problems. Finally, the model automatically finds the optimum solution in order to satisfy all constraints giving integer result which is the optimal number for each position who must go to work at offshore in each month throughout a year.

1.3 Scope of work

Our test data is extracted from the inspection planning work orders number recorded in the year 2009 which was obtained from inspection discipline in operation maintenance and inspection (OMI) department of the petroleum company in Thailand. The size of the original offshore assignment problem is 11,520 [12(*number of positions*)*40(*number of job plan*s)*2(*number of stations*)*12(*number of months*)*1(*number of year*s)] and the offshore multi-skilled assignment problem size is 138,240 [12(*number of positions* 1)*12(*number of positions* 2)*40(*number of job plan*s)*2(*number of stations*)* 12(*number of months*)*1(*number of year*s)]. The open source software, GUSEK (GLPK Under Scite Extended Kit), software is run on Intel® Core™2 QuadCPU Q9550 2.83 GHz, with 1.93 GB of RAM for finding the optimal solution.

There are some concepts and restrictions that need to be taken into the account.

- A work order is an instantiate of a job plan. Each operational working time to finish work order cannot exceed their job plan duration.
- Due to the requirement, any offshore work cannot be done during the typhoon season. We specify two types of work orders: complex work order and remote work order. The remote work order cannot be assigned during typhoon season. The complex work order can be assigned throughout the year.
- Personnel (staff) with given positions will have a specific number of work hours. Therefore, a specific personnel who works with two positions in a job plan, both work hours must be added.
- One work order may require more than one position. However, to complete this work order all positions must be filled and completed by personnel.

The data from inspection department are available only 2009 because the CMMS project was first launched in the end of year 2008.

1.4 The definition of the research

Workload leveling optimization problem is proposed in the situations to satisfy the equilibrium distribution of scarce resources. Therefore, all jobs in the list can be managed within limited resources by leveling or distributing.

1.5 Expected Advantages

This advantage of this research will balance and decrease the number of personnel who need to go to work offshore while satisfying all restrictive resource constraints.

1.6 Research Processes

In order to achieve the defined objective above, the following processes are stated:

1. To define a problem and determine a technique suitable for such a problem.
2. To study concepts and methodologies by reviewing related literatures, requesting and getting data from PTTEP.
3. To study the feasibility and available technology for this problem.
4. To pre-process data.
5. To write objective function and constraint in mathematical terms.
6. To code a mathematical function in GUSEK programming modeling language.
7. To extend scope and data for the experiment.

1.7 Literature Review

Many optimization researches of the petroleum industry [4],[5] have focused on operational optimization such as operating and drilling costs, field development, offshore production platform position, platform layout and infrastructure, the reservoir modeling, production planning and operations. While most of the restrictive resource constrained (resource allocation) researches focused on managing resource and constraints in efficient way to satisfy their objectives [6],[7], we especially pay attention to the objective in maintenance and inspection [8]. Most of the workload leveling researches applied Minimax approaches [9]. It is helpful to ensure the balance of load for each assigned agent. Huang, Lee and Xu [10] balanced the workload between two air cargo terminals to improve the operational efficiency using stochastic mixed integer linear program model. Several techniques e.g. Hungarian method, genetic algorithm, branch and cut, column generation based, bilevel decomposition, bender decomposition are applied in this research area [6],[7],[11].

Human resource planning is one of the optimization problems found in various industries, such as software industry [12],[13], call center industry[14], cellular manufacturing system[15] and transport system[16] etc. Most researches related to assignment and scheduling within the petroleum industry are concerned with the assignment of platforms to wells, production planning or operations scheduling and equipment pair matching. Furthermore, the multi-disciplinary aspects [14],[15] of each personnel plays an important role in the problem by decreasing number of staff .This means some personnel are able to work in different positions within the same or different work orders. The use of multi-skilled personnel has been increasing and becoming more common for improving management in the workplace. Shen, Tzeng and Liu [12] applied fuzzy set theory to overcome the lack of role-based task assignment by proposing a multi criteria assessment. The cross-trained worker allocation [17] is proposed and later on, the assignment heuristic base on linear assignment approximation for multiple departments was developed base on [17] by Campbell and Diaby [18]. Moreover, Li and Womer[13] minimize the total cost of staff by modeling resource constrained assignment with multi-skilled personnel. Mostly, the resource allocation problems focus on managing available resources and constraints to meet the goal. Due to restrictive available resources, the balance of workload is needed to assure that each personnel are working at the same level of loads.

The rest of this thesis is organized into five sections as follows. Chapter 2 mentions about the basic knowledge in this research. Linear programming (LP), Mixed Integer Linear programming (MILP) with the workload leveling problem on offshore platform of Petroleum Company is summarized. Also, the branch-and-cut methodology is explained in this chapter. Chapter 3 discusses the research processes which are problem formulation in mathematical terms. Objective function and constraints are given in this chapter. Chapter 4 summarizes the experiment and results. Chapter 5 concludes the study and future work.

CHAPTER II

THEORETICAL BACKGROUND

This chapter provides the basic knowledge in this research such as Linear Programming, Mixed Integer Linear Programming, Resource allocation, Assignment, Scheduling, Workload leveling, Multi-skilled and Branch-and-Cut methodology. Moreover, many examples, clarifying, illustrative, and computational, are provided.

2.1 Linear Programming

Linear Programming (LP) is a technique that is widely seen in the Operation Research (OR) in order to allocate the resources. Generally speaking, linear programming is routinely solved even if they involve hundreds of thousands of variables and constraints. In some large-scale problems, using the LP model is helpful. The optimum solution can be fractional values when the numbers of variables are likely to be large.

The linear programming models compose of a set of variables, an objective function and the constraints. Here is the linear programming model.

Objective function:

$$z = a_1x_1 + a_2x_2 + a_3x_3 + \dots + a_nx_n$$

Constraints:

$$b_{11}x_1 + b_{12}x_2 + b_{13}x_3 + \dots + b_{1n}x_n \le c_1$$

$$b_{21}x_1 + b_{22}x_2 + b_{23}x_3 + \dots + b_{2n}x_n \le c_2$$

$$\vdots$$

$$b_{m1}x_1 + b_{m2}x_2 + b_{m3}x_3 + \dots + b_{mn}x_n \le c_m$$

$$x_1 + x_2 + x_3 + \dots + x_n \ge 0$$

or turn into another short form as below:

given $M = \{1,2,3,\ldots,m\}$ and $N = \{1,2,3,\ldots,n\}$

Objective function: $$z = \sum_{j=1}^{N} a_j x_j \qquad (2.1.1)$$

Constraints: $$\sum_{j=1}^{N} b_{ij} x_j \leq c_i\,,\ \ i \in M \qquad (2.1.2)$$

$$x_j \geq 0,\ \ j \in N \qquad (2.1.3)$$

This LP has *m* constraints with *n* variables which (2.1.1) is an objective function for finding minimal value and satisfying constraints (2.1.2). (2.1.3) is the decision variables that the value are greater or equal to zero.

When z is the optimal value of objective function,

x_j is a decision variable which optimal value can be found,

a_j , b_{ij} and c_i are constants derived from the problem specifics.

There are problems in many aspects of business that use LP to solve the problems such as product mix planning, distribution networks, truck routing, staff scheduling, and financial portfolios.

2.2 Mixed Integer Linear Programming

Some problems need a numeric solution in which the variables take integer values. Therefore, Integer Programming (IP) is useful when the decisions are essentially discrete such as yes-no question. The options must be chosen from a finite set of alternatives. IP is often called *discrete optimization* or *combinatorial optimization* which indicates the extremely large increasing in the number (combinatorial) of possible solutions as the problem size increase. Problems whose some variables can take only integer values and some variables can take fractional values are called *Mixed Integer Linear Programming* (*MILP*)[19]. A variable is discrete if it is limited to a fixed or countable set of values. More often than not, the choices are only 0 and 1 and a variable is continuous if it can take on any value in a specified interval. When there is an option, such as optimal variable are likely to be large enough that fractions have no practical importance then modeling with continuous variables is more preferable than discrete because optimizations over continuous variables are generally more tractable than the ones over discrete variables[20].

2.3 Assignment

Assignment Problems (AP) involve optimum matching of two or more elements sets, where the number of sets of elements that need to be matched refers to the dimension of the problem. Mostly when there are only two sets, they are referred to as "tasks" and "agents". For example, "tasks" are jobs to be done and "agents" are the personnel or machines that can perform on such a task. The original version of AP involves assigning each task to a different agent, with each agent being assigned at most one task (a one-to-one assignment). While the following two models to be discussed below involve assigning multiple agents to a task [21], vice versa the models do assign multiple tasks to the same agent (a one-to-many assignment). The first models to be discussed, however, assign no more than one task to any given agent. Assignment problems mainly focus on matching the elements of two or more sets in such a way that some objective function is optimized.

The classic assignment problems(classic AP), involve matching the elements of two sets on a one-to-one basis in order to minimize the sum of their associated weights, has produced a wide variety of derivatives. The classic assignment problem take agent qualification in to an account for assignment problem with side constraints then section their work in a mathematical model of the classic AP in term of m agents and n tasks, not every agent is qualified to do every task, and the objective is utility min(max)imization:

Minimize $$\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij} \tag{2.3.1}$$

Subject to: $$\sum_{i=1}^{m} q_{ij}x_{ij} \le 1, \quad j = 1,\ldots,n \tag{2.3.2}$$

$$\sum_{j=1}^{n} q_{ij}x_{ij} \le 1, \quad i = 1,\ldots,m \tag{2.3.3}$$

$$x_{ij} = 0 \text{ or } 1 \tag{2.3.4}$$

where x_{ij} = 1 if agent i is assigned to task j, 0 if not

q_{ij} = 1 if agent i is qualified to perform task j, 0 if not

c_{ij} = the utility of assigning agent i to task j (with $c_{ij} = 0$ if $q_{ij} = 0$).

The first set of constraints (2.3.2) ensures that no more than one qualified agent is assigned to any task and the second set of constraints (2.3.3) enforces that no agent is assigned to more than one task. Even though, if m is greater than or equal to n it may be impossible to assign a qualified agent to every task or to give all agents a task for which they are suited for.

The generalized assignment problems (GAP), find an optimal assignment of agents to tasks when an agent can be assigned to multiple tasks. The same agent is allowed or required for assigning to more than one task in this type of problem, unlike the classical assignment problem which provides a one-to-one pairing of agents and tasks. However, each task is performed exactly once. This model assumes, as in the classic AP, that each task will be assigned to one agent. But it additionally allows assigning more than one task to an agent, while concerning the maximum capacity of each agent to do those tasks. Thus, GAP is one-to-many assignment problem that realizes capacity limits when each task may use only part of an agent's capacity rather than all of it (AP). The GAP is shown in the following model:

Minimize $$\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij} \tag{2.3.5}$$

Subject to: $$\sum_{i=1}^{m} x_{ij} = 1, \quad j = 1,\ldots,n \tag{2.3.6}$$

$$\sum_{j=1}^{n} a_{ij}x_{ij} \le b_i, \; i = 1,\ldots,m \tag{2.3.7}$$

$$x_{ij} = 0 \text{ or } 1 \tag{2.3.8}$$

where $x_{ij} = 1$ if agent i is assigned to task j, 0 if not

c_{ij} = the cost of assignment agent i to task j

a_{ij} = the amount of agent i's capacity used if that agent is assigned to task j

b_i = the available capacity of agent i

The first set of constraints (2.3.6) ensures that every task is assigned to only one agent and the second set of constraints (2.3.7) ensures that the set of tasks assigned to an agent do not exceed its capacity. There are many operation research and management science literatures relate with applications of GAP such as machine scheduling, lump sum capital rationing, computer networking and facility location problems.

2.4 Constraint Satisfaction

Constraint Satisfaction Problems can be defined as a set of variables and set of constraints among the values of the variable. Typically, Constraint Programming is used for solving such a problem which allows users to describe data and constraints of the problem without explicitly solving in the declarative phase. The main interest of constraint programming lies in actively using the constraints to reduce the computational effort needs to solve a problem in the same time achieving good declarative problem formulation[22]. Constraints not only use for testing the validity of a solution, but also in a constructive mode to deduce new constraints and detect inconsistencies. This process is called constraint propagation.

2.5 Resource Allocation

Resource allocation is used to assign the available resources in an economic way. It is the part of resource management. In project management, resource allocation is the activities scheduling and the required resources by those activities while taking both the resource availability and the project time into an account. In other word, it is a plan for using available resources, for example human resources, especially in short term of a company mission, to achieve goals for the future. It is the process of allocating resources among the various projects or business units. The plan consists of two parts: the first part is the basic allocation decision and the second part is contingency mechanisms. The basic allocation decision is the choice of which items to invest in the plan, and what level of funding it should receive, and which to leave unfunded: the resources are allocated to some items, not to others. There are two contingency mechanisms. There is a priority ranking of items excluded from the plan, showing which items to fund if more resources should become available; and there is a priority ranking of some items included in the plan, showing which items should be sacrificed if total funding must be reduced.

2.6 Scheduling

Scheduling is an important problem in computer science and operation research. Most computer scientists and operation researchers may focus on different issues such as timeliness in computer science issued and cost in the manufacturing or any other operations[23]. A good scheduling brings improvement both in process management and cost reduction. In many real-life situations, delays in the execution time of certain activities occur when resources required by these activities are not sufficient quantities during the time interval when they are scheduled to take place. The problem involves finding the optimal sequence of activities with given resource constraints. This particular problem is known as the resource-constrained scheduling problem.

2.7 Workload leveling

Workload leveling problem is mainly to find the set of assignments that will either minimize the maximum value of the costs of the assignments or vice versa. One example given is based on how to assign printing jobs to presses while minimize time to which all jobs would be complete. Another example is how to transport perishable goods from warehouses to markets without spoilage or military supplies from warehouses to command posts during an emergency. In either case, the objective is to minimize the time by which all the transfers have taken place.

The mathematical model is given as: $\text{Minimize } \max_{i,j}\{c_{ij}x_{ij}\}$

The main objective is to smooth resources requirements by shifting slack jobs beyond periods of peak requirements. Some methods essentially replicate what a human scheduler would do if he had enough time; others make use of unusual devices or procedures designed especially for the computer.

2.8 Multi-skilled

Multi-skilled is a process of training maintenance employees in specific skills that cross the traditional trade or craft lines, and then ensuring that the work is performed. The advantage of multi-skilled is that particular jobs which historically require more than one position, not necessarily more than one individual, are now performed by just one person. Using cross-trained agents, those capable of handling multiple types of jobs can make the operation more efficient and effective. Achieving those results in the real world is another matter. Cross-trained agents with multiple skills make the scheduling process more complex. It is no longer enough to simply have the right number of agents scheduled; the scheduler has to take into account agents' individual skill sets when creating schedules. Mathematical formulas often used to plan workforce scheduling are no longer accurate or effective when agent skills must be considered. Multi-skilled feature helps the organization make the most of their multi-skilled and cross-trained agents.

2.9 Branch-and-Cut

Branch and Cut has been widely used in Mixed integer linear programming (MILP) and Non-Mixed integer linear programming (MINLP) for a few decades[24]. They are several extensions of the branch and cut in order to enhance its efficiency i.e. Branch-and-Cut-and-Price[25]. Branch and cut is the methodology that combines advantages of two methods. The first one is cutting plane method which is “cutting” and tightening the feasible region thus they hope to find the solution faster due to the feasible area is shrunk. This method is much faster for solving but not guarantees the reliable of the optimal solution. Another one is *branch and bound method* which is the well-known method for solving the TSP and Knapsak problem. Branch and bound is a recursive programming that seeking for the optimal value by enumeration tree of all possible solutions. Even though, the solution is reliable nevertheless it is very cumbersome. Hence, we can get the optimal solution even faster and better by combining “the faster” from cutting plane method and “the reliable” from branch and bound method.

The branch and cut algorithm overview and the branch and cut algorithm flow are shown as Figures 2.1 and 2.2, respectively. Figure 2.1 shows the general overview of how the branch and cut work in iterative process by divide the problem into sub-problem then cut the infeasible region out (cut parts of the polytope out by adding new constraints) and solve the small problem under the feasible solution area while trying to find the integer solution .

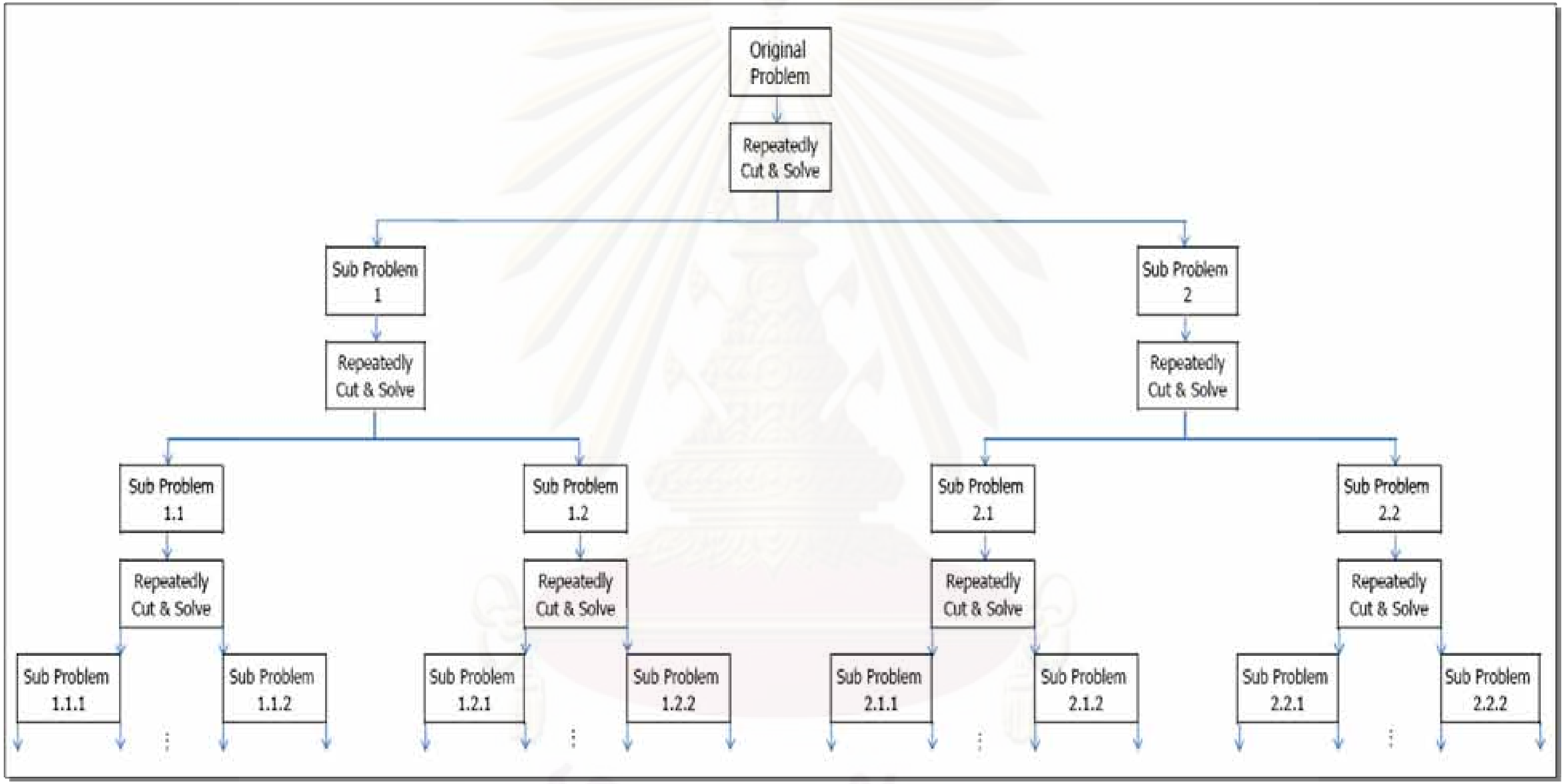

Figure 2.1 : The Branch and Cut Algorithm Overview.

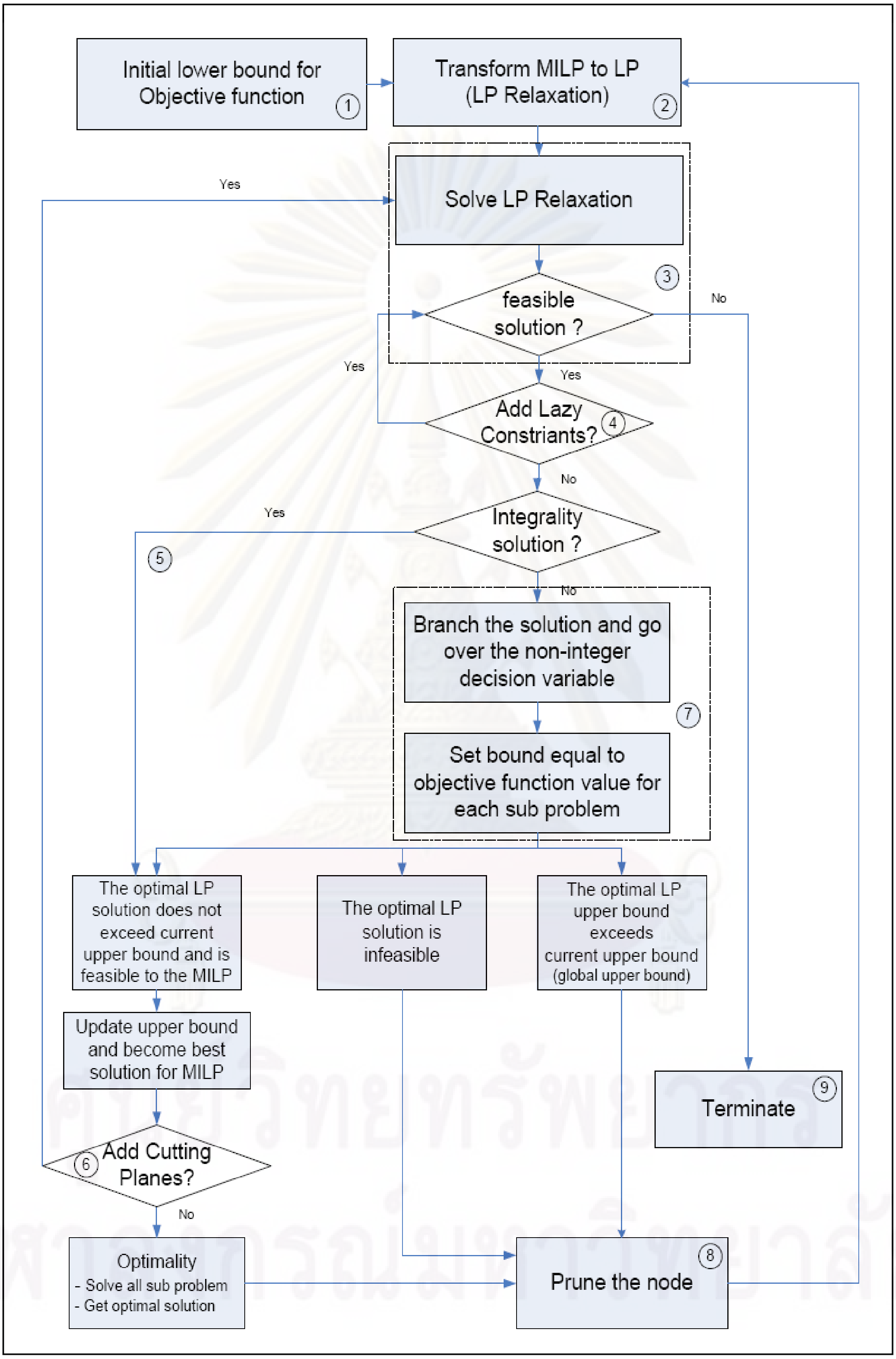

Figure 2.2 : The Branch and Cut Flow.

Here is the explanation of the processing phase of Figure 2.2:

Phase 1: Set the initial lower bound for the minimization problem.

Phase 2: Linear programming relaxation of MILP. This relaxation technique makes the hard problem like MILP easy to solve in polynomial time. LP relaxation is the generated LP from MILP using the same objective and constraints without the integrality of variables.

Phase 3: Solve each LP and see whether the LP is infeasible then fathom it by going to pruning phase, if LP is feasible go to next phase. In fact, feasible solution to the problem exists when there is a vector x that satisfies all problem constraints.

Phase 4: Adding lazy constraints : add the essential constraints that are violated at solution value of the LP relaxation current sub-problem (Z_{LP}) and not yet include in original MILP problem then go to phase 3.

Phase 5: Check for integrality : possible to convert the current fractional solution to one that is integral? If yes ($Z_{new} < Z_{best}$: new solution value more than best global solution value) after that update the current best global feasible solution, then go to phase 8.

Phase 6: Adding cutting plane : identify a violated valid inequality at the locally optimal point (Z_{LP}), if there are ($Z_{LP} > Z_{best}$), add in such a plane to the solver in order to bound the feasible area (add the generated constraints to the formulation of the current sub-problem) then go to phase 3 to solve again.

Phase 7: Branching : two nodes are created from current node (create two new sub-problems called down-branch and up-branch) then add both sub-problems in the active list after that go to phase 2.

Phase 8: Pruning : Remove from the active lists all sub-problem include the current one, then go back to phase 2.

Phase 9: Termination : the original MILP has no integer feasible solution , otherwise the last integer feasible solution stored on phase 5 is the integer optimal solution then stop.

CHAPTER III

OFFSHORE WORKLOAD LEVELING PROBLEM FORMULATION

Our effort is to find the optimal solution of offshore workload leveling problem under scarce qualified personnel while taking the limited offshore accommodations into account. The MILP model using the branch and cut technique is applied to solve such a problem. The model automatically finds the optimum solution in order to satisfy all constraints giving integer result which is the optimal number for each position who must go to work at offshore in each month of a year.

The optimal solution that fits the number of qualified positions with the amount of offshore work orders under the limited accommodations is the needed in order to solve the offshore workload leveling problem. Figure 3.1 illustrates the concise research process.

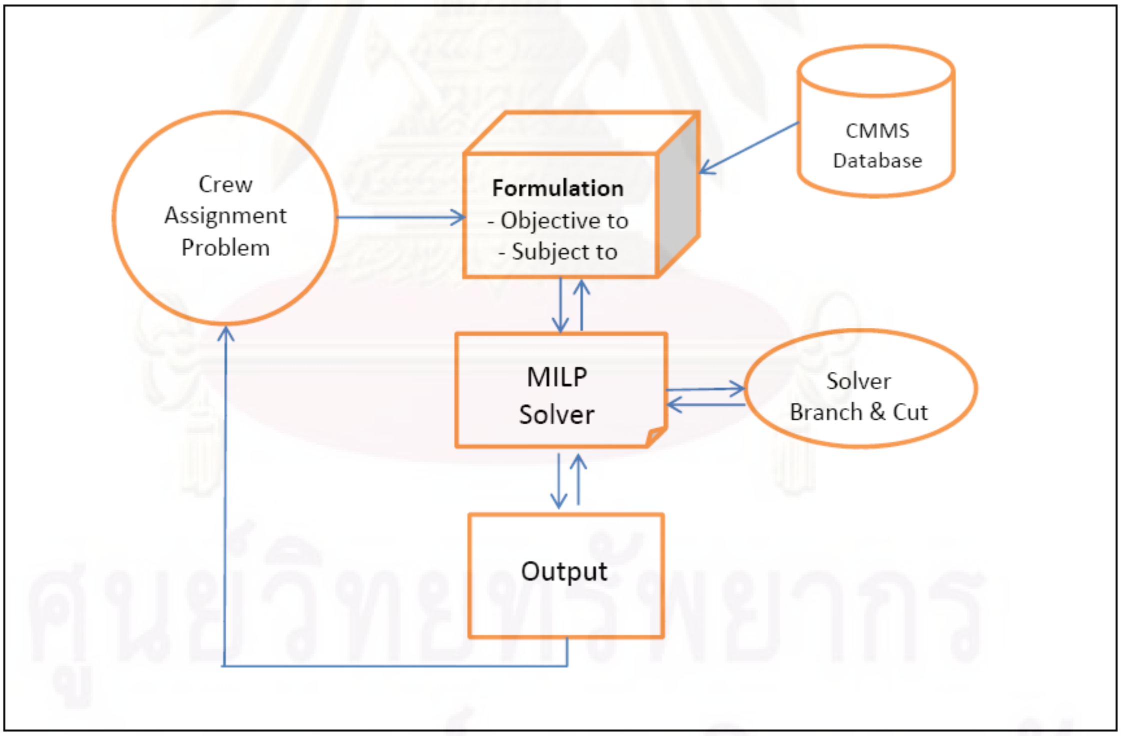

Figure 3.1 : Example of research process.

From the needs above with the available data in CMMS database, the real record of maintenance and inspection is extracted and described in matrix representation. The problem is transformed into a mathematical model (objective function and constraints) by taking LP relaxation into account. The number of qualified personnel who can do the work order in each month of the year at offshore platform is presented by a discrete variable. The optimization of relevant objective function is derived and converged for the offshore workload leveling problem. Then, the proposed of MILP is applied to solve this problem. Finally, the output (optimal solution) is obtained using MILP solver in order to answer the offshore workload leveling problem.

Figure 3.2 shows the scenario of offshore assignment when the human icon on the left hand side relates the position with the ability of each personnel. The work order is illustrated by the picture on the right hand side and the duration of each work orders are also represented. The middle layer shows the job plan with its relation to positions and work orders and the station layer is accompanied with the job plan.

Table 3.1 shows the table of job plan that are extracted from inspection planning work order that test generated from the Computer Maintenance Management System (CMMS) system.

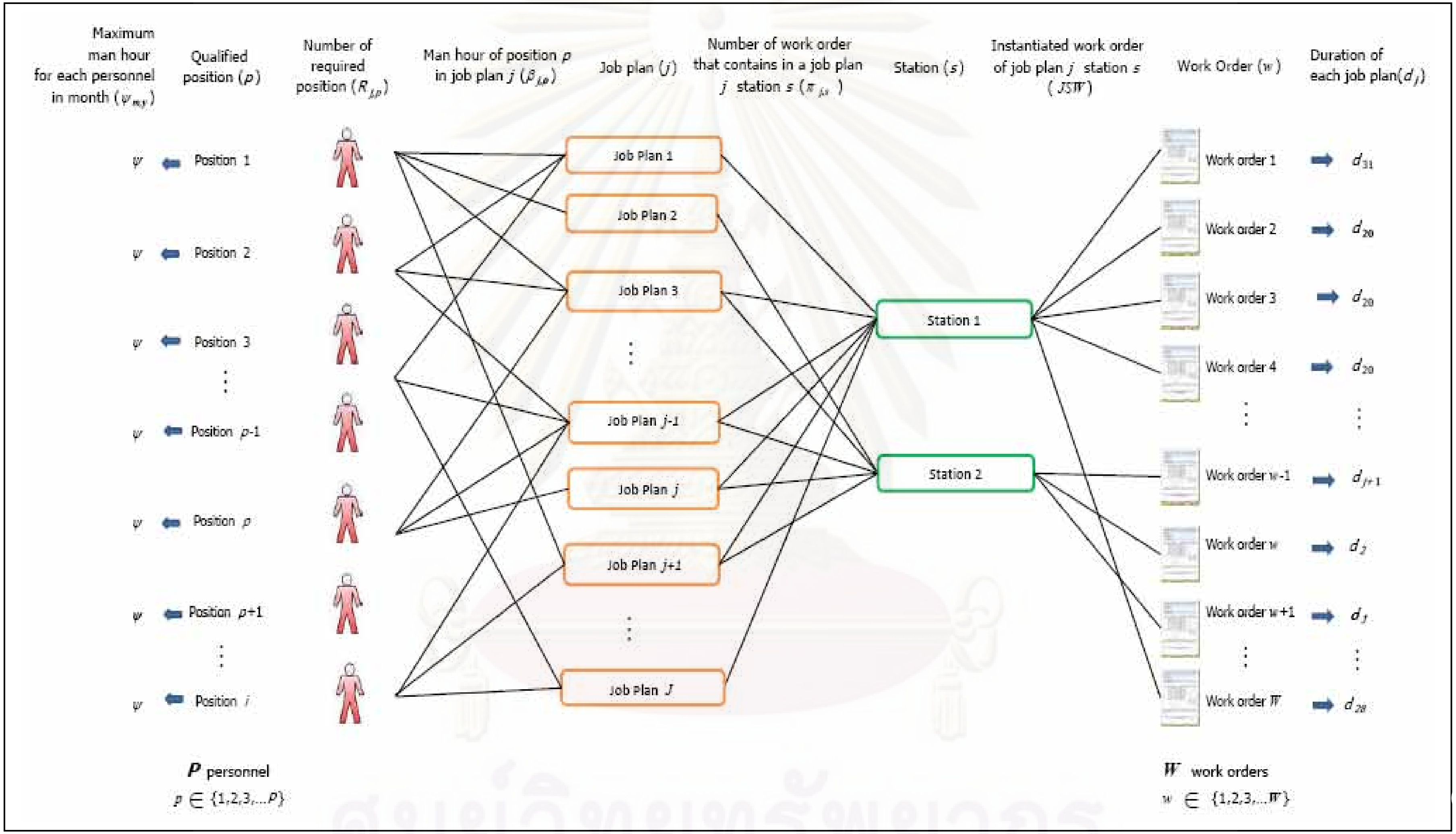

Figure 3.2 : The example of offshore assignment scenario

Job Plan(JP)	Frequency (Number of WO)	Duration (Month unit)	Reference JP (Original)
JP1	2	0.002777778	G-JP-IP036
JP2	4	0.00297619	G-JP-IP019
JP3	44	0.004166667	G-JP-IP012
JP4	3	0.004166667	G-JP-IP018
JP5	1	0.004166667	G-JP-IP074
JP6	3	0.005376344	G-JP-IP078
JP7	1	0.005555556	G-JP-IP025
JP8	19	0.005952381	G-JP-IP024
JP9	7	0.005952381	G-JP-IP028
JP10	1	0.008333333	G-JP-IP057
JP11	2	0.008333333	G-JP-IP058
JP12	2	0.008333333	G-JP-IP077
JP13	137	0.009408602	G-JP-IP014
JP14	25	0.009722222	G-JP-IP005
JP15	17	0.010752688	G-JP-IP029
JP16	1	0.010752688	G-JP-IP067
JP17	1	0.0125	G-JP-IP069
JP18	47	0.014583333	G-JP-IP011
JP19	43	0.016129032	G-JP-IP026
JP20	1	0.016129032	G-JP-IP064
JP21	2	0.016129032	G-JP-IP095
JP22	1	0.016666667	G-JP-IP041
JP23	1	0.016666667	G-JP-IP096
JP24	1	0.016666667	G-JP-IP042
JP25	1	0.016666667	G-JP-IP050
JP26	5	0.017857143	G-JP-IP017
JP27	5	0.019345238	G-JP-IP033
JP28	29	0.021505376	G-JP-IP022
JP29	1	0.022222222	G-JP-IP084
JP30	2	0.02688172	G-JP-IP031
JP31	1	0.032258065	G-JP-IP100
JP32	1	0.045833333	G-JP-IP027
JP33	29	0.047043011	G-JP-IP001
JP34	4	0.063888889	G-JP-IP030
JP35	9	0.063988095	G-JP-IP023
JP36	6	0.097222222	G-JP-IP003
JP37	1	0.113888889	G-JP-IP034
JP38	21	0.12202381	G-JP-IP021
JP39	1	0.145833333	G-JP-IP035
JP40	1	0.188888889	G-JP-IP032

Table 3.1 : The Job Plan list with its details

The two models are formulated in order to cope with two situations; the first model is the original offshore assignment problem presented in section 3.1 and the second model is the multi-skilled model of offshore assignment problem presented in section 3.2.

3.1 Original Offshore Assignment Problem

The model of the original offshore assignment problem is proposed as follows:

3.1.1 *Model Factors and Variables*

The following sets of factors are concerned in our study:

(1) a set of job plans indexed by j;

(2) a set of work orders indexed by w;

(3) a set of personnel indexed by e;

(4) a set of positions indexed by p;

(5) a set of months indexed by m;

(6) a set of stations indexed by s;

(7) a set of years indexed by y; and

(8) a set of duration time for each job plan indexed by j.

These factors are related by the variables defined as follows.

$X1_{p,j,s,m,y}$: a number of personnel assigned to position p for the work order under job plan j at station s in the month m of the year y. The value of $X1_{p,j,s,m,y}$ must be a positive number less than or equal to the number of available personnel in each position p.

$X2_{p,j,s,m,y}$: a decision variable whose value is defined as follows.

$$X2_{p,j,s,m,y} = \begin{cases} 1 \text{ ; when } X1_{p,j,s,m,y} > 0 \\ 0 \text{ ; otherwise} \end{cases}$$

$X3_{j,s,w}$: a decision variable whose value is defined as follows.

$$X3_{j,s,w} = \begin{cases} 1\ ; \text{when work order } w \text{ is assigned under} \\ \quad \text{job plan } j \text{ at station } s \\ 0\ ; \text{otherwise} \end{cases}$$

$A_{j,s,w}$: the total number of assigned position types in each work order.

In addition to the above factors and variables, the following constants must be pre-specified for the boundary constraints.

$R_{j,p}$: the maximum number of required personnel in position p of job plan j concerning all considered months and years.

$\pi_{j,s}$: the maximum number of work orders under job plan j at station s.

d_j : the duration of job plan j.

$\beta_{j,p}$: the total working hours required for position p in job plan j.

$\psi_{m,y}$: the total working hours of each month m in each year y concerning all stations, job plans, and positions.

Since not all possible cartesian products obtained from the sets of job plans, work orders, personnel, positions, months, and stations are considered in reality, we define the following considered sets of cartesian product sets.

Ω : the set of considered Cartesian products from sets of job plans, stations, and work orders ,determine which work order are under job plan j station s, $(j,s,w) \in \Omega$.

$\alpha_{j,p}$: the set of cartesian products from sets of job plans and positions. This set is many-to-one relation of position p who have skill required by job plan j. It means several positions can work under a single job plan j.

$Typhoon$: the set of cartesian products from sets of job plans, stations, and months which cannot be executed during Typhoon season; $(j,s,w) \in Typhoon$.

3.1.2 *Formulation*

The formulation of MILP with an objective function is defined in (1.1) and the constraints are given in (1.2)-(1.11) :

Objective function:

$$\text{Minimize } T,\ T \geq 0 \tag{1.1}$$

The objective function in (1.1) is to minimize the total number of personnel in each position who need to go to work offshore in all months of the year.

The constraints are represented in (1.2)-(1.11).

$$\sum_{s \in S} \sum_{j \in J} \sum_{p \in P} X1_{p,j,s,m,y} \leq T, \forall m, \forall y \tag{1.2}$$

Constraints (1.2) enforces T to be the largest value among number of personnel every month in a year that means T act as an upper bound for the number of personnel in every month.

$$\sum_{y \in Y} \sum_{m \in M} X1_{p,j,s,m,y} \geq R_{j,p}, \forall p, \forall (j,s,w) \in \Omega \tag{1.3}$$

Constraints (1.3) ensure the number of personnel who work under position p, job plan j, station s, in month m, and year y are not less than the total number of required positions in the job plan j.

$$\sum_{y \in Y} \sum_{m \in M} \sum_{p \in P} X1_{p,j,s,m,y} \geq X3_{j,s,w}, \forall (j,s,w) \in \Omega \tag{1.4}$$

Constraints (1.4) state that the number of assigned personnel must be over or equal to the number of work orders.

$$\sum_{w \in W} X3_{j,s,w} \leq \pi_{j,s}, \forall j, \forall s \tag{1.5}$$

Constraints (1.5) ensure the total work order under job plan j station s is not over the number of work orders in $\pi_{i,j}$.

$$\sum_{p \in P} X1_{p,j,s,m,y} \leq 0, \forall y, \forall (j,s,m) \in Typhoon \tag{1.6}$$

Constraints (1.6) ensure personnel are not assigned to work on particular work orders which are based on remote platform (station 2) during typhoon season that begins in October through December.

$$\sum_{y \in Y} \sum_{m \in M} \sum_{p \in P} X1_{p,j,s,m,y} \geq 1, \forall (j,s,w) \in \Omega \tag{1.7}$$

Constraints (1.7) enforce that the work order must be completed by at least one personnel.

$$\sum_{s\in S}\sum_{j\in J}\sum_{p\in P}\beta_{j,p} * X2_{p,j,s,m,y} \le d_j, \forall m, \forall y, \forall (j,s,w) \in \Omega \qquad (1.8)$$

Constraints (1.8) ensure the individual man hour is not over the job plan duration.

$$\sum_{s\in S}\sum_{j\in J}\sum_{p\in P}\beta_{j,p} * X2_{p,j,s,m,y} \le \psi, \forall m, \forall y \qquad (1.9)$$

Constraints (1.9) enforce the man hour of each individual position not exceed working hour (in month unit) for each month of a year.

$$\sum_{p\in\alpha} 1 = A_{j,s,w}, \forall (j,s,w) \in \Omega \qquad (1.10)$$

Constraints (1.10) count the number of position types in assigned work order.

$$\sum_{y\in Y}\sum_{m\in M}\sum_{p\in P} X2_{p,j,s,m,y} \ge A_{j,s,w}, \forall (j,s,w) \in \Omega \qquad (1.11)$$

Constraints (1.11) state the number of position types in each work order must be more or equal to the given number of assigned position.

3.2 Offshore Multi-skilled Assignment Problem

All generated work orders along with offshore restrictive constraints need the optimal number of personnel to manage both factors. Getting the job done while using the least number of personnel is the main objective for this multi-skilled assignment and scheduling problems. From the above requirement, using inspection planning work order generated since the previous year, a foresight work plan(so called a look-ahead plan) can be created. The improvement version for Offshore Assignment Problem by taking multi-skilled personnel into account is described as below.

3.2.1 *Model Factors and Variables*

The model notations for an offshore multi-skilled assignment problem are shown as follows:

j : the index for the set of job plans, denoted by K

w : the index for the set of work orders , denoted by Q

$p, p1, p2$: the indices for the set of positions , denoted by I

m : the index for the set of months, denoted by M

y : the index for the set of years , denoted by U

s : the index for the set of stations ,denoted by V

d_j : duration of operational time for each job plan j

Ω : set of ordered triples which is the Cartesian product of sets K x V x Q that detail which instantiated work ordered are under job plan j, station s.

$\pi_{j,s}$: number of instantiated work order. The instantiated work orders number under job plan j station s, is described in this set. For example $\pi_{1,2}$ = 3 means job plan 1 that operates on station 2 has 3 instantiated work orders.

$\beta_{j,p}$: the operational time in month unit. Set of given total working hour for position p required to work in job plan j. For example $\beta_{1,2}$ = 0.05 means each personnel who is qualified to work in position 2 under job plan 1 required 36 hours in order to complete this job plan.

Typhoon : set of Cartesian product of sets K x V x M that specifying which work order under job plan j station s cannot work during typhoon season (Oct – Dec) in a year.

$\alpha_{j,p}$: set of pairs of job plan and position. This is many-to-one relation which means several positions can work under a single job plan j.

$R_{j,p}$: the cardinality of the set of the number of required positions of personnel who is assigned to work in each job plan j.

G_p : the maximum number of available personnel in position p which is a member in a set of the number of maximum available number of personnel in each position p.

ψ : the constant number that represents the working ability of personnel, i.e. 11 hours per day. Thus, 11/24 is in the month unit.

$\gamma_{j,s}$: the constant number of the summation of total work order in each job plan which calculate by sum up the instantiate work order under job plan j, and station s.

Λ : set of the scope subsets for personnel to work on two different positions for the job plan j. It is the set of cartesian product of sets I x I x K x V - $\{(p_1, p_2, j, s)\}$ when $p_1 \neq p_2$ and $p_1 < p_2$; $(p_1, p_2, j, s) \in \Lambda$

Those factors are related by the variables defined as follows.

$X1_{p,j,s,m,y}$ = number of personnel assigned to position p in work order w under job plan j station s in month m year y

$X2_{p1,p2,j,s,m,y}$ = number of personnel who can work in both position1($p1$) and position2 ($p2$) in work order w under job plan j station s in month m year y.

$X3_{p,j,s,m,y} = 1$ when variable $X1_{p,j,s,m,y} > 0$

$X4_{p1,p2,j,s,m,y} = 1$ when variable $X2_{p1,p2,j,s,m,y} > 0$

$O_{w,m,y} = 1$ when work order w is assigned in month m year y

3.2.2 *Formulation*

The formulation of an objective function is shown in (2.1) and restricted constraints are shown in (2.2)-(2.13):

Objective function:

$$\text{Minimize } \mu,\ \mu \geq 0 \tag{2.1}$$

The objective function in (2.1) is to minimize the total number of personnel in each position who need to go to work offshore in each month of the year.

The constraints in (2.2)-(2.11) with the explanation are expressed as follows:

$$\sum_{s \in S} \sum_{j \in J} \sum_{p \in P} X1_{p,\,j,\,s,\,m,\,y} + \sum_{p1,p2,j,s \in \Lambda} X2_{p1,\,p2,\,j,\,s,\,m,\,y} \leq \mu, \forall m, \forall y \tag{2.2}$$

Constraints (2.2) enforce μ to be the largest value among number of personnel all month in a year. That means μ act as an upper bound for the number of personnel in every month of a year.

$$\sum_{y \in Y} \sum_{m \in M} [X1_{p,\,j,\,s,\,m,\,y} + \sum_{p1,p2,j,s \in \Lambda} X2_{p1,\,p2,\,j,\,s,\,m,\,y}] \geq R_{j,\,p}, \forall p, \forall j, \forall s \tag{2.3}$$

Constraints (2.3) state the number of required personnel for position p under job plan j in every month should be less than or equal to the summation of personnel (both personnel who is capable of one skill and two skills) who are assigned in position p under job plan j station s.

$$\sum_{y\in Y}\sum_{m\in M}\sum_{p\in P}X3_{p,j,s,m,y}+\sum_{y\in Y}\sum_{m\in M}\sum_{p2\in P}\sum_{p1\in P}X4_{p,j,s,m,y}\leq \pi_{j,s},\forall j,\forall s \qquad (2.4)$$

Constraints (2.4) ensure that the summation of assignment ,binary decision variables : $X3_{p,j,s,m,y}$ and $X4_{p,j,s,m,y}$, should not be more than the maximum number of the work orders under job plan j station s.

$$\sum_{p\in P}X1_{p,j,s,m,y}+\sum_{p1,p2,j,s\in\Lambda}X2_{p1,p2,j,s,m,y}\leq 0,\forall(j,s,m)\in Typhoon \qquad (2.5)$$

Constraints (2.5) ensure that personnel are not assigned to work on a particular work orders which are based on remote platform (station 2) during typhoon season in October through December.

$$C*X3_{p,j,s,m,y}-X1_{p,j,s,m,y}\geq 0,\forall p,\forall j,\forall s,\forall m,\forall y \qquad (2.6)$$

Constraints (2.6) is $C*X3_{p,j,s,m,y}$ - $X1_{p,j,s,m,y}$ when $C > X1_{p,j,s,m,y}$ which is the relationship between $X1_{p,j,s,m,y}$ and $X3_{p,j,s,m,y}$ where C is a large number that $X1_{p,j,s,m,y}$ is never be reached and $X3_{p,j,s,m,y}$ is a binary variable value.

$$\sum_{j\in J}\sum_{p\in P}\sum_{s\in S}\beta_{j,p}*X3_{p,j,s,m,y}\leq\psi,\forall m,\forall y \qquad (2.7.1)$$

Constraints (2.7.1) ensure the man hour of each individual position not exceed working hour in each month of a year for one skill personnel.

$$\sum_{j\in J}\sum_{p2\in P}\sum_{p1\in P}\sum_{s\in S}\beta_{j,p1}*X4_{p1,p2,j,s,m,y}+\sum_{j\in J}\sum_{p2\in P}\sum_{p1\in P}\sum_{s\in S}\beta_{j,p2}*X4_{p1,p2,j,s,m,y}\leq\psi,\forall m,\forall y \qquad (2.7.2)$$

Constraints (2.7.2) ensure the man hour of each individual position not exceed working hour in each month of a year for both case of two skills personnel.

$$\sum_{p\in P}\beta_{j,p}*X3_{p,j,s,m,y}\leq d_j,\forall j,\forall s,\forall m,\forall y \qquad (2.8.1)$$

Constraints (2.8.1) ensure the total man hour in work order should be less than the duration of the work order w under job plan j (determines the completed job plan, the total man hours must be less than its duration) for one-skilled personnel.

$$\sum_{p1,p2,j,s\in\Lambda}\beta_{j,p1}*X4_{p1,p2,j,s,m,y}+\sum_{p1,p2,j,s\in\Lambda}\beta_{j,p2}*X4_{p1,p2,j,s,m,y}\leq d_j,\forall j,\forall s,\forall m,\forall y \qquad (2.8.2)$$

Constraints (2.8.2) ensure the total man hour in work order should be less than the duration of the work order w under job plan j. (the total man hours must be less than its duration) for two-skilled personnel.

$$\sum_{w,p\in\Omega}[X1_{p,j,s,m,y} + \sum_{p1,p2,j,s\in\Lambda} X2_{p1,p2,j,s,m,y}] \geq \sum_{w\in W\subset\Omega} O_{w,m,y}, \forall j, \forall s, \forall m, \forall y \qquad (2.9)$$

Constraints (2.9) state the numbers of one-skilled personnel combined with the summation of two-skilled personnel should not be less than the total number of work orders in each month in a year.

$$\sum_{y\in Y}\sum_{m\in M}\sum_{p\in P} X3_{p,j,s,m,y} + \sum_{y\in Y}\sum_{m\in M}\sum_{p2\in P}\sum_{p1\in P} X4_{p1,p2,j,s,m,y} \geq \gamma_{j,s}, \forall j, \forall s \qquad (2.10)$$

Constraints (2.10) ensure that the summation of binary decision variables $X3_{p,j,s,m,y}$ and $X4_{p1,p2,j,s,m,y}$ is not more than the total number of the work orders under job plan *j* station *s* which is $\gamma_{j,s}$.

$$\sum_{w\in W\subset\Omega} 1 = \gamma_{j,s}, \forall j, \forall s \qquad (2.11)$$

Constraints (2.11) count the number of assigned work orders under job plan j station s in Ω.

$$\sum_{y\in Y}\sum_{m\in M} O_{w,m,y} = 1, \forall w \qquad (2.12)$$

Constraints (2.12) count the number of work orders in each month of a year.

$$\sum_{s\in V}[X1_{p,j,s,m,y} + \sum_{p1,p2,j,s\in\Lambda} X2_{p1,p2,j,s,m,y}] \leq G_p, \forall j, p\in\alpha, \forall m, \forall y \qquad (2.13)$$

Constraints (2.13) enforce the number of personnel in position p, job plan j in each month should not be more than the maximum number of available personnel in each position.

In this chapter, we showed the mathematical programming formulation that we extracted from the real problem. We separate the model into two main problems which are original offshore assignment problem and multi-skilled offshore assignment problem.

CHAPTER IV

EXPERIMENTAL RESULTS AND NUMERICAL COMPUTATIONAL

4.1 Experimental Results

4.1.1 Original Offshore Assignment Experimental Results

The computational time used is 133.6 seconds and memory used is 635.6 Mb. Figure 4.1 compares the experimental results using MILP model with the original data of the number of personnel in each month of a year. Figure 4.2 compares the experimental result using MILP model with the original data of the number of position type in each month of a year.

4.1.2 Comparison Results

The graph denoted by Figure 4.1 and Figure 4.2 show that the experimental results provide a smoother line than the original data – in other words, after applying the MILP model the workload at offshore platform received improved leveling.

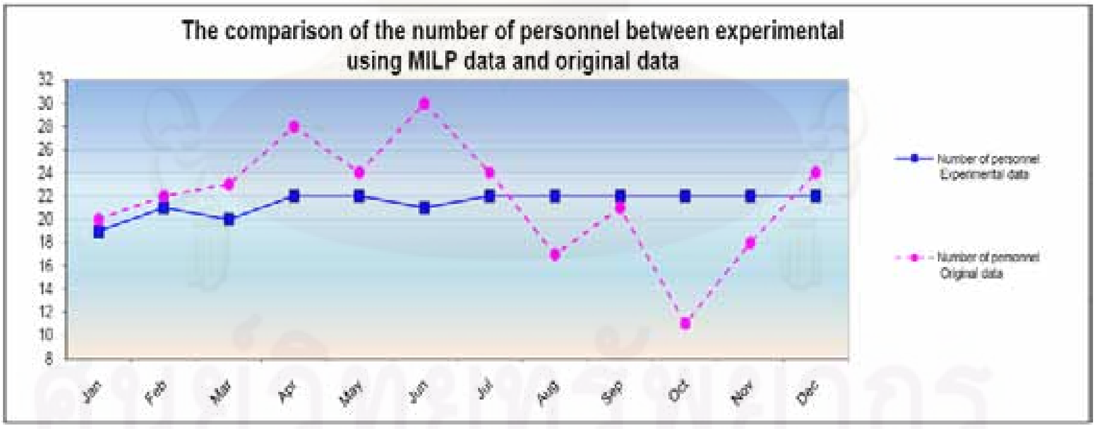

Figure 4.1 : The comparison experimental result using MILP model with the original data of the number of personnel in each month.

Figure 4.1 compares the experimental result using MILP model with the original data of the number of personnel in each month of a year. The dashed line represents the original data set and the solid line represents the experimental result using MILP model. X-axis denotes the number of personnel and Y-axis denotes months in a year.

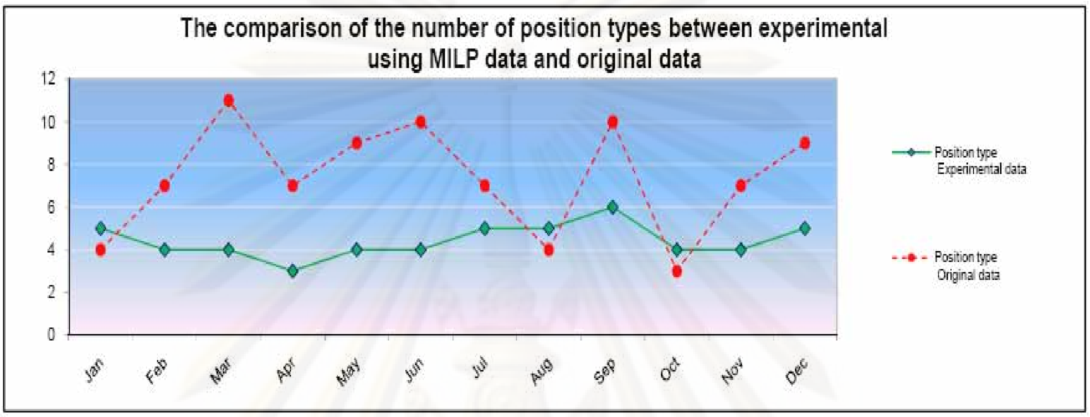

Figure 4.2 : The comparison experimental result using MILP model with the original data of the number of position types in each month.

Figure 4.2 compares the experimental result using MILP model with the original data of the number of position types in each month of a year. The dashed line and solid line represent the original data set and the experimental result using MILP model, respectively. X-axis denotes the number of position type and Y-axis denotes months in a year.

4.2.1 Offshore Multi-skilled Assignment Experimental Results

We compare the experimental result with various options in MILP solver as follows: (1) No option; (2) mipgap option; (3) mipgap + bfs; (4) mipgap + dfs. The result shows that the mipgap option is a good option because it extremely reduces the time used, memory used and iterations. But there is no difference in the result from other setting (bfs /dfs) with the mipgap, For example, the no option takes, approximately, more than 1,024,000 seconds, over 2,000 megabytes memory used, and more than 53,664,000 iterations. But with the mipgap, the time used is reduced approximately to

860 seconds, 173 megabytes in memory used and about 43,721 iterations in order to find the result. Moreover, Figure 4.3 compares the experimental results using the MILP model and original data of personnel number in each month of a year.

4.2.2 Comparison Results

The graph denoted by Figure 4.3 shows an improving experimental line which is smoother than the original line.

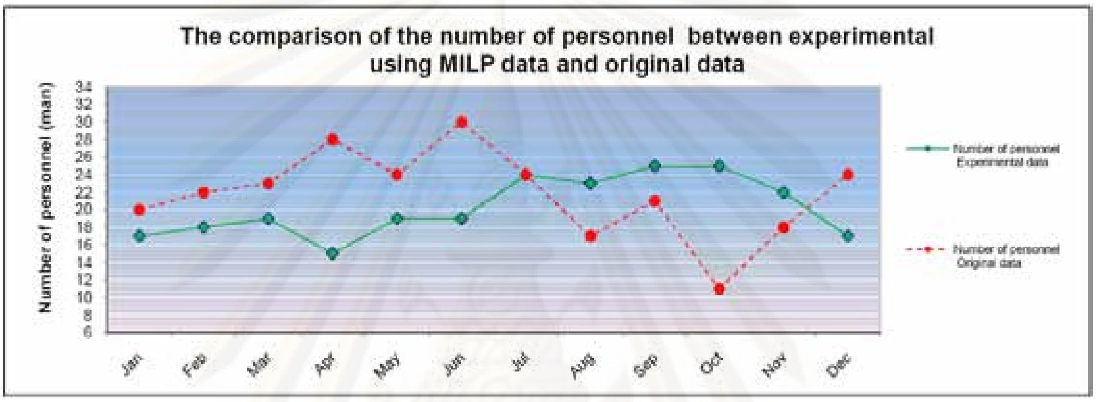

Figure 4.3 : The comparison multi-skilled experimental result using MILP model with the original data of the number of personnel in each month.

Figure 4.3, the dashed line represents the original data and the solid line represents experimental results. The X-axis and Y-axis denote the number of personnel and each month of the year, respectively. This figure shows the resulted line is an improvement over the original line.

In this chapter, we present the experimental results after applying the MILP model to both the original offshore assignment problem (refer to the formulation 1.1-1.11 in chapter 3) and the multi-skilled offshore assignment problem (refer to the formulation 2.1-2.13 in chapter 3). Our experimental results give the better solution for leveling and minimizing the offshore personnel number as shown in Figures 4.1 and 4.3, and also for the number of position types shown in Figure 4.2. We have found that MILP is a good technique for finding optimal solution in a feasible region which is the region of possible solutions satisfied by all constraints. The performance of is based on the following reason. MILP solver first generates the possible solutions which satisfying each constraint and, then, seeks for the optimal solution satisfying all constraints.

Due to the combinatorial nature of the problems, we then further determine the nearly optimal solution by additionally using mipgap. Mipgap option is helpful in reducing time used because it cuts down the number of iterations. The tolerance is set as the gap between the best integer objective and the objective of the remaining best node. The mixed integer optimization is stopped when this difference falls below the value of the mipgap parameter.

CHAPTER V

CONCLUSION

The discussion on workload leveling problem on offshore platform both original and multi-skilled model are studied. These problems appear in the literatures from several main ideas: workload leveling assignment problems, scheduling problems and resource allocation problems. There are numerous literatures of multi-skilled personnel assignment and scheduling. But this study has focused on the multi-skilled personnel assignment and scheduling maintenance and inspection offshore work order planning. Most attention has been paid to automate the traditional assignment and scheduling. After formulating the problem using a mathematical model, the MILP solver, from GLPK via GUSEK is used in order to find the optimal solution. Our experiment shows that MILP model can level the number of personnel while taking all constraints into account. Hence, it is proved to be an efficiency model in order to find the optimal solution for workload leveling on offshore platform in Thai petroleum company. The experiment shows that the MILP model using branch and cut technique can be minimizing and leveling the number of personnel who need to go to work on offshore platform in a month of a year.

The problem of multi-skilled personnel assignments at offshore platforms is also studied in this dissertation. We have represented the formulation which improves from original version for solving such a problem. A GLPK solver is used to find the optimal solution after formulating the problem in a mathematical model. We experimented by adding some options into the MILP solver and found that the mipgap option is very helpful in order to get the result less than an hour. The experiment also shows that the MILP model using branch and cut technique can minimize the number of personnel while taking all constraints into account. Therefore, they are proved to be extremely useful tools for offshore inspection and maintenance work orders assignment for planning engineers when taking multi-skilled personnel into account. It is faster and less cumbersome in planning process.

Therefore, our models have proven to be more useful tools in finding the optimal solutions for workload leveling problems found in the gas and oil operation field in Thailand.

We encourage other researchers to take more offshore factors into an account such as equipment, platform location, individual personnel and inspection or maintenance due date for each equipment etc. for the future work.

REFERENCES

[1] Cox, S., and Cheyne, A. 2000. Assessing safety culture in offshore environments. Safety Science 34 : 111-129.

[2] Rasche, T. 2001. Development of a safety case methodology for the minerals industry-a discussion paper. Minerals Industry Safety and Health Centre (MISHC),The University of Queensland: 1-17.

[3] Jones, K., and Collis S.1996. Computerize Maintenance Management Systems. Property Management 14 : 33-37.

[4] Wartmann, M.,Gunnerud, V., Foss, B., and Ydstie, B. 2008. Distributed Optimization and Control of Offshore Oil Production: The Intelligent Platform. Proceedings FOCAPO.

[5] Haugen, K. 1996. A Stochastic Dynamic Programming model for scheduling of offshore petroleum fields with resource uncertainty. European Journal of Operational Research 88 : 88-100.

[6] Huang, L. 2005. Solution of the unequal of workers and tasks assignment problem with restriction of qualification. Proceedings of Fourth International Conference on Machine Learning and Cybernatics, pp.1297-1301.

[7] Frankola, T., Golub, M., and Jakobovic, D. 2008. Evolutionary Algorithm for the Resource Constrained Scheduling Problem. Proceedings ITI 2008 30th International Conference on Information Technology Interfaces, pp.295-298.

[8] Dekker, R.1996. Applications of maintenance optimization models:a review and analysis. Reliability Engineering and System Safety 51 : 229-240.

[9] Pardalos, P., Romeijn, H., and Tuy, H. 2000. Recent developments and trends in global optimization. Journal of Computational and Applied Mathematics 124 : 209-228.

[10] Haung, H., Lee C., and Xu Z. 2006. The workload balancing problem at air cargo terminals. OR spectrum 28 : 705-727.

[11] Zeghal, F., and Minoux, M.1995. Modeling and Solving a Crew Assignment Problem in air transportation. European Journal of Operational Research 175 : 187-209.

[12] Shen, M.,Tzeng, G., and Liu, D. 2003. Multi-Criteria Task Assignment in Workflow Management Systems. Proceedings of the 36th Hawaii International Conference on System Sciences, pp.202-210.

[13] Li, H., and Womer, K. 2009. Scheduling projects with multi-skilled personnel by a hybrid MILP/CP benders decomposition algorithm. Journal of scheduling 12 : 281-298.

[14] Emil, E., Ormeci, E., and Salman, F. 2007. Shift scheduling in call centers with multiple skill sets and transportation costs. IEEE International Conference on Service Operations and Logistics, and Informatics.

[15] Cesani, V., and Steudel, H. 2005. A study of labor assignment flexibility in cellular manufacturing system. computer & industrial engineering 48 : 571-591.

[16] Peters, E., Matta, R., and Boe, W. 2007. Short-term work scheduling with job assignment flexibility for multi-fleet transport system. European Journal of Operational Research 180 : 82-98.

[17] Campbell, G. 1999. Cross-Utilization of Workers Whose Capabilities Differ. MANAGEMENT SCIENCE 45 : 722-732.

[18] Campbell, G., and Diaby, M. 2002. Development and evaluation of an assignment heuristic for allocating cross-trained workers. European Journal of Operational Research 138 : 9-20.

[19] Conejo, A.J., Castillo, E., Minguez, R., and Garcia-Bertrand, R. 2006. Decomposition Techniques in Mathematical Programming: Engineering and Science Applications. First edition. Springer.

[20] Rardin, L.R. 1997. Optimization in Operations Research. First edition. Prentice Hall.

[21] Pentico, W. D. 2007. Assignment problems: A golden anniversary survey. European Journal of Operational Research 176 : 774-793.

[22] Jolevski , I., Loskovska, S., Chorbev, I., Mihajlov, D., and Murgovski, N. 2005. Constraints Modeling of the High School Scheduling Problem. Proceedings of EUROCON 2005 - The International Conference on "Computer as a Tool".

[23] Chen, K.,Liu, A., and Lee, L. C. 2003. A Multiprocessor Real-Time Process Scheduling Method. Proceedings of IEEE Fifth International Symposium on

Multimedia Software Engineering, pp.29-36.

[24] Zhu, Y.,Hu, Y., ,Wu, H., and Nakaiwa, M. 2003. An improved Branch-and-Cut Algorithm for mixed –integer nonlinear systems optimization problem. AIChE journal 54 : 3239-3247.

[25] Ricardo, F., Jens, L., Marcus, P., Marcelo, R., Eduardo, U., and Renato, F. W. 2003. Robust branch-and-cut-and-price for the capacitated vehicle routing problem. Proceedings of the International Network Optimization Conference, pp.231-236.

[26] Makhorin, A., and Bettoni, L. 2009. GUSEK(GLPK Under Scite Extended Kit) [free software program]. LASCA, CPGEI, UTFPR, Curitiba, Brazil : http://gusek.sourceforge.net, Copyright © 2000 – 2009.

APPENDIX

The appendix presents the input data that are used in our experiment in specific format for GUSEK programming.

```
param Nmonth := 12;                                // define number of month
param Nyear := 1;                                  // define number of year

set JobPlan := JP1,JP2,JP3,JP4,JP5,JP6,JP7,JP8,JP9,JP10,JP11,
               JP12,JP13,JP14,JP15,JP16,JP17,JP18,JP19,JP20,
               JP21,JP22,JP23,JP24,JP25,JP26,JP27,JP28,JP29,
               JP30,JP31,JP32,JP33,JP34,JP35,JP36,JP37,JP38,
               JP39,JP40;                          // define set of JP

set  WorkOrder := 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,
                  21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,
                  38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,
                  55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70;
                                                   // define set of WO

set Station := 1, 2;          // platform type when1 is complex and 2 is remote

set Position := BN_IP_SUPV,CON_CON,BN_ME_SUPV,BN_OP_PD,
                TBF_SAFT_OFF,ME_CON,IT,CON_ENG_IP,IP_CON_DC,
                IP_CON_PC,IP_ENG_SKG,IP_ENG_BKK;     // define set of position

set JP_ST_WO :=  (JP31,1,1),(JP20,1,2),(JP20,1,3),(JP20,1,4),(JP16,1,5),
                 (JP16,1,6),(JP15,1,7),(JP30,1,8),(JP28,1,9),(JP28,1,10),
                 (JP28,1,11),(JP28,1,12),(JP28,1,13),(JP19,1,14),(JP19,1,15),
                 (JP21,1,16),(JP21,1,17),(JP28,1,18),(JP28,1,19),(JP28,1,20),
                 (JP28,1,21),(JP6,1,22),(JP19,1,23),(JP19,1,24),(JP19,2,25),
                 (JP33,1,26),(JP33,1,27),(JP33,1,28),(JP33,1,29),(JP33,1,30),
```

(JP33,1,31),(JP33,2,32),(JP33,2,33),(JP33,2,34),(JP28,1,35),
(JP13,1,36),(JP26,1,37),(JP27,1,38),(JP27,1,39),(JP26,1,40),
(JP8,1,41),(JP9,2,42),(JP38,2,43),(JP9,2,44),(JP19,2,45),
(JP19,2,46),(JP9,2,47),(JP38,2,48),(JP9,2,49),(JP9,2,50),
(JP38,2,51),(JP35,2,52),(JP9,2,53),(JP9,2,54),(JP2,2,55),
(JP28,1,56),(JP8,2,57),(JP19,2,58),(JP19,2,59),(JP19,2,60),
(JP26,1,61),(JP2,2,62),(JP8,2,63),(JP19,2,64),(JP19,2,65),
(JP19,2,66),(JP13,2,67),(JP19,1,68),(JP19,1,69),(JP3,1,70);
// define set of Ω

set JP_ST_ExcludeMonth := (JP13,2,10),(JP13,2,11),(JP13,2,12),(JP14,2,10),
(JP14, 2,11),(JP14,2,12),(JP18,2,10),(JP18,2,11),
(JP18,2,12),(JP19,2,10),(JP19,2,11),(JP19,2,12),
(JP2,2,10),(JP2,2,11),(JP2,2,12),(JP26,2,10),
(JP26,2,11),(JP26,2,12),(JP28,2,10),(JP28,2,11),
(JP28,2,12),(JP3,2,10),(JP3,2,11),(JP3,2,12),
(JP32,2,10),(JP32,2,11),(JP32,2,12),(JP33,2,10),
(JP33,2,11),(JP33,2,12),(JP35,2,10),(JP35,2,11),
(JP35,2,12),(JP36,2,10),(JP36,2,11),(JP36,2,12),
(JP38,2,10),(JP38,2,11),(JP38,2,12),(JP4,2,10),
(JP4,2,11),(JP4,2,12),(JP7,2,10),(JP7,2,11),
(JP7,2,12),(JP8,2,10),(JP8,2,11),(JP8,2,12),
(JP9,2,10),(JP9,2,11),(JP9,2,12); *// define set of Typhoon*

set JP_PO := (JP1,BN_IP_SUPV),(JP1,IP_CON_DC),(JP2,BN_IP_SUPV),
(JP2,IP_CON_DC),(JP3,BN_IP_SUPV),(JP3,IP_ENG_SKG),
(JP3,CON_ENG_IP),(JP4,BN_IP_SUPV),(JP4,IP_CON_DC),
(JP4,CON_CON),(JP5,BN_IP_SUPV),(JP5,IP_CON_DC),
(JP5,CON_CON),(JP6,BN_IP_SUPV),(JP6,IP_CON_DC),
(JP7,BN_IP_SUPV),(JP7,TBF_SAFT_OFF),(JP7,BN_OP_PD),

(JP8,BN_IP_SUPV),(JP8,CON_CON),(JP9,BN_IP_SUPV),
(JP9,IP_CON_DC),(JP9,CON_CON),(JP10,BN_IP_SUPV),
(JP10,IP_CON_DC),(JP10,CON_CON),(JP11,BN_IP_SUPV),
(JP11,IP_CON_DC),(JP11,CON_CON),(JP12,BN_IP_SUPV),
(JP12,IP_CON_DC),(JP12,CON_CON),(JP13,BN_IP_SUPV),
(JP13,IP_CON_DC),(JP14,BN_IP_SUPV),(JP14,CON_ENG_IP),
(JP14,IP_CON_PC),(JP15,BN_IP_SUPV),(JP15,IP_CON_DC),
(JP15,CON_CON),(JP16,BN_IP_SUPV),(JP16,IP_CON_DC),
(JP16,CON_CON),(JP17,BN_IP_SUPV),(JP17,IP_CON_DC),
(JP17,CON_CON),(JP18,BN_IP_SUPV),(JP18,IP_CON_PC),
(JP18,IP_ENG_SKG),(JP18,CON_ENG_IP),(JP19,BN_IP_SUPV),
(JP19,CON_CON),(JP20,BN_IP_SUPV),(JP20,IP_CON_DC),
(JP20,CON_CON),(JP21,BN_IP_SUPV),(JP21,IP_CON_DC),
(JP21,CON_CON),(JP22,BN_IP_SUPV),(JP22,IP_CON_DC),
(JP22,CON_CON),(JP23,BN_IP_SUPV),(JP23,IP_CON_DC),
(JP23,CON_CON),(JP24,BN_IP_SUPV),(JP24,IP_CON_DC),
(JP24,CON_CON),(JP25,BN_IP_SUPV),(JP25,IP_CON_DC),
(JP25,CON_CON),(JP26,BN_IP_SUPV),(JP26,IP_CON_DC),
(JP26,CON_CON),(JP27,BN_IP_SUPV),(JP27,IP_CON_DC),
(JP27,CON_CON),(JP28,BN_IP_SUPV),(JP28,IP_CON_DC),
(JP28,CON_CON),(JP29,BN_IP_SUPV),(JP29,IP_CON_DC),
(JP29,CON_CON),(JP30,BN_IP_SUPV),(JP30,IP_CON_DC),
(JP30,CON_CON),(JP31,BN_IP_SUPV),(JP31,IP_CON_DC),
(JP31,CON_CON),(JP32,BN_IP_SUPV),(JP32,BN_OP_PD),
(JP32,TBF_SAFT_OFF),(JP32,ME_CON),(JP33,IT),(JP33,CON_CON),
(JP33,IP_CON_DC),(JP34,BN_IP_SUPV),(JP34,IP_CON_DC),
(JP34,BN_ME_SUPV),(JP34,ME_CON),(JP34,BN_OP_PD),
(JP34,TBF_SAFT_OFF),(JP35,BN_IP_SUPV),(JP35,IP_CON_DC),
(JP35,BN_ME_SUPV),(JP35,ME_CON),(JP35,BN_OP_PD),
(JP35,TBF_SAFT_OFF),(JP36,BN_IP_SUPV),(JP36,IP_ENG_BKK),

(JP36,BN_OP_PD),(JP36,IP_CON_DC),(JP37,BN_IP_SUPV),
(JP37,IP_CON_DC),(JP37,BN_ME_SUPV),(JP37,ME_CON),
(JP37,BN_OP_PD),(JP37,TBF_SAFT_OFF),(JP38,BN_IP_SUPV),
(JP38,IP_CON_DC),(JP38,BN_ME_SUPV),(JP38,ME_CON),
(JP38,BN_OP_PD),(JP38,TBF_SAFT_OFF),(JP39,BN_IP_SUPV),
(JP39,IP_CON_DC),(JP39,BN_ME_SUPV),(JP39,ME_CON),
(JP39,BN_OP_PD),(JP39,TBF_SAFT_OFF),(JP40,BN_IP_SUPV),
(JP40,IP_CON_DC),(JP40,BN_ME_SUPV),(JP40,ME_CON),
(JP40,BN_OP_PD),(JP40,TBF_SAFT_OFF); *//define* $\alpha_{j,p}$ *set*

param workSpecific := [JP1,1] 2,[JP2,2] 6,[JP3,1] 20,[JP3,2] 68,[JP4,2] 3 ,
[JP5,1] 1, [JP6,1] 3,[JP7,1] 1,[JP8,1] 4,[JP8,2] 15,
[JP9,2] 7,[JP10,1] 3,[JP11,1] 2,[JP12,1] 2,
[JP13,1] 44,[JP13,2] 93,[JP14,1] 7,[JP14,2] 18,
[JP15,1] 17,[JP16,1] 2,[JP17,1] 1, [JP18,1] 9,
[JP18,2] 38,[JP19,1] 13,[JP19,2] 30,[JP20,1] 3,
[JP21,1] 2,[JP22,1] 12, [JP23,1] 1,[JP24,1] 1,[JP25,1] 1,
[JP26,1] 7,[JP27,1] 5,[JP28,1] 29,[JP29,1] 1,[JP30,1] 2,
[JP31,1] 1,[JP32,2] 1,[JP33,1] 6,[JP33,2] 23,[JP34,1] 4,
[JP35,1] 7,[JP35,2] 2,[JP36,2] 6,[JP37,1] 1,[JP38,1] 17,
[JP38,2] 4,[JP39,1] 1,[JP40,1] 1; *// define set of* $\gamma_{j,s}$

param duration := JP1 0.00277777777777778, JP2 0.00277777777777778,
JP3 0.00277777777777778, JP4 0.00277777777777778,
JP5 0.00297619047619048, JP6 0.00416666666666667,
JP7 0.00416666666666667, JP8 0.00416666666666667,
JP9 0.00416666666666667, JP10 0.00416666666666667,
JP11 0.00416666666666667, JP12 0.00416666666666667,
JP13 0.00416666666666667, JP14 0.00416666666666667,
JP15 0.00416666666666667, JP16 0.00416666666666667,

```
JP17 0.00416666666666667, JP18 0.00416666666666667,
JP19 0.00416666666666667, JP20 0.00416666666666667,
JP21 0.00416666666666667, JP22 0.00416666666666667,
JP23 0.00416666666666667, JP24 0.00416666666666667,
JP25 0.00416666666666667, JP26 0.00416666666666667,
JP27 0.00416666666666667, JP28 0.00416666666666667,
JP29 0.00416666666666667, JP30 0.00416666666666667,
JP31 0.00416666666666667, JP32 0.00416666666666667,
JP33 0.00416666666666667, JP34 0.00416666666666667,
JP35 0.00416666666666667, JP36 0.00416666666666667,
JP37 0.00416666666666667, JP38 0.00416666666666667,
JP39 0.00416666666666667, JP40 0.00416666666666667;
                // operational duration for complete the job

param maxPosition :=  BN_IP_SUPV 6,CON_CON 12,BN_ME_SUPV 6,
                      BN_OP_PD 4, TBF_SAFT_OFF 4, ME_CON 12,
                      IT 4, CON_ENG_IP 2, IP_CON_DC 6, IP_CON_PC 4,
                      IP_ENG_SKG 2, IP_ENG_BKK 4;
                      // maximum number of available position (G_p)

param requiredPosition:= [JP1,BN_IP_SUPV] 1, [JP1,IP_CON_DC] 1,
         [JP2,BN_IP_SUPV ]  1, [JP2,IP_CON_DC] 2,  [JP3,BN_IP_SUPV]1,
         [JP3,IP_ENG_SKG] 1,[JP3,CON_ENG_IP   ]  1, [JP4,BN_IP_SUPV] 1,
          [JP4,IP_CON_DC] 2, [JP4,CON_CON] 4, [JP5,BN_IP_SUPV] 1,
         [JP5,IP_CON_DC] 2, [JP5,CON_CON] 2, [JP6,BN_IP_SUPV] 1,
         [JP6,IP_CON_DC] 3,  [JP7,BN_IP_SUPV] 1, [JP7,TBF_SAFT_OFF] 1,
         [JP7,BN_OP_PD] 1, [JP8,BN_IP_SUPV]1, [JP8,CON_CON] 4,
         [JP9,BN_IP_SUPV] 1, [JP9,IP_CON_DC] 2, [JP9,CON_CON] 4,
         [JP10,BN_IP_SUPV] 1, [JP10,IP_CON_DC] 2, [JP10,CON_CON] 4,
```

[JP11,BN_IP_SUPV]1, [JP11,IP_CON_DC] 2, [JP11,CON_CON] 4, [JP12,BN_IP_SUPV] 1, [JP12,IP_CON_DC] 2, [JP12,CON_CON] 2, [JP13,BN_IP_SUPV] 1,[JP13,IP_CON_DC] 1, [JP14,BN_IP_SUPV] 1, [JP14,CON_ENG_IP] 1, [JP14,IP_CON_PC] 1, [JP15,BN_IP_SUPV] 1, [JP15, IP_CON_DC] 1, [JP15,CON_CON] 3, [JP16,BN_IP_SUPV] 1, [JP16,IP_CON_DC] 2, [JP16,CON_CON] 4, [JP17,BN_IP_SUPV] 1, [JP17,IP_CON_DC] 2, [JP17,CON_CON] 4, [JP18,BN_IP_SUPV] 1, [JP18,IP_CON_PC] 2, [JP18,IP_ENG_SKG]1, [JP18,CON_ENG_IP] 1, [JP19,BN_IP_SUPV] 1, [JP19,CON_CON] 4, [JP20,BN_IP_SUPV] 1, [JP20,IP_CON_DC] 2, [JP20,CON_CON] 4, [JP21,BN_IP_SUPV] 1, [JP21,IP_CON_DC] 2, [JP21,CON_CON] 2, [JP22,BN_IP_SUPV] 1, [JP22,IP_CON_DC] 2, [JP22,CON_CON] 4, [JP23,BN_IP_SUPV] 1, [JP23,IP_CON_DC] 2, [JP23,CON_CON] 3, [JP24,BN_IP_SUPV] 1, [JP24,IP_CON_DC] 5, [JP24,CON_CON] 4, [JP25,BN_IP_SUPV] 1, [JP25,IP_CON_DC] 1, [JP25,CON_CON] 4, [JP26,BN_IP_SUPV] 1, [JP26,IP_CON_DC] 2, [JP26,CON_CON] 4, [JP27,BN_IP_SUPV] 1, [JP27,IP_CON_DC] 1, [JP27,CON_CON] 3, [JP28,BN_IP_SUPV] 1, [JP28,IP_CON_DC] 2, [JP28,CON_CON] 4, [JP29,BN_IP_SUPV] 1, [JP29,IP_CON_DC] 2, [JP29,CON_CON] 4, [JP30,BN_IP_SUPV] 1, [JP30,IP_CON_DC] 1, [JP30,CON_CON] 3, [JP31,BN_IP_SUPV] 1, [JP31,IP_CON_DC] 1, [JP31,CON_CON] 3, [JP32,BN_IP_SUPV] 1, [JP32,BN_OP_PD] 2, [JP32,TBF_SAFT_OFF] 1, [JP32,ME_CON] 3, [JP33,IT] 2, [JP33,CON_CON] 3, [JP33,IP_CON_DC] 3, [JP34,BN_IP_SUPV] 1, [JP34,IP_CON_DC] 2, [JP34,BN_ME_SUPV] 1, [JP34,ME_CON] 4,[JP34,BN_OP_PD] 2, [JP34,TBF_SAFT_OFF] 1, [JP35,BN_IP_SUPV] 1, [JP35,IP_CON_DC] 2, [JP35,BN_ME_SUPV] 1, [JP35,ME_CON] 4, [JP35,BN_OP_PD] 2, [JP35,TBF_SAFT_OFF] 1, [JP36,BN_IP_SUPV] 1, [JP36,IP_ENG_BKK] 2, [JP36,BN_OP_PD] 2, [JP36,IP_CON_DC] 2,[JP37,BN_IP_SUPV] 1, [JP37,IP_CON_DC] 2,

[JP37,BN_ME_SUPV] 1, [JP37,ME_CON] 4, [JP37,BN_OP_PD] 2,
[JP37,TBF_SAFT_OFF] 1, [JP38,BN_IP_SUPV] 1, [JP38,IP_CON_DC] 2,
[JP38,BN_ME_SUPV] 1, [JP38,ME_CON] 4, [JP38,BN_OP_PD] 2,
[JP38,TBF_SAFT_OFF] 1,[JP39,BN_IP_SUPV] 1, [JP39,IP_CON_DC] 2,
[JP39,BN_ME_SUPV] 1,[JP39,ME_CON] 4, [JP39,BN_OP_PD] 2,
[JP39,TBF_SAFT_OFF] 1,[JP40,BN_IP_SUPV] 1, [JP40,IP_CON_DC] 2,
[JP40,BN_ME_SUPV] 1, [JP40,ME_CON] 4, [JP40,BN_OP_PD] 2,
[JP40,TBF_SAFT_OFF] 1;

// number of required position in each JP

param manHr := [JP1,BN_IP_SUPV] 0.00138888888888889,
[JP1,IP_CON_DC] 0.00138888888888889, [JP2,BN_IP_SUPV] 0.00138888888888889,
[JP2,IP_CON_DC] 0.00138888888888889, [JP3,BN_IP_SUPV] 0.000694444444444444,
[JP3,IP_ENG_SKG] 0.000694444444444444,
[JP3,CON_ENG_IP] 0.00277777777777778, [JP4,BN_IP_SUPV] 0.00138888888888889,
[JP4,IP_CON_DC] 0.00138888888888889, [JP4,CON_CON] 0.0138888888888889,
[JP5,BN_IP_SUPV] 0.00138888888888889, [JP5,IP_CON_DC] 0.000694444444444444,
[JP5,CON_CON] 0.00138888888888889, [JP6,BN_IP_SUPV] 0.00208333333333333,
[JP6,IP_CON_DC] 0.00416666666666667, [JP7,BN_IP_SUPV] 0.00208333333333333,
[JP7,TBF_SAFT_OFF] 0.000694444444444444,
[JP7,BN_OP_PD] 0.00277777777777778,
[JP8,BN_IP_SUPV] 0.00277777777777778, [JP8,CON_CON] 0.0138888888888889,
[JP9,BN_IP_SUPV]0.00138888888888889, [JP9,IP_CON_DC] 0.00138888888888889,
[JP9,CON_CON] 0.00277777777777778, [JP10,BN_IP_SUPV]0.00138888888888889,
[JP10,IP_CON_DC] 0.00138888888888889, [JP10,CON_CON] 0.00555555555555555,
[JP11,BN_IP_SUPV]0.00138888888888889, [JP11,IP_CON_DC]0.00138888888888889,
[JP11,CON_CON] 0.0037037037037037, [JP12,BN_IP_SUPV] 0.00138888888888889,
[JP12,IP_CON_DC] 0.00138888888888889, [JP12,CON_CON] 0.00555555555555555,
[JP13,BN_IP_SUPV]0.00104166666666667, [JP13,IP_CON_DC] 0.00833333333333333,
[JP14,BN_IP_SUPV] 0.000694444444444444,

[JP14,CON_ENG_IP] 0.00694444444444444,

[JP14,IP_CON_PC] 0.00277777777777778, [JP15,BN_IP_SUPV] 0.00277777777777778,

[JP15,IP_CON_DC]0.00208333333333333, [JP15,CON_CON] 0.00694444444444444,

[JP16,BN_IP_SUPV] 0.00138888888888889, [JP16,IP_CON_DC]0.00138888888888889,

[JP16,CON_CON] 0.00833333333333333, [JP17,BN_IP_SUPV] 0.00138888888888889,

[JP17,IP_CON_DC] 0.00138888888888889, [JP17,CON_CON] 0.00972222222222222,

[JP18,BN_IP_SUPV] 0.000694444444444444, [JP18,IP_CON_PC] 0.0083333333333333,

[JP18,IP_ENG_SKG] 0.0125, [JP18,CON_ENG_IP] 0.00972222222222222,

[JP19,BN_IP_SUPV] 0.00277777777777778, [JP19,CON_CON] 0.0138888888888889,

[JP20,BN_IP_SUPV]0.00138888888888889, [JP20,IP_CON_DC] 0.00138888888888889,

[JP20,CON_CON] 0.0138888888888889, [JP21,BN_IP_SUPV] 0.00138888888888889,

[JP21,IP_CON_DC] 0.00138888888888889, [JP21,CON_CON] 0.0138888888888889,

[JP22,BN_IP_SUPV]0.00138888888888889, [JP22,IP_CON_DC] 0.00138888888888889,

[JP22,CON_CON] 0.0138888888888889, [JP23,BN_IP_SUPV]0.00138888888888889,

[JP23,IP_CON_DC] 0.00138888888888889, [JP23,CON_CON] 0.0138888888888889,

[JP24,BN_IP_SUPV]0.00138888888888889, [JP24,IP_CON_DC] 0.00138888888888889,

[JP24,CON_CON] 0.0138888888888889, [JP25,BN_IP_SUPV]0.00138888888888889,

[JP25,IP_CON_DC] 0.00138888888888889, [JP25,CON_CON] 0.0138888888888889,

[JP26,BN_IP_SUPV]0.00138888888888889, [JP26,IP_CON_DC] 0.00138888888888889,

[JP26,CON_CON] 0.0138888888888889, [JP27,BN_IP_SUPV]0.00138888888888889,

[JP27,IP_CON_DC] 0.00138888888888889, [JP27,CON_CON] 0.0152777777777778,

[JP28,BN_IP_SUPV]0.00138888888888889,[JP28,IP_CON_DC] 0.00416666666666667,

[JP28,CON_CON] 0.0166666666666667,[JP29,BN_IP_SUPV] 0.00138888888888889,

[JP29,IP_CON_DC] 0.00138888888888889, [JP29,CON_CON] 0.0194444444444444,

[JP30,BN_IP_SUPV]0.00138888888888889,[JP30,IP_CON_DC] 0.00277777777777778,

[JP30,CON_CON] 0.0236111111111111,[JP31,BN_IP_SUPV] 0.00555555555555555,

[JP31,IP_CON_DC] 0.00138888888888889, [JP31,CON_CON] 0.0263888888888889,

[JP32,BN_IP_SUPV]0.00555555555555555,[JP32,BN_OP_PD] 0.0138888888888889,

[JP32,TBF_SAFT_OFF] 0.00277777777777778,[JP32,ME_CON] 0.0236111111111111, [JP33,IT] 0.00277777777777778, [JP33,CON_CON] 0.0388888888888889,

[JP33,IP_CON_DC] 0.00462962962962963, [JP34,BN_IP_SUPV] 0.0013888888888889,

[JP34,IP_CON_DC] 0.00833333333333333, [JP34,BN_ME_SUPV] 0.009722222222222,

[JP34,ME_CON] 0.0291666666666667,

[JP34,BN_OP_PD]0.0236111111111111,[JP34,TBF_SAFT_OFF] 0.00138888888888889,

[JP35,BN_IP_SUPV] 0.00555555555555555,[JP35,IP_CON_DC]0.00277777777777778,

[JP35,BN_ME_SUPV] 0.00694444444444444, [JP35,ME_CON] 0.025,

[JP35,BN_OP_PD] 0.0236111111111111, [JP35,TBF_SAFT_OFF] 0.00277777777777778,

[JP36,BN_IP_SUPV] 0.000694444444444444,

[JP36,IP_ENG_BKK] 0.00416666666666667,   [JP36,BN_OP_PD] 0.05,

[JP36,IP_CON_DC] 0.025, [JP37,BN_IP_SUPV] 0.00416666666666667,

[JP37,IP_CON_DC] 0.025, [JP37,BN_ME_SUPV] 0.0277777777777778,

[JP37,ME_CON] 0.0555555555555556, [JP37,BN_OP_PD] 0.0263888888888889,

[JP37,TBF_SAFT_OFF] 0.00277777777777778,

[JP38,BN_IP_SUPV] 0.00138888888888889,

[JP38,IP_CON_DC] 0.00138888888888889,

[JP38,BN_ME_SUPV] 0.00277777777777778,

[JP38,ME_CON] 0.0583333333333333, [JP38,BN_OP_PD] 0.0236111111111111,

[JP38,TBF_SAFT_OFF] 0.00277777777777778,

[JP39,BN_IP_SUPV] 0.00416666666666667,

[JP39,IP_CON_DC] 0.00833333333333333,

[JP39,BN_ME_SUPV] 0.0277777777777778,[JP39,ME_CON] 0.101388888888889,

[JP39,BN_OP_PD] 0.0291666666666667,

[JP39,TBF_SAFT_OFF] 0.00277777777777778,

[JP40,BN_IP_SUPV] 0.00416666666666667,

[JP40,IP_CON_DC] 0.00833333333333333, [JP40,BN_ME_SUPV] 0.0486111111111111,

[JP40,ME_CON] 0.143055555555556, [JP40,BN_OP_PD] 0.0305555555555556,

[JP40,TBF_SAFT_OFF] 0.00138888888888889;

// man hour of required position in each JP(working hour per person)

VITAE

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