DUE DATE ASSIGNMENT SYSTEM FOR AUTO BODY REPAIR AND PAINT SERVICE

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วิทยานิพนธ์นี้มีวัตถุประสงค์เพื่อพัฒนาระบบสารสนเทศใช้ในการกำหนดวันนัดหมายรับรถยนต์สำหรับการบริการซ่อมตัวถังและสีรถยนต์ของบริษัทกรณีศึกษา นอกจากจะได้ช่วยให้กำหนดวันนัดหมายรถยนต์ที่แม่นยำมากขึ้น ระบบนี้ยังช่วยให้การทำงานบริการมีประสิทธิภาพมากยิ่งขึ้น ส่งผลดีต่อความพึงพอใจของลูกค้าที่เข้ารับบริการ

หลักการทำงานในการซ่อมตัวถังและสีรถยนต์มีความสำคัญเป็นอย่างมากในการพัฒนาระบบการนัดหมายรถยนต์ ข้อมูลและความรู้ทางเทคนิคได้รวบรวมมาจากผู้เชี่ยวชาญและกระบวนการทำงานในปัจจุบันของการซ่อมตัวถังและสีรถยนต์ นโยบายที่เหมาะสมสำหรับการกำหนดวันนัดรับรถยนต์จะประกอบไปด้วยวิธีการกำหนดวันนัดรับและวิธีการจัดลำดับรถเข้าซ่อม ซึ่งหลักการดังกล่าวจำเป็นเพื่อใช้ในการคำนวณวันนัดรับรถยนต์ที่แม่นยำมากยิ่งขึ้น

ผลที่ได้รับจากวิทยานิพนธ์นี้คือระบบสารสนเทศสำหรับการกำหนดวันนัดหมายรถยนต์ซึ่งพัฒนาโดยเว็บเทคโนโลยี ระบบดังกล่าวประกอบไปด้วยนโยบายในการกำหนดวันนัดรับรถยนต์ที่ได้มาตรฐานและโมดูลในการคำนวณวันนัดรับรถยนต์ที่มีประสิทธิภาพ ข้อมูลที่นำมาใช้ในการพัฒนาระบบเป็นข้อมูลทางสถิติของบริษัทกรณีศึกษา

ประโยชน์สำคัญที่ได้รับจากระบบสารสนเทศนี้ได้แก่ การกำหนดวันนัดรับรถยนต์ได้แม่นยำมากขึ้น มีมาตรฐานและนโยบายที่ชัดเจนในการกำหนดวันนัดรับรถยนต์ มีวิธีการจัดการรถที่เข้ารับบริการที่มีประสิทธิภาพ อีกทั้งยังสามารถติดตามและควบคุมรถยนต์ที่มีอยู่ในระบบได้ดีขึ้น

จากการทดลองระบบสารสนเทศที่พัฒนาขึ้น พบว่าการกำหนดวันนัดรับรถยนต์แม่นยำขึ้น ปริมาณงานที่ซ่อมเสร็จหลังจากวันนัดรับรถยนต์มีจำนวนลดลง ในขณะเดียวกันสามารถส่งมอบรถยนต์ได้ตรงเวลามากขึ้น ส่งผลโดยตรงต่อความพึงพอใจของลูกค้า กระบวนการควบคุมและตรวจสอบสถานะรถยนต์ในระบบที่มีประสิทธิภาพมากขึ้น สามารถแจ้งเตือนลูกค้าได้ทันเวลาในกรณีที่ส่งผลกระทบต่อวันนัดรับรถยนต์

ภาควิชา ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต ลายมือชื่อนิสิต .....

สาขาวิชา การจัดการทางวิศวกรรม ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

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The purpose of this thesis is to design and develop an information system for supporting in due date assignment for auto body repair and paint service. It will help to estimate more accurate due date given to customers at their arrival time. Moreover, operation management will be more efficient and effective that can lead to customer satisfaction. Know-how of auto body repair and paint processes is the most necessary to be firstly considered. The policy of due date is then formulated consisting of due date assignment rule and sequencing rule. These rules are used for estimating due date and standardizing job order in processes.

The outcome from this thesis is web-based information system which includes due date assignment policy, data processing modules and monitoring and controlling platform. Major advantages gained from due date assignment system include more accurate due date given to customers, standard due date management policy, better operation management, and the ability to monitor and control jobs within processes.

For system evaluation, it is found that due date assignment system helps reducing the number of tardy job by providing more accurate due date. The ability to on-time delivery considerably increases. More efficient tracking and controlling jobs within processes help reducing impacts from unexpected problems affecting promised due date. The problems will be instantly notified to customers. It definitely leads to better service reliability and customer satisfaction.

Department: Regional Centre for Manufacturing Systems Engineering
Student's Signature .....
Advisor's Signature .....
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1 Introduction

1.1 Introduction

Nowadays, most businesses are encountering with fierce competition. There are many issues that need to be considered such as dramatic changes in demand, increasing of potential competitors, and lack of capabilities for gaining customer satisfaction. In case of auto body repair and paint service business, the number of car usage in Thailand extremely increases over a past few years as shown in Figure 1-1. Due to populism policy of Thai government in 2012 called “First-car-buyer project”, every customer is able to refund tax from first car buying. This policy probably leads to higher demand in auto maintenance and repair service business. Meanwhile, there are many newcomers entering into this market segment consecutively.

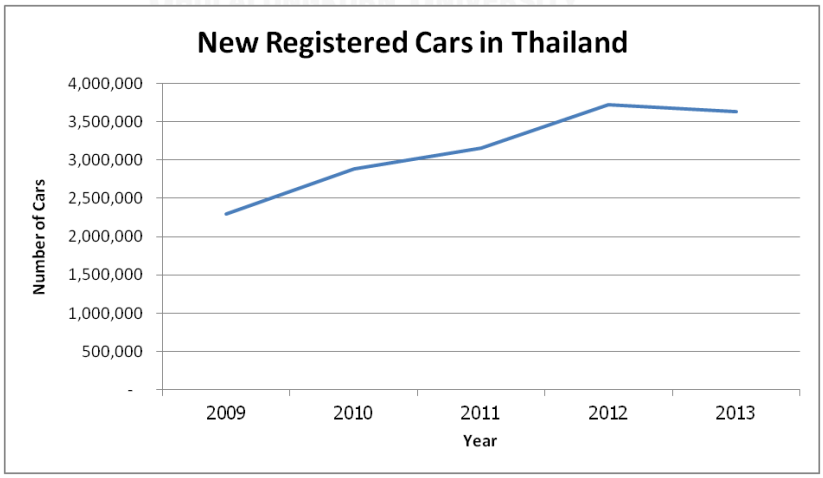

Figure 1-1 The number of new registered cars in Thailand between 2009 and 2013.

Reference: (Planning Division, Department of Land Transport, 2014)

Consequently, various service businesses in automobile industry are trying to continually improve their service level in order to satisfy customer needs and achieve long-term growth. Regarding to(Golding 2013), the professional survey was conducted to realise what is the most important things to customers in term of service. The result is shown as in Figure 1-2. The top three customer expectations from service are value of money, customer service, and service reliability. Since the inability of keeping promises is a key driver to customer dissatisfaction, organization has to do as saying to customers. Otherwise, it will affect on the relationships with customers. Moreover, customers always look for satisfying experiences including knowledgeable employees, quick information access, and the ability to understand needs on first contact. Companies that can provide these characteristics will win their loyalty.

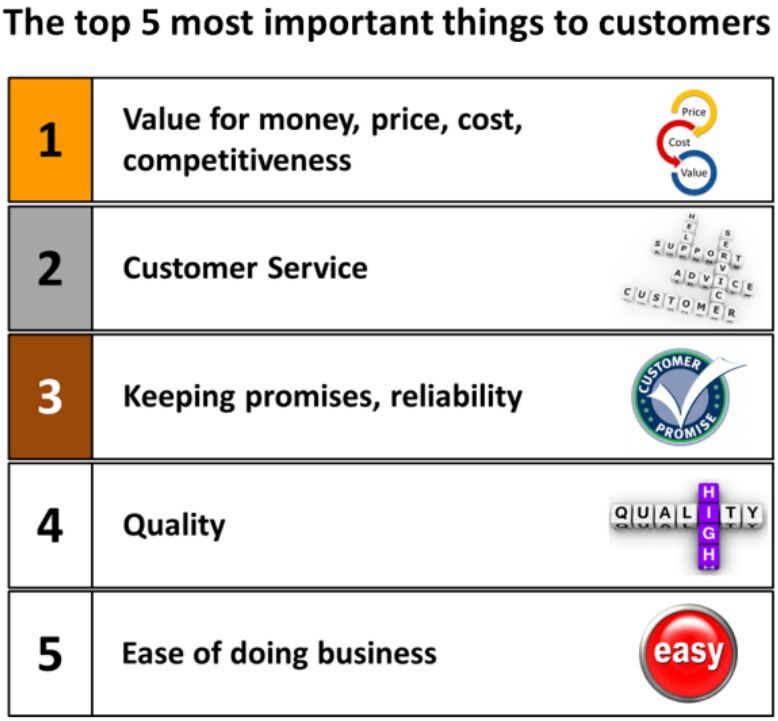

Figure 1-2 Top fives of what customer wants. Reprinted from(Golding 2013).

The case company in this research is medium-sized auto body repair and paint service company. It headquarters in Chonburi province where the area is a famous industry district in Thailand. It was established since 1980 as a family business. The case company provides integrated auto body repair and paint service including body dent repair, panel repair, painting, and polishing. The business also makes a contract with several insurance companies who will transfer broken cars to the case company.

The overview of operation of the case company is shown as Figure 1-3. Firstly, customers who need car painting service contact a receptionist at front to ask for inspecting their broken cars from specialists. The list of car repair jobs is considerably created concurrent with price quotation typically called “Job order” (JO). After quotation and JO approval, specialist will estimate a due date based on repair price and severity level to customers. Then, this job order will be input into auto body repair and paint processes. There are total eight processes including removal of parts, body dent repair, panel repair, primer spraying, car painting, assembling parts, polishing, and car wash. All processes are clearly a sequential process which iteration is not allowed. The job order will be successfully completed through quality control at the end of all processes. The inspectors will examine the quality of each repaired job. Finally, the finished car will be delivered to customers on promised due date.

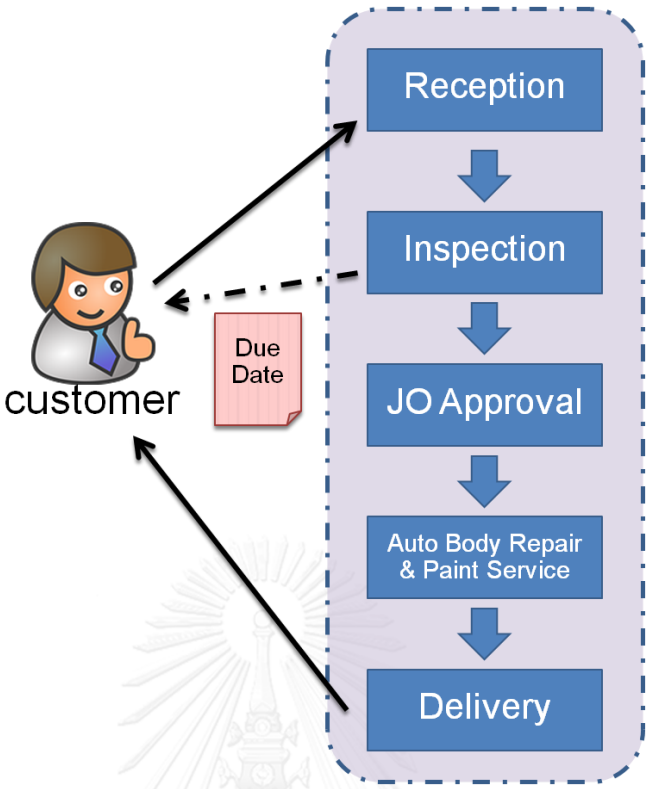

Figure 1-3 The overview operational workflow of the case company.

However, in order to compete in service business and gain competitive advantages, it is not only operations, service quality and human resource that need to be continually improved; using of information technology for supporting all operations to work efficiently is also vital.

This research will develop web-based information system to support decision making on due date to customers. The implementation of the system can provide the case company better service reliability and service quality in term of ability of keeping promises. It can definitely lead to customer satisfaction and loyalty.

1.2 Problem Statement

After gathering data and interviewing with a managing director of the case company, major problem that directly affects the overall service performance is overdue date for delivering finished cars to customers. Since quick response and reliable service are the most significant to service business, inconsistent and inaccurate due date definitely affect customer dissatisfaction and low loyalty level. The possible causes for overdue date problem are considered to be inefficient due date assignment policy resulting in variation of due date and inefficient job monitor and control.

Firstly, the case company lacks of appropriate due date assignment policy. Due date assignment policy will provide an appointment date to customers at their arrival time. At present, due date is roughly estimated by inspectors or senior experts. Each inspector may assign different due date to the same customers because it is based on their skills and former experiences. Moreover, sequencing policy for selecting each job in a process is usually randomness. As a result, the case company is not able to deliver job orders on time. Most jobs are finished later than their promised date. Since each job has different required processes that depended on its damaged parts and severity level, processing time of a job is totally different from the others. Moreover, existing job orders in the system are major factor to directly affect the total service time of a new arrival job due to limited service resources. These factors are needed to be considered for making decision on due date to customers. Therefore, efficient due

date assignment policy is fully required for better service reliability. In Figure 1-4, the overall service performance of the case company can be represented as the percentage of tardy job, early job, and on-time job. There are only 27% of on-time job. Whereas tardy job is approximately 55% of total job gathered from year 2012 to 2013.

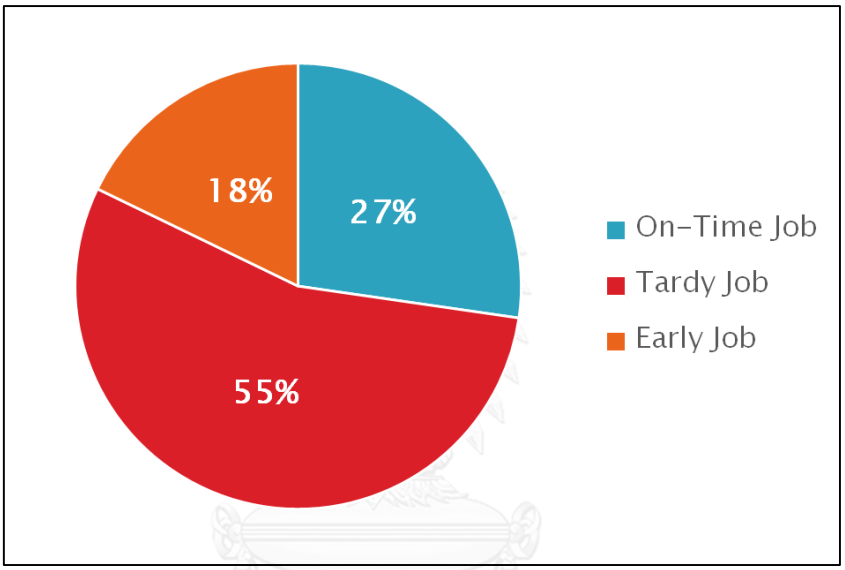

Figure 1-4 The overall service performance of the case company

Furthermore, since current due date given to customers is estimated by senior workers who are responsible for damage inspection. There may be human error and emotional bias due to different level of experiences.

Figure 1-5 shows examples of inconsistent due date assignment to customers with the same severity of damage inspection.

Job No.	Severity	Price (THB)	Arrival Date	Due Date	Due-date Lead Time (days)	Finished Date	Lead Time (days)
1	L	4,250.00	3/3/2014	15/3/2014	12	20/3/2014	17
2	L	3,506.25	1/4/2014	11/4/2014	10	23/4/2014	22
3	M	22,199.80	30/10/2012	20/11/2012	21	8/12/2012	39
4	M	15,587.30	4/1/2014	30/1/2014	26	20/1/2014	16
5	H	31,489.10	19/4/2013	31/5/2013	42	26/5/2013	37
6	H	50,616.65	26/3/2012	30/4/2012	36	20/4/2012	25

Figure 1-5 Examples of inconsistent due date assignment of the case company

It is obviously seen that due date setting cannot provide a consistent due date which nearly close to their actual lead time in the service. For instance, the cars with medium severity level are roughly assigned a due date within 20-30 days after arrival date. In fact, job no.3 had a late due date with 39 days service lead time, whereas job no.4 which has due date setting as 26 days could be finished before due date with only 16 days actual service lead time.

Secondly, the problem for monitor and control is that the planning time of a job order can be unrealized by operation supervisor and reception. When customers need to follow up their jobs, receptionists can give only information of what current status of their jobs. Information of expected finish time of job is not able to be responded. Some job that has some problem and needs more time than initial plan will be not foreknown. As a result, customers cannot be notified instantly by the case company.

In order to standardize due date assignment and support job monitoring and controlling, IT system is important to efficiently provide more accurate and consistent due date. It also leads to quick service and better performance to an increasing of customers because it will help to manage operation by processing a lot of data, and

visualizing in many aspects based on business purposes. IT system can avoid the variation of due date assignment by providing steady processing of data and standard output. It also rapidly visualizes some useful data used to monitor and control existing jobs in the service. Therefore, IT system for supporting due date assignment is necessary for the case company.

1.3 Objective

The objective of this research is to develop due date assignment system for auto body repair and paint service. Due date assignment system refers to web-based information system used to support assigning more accurate due date to customers. It includes due date management policy, data processing modules, and monitoring and controlling platform.

1.4 Scope and Limitations

1.4.1 Scope

The study focuses on problem solving of overdue delivery date of the case company by developing due date assignment system. Due date assignment system refers to IT support system used to help assigning an efficient due date to customers. Input of the system is job information and system information such as damaged parts, severity level, and existing cars in the system. Output will be a due date given to customers at their arrival time and the action plan of a job that can indicate start and end time of

each required process. Due date assignment system is developed by using web-based information system with user interface. The historical data from 2012 to 2013 used to support due date assignment system includes job information, part name, severity level, arrival time, service time in every process, finish time, and promised due date. For developing of due date assignment system, the current operational processes will be firstly analysed to identify processing time for low and medium severity level. The due date assignment policy will be developed corresponding to current processes. The improved due date assignment system will be measured its performance comparing to current due date assignment policy by simulation study.

1.4.2 Limitations

1. The working time of company ABC is eight hours per day, five days per week, and no overtime working allowed.
2. The research will focus on the low and medium severity level of damaged cars.
3. There are eight sequential processes that can be skipped. Iterative processes are not allowed.
4. Transit time between processes and preparation time are assumed to be null.
5. All job orders are assumed that there are no defects.
6. Each server within the same process is assumed to have same performance
7. There are no job interruption between processes

1.5 Methodology

1. Review current operational processes and workflow of auto body repair and paint service.
2. Identify the problems regarding due date management policy after interviewing with managing director of the case company.
3. Literature review on the relevant theories; auto body repair and paint processes, due date management policy, web-based information system, and simulation tools and techniques.
4. Gathering historical data of operational processes; for examples, arrival date of jobs, start and end time for each job order, service time for each process, and the number of processes required for each job order.
5. Identify due date assignment policy that are corresponding to current operational processes.
6. Analyze the gathered data to analyze and identify data structure of service time standard for every process.
7. Identify waiting time calculation model with sequencing order that is the most suitable for current operational processes.
8. Implement web-based information system by using due date assignment policy model.

9. Simulate new due date assignment policy comparing to current due date assignment policy in the virtual service system environments by using simulation tools.
10. Measure and analyze the simulation results.
11. Conclude the outcome.
12. Thesis completion

1.6 Expected Benefits

1. Due date assignment system for auto body repair and paint service in order to assign more reliable job delivery date to customers at their arrival time.
2. Efficiency of monitor and control for all job orders within the service.
3. Improving the ability of keeping promises and customer satisfaction.
4. Providing the framework of due date assignment policy development for similar service businesses.

2 Literature Review

This chapter will describe the related theories in the research. Firstly, the concept of due date management is generally discussed including scheduling policy and due date setting rules for both static and dynamic model. Second section will explain an auto body repair and paint service with major factors for severity inspection. Moreover, the processes used for body repair and paint are totally described. Then, the queue theory is discussed in term of queue definition, typical elements of queuing system, and also queuing disciplines. By the end of this chapter, web-based information system which is considered to be used for developing due date appointment system is presented.

2.1 Due Date Management (DDM)

In order to gain advantages over competitors in the rapid growth of marketplace, most companies are trying to differentiate themselves by providing more values to their customers. Customer satisfaction is considered to be a major indicator for measuring service performance. To sustain long-term satisfaction, service reliability is important including the ability to do as promised to the customers.

2.1.1 Definition of due date management

According to(Keskinocak and Tayur 2004), due date management (DDM) mainly considers quoting a due date to customers. Realizable due date is vital for customer confidence especially business to business customers because it needs to use due

date for various internal purposes such as operation planning. Moreover, lead time in due date management which is defined as due-date lead time (DDLT) typically refers to the length of time between a promised delivery date and job's arrival time to the system. Most companies apply due date management policy for DDLT minimization and service level maximization. In general, due date management policy consists of due date setting rule and a priority sequencing rule denoted by D-S, where D is due date setting rule and S is sequencing rule respectively.

Regarding to(Chun Wang, Ghenniwa et al. 2011), due date management is considered in timely manner on when an order can be fulfilled profitably. DDM involves various types of decisions; pricing, order acceptance or demand management, due date setting, and scheduling. In typical, customer demand can be related to the market price and delivery time. In the other word, customer demand will usually increase with lower prices and shorter delivery times. DDM plays an important role for conducting strategy over market competition. There are three competition strategies including quick service with minimal wait, uniform lead time guarantee, and due date quotation. First strategy aims to serve customers as fast as possible with lower waiting time. Second strategy will promise a lead time guarantee to customers. Meanwhile, third strategy tries to provide a due date before servicing as the quoted due date can be calculated based on the schedule of accepted job orders in the system. This strategy is an integration of due-date quotation and scheduling decision.

2.1.2 Characteristics of Due Date Management

There are three main aspects of due date management including decisions, modeling dimensions, and the objectives.

- Due Date Management Decisions

  Due date management policy is needed to be critically determined in order to provide the most suitable due date for both customers and the business. The decisions in DDM focus on order acceptance or customer demand, due date setting, and scheduling. Due date setting and scheduling are considered sequentially where due date rule are first set before determining job order scheduling. In term of order acceptance or customer demand, quoted price and delivery times are major factors for making DDM decisions. In reality, the quoted due date can obviously influence customers willing to the service. Customers usually expect to receive fast service as well as lower price. Service business that can promise a due date to customers as fast as possible can gain more competitive advantages in the marketplace. However, DDM decisions can be limited depended on each business industry, for example, mail and telephone service within 3-5 days.

- Dimensions of Due Date Management

There are many dimensions that can distinguish due date management based on the system; manufacturing or service business. These dimensions can directly affect setting of DDM mathematical model.

Offline vs. Online: all information such as job arrival times and processing times are properly available for scheduling on an offline system. In contrast, online system refers to the system that has uncertain arrival times. The information about job order is available at a time of its arrivals. In general, an online system that has to make decision about due date immediately at arrival times is called stringent. In addition, an online system with lookahead refers to the system that can wait before due date quoting. However, there is usually penalty for this delay.

Single vs. Multiple servers: for single server system, one resource is needed to consider for serving to customers. In contrast, there are many available resources for multiple servers system that are used for modeling due date management. Moreover, multiple servers system can be categorized into identical and non-identical multiple servers. In case of non-identical multiple servers; each job will be sequentially processed in different machine groups called job shop. Meanwhile, the sequence of operations is always the same for each job called flow shop.

Stochastic vs. Deterministic processing times: the processing times are clearly unknown; hence, it typically applies probability distribution to estimate

mean and variance of each processing time. For deterministic processing times, standard time is usually considered to identify processing times.

Setup times/costs: an inter-procedure time called transition time may be occurred when changing each job order. However, it is a little bit of time during operation. Current researches of DDM usually ignore the setup and transition times.

Server reliability: in general, the maximum capacity of resources is probably known during operation planning. There may be some random situation due to machine breakdown.

Single vs. Multiple classes of job order: there may be various kinds of job order based on demand characteristics such as different processing times and operation requirements.

Service level constraints: most service businesses are commonly needed to identify service level constraints at the planning process in order to measure their service performance. The major indicators are clearly defined based on their organizational goals and strategies; for examples, the percentage of finished orders after their due date, the average tardiness, the average earliness and the average order processing time.

Common and Distinct due date: common due date refers to a due date that all job orders in the system will receive the same due date. In the other words, companies guarantee same due date to every customer based on class

of customer. For distinct due date, each job order has different due date. The company can quote due date by considering job order information including processing time required and existing job order in the system.

- Objectives of Due Date Management

The important decisions of due date management mainly focus on due date setting rule and scheduling policy. These decisions have obviously some conflict as due date typically needs to be set as tight as possible, whereas it seems to be more difficult for operation scheduling with short due date lead time. Therefore, two approaches are proposed to solve this conflict. Firstly, objective function integrates both decision of due date setting and scheduling policy, for examples, the weighted sum of earliness, tardiness, and also lead times where these weights can represent the relevant between short lead times and efficient due date. Second approach is to consider the objective of one decision and make a constraint to another decision. For example, the first objective aims to achieve service level constraint and then try to set due date as tight as possible with this constraint.

In addition, the objective of DDM is commonly to minimize these factors as following:

- External measures of customer service

- Average lateness; standard deviation of lateness, sum of the square of lateness, mean absolute lateness

  Lateness is usually used to measure reliability of quoted due date such as the accuracy of due date. More efficient due date can attract newcomers and sustain customer loyalty. Furthermore, standard deviation of lateness can lead to a precision of due date by measuring the magnitude of digression from quoted due date.

- Average tardiness; number or percentage of tardy jobs, maximum tardiness, conditional mean tardiness

  Minimizing tardiness and the number (or percentage) of tardy jobs can definitely increase the reputation and goodwill for customer service. Some penalty cost can be occurred due to delays. Moreover, since the product of number of tardy jobs and conditional mean tardiness is equal to the average tardiness, these two measures can better represent system performance than considering only average tardiness.

- Average earliness; number or percentage of early jobs

  Minimizing earliness is important for reducing holding cost such as inventories and other cost that can be occurred if jobs finish before their due date. There may be lost opportunities for customer satisfaction

because a due date with shorter lead time can be quoted to customers instead. It can lead to gain more competitive advantages.

- Average/total (weighted) due date (based on service level constraints)
- Total (weighted) earliness and tardiness
- Total (weighted) earliness, tardiness, and lead times

- Internal measures of the operation (shop floor)
  - Average queue length; waiting time, flow time, standard deviation of flow time, number of unfinished jobs (WIP), total processing times of unfinished jobs (CWIP), variance of queue length of all processes.

    WIP is used to measure congestion in the system. Moreover, when investment in a finished job is the proportional to the completed processing times, CWIP is commonly used to measure the average investment in work-in-process inventory.

Additionally, the performance of due date management policy is mainly based on due date setting and sequencing decisions. Objective functions are major factors for developing due date management policy. However, there are both direct and indirect impacts for making any decision that needs to be considered. For example, objective function is to minimize lateness or tardiness; direct impact is the type of due date setting rule and its parameters that can provide a tight due date as possible, for indirect one, due date will play an important role in the operation planning including

dispatching and labor assignment rules. Most companies are trying to select the most suitable objective function for DDM policy which can meet their business goals. For example, although some DDM policy is able to achieve the zero average of lateness, other measures may represent approximately 50% of early jobs and 50% of tardy jobs. Since cost of earliness is less than tardiness, objective function which is to minimize lateness is inefficient and not appropriate for this company. Therefore, the highest impact on performance depends on the defined objective function (measure of performance), chosen DDM policy and parameters, service level constraints, and system conditions.

2.1.3 Scheduling Policies in Due Date Management

Due to major components of DDM; scheduling and due date setting, most researches highly focus on an effective sequence of decision making among these two components. The two-step approaches for DDM policies are purposed which are to assign due date first and then plan a schedule by using priority dispatch policy. However, prior quoted due date seems to be difficult to handle when unexpected scheduling problem occurs. In reality, it properly needs to consider both due date setting and scheduling decision simultaneously.

A priority dispatching rule/policy is determined for every job that is waiting to be processed in the system. The job that has higher priority will be processed before job

with less value of priority. The priority dispatching rules of DDM policies are summarized as Table 2-1.

Table 2-1 The priority dispatching rules of DDM policies. Reprinted from (Keskinocak & Tayur, 2004)

Policy	Priority value
RANDOM	β_j ~Uniform[0,1]
First come first serve (FCFS, FCFS$_o$)	r_j (or r_{jo})
Shortest processing time (SPT, SPT$_o$)	p_j (or p_{jo})
Least remaining operation time (LROT)	$\sum_{o \in U_{jt}} p_{jo}$)
LROT/NOP	$\sum_{o \in U_{jt}} p_{jo}/\lvert U_j \rvert$
Truncated SPT (SPTT)	p_{jo}, if $W_{jo} < \alpha\ \forall o$ in queue; W_{jo}, otherwise
Weighted SPT (WSPT)	$w_j p_{jo}$
Longest processing time (LPT, LPT$_o$)	$1/p_j$ (or $1/p_{jo}$)
Truncated LPT (LPTT)	$1/p_{jo}$, if $W_{jo} < \alpha\ \forall o$ in queue; W_{jo}, otherwise
Earliest finish time (EFT)	$r_j + p_j$
Earliest due date (EDD, EDD$_o$)	d_j (or d_{jo})
Slack (SLK, SLK$_o$)	$d_j - t - \sum_{o \in U_{jt}} p_{jo} - \alpha$, $d_{jo} - t - p_{jo}$
SLK'	Put jobs with SLK$\leq$ 0 into a priority queue and SLK$>$ 0 into a normal queue. Apply SPT to each queue.
SLK/P	$(d_j - t - \sum_{o \in U_{jt}} p_{jo}) / \sum_{o \in U_{jt}} p_{jo})$
SLK/OPN	$(d_j - t - \sum_{o \in U_{jt}} p_{jo})/g_j$
SLK/RAT	$(d_j - t - \sum_{o \in U_{jt}} p_{jo})/(d_j - t)$
COVERT	c_j/p_{jo}, where $c_j = 0$, if the job is ahead of schedule; $c_j = 1$, if the job has no slack; and $c_j = \bar{c}_j$, otherwise, where $\bar{c}_j$ is the proportion of the job's planned waiting time that has been consumed
Critical ratio (CR, CR$_o$)	$(d_j - t)/\sum_{o \in U_{jt}} p_{jo}$, $(d_{jo} - t)/p_{jo}$
R/OPN	$(d_j - t)/g_j$
Modified Due Date (MDD, MDD$_o$)	$\max\{d_j, t + p_j\}$, $\max\{d_{jo}, t + p_{jo}\}$
Earliest operation due date (OPNDD)	$r_j + (d_j - r_j)(o/g_j)$
P+S/OPN	$\alpha p_{jo} + (1-\alpha)\frac{d_j - t - \sum_{i=o}^{g_j} p_{ji}}{(g_j - o + 1)^\beta}$

According to Table 2-1, RANDOM and FCFS (first come first serve) refers to the sequencing rules that require only the arrival time of job to assign priority value. Other

sequencing rules that use more information of operations required of the jobs are SPT (shortest processing time), LPT (longest processing time), LROT/NOP, EFT (earliest finish time), and WSPT (weighted short processing time). Furthermore, there are sequencing rules that focus more on due date such as EDD (Earliest due date), SLK (slack), and MDD (modified due date). In practice, most service organizations widely use the due date based rule; EDD as sequencing rule for their DDM policy. Meanwhile, other rules are mainly used only in the researches due to their complexity.

In addition, sequencing rules can be classified as static and dynamic rule. Static sequencing rule refers to a rule that its priority value of a job does not change until the end of processes; e.g. SPT and EDD. In contrast, priority value can probably change while job in the system called dynamic sequencing rule such as SLK. Some sequencing rule is considered to be parametric because there are parameter α and β in computation model. These parameters found by simulation approach have direct effects on the performance of DDM policies. However, the chosen parameters are effective and efficient enough usually based on system environment factors.

To conclude, there are many factors that can influence the performance of sequencing rules including due date setting rules, the objective functions, the tightness of due date, workload of the system. The sequencing rule significantly affects on the performance of due date setting rule under system workload consideration. Moreover, the sequencing rule probably has major impacts on system with high variability of flow

times. Because variability of the system is quite low, the company is able to estimate the flow times efficiently that can lead to quote more precise due date.

2.1.4 Due Date Management Setting Rules

Due date setting rule that is an important part for DDM policies can be categorized into two models; offline and online models. Firstly, offline model refer to the system that has arrival times and processing time at the beginning of scheduling planning. In contrast, online model cannot realize the information of job including job's class and its processing time. All job information will be available at the arrival time which is also unknown in advance.

2.1.4.1 Offline Models

Offline or static models can be classified into two types based on their order arrival times which are equal and distinct order arrival times.

2.1.4.2 Equal order arrival times

Due date setting rule that all jobs will be assigned a common due date (d) is abbreviated as CON. This rule is used to joint common due date and sequence. In case of objective functions or measures, the general form of earliness (E), tardiness (T), and the due date (d) are properly formulated as the following function:

$$\sum j \; \beta_j \, E_j^a + \gamma_j T_j^b + \alpha_j d \quad \text{;where a = b = 1}$$

For general form of common due date, parameter a and b are set value to be one. All the jobs before job; j are considered to be early finished jobs, whereas jobs after j are called tardy jobs. The Table 2-2 shows the due date setting rules which are widely used in real world practice and many research studies

Table 2-2 Examples of due date setting rules. Reprinted from (Keskinocak & Tayur, 2004)

Policy	Flow allowance
RND	$\alpha\beta_j$, β_j ~Uniform[0,1]
CON	α
SLK	$p_j + \alpha$
TWK	αp_j
TWK′	$\alpha(p_j)^{\beta}$
NOP	αg_j
TWK+NOP	$\alpha p_j + \beta g_j$
BN	$\max\{d_{j-1} - r_j\} + \alpha_j p_j$
JIQ	$\alpha p_j + \beta Q_j$, where Q_j is the number of jobs waiting to be processed ahead of job j
JIS	$\alpha p_j + \beta WIS_j$, where WIS_j is the total number of jobs waiting to be processed in the system at time r_j
WIQ	$\alpha p_j + \beta WIQ_j$, where WIQ_j is the total processing time of the jobs waiting to be processed ahead of job j
WINS	$\alpha WINS$, where WINS is the sum of processing times of all the jobs currently in the system
TWKCP	$\alpha TWKCP$, where TWKCP is the sum of all operation times on the critical path of the BOM

FRY-ADD1	$\alpha TWKCP + \beta WINS$
FRY-ADD2	$\alpha p_j + \beta WINS$
FRY-MULT1	$\alpha p_j(WINS)$
FRY-MULT2	$\alpha(TWKCP)(WINS)$
RMR	$\alpha W_{SPT} + \sum_{i=1}^{k} \alpha_i WIQ_{ij} + \beta_1 g_j +$ $\sum_{i=1}^{k} \gamma_i JIQ_{ij} + \beta_2 WIS_j + \beta_3 WIQ_j +$ $\beta_4 JIS_j$ where WIQ_{ij} and JIQ_{ij} are the work and the number of jobs in queue on the i-th machine in the routing of job j
FTDD	$E[F] + \alpha\sigma_F$
TWK-RAGATZ	$p_j(1 + \alpha W_j'/E[W])$, where W_j' is the estimated workload in the system when j arrives
EC3	$\alpha p_j + \beta E[W]$
WEEKS6	$\alpha p_j + \beta g_j W^\circ$ where W° is the expected wait time per operation
WEEKS7	$\alpha p_j + \beta W'$, where W' is an estimated wait time based on shop congestion level
OFS	$\alpha F n_j + \beta n_j + \gamma P_j$ where F is the average operation time of the last three jobs that are completed
COFS	$\alpha F n_j + \beta_1 Q_j + \beta_2 n_j + \gamma P_j$
MFE	$(1-\alpha) f_{sj} + \alpha f_{dj}$ where f_{sj} and f_{dj} are static and dynamic flowtime estimates
CON-BB	α_j, where $\alpha_j = a(W_j'/E[W])$
SLK-BB	$p_j + \alpha_j$, where $\alpha_j = E[p](a-1)W_j'/E[W]$
TWK-BB	$\alpha_j p_j$, where $\alpha_j = aW_j' + E[p]/W$
BERTRAND	$p_j + \alpha E[p_{j\circ}]g_j + \gamma_j$, where γ_j is the additional flow allowance based on the congestion/workload in the shop
WEIN-PAR I	Equation (999.1)
WEIN-PAR II	Equation (999.2)
HRS	$E[F(n_j)] + \beta z_\alpha \sigma_{LT}(n_j)$ where α is the service level and z_α is the α-percentile of the standard normal distribution

According to (Cheng 1984), due date setting rule; TWK was studied under the objectives of minimizing total lateness. The processing time (P_j) was considered from deterministic and random. The simulation model was typically used to find the most

suitable parameter ($\propto$). As a result, the sequencing priority policy is short processing time (SPT) that can lead to better system performance. Another study by (Cheng 1989) was to use SLK due date setting rule in order to minimize the weight flow allowance and the maximum tardiness. The result was more efficient when the priority rule of earliest due date (EDD) was chosen.

Furthermore, (Soroush 1999)proposed the study of random processing time with the objectives of minimizing the weighted earliness and tardiness. In consequence, he found that the due dates were based on costs of earliness and tardiness and also the mean value and standard deviation of the job's finished times.

2.1.4.3 Distinct Order Arrival Times

In case of distinct arrival times of job in DDM, job or order preemption commonly occurs in offline system setting. Regarding to (Bakera and Bertrandb 1981), they studied job preemption in DDM for minimizing the average due date to 100%. In the other word, the system needs to provide 100% guarantee that every job has to finish on time. The sequencing rule of SPT can give the best result. However, the limitation of this study is that all job information has to be known in advance.

In addition, there is some study that prefers to consider the perspective of profit maximization rather than cost minimization. For example, (K. Charnsirisakskul 2004)proposed the model consisting of an order that has various known attributes including unit revenue, arrival time, processing time, tardiness penalty cost, and

preferred and latest acceptable due dates. Moreover, the system allows job preemption. The delivery date of order must be during the interval between arrival time and latest acceptable due date. Therefore, orders that cannot complete among these times will be charged with penalty cost for delay. This study needs to make decision on how much each order to produce to maximize profit.

2.1.4.4 Online models

In quoting a due date, there are different types of job information that is important to be used such as job content, system congestion (workload), required processes for a job and also process routing, and sequencing policy. According to Table 2-2, the simplest due date rules are RND and CON which ignore job information and system workload for quoting due date. Therefore, many researches try to improve by considering the processing time, and the number of operations required in due date setting. The due date setting rules that need job information are SLK, TWK, NOP, TWK+NOP, and BN. Moreover, there are also some rules that consider both job and system information (workload in the system) to assign a due date, e.g. EC3, JIQ, OFS, COFS. In general, the simulation approach is widely used to ensure that the chosen due date setting rule is best fit for the system environment.

2.1.4.5 Due Date Rules with Job Information

Job information such as the processing time, and the number of operations is mainly considered for defining a due date.

Regarding to(Conway 1965), the four due date setting rules were studied under the objectives of minimizing average tardiness including CON, NOP, TWK, and RND. Furthermore, the nine priority sequencing rules were tested in order to measure the performance. As a result, for FCFS sequencing policy, the performance of all due date rules were quite the same, whereas, the rules of TWK and NOP obviously provided the good performance by using the EDD and SPT sequencing priority. Hence, this study summarized that the due date rules will perform better performance when considering the job information.

According to(Bertrand 1981), they studied the performance of three due date setting rules; CON, SLK, TWK with five sequencing priority rules; FCFS, SPT, EDD, EFT, MST by using simulation approach in order to minimize the average tardiness. The studied system has queue model as M/M/1 which contains single server with exponential distribution of arrival time and service time. Consequently, the sequencing rule of SPT and EDD provided good result over other rules. Meanwhile, the due date setting rule; TWK definitely performed better than SLK and CON rule that could ensure the importance of involving job information in quoting a due date.

2.1.4.6 Due Date Rules with Job and System Information

In order to include system information in quoting due date, the flow time of a job will be estimated. The flow time consists of two components including processing time and waiting time. The due date is properly assigned by using these estimated flow time. Hence, there are various methods for estimating flow time based on these following measures:

- the number of waiting jobs in the system (JIS)
- the number of waiting jobs ahead of job j (JIQ)
- the total processing time of all waiting jobs ahead job j (WIQ)
- the number and total processing time of all waiting jobs in the same operation routing with job j (RMR)
- the sum of processing times of all current jobs in the system (WINS)
- the sum of all operation times on the critical path of the BOM (TWKCP)

The flow time can be static or dynamic depending on time consideration. Static flow time estimation mainly focuses on queuing model with steady-state and average flow time. In contrast, the estimation of dynamic flow time has to give an important on current jobs and current system conditions. Since, the estimation of flow time is quite difficult, the measure for evaluating the performance of estimation is necessary. There are two types of measures which are accuracy and precision. Accuracy refers to the

similarity between estimated value and true value. While, the measure in variability of prediction errors is called precision. In case of quoted due date lead time is equivalent to estimated flow time, the average of lateness will indicate the accuracy and also standard deviation of lateness can lead to the precision.

Most researches in DDM policy are trying to consider both job and system workload information for due date setting. For examples, according to(Eilon and Chowdhury 1976), they aimed to study workload-dependent due date setting rules; EC3 and JIQ in order to minimize the weight sum of earliness and tardiness. These rules considered mean waiting time and the number of all operations required before a job (j). For sequencing rules, they decided to use FCFS, SPT and SLK via simulation. The result showed that JIQ performed the better in due date setting with the sequencing policy; SLK than the others.

Additionally, there may be some due date setting rules that are developed based on each system conditions and environment. Regarding to(Bertrand 1983), the due date policy called BERTRAND aimed to involve work information of a job and workload of the system at the time (t) when job arrived. The simulation was used to compare the developed model with another rule that ignored system congestion. The performance of DDM policies was evaluated by using the value of mean and standard deviation of lateness. As a result, DDM policy under consideration of current workload at time of an arriving job performed quite well.

2.1.5 Due Date Management in Thailand

At present, due date management is typically considered only in manufacturing sectors in Thailand. Most companies applied due date setting principle for supporting operations to work properly as plan. Since due date operation plays important role on job planning, planners are able to control and monitor system throughput which can directly affect the operation performance and productivity. Moreover, missed due date of jobs can lead to the loss in term of opportunity and penalty cost. It also leads to continual impacts to other parties in the supply chain. However, due date management for service businesses in Thailand is less consideration. Most small and medium service businesses are currently depended on experts or senior workers for estimating due date. Since arrival time and processing time of each job for service business is obviously uncertain, there are no principles to exactly estimate due date. Due date setting for service business requires being personalized and fit with its core service business because there are different factors affecting job characteristics and due date estimation.

2.2 Auto Body Repair and Paint Service

In order to repair damage of car body, it seems to be quite difficult to make broken car body to be as a never crashed car. All staffs need to have both technical knowledge and skills about car body structure, characteristics of damages, and also necessary equipments used for repairing. However, there are major aspects to better understand

body repair and paint service including concept and importance of auto body repair, severity inspection, car body structure and components, and also significant processes of auto body repair and paint service.

2.2.1 Concept of Body Repair

In general, car damage that needs body repair service is caused by collision or crash. According to(Duffy 2015), collision typically occurs when any impact hit on vehicle. The impact can probably happen from another vehicle or object. The collision can make either a minor damage such as scratch on paint or major damage resulting in unshaped body structure.

Figure 2-1 Examples of collision between two vehicles. Reprinted from (Duffy, 2015)

Auto body repair can refer to collision repair involves fixing damaged car from accidents, for examples, in case of minor damage, the processes of sanding and repainting are required, whereas, with serious damage, a large part of frame and structure is needed to be straighten and sometimes replaced by a new one.

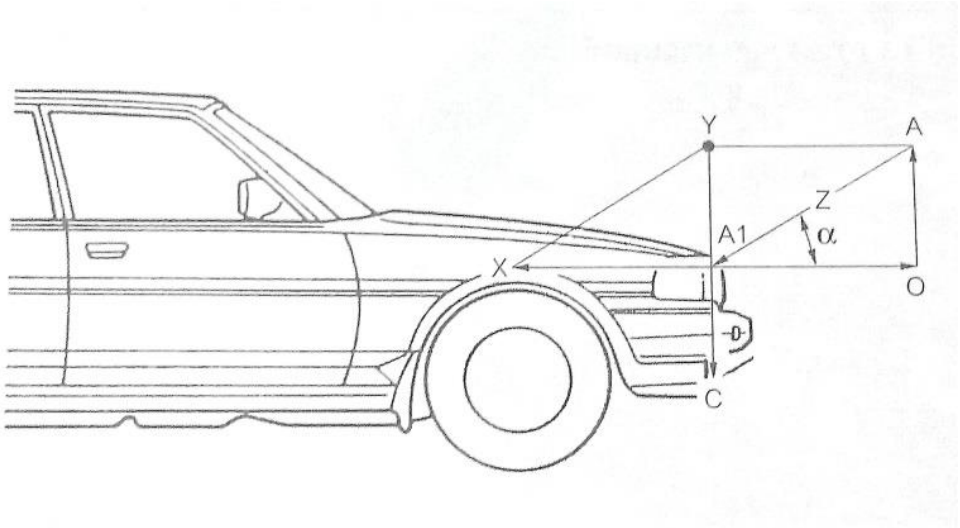

Figure 2-2 The direction of dent damage repair. Reprinted from (บุญธรรมกุล, 2009)

In Figure 2-2, the dent damage of a car occurs at the point A1. In order to dent repair, the specific tools are properly used. The dent damage will be strengthened along with the direction of A1-0. It can lead to be the same body structure. Therefore, the three dimension of body structure (X,Y,Z) is important for finding the suitable force direction for repairing any dents.

2.2.2 Importance of Auto Body Repair

Regarding to(บุญธรรมกุล 2009), most typical cars including sedan, truck, mini car, and van will have steering system, choke and basic driving systems attached to the body frame or car structure. In case of uncertain accidents, a car may be ill-formed that can lead to major affects to driving system. Car will lose the ability to balance and control when serious damage of body structure occurs. Therefore, body car repair is also vital for driving safety as well as repairing of engine and other systems. Moreover, well-trained technician is major factors for efficient and effective body repair.

2.2.3 Auto Body Structure and Components

Due to the rapid changing of customer's behaviours and more comfortable lifestyles, most car manufacturers are trying to differentiate their products by providing new experiences to customers. They highly focus on a creative and attractive car design in order to gain more advantages over their competitors. Therefore, various car exterior are totally designed in the current marketplace. Car designs are usually based on each brand characteristic and car model; e.g. Mazda which is famous Japanese car manufacturers has recently launched Mazda 2 with Skyactive technology and KODO design for car exterior. Although each brand has different exterior design, the structure and components of car are quite similar when comparing with the same categories such as sedan, truck, and van. The basic exterior components of sedan are shown in Figure 2-3:

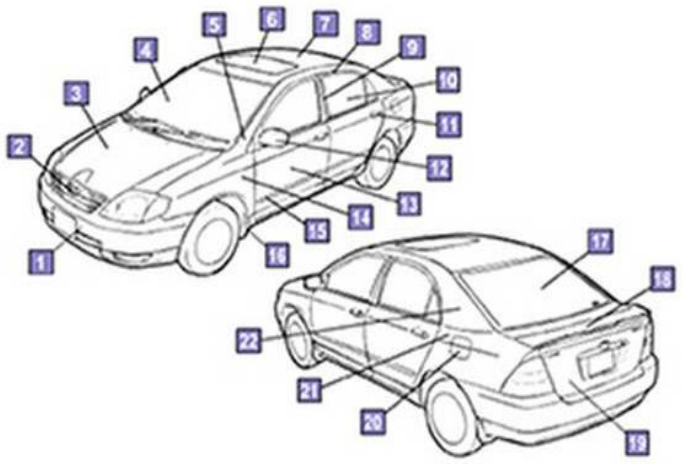

Figure 2-3 The basic exterior components of sedan. Reprinted from (stillen.com, n.d.)

1) Bumpers 2) Car's cowl 3) Front hood 4) Front window 5) Pillar (“A” Pillar) 6) Roofs 7) Hardtops 8) Door pillar (“D” Pillar) 9) Pillar (“B” Pillar) 10) Side windows 11) Door handles 12) Side view mirror 13) Car doors 14) Front fenders 15) Side skirts 16) Mud flaps 17) Rear window 18) Rear skirt 19) Rear hood 20) Fuel door cover 21) Rear fenders 22) Pillar (“D” pillar)

However, in case of body repair service shops, they mainly focus on the body parts that are able to be frequently bent and damaged from accidents. Therefore, all car windows, mirrors, mud flaps, and all frame pillars are less important to consider for most body repair shops. These parts are typically replaced with a new one when some damage occurs.

2.2.4 Severity Inspection

The vehicles that have been crashed in accident will be brought to the body repair shop. According to(Duffy 2015), damage estimation is considered to be a first step of body repair to inspect severity level and estimate cost for repairing. Moreover, the labor, required materials, and part replacement will be calculated to total cost for offering to customers. It is considered to be important for service business since the too high cost is quoted to customers, a shop will lose opportunity to other competitors to get this job, whereas the estimated cost is too low, a shop may not make a profit and has a chance to lose more money if estimated cost cannot cover actual repair cost. Furthermore, estimation or inspection includes damage analysis as major and minor severity level. These level inspections are also vital for car insurance claim.

In most body repair shops, staffs who are well-trained estimators will inspect car damage and indicate what processes are required. This person must have technical knowledge about structure of various vehicles and also useful skills in numeric value, information technology and communicating in order to satisfy customers. Due to the growth of advance technology, people who are responsible for damage estimation often use an electronic device and expert system in order to assist them for inspection as shown in Figure 2-4.

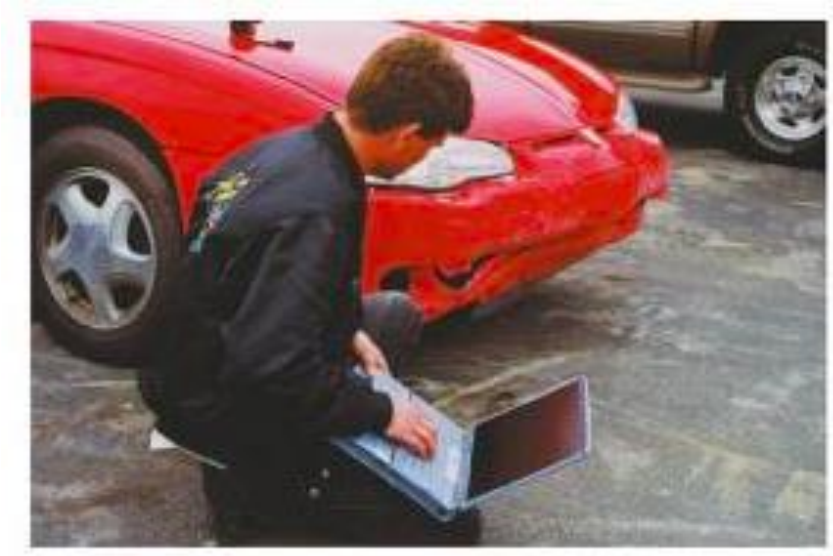

Figure 2-4 An example of electronic device used for damage estimation. (Duffy, 2015)

In Figure 2-4, there is computerized measuring system used in most current repair shops for accessing vehicle information including mileage, engine identification number, and other useful information. Moreover, this system is commonly used to determine that major body parts are force out of structure alignment due to collision.

Figure 2-5 Expert system used for damage estimation. Reprinted from (Duffy, 2015)

Regarding to(บุญธรรมกุล 2009), many factors are required in damage inspection including major position of damage, other possible areas that may be affected, and the severity level. The accuracy of these factors can lead to higher efficiency in operation performance and also repairing cost estimation. Figure 2-6 shows the process flow of damage inspection in typical body repair shops.

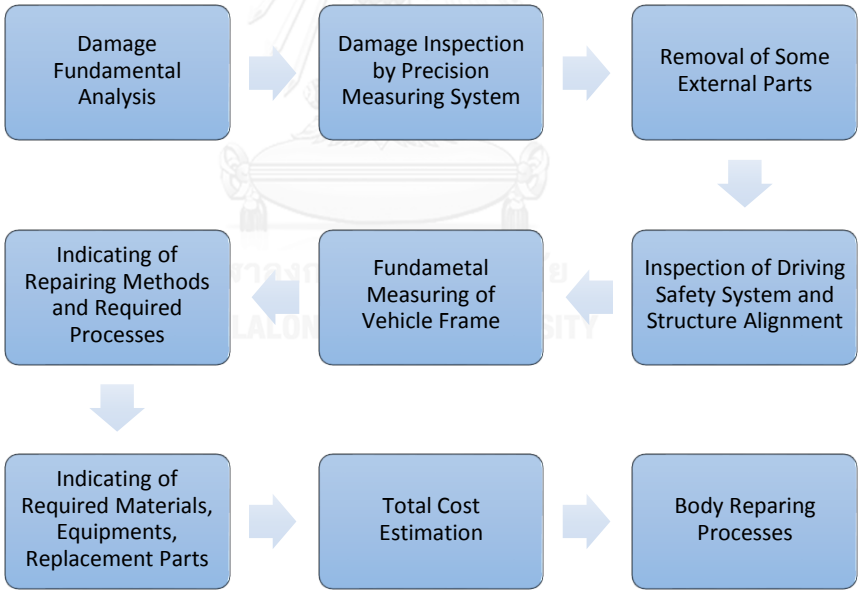

Figure 2-6 Typical process flow of damage inspection. Reference (Duffy, 2015)

2.2.4.1 Major factors for damage estimation

- Indicating of damage areas affected by collision
  - Size, shape, position, and characteristics of collision

- Velocity of two cars while accident occurs
- Angle and direction of collision
- Number of passengers and sitting position while collision
- Size, shape, hardness of stuff on a vehicle as it may cause rear fender to be dented.
- History of collision and body repair

- Damage analysis
  - Damage characteristics; e.g. dent, bent, unbalanced shape, and etc.
  - The number of damage parts and positions
  - Alignment of gap between pillars since collision can cause unbalanced frame

Figure 2-7 An example of dent damage. Reprinted from (honeyiscratchedthecar.com, n.d.)

Figure 2-8 An example of minor dent damage with painting scratch. Reprinted from (honeyiscratchedthecar.com, n.d.)

2.2.5 Auto Body Repair and Paint Processes

Due to growth of customer demand in vehicle, body repair shop is considered to be important as well as auto engine and technical repair. In order to meet that demand, many body repair service shops are also increasing continually. According to(Duffy 2015), typical body repair shops have five major processes of body repair and paint service with well-trained staffs. Figure 2-9 presents common processes of body repair and paint shop.

Figure 2-9 Typical processes of auto body repair and paint. Reference (Duffy, 2015)

2.2.5.1 Frame and Unibody Straightening

Damage of frame and unibody such as frame misalignment refers to be highly severe damage that is typically caused by major collision. Since frame misalignment is estimated and required processes are known at the first procedure of body repair service, specific equipments and heavy equipments are properly used to pull a body frame in the right direction and amount of power in order to straighten misalignment body into its original structure. Frame straightening equipment is called frame rack is a large steel framework with pulling chains and hydraulic rams as shown in Figure 2-10.

Figure 2-10 Frame straightening equipment called frame rack. Reprinted from (Duffy, 2015)

After using frame rack to straighten vehicle body, skilled staffs will deeply determine and inspect in order to ensure that a body frame is in its right position and specification. They usually use some measurement tool for measuring efficiency of body alignment as illustrated in Figure 2-11. Further body frame pulling is always needed when this tool results in a mismatch between the damaged frame and its reference points (original specification).

Figure 2-11 An example of tool used for measuring efficiency of body alignment. Reprinted from (Duffy, 2015)

2.2.5.2 Panel Replacement

Panel refers to a large body part which is made by metal or plastic such as hood, fender, and roof panel. Panel replacement usually takes place when the panel is too difficult to be repaired. A new part of body will be properly fit to original body by welding technique, hence, staffs is needed to have specialized skills to efficiently perform panel replacement. In Figure 2-12 and Figure 2-13, the damaged panel part that needs to be replaced will be cut by using plasma, then, the new one will be attached to its body with spot welds. In case of major damage on a structural panel, it requires heavy and specific equipments to remove and replace by a new one because it needs high precision of position and alignment. The measurement tool is typically used before and after welding in order to ensure the right location of replacement. Clamping pliers are also used to properly hold a new structural panel while welding in place as shown in Figure 2-12 and Figure 2-13.

Figure 2-12 Panel replacement. Reprinted from (Duffy, 2015)

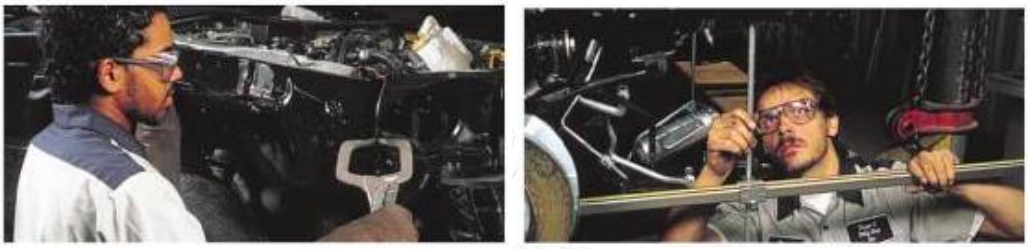

Figure 2-13 Structural panel replacement with specific tools. Reprinted from (Duffy, 2015)

Moreover, collision may cause some panel part to be shifted from its original position. Panel adjustment is significant solution to adjust some minor damaged part rather than changing to a new one. The total repair budget for customers can be cheaper. However, accurate panel adjustment is often made by well-trained technicians. Since inaccurate adjustment or assembly of vehicle doors may lead to inappropriate utilization such as rattle and harm while driving.

2.2.5.3 Panel Straightening

In general, vehicle collision may cause a dent based on major or minor damage. Panel straightening or dent repair is considered to be a common process for several body repair shops. There are various kinds of hand equipment used to repair dent depended on severity and position of a damaged part including specific body hampers, body

fillers, sanders and sanding paper. Moreover, some tools are appropriate to use for repairing a plastic part. Figure 2-14 illustrates the basic steps of how to remove dent on damaged area. Firstly, staffs will use grinder to remove paint on damaged part. Then small pin are taken place on the lowest area of a dent. Next step is to attach a puller tool with installed pins. Finally, a dent is strongly pulled to be back into its original shape. All steps can be repeated until the shape is totally satisfied.

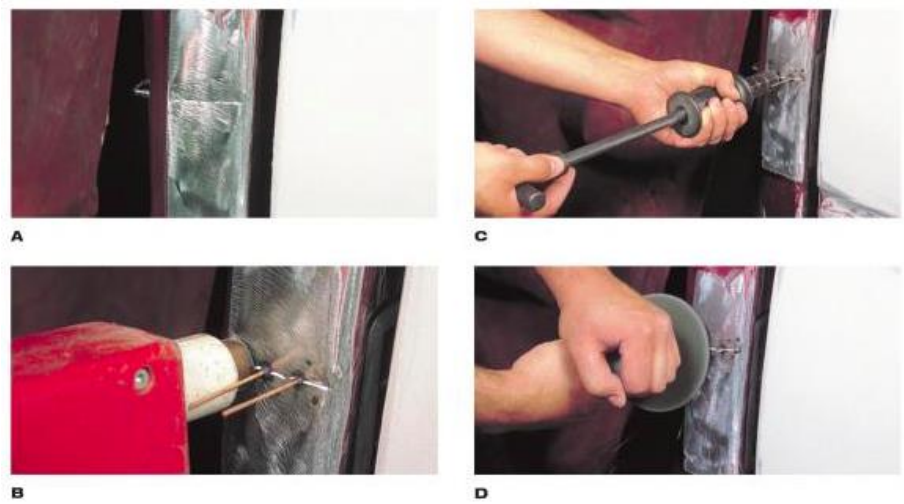

Figure 2-14 The basic step of removing a dent. Reprinted from (Duffy, 2015)

In addition, body filler aims to fix and cover any small imperfection areas after panel straightening. It is good at to level metal to be smoother surface. The damaged area should be clean of dust by using compressed air. As body filler is hardened quickly over the damaged area, skill is definitely required for applying body filler. After applying body filler, air sander and sand papers are next used to cut exceeding filler and make it to be better surface and in the same level with the whole panel part. (Figure 2-15)

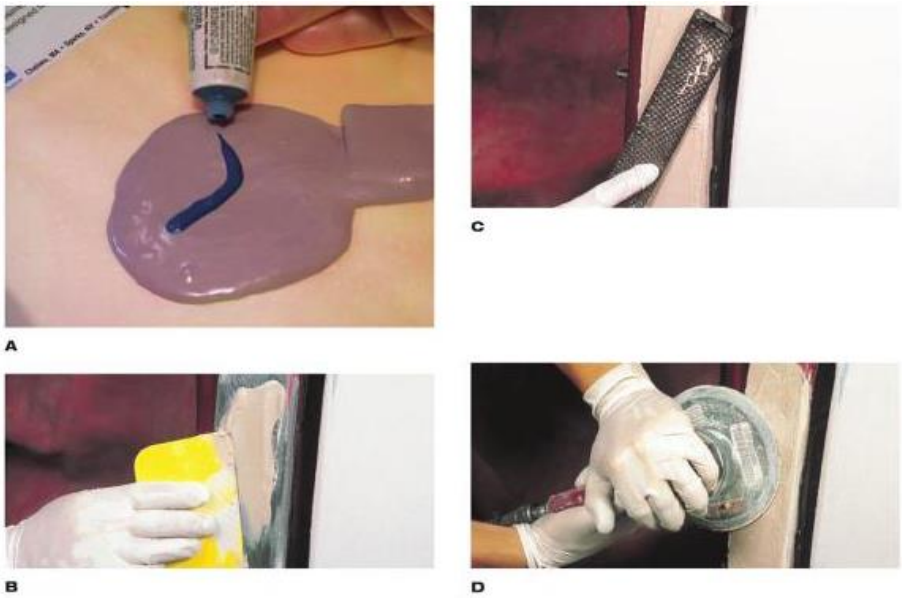

Figure 2-15 Panel repair procedure with sanding machine. Reprinted from (Duffy, 2015)

2.2.5.4 Paint Preparation and Painting

After finishing of metalworking, damaged vehicle will be brought to the area of painting preparation. The compressed air is typically used to dust off before coating and painting. Next, masking is important step for protecting other parts from paint spray and some dirt such as windows, chrome, light and etc.

Primer is applied before color painting because painting alone cannot make paint color to efficient stick to body metal. It also can lead to unbalance of color spray. Staffs often apply a primer by using spray can or spray gun to cover on the required metal surface. Currently, the painting of vehicle consists of several coats of different materials in order to make a smooth surface. Most body repair shops commonly have three basic coats including primecoat, topcoat and clearcoat.

Primecoat or primer is used to improve the property of metal adhesion as well as a primer prior color painting. Without a primecoat, the color paint will peel and be rough. Moreover, primer-sealer will help to prevent some chemical

Topcoat or colorcoat is color coating used to apply over primecoat. It typically has many thin layers of color paint covering the vehicle surface. This coating is considered to be glamorous gloss coating.

Clearcoat or barecoat is sometimes called water-based paint because it is able to protect a vehicle surface from water-based and oil-based elements. Clearcoat will also help a surface to be shiny and glossy on the true color paint. Therefore, it is commonly applied after colorcoat.

In general, most painting shops mainly use painting tools called spray gun to apply on surface (Figure 2-16). Spray gun can be properly adjusted to make a smooth surface.

Figure 2-16 An example of painting tool called spray gun. Reprinted from (Duffy, 2015)

Figure 2-17 Painting process. Reprinted from (Duffy, 2015)

Figure 2-17 illustrates painting operation on a car surface of hood using spray gun. Professional printer should have excellent coordination of hand and eyes and specialized knowledge in order to perform efficiently. The speed and distance between spray gun and surface are important since color paint mistakes may be occurred if painter moves the gun at different speeds or move it further or closer while painting on surface. Additionally, some shops usually have drying equipments such as special heat lamps to help color drying to be faster.

2.2.5.5 Post-Painting Operation

Post-painting operation refers to operation that needs to be done after painting process. The main tasks in this process are removing masking tape, re-installation of vehicle accessories, and sanding and cleaning. After color coating, there may be some rough or textured surface. Hence, surface polishing and sanding are powerful approaches to remove unexpected paint roughness. There are three steps of finishing in body painting before delivering to customers including wet sanding, compounding, and detailing. Wet sanding refers to a process that uses water and ultrafine sandpaper to apply on the paint. It can reduce minor imperfection of surface such as dirt and

small peeling. After wet sanding, compounding is typically used to make a surface smoother and shinier. There is an electronic buffing machine with soft pad to cut a thin layer of topcoat in order to brighten color paint. Final step is detailing which involves all cleaning tasks such as exterior washing, and interior and glass cleaning. Then, this vehicle will be returned back to the customers.

Figure 2-18 Polishing process. Reprinted from (Duffy, 2015)

2.3 Web-based Information System

With the development of internet, useful information and knowledge are distributed over the internet. Web-based information system is able to provide necessary online information used for achieving some specific business purposes. The user is able to access this information from anywhere at any time via the internet.

2.3.1 Definition of Web-based Information System

According to(Isakowitz, Bieber et al. 1998), web refers to a hypermedia application that is widely used in various business fields. Business can reach customers easily through online marketing and social media. The scope of web-based applications has been

rapidly growing. Currently, there are commonly four parts for web-based system as following:

Intranets: to support internal wok such as collaboration among teams or departments.

Web-presence site: web interface as marketing tool is designed to reach customers by delivering useful information through website.

Electronic commerce system: to support interaction between business and customers such as online shopping and payment.

Extranets: an integration of internal and external system to support communication between business and business.

However, web platform is not used only as a marketing tool but it is also transformed to support all aspects of organizational tasks. Information system which is developed on web technology platform is typically called web-based information system (WIS). This kind of information system will become prevalent rather than traditional client/server system because web has potential to reach much wider customers through limitless network.

In addition, the obvious difference that can distinguish WIS from traditional set of web pages is supporting of operation. In the other word, WIS will properly assist internal organizational tasks to run smoothly and efficiently by integrating with an electronic storage; database and transaction processing system. Therefore, WIS requires specialized knowledge and approaches to design and develop in order to reach various kinds of end users.

2.3.2 Basic Architecture of Web-based Information System

Generally, web-based information system applies three-tier architecture for building various kinds of website and web application. The architecture of web-based information system was firstly developed by John J. Donovan in Open Environment Corporation (OEC). It is used to divide the user interface for clients, application logic, and database into many independent modules as shown in Figure 2-19. Three-tier architecture consists of presentation tier, logic tier, and data tier. This design will help us to develop and maintain the system efficiently and effectively.

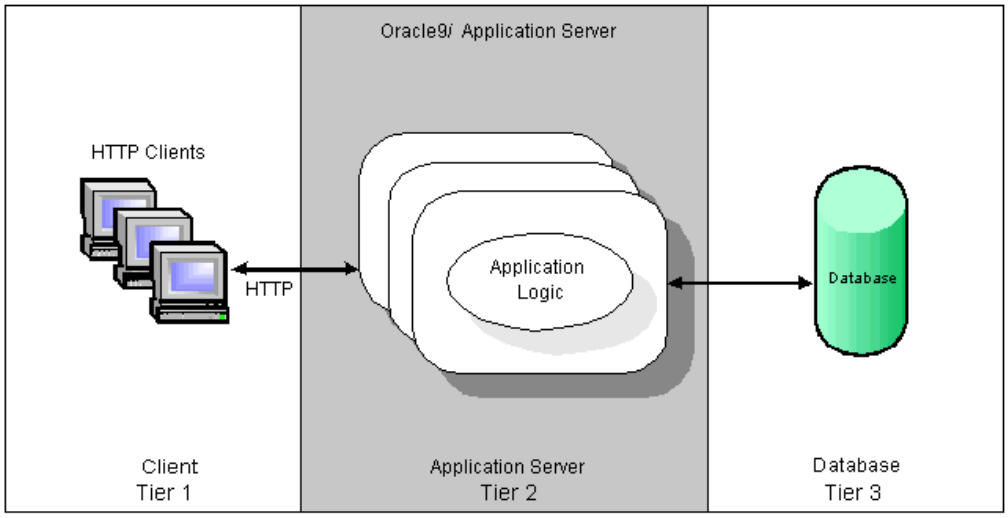

Figure 2-19 Three tier web architecture. Reference: (Oracle Corporation, 2000).

- *Presentation Tier* is the top level of the website. This tier will represent the data such as images or articles and also interact with end user via user interface. Whenever a user is able to click on hyperlink or any button or manipulation, the data will be sent to logic tier. When the data is responded back, this user

interface will be updated and visualized to user. Commonly, application tier refers to desktop, laptop, or mobile which user can use to browse the websites

- *Logic tier* or *middle tier* is an application in web server. This application will run based on data request from presentation tier. This tier will use the date either from user or database in data tier to perform application logic which can be simple as list all customers.
- *Data tier* includes data persistence module such as database server, file server. This tier can be called as data access layer which will support logic tier in term of data query or data storing as requested.

2.3.3 Benefits of Web-based Information System

Web-based information system is considered to have better performance and many advantages when comparing to traditional information system as following:

- Efficient data security

Data is stored in traditional information system is unsecure because everyone can store it in their own laptops, hard drive, or personal server. There may be crashed or lost data due to unexpected broken machines and improper backup. Moreover, confidential data can be stolen easily through unsecure devices. Web-based information system (WIS) provides more secure data

storage, up-to-date system update, and also automatically backup on daily basis.

- Cost efficiency

  Web-based information system can help to run business processes smoothly and efficiently allocate resources to all activities. It also leads to lower company's expenses by reducing operation inefficiency and increasing of sales and profits. Furthermore, WIS is able to assist business operation to run faster, hence, there is more time to highly focus on business competitions through strategy development and improvement.

- Easily managed and updated

  For system implementation, web-based information system is installed once at the first time. It does not need to be installed on several workstations. Therefore, updating and managing of the system is easily done with short time.

- Platform compatibility

  Platform compatibility is major advantage for web-based information system since it totally requires common web browsers such as Google Chrome or Mozilla Firefox for running the system. Restriction of operating system (OS) is not much considered unlike from traditional information system. In the other word, an information system developed for Windows, Mac OS or Linux has

different implementing platform and prerequisite requirements to run the system.

- Highly accessible

  Since internet connection is widely used for enhancing various business operations, web-based information system mainly uses the internet to access the system via web browser or mobility devices. Therefore, both internal and external party including end users, clients, or stakeholders is able to access and communicate from remote areas at anytime. Furthermore, it will increase business opportunities and enhance business operations by providing jobs that can work from home.

- Enhance business operations

  Using web-based information system can totally improve all business operations. It is able to make various operations to be more efficient and effective rather than paper-based business such as inventory management system, quality control system, or document and filing system. As reducing of time and cost is vital for competing in today's business environment, web-based information system can properly lead to better performance in productivity and profitability.

3 Research Background and Problems

3.1 Introduction

This chapter mainly focuses on company background, current operation management system, and problems in due date management of the chosen company. Firstly, company background is discussed in term of available resources and capacity, operational workflow and management. Then, current problems in due date management are clarified which focuses on due date assignment policy. Finally, the problems of monitor and control are explained for better understanding of due date information system.

3.2 Company Overview

This research is a part of the case company located in eastern province of Thailand; Chonburi province. The case company was established in 1980 provides auto body repair and paint services for various vehicles. With growth of advanced technology, this company has been trying to compete in auto body repair and paint business by offering efficient and reliable services with modern equipments and tools. In body repair, various hand equipments were fully available for repairing of minor damaged vehicle such as body hampers, fillers, sanders and measurement tools. The colour paints used in panting process is high quality and specialized colours which properly provide a quick dry painting without incentive tools. It is considered to be a major factor to

reduce total processing time of a job order. Painting tools was efficient in order to help painting to be easier including high quality spray gun. In case of facility, painting rooms have standard quality to efficiently avoid dusts and other contaminations that can directly affect painting quality. For operation management, the case company gives importance on information technology. In-house information system is developed to support internal operations such as collecting job data in electronic storage and job control board that can display the current status of each job order. Moreover, IT is also used to assist in-office working including accounting, inventory control, human resource and file system.

In addition, company's staffs are mainly divided into two categories which are body repair staffs who have specialized skills in body repair and painting staffs that are well-trained in colour theory and painting techniques. Every staff in the case company has distinct skills and responsibilities. Therefore, staffs that are responsible for body repair cannot work on painting job.

3.2.1 Types of Service Offered

The case company currently offers auto body repair and paint service to customers in Chonburi province. The service of the case company can be mainly divided as following:

- *Body repair service of light and medium severity*; it includes dent repair, and panel repair of all body car parts. There are well trained workers who are particularly responsible for body repair with various quality equipments.
- *Painting repair service*; it covers all painting repairs and surface polishing. There are various high quality and specialized painting colors based on customer requirements. Workers need specific skills for painting repair.

Moreover, some damage parts may be severe and difficult to be repaired by both body repair and painting repair. The case company also provides replacement service for changing parts to the customers. There are official contacts with various manufacturers to supply their genuine spare parts.

3.2.2 Service Capability

Currently, the case company totally consists of eight processes of auto body repair and paint service including removal of parts, body dent repair, panel repair, primer spraying, painting, assembling parts, polishing, and car wash. Moreover, there are totally thirty-two servers in eight processes with different number of servers in each process. All servers can properly work on many job orders simultaneously. The number of server in each process is illustrated in Figure 3-1.

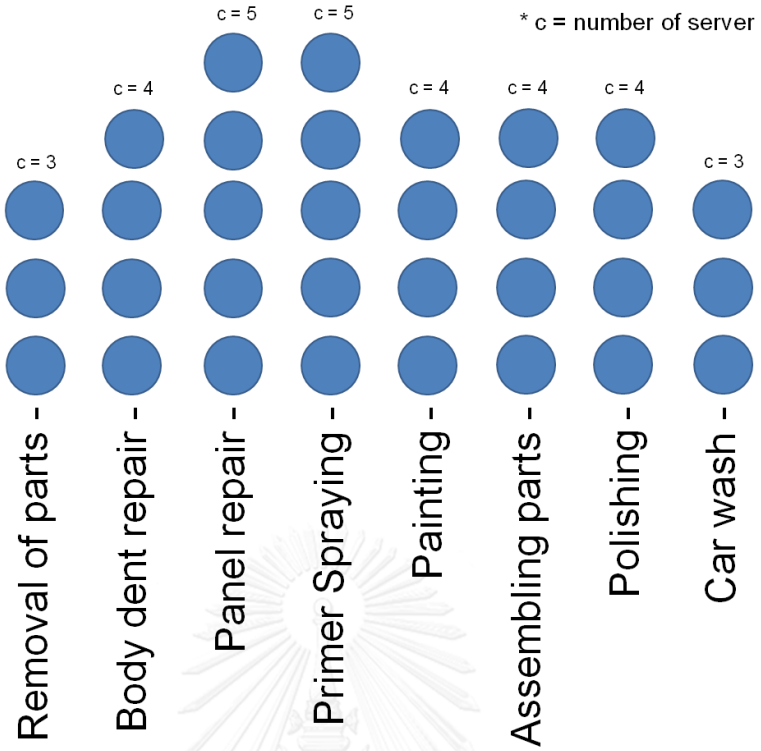

Figure 3-1 Number of servers in each process of the case company

Each server in a process must have two workers who are responsible for a job order. The case company aims to encourage the learning skills of all workers by matching workers in each server based on skill level and working life time. In the other word, senior and junior workers usually are assigned job responsibility together at one server in order to practice useful skills and exchange knowledge among them. Therefore, the current total number of staffs in the case company is eighty-four persons with sixty-nine operation workers, eleven office staffs, and four people of security guards and housekeepers.

In addition, the case company properly provides car parking space at maximum of thirty waiting cars. However, customers can take their cars back and make appointment

in advance to access our service because some minor damage of body may not affect the efficiency of car driving and engine. In order to gain customer satisfaction and avoid loss of opportunity, service flexibility is important to be considered.

Although the case company focuses on customer satisfaction and reliable services, available resources at some period of time are not highly concerned by operational level. In the other word, reception staffs usually receive a new job order and provide them an appointment date without considering existing resources. Hence, customer complaints about unreliable service and lateness will commonly occur when internal service capacity is completely full.

3.2.3 Demand Profile

3.2.3.1 Service Volume

Due to the growth of urbanization concurrent with populism policy, car is considered to be a major factor for better life quality and convenient travelling. In 2013, the total amount of cars needed auto body repair and paint service slightly increase from previous year; 2012 Figure 3-2. Company ABC provides services to all types and sizes of car such as city car, sedan, SUV, and truck. At front of reception, specialists will carefully inspect customer's broken cars and assign required processes. The operation needed for each car can be classified based on the level of severity of car damage which includes high, medium and low. The number of cars categorized by severity

level is illustrated as Figure 3-3. During 2012 to 2013, there are the most low severity cars that are approximately 84% of the total cars.

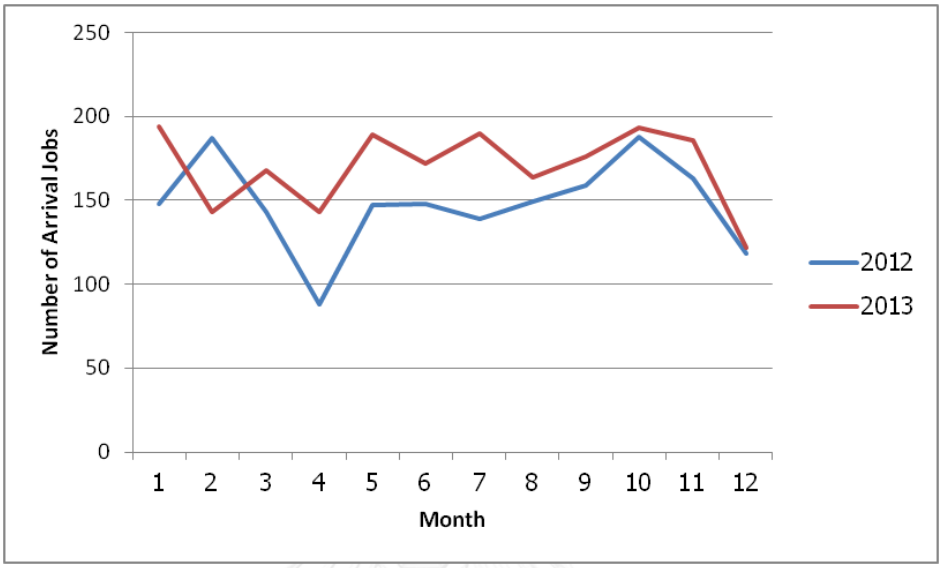

Figure 3-2 The total number of job arrivals in each month during 2012 to 2013.

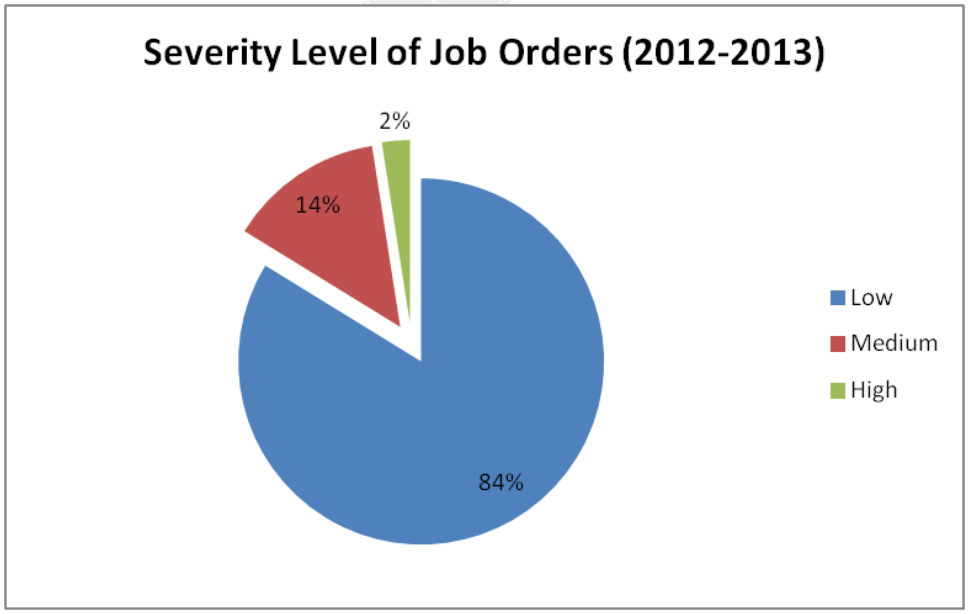

Figure 3-3 The number of job orders categorized by severity level.

It is obviously seen that trend of service demand continually rise on the next following years. Therefore, company ABC should give important on improving operation performance and maintaining loyalty customers.

3.3 Current Operation Systems

3.3.1 Facility Layout (Shop Layout)

Since the case company is considered to be a small and medium service business, the area of floor plan or shop layout is quite compact with full body repair and painting facility as shown in Figure 3-4.

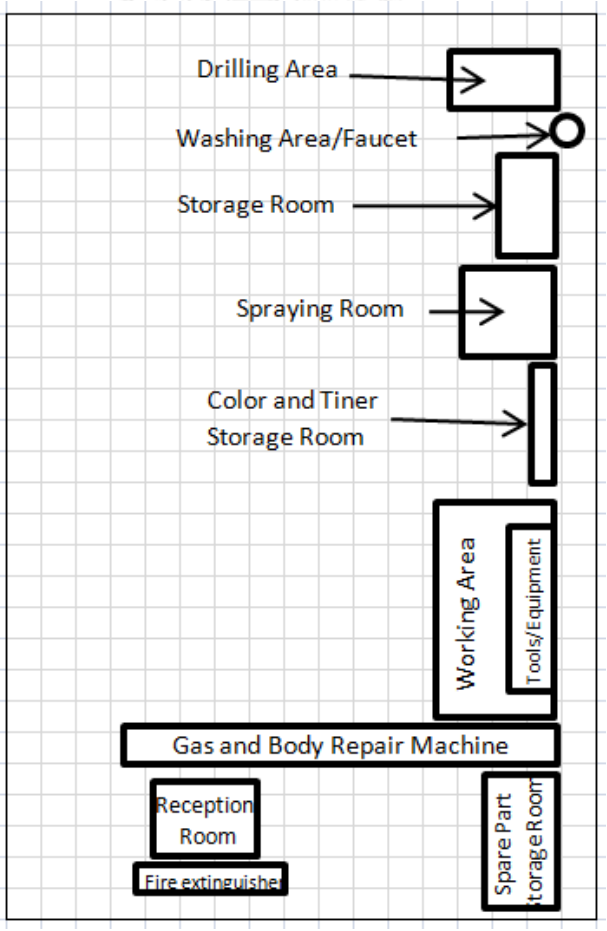

Figure 3-4 Layout floor plan of the case company

There are three common factors that need to be concerned for designing body repair and paint service garage. First is ventilation. As painting dusts can clearly harm breathing system of people, hence, consideration of natural air flow inside the garage is important for long term health of participant staffs. Secondly, car storage or car park is another vital factor. Storage should have enough for maximum capacity of each garage. Last one is building design. One shop floor building is widely used for auto body repair and paint service because it is more efficient to manage and easy to expand the garage area.

In Figure 3-4, the one shop floor of the case company is clearly illustrated with various facilities including living area for customers, reception area, office, body repair shop, painting room, color storage room, and utility room for keeping several equipments. The rest of area is for car park and waiting or queuing area for cars to be processed.

3.3.2 Working Processes

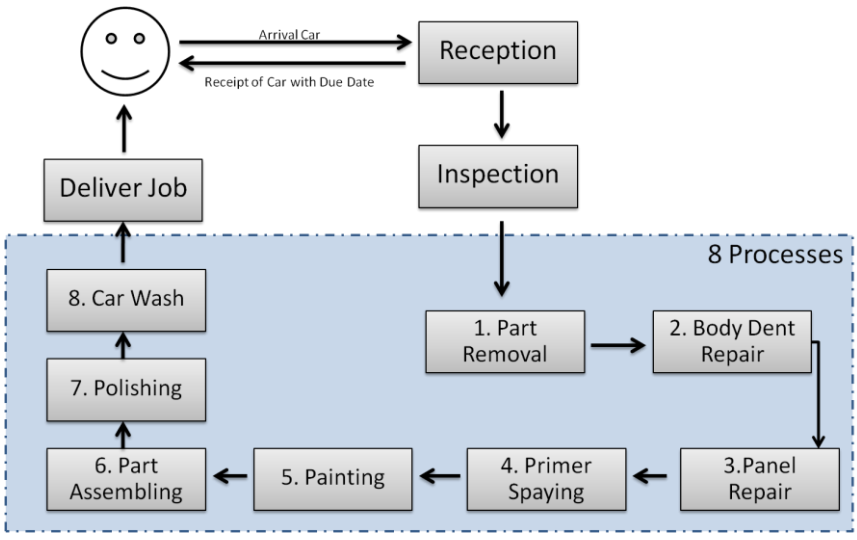

Figure 3-5 The overview of current processes of the case company

The overview of current process of the case company is shown as in Figure 3-5. Job firstly arrives at front or reception. Staffs at front will provide information and suggestions about body repair service to customers. Then, damage of arrival car is estimated by specialized staffs in order to identify required processes and quote a repair price to customers. After job order approval, the receipt of car with estimated finished date is issued by reception. This job order is sent to the waiting area when its process is not available at that time. Operation supervisor who is responsible for daily job planning randomly selects each job order to be processed without considering priority order. The job order selection is usually based on supervisor's experiences that can lead to job lateness. The detail of eight processes of body repair and paint service is clearly described by using flowchart diagram.

3.3.2.1 Removal of part

Removal of part refers to preparation process before body repair and painting. Most damaged cars require to be removed of their exterior accessories such as light cover and other undamaged parts. The removed parts will be kept in either storage room or waste room if this part is unusable.

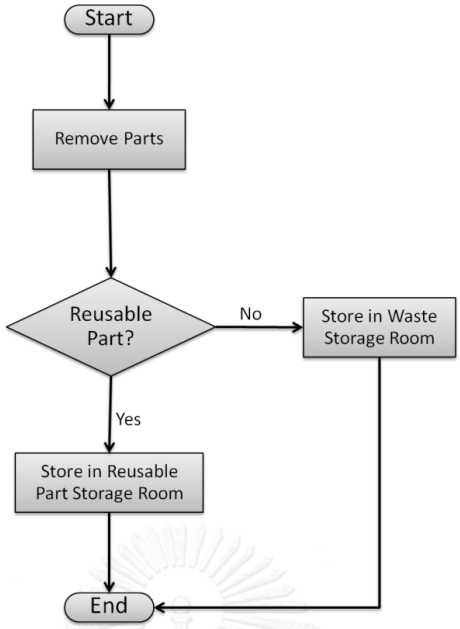

Figure 3-6 The flow chart diagram of part removal process

3.3.2.2 Body dent repair

Body dent repair is considered to be time-consuming process based on severity level. The damaged cars will be firstly classified on what parts or structure needed to be repaired. There are many hand tools used in body dent repair including hammer, vacuum suction cup handle to pull a dent. After process finishing, every damaged car is inspected by process supervisor in order to control quality and defects.

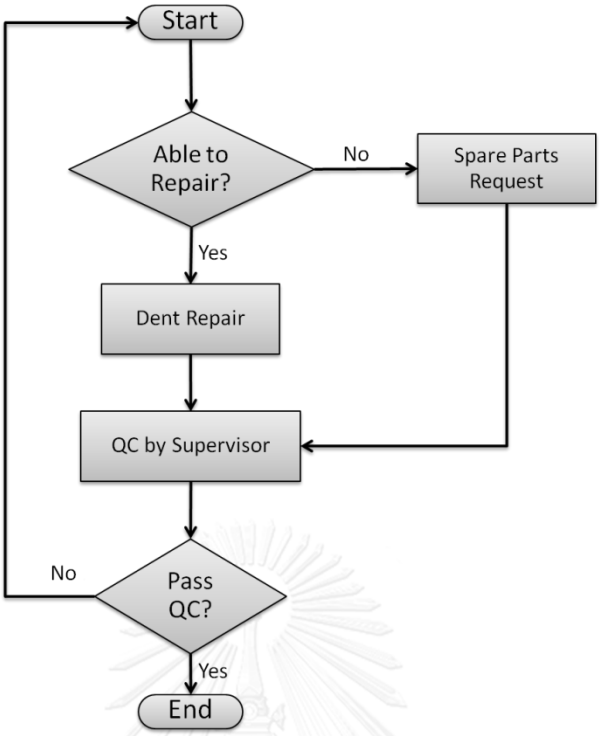

Figure 3-7 The flow chart diagram of dent repair process

3.3.2.3 Panel repair

Panel repair is necessary process after body dent repair. Some major damaged vehicle is difficult to repair a dent to be as an original surface. Panel repair will use specific chemical to cover rough surface and sanding machine to smoothen a surface before painting.

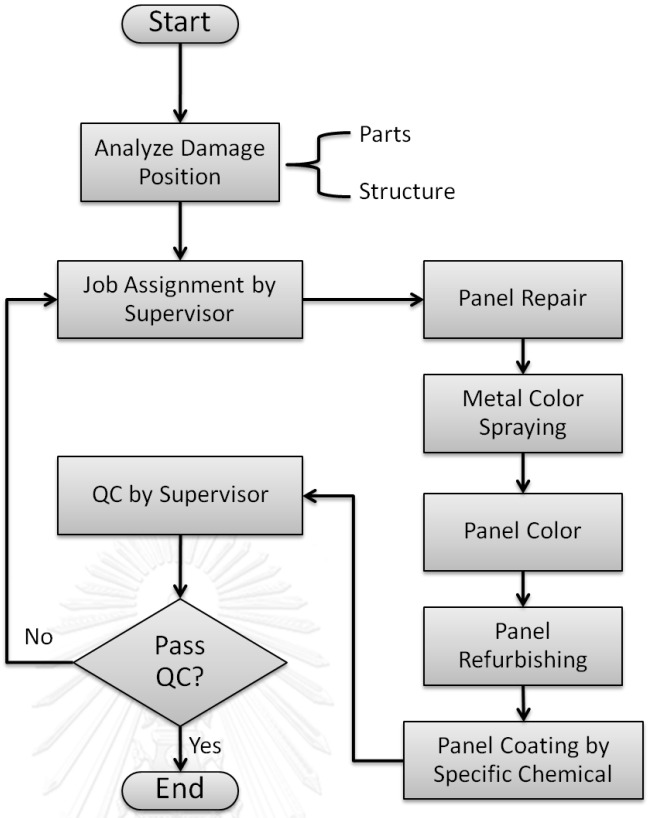

Figure 3-8 The flow chart diagram of panel repair process

3.3.2.4 Primer spraying

In order to make painting color to fully and smoothly cover damaged part, primer spraying is important to help painting process to be more efficient. Workers will use spraying gun to perform in this process. Painting skills and techniques are well-trained for all workers.

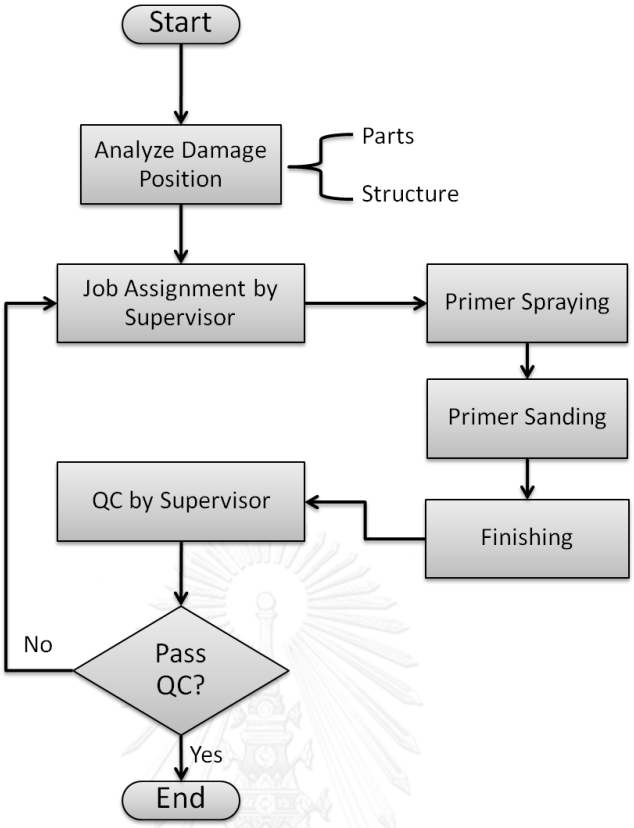

Figure 3-9 The flow chart diagram of primer spraying process

3.3.2.5 Painting

Painting process requires specialized skills since mixing color to color spraying. As painting defects are obviously noticed by most people such as different color shade and unbalance of painting surface, it can directly affect to performance and quality. Therefore, the process of mixing color needs experts who specialized in all specifications of each main color. Moreover, all painting workers need to attend training courses and practices for a year.

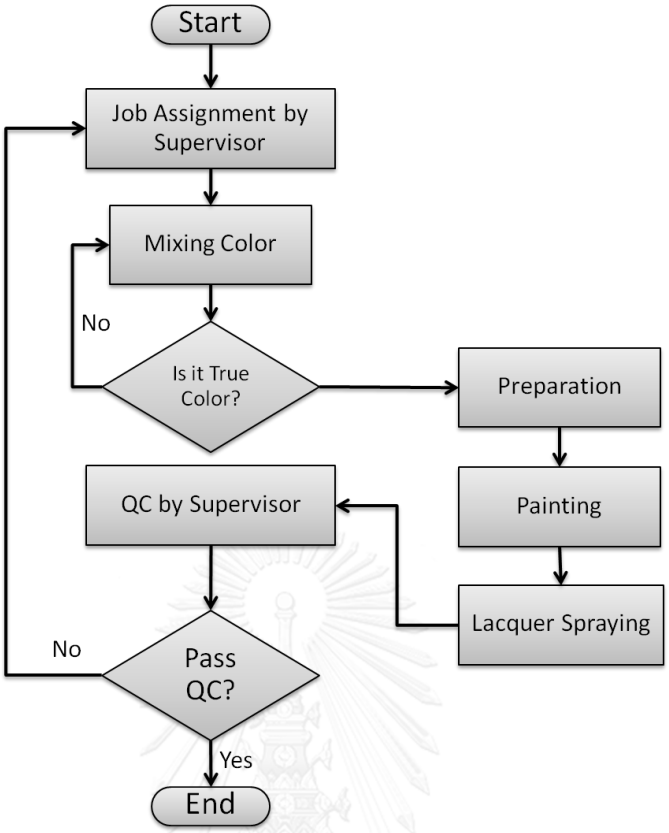

Figure 3-10 The flow chart diagram of painting process

3.3.2.6 Assembling part

After repairing all damaged parts, assembling supervisor will request either new parts or reusable parts from the central operation room. All removal parts and accessories are carefully assembled in order to avoid minor defects from transferring.

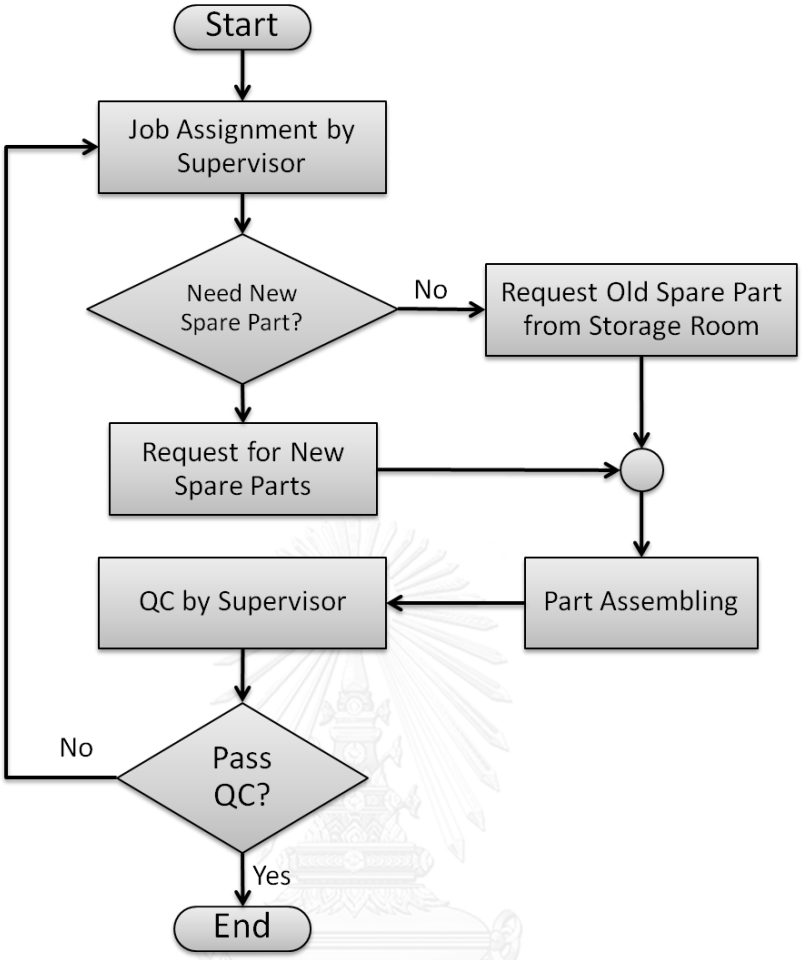

Figure 3-11 The flow chart diagram of assembling part process

3.3.2.7 Polishing

Polishing refers to finishing process of body repair and painting. There may be some dirt and painting dust from repairing that needs to be removed. The main tools used in this process include sanding paper, sanding machine, and also cleaning chemicals and solutions that can remove sticky dirt easily.

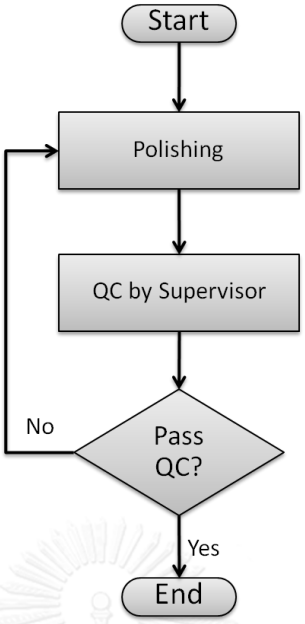

Figure 3-12 The flow chart diagram of polishing process

3.3.2.8 Car wash

Before vehicle delivery to customers, every car will be fully cleaned. Pressure washer is properly used to clean the damaged car with quality washing shampoo. It is not only clean exterior body but also interior of car will be cleaned by vacuum cleaners. Moreover, car wax is lastly applied for making surface a high shiny look.

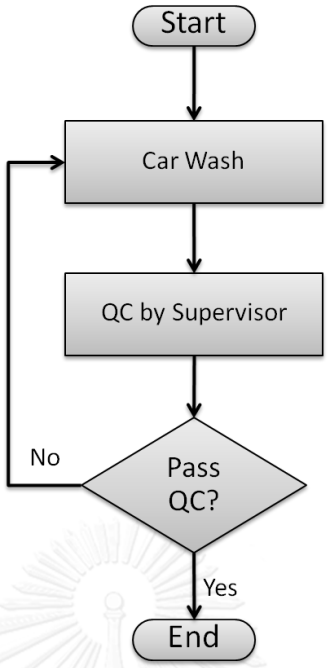

Figure 3-13 The flow chart diagram of car wash process

3.3.3 IT Supporting System

The case company gives an important on information technology for supporting all operations. Information system called operation management system as shown in Figure 3-5 is fully installed in order to help in history data storage via electronic storage and job status monitoring. Operation management system will assist all repair processes by storing data of processing time through clock-in and clock-out tools. These data can be kept in the history record for various purposes such as performance evaluation. It is also used to track status of each job order via visualized tool namely job control board. Job control board can properly sync data from every repair process and display all real-time job status as shown in Figure 3-14.

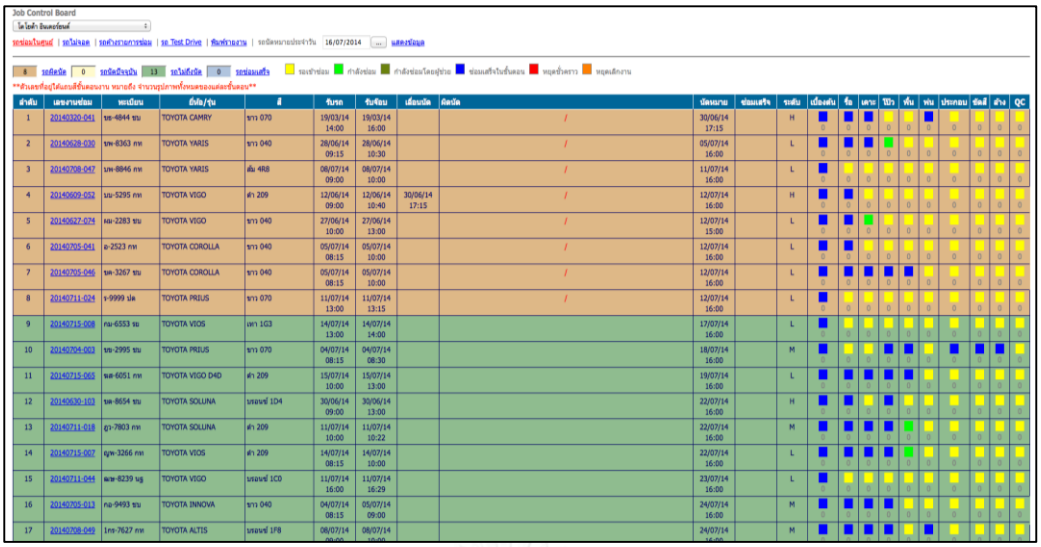

Figure 3-14 Job control board of the case company

According to Figure 3-14, job control board will properly display job order information including number of job order, car registered number, car model, arrival time, starting time, and appointment date. Moreover, the status of each job order in process will be shown. Each process status is categorized by using several color; yellow means waiting for repairing a required process, green means in-process execution, blue means process finishing, and red means process halt. However, job control board can provide limited in-process of job order. Receptions can only provide job's information of current status to customers. The expected time to finish cannot be known.

3.4 Current Problems Analysis

Although operation management system is developed to help internal operations to work efficiently, there are still some problems that definitely lead to unreliable service and customer dissatisfaction in term of inability of on-time job delivery or job lateness.

In consequence, the performance of the case company is currently dissatisfied which is caused by existing due date assignment policy and IT supporting system.

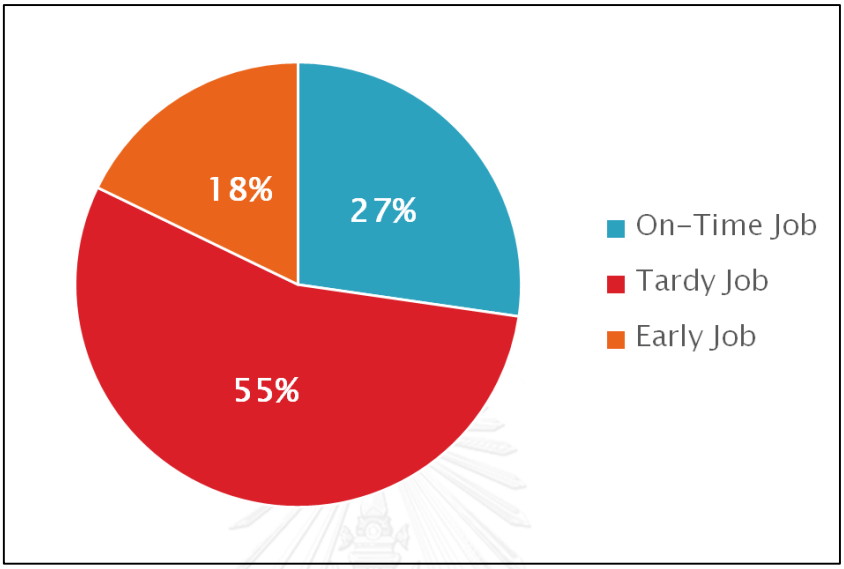

Figure 3-15 The percentage of overdue and on-time jobs of the case company

Since the case company provides services to customers, increasing of customer satisfaction is considered to be important for every service businesses. Typically, possible reason that can reduce customer satisfaction is overdue delivery date because they will lose opportunity to use their cars and waste more time. Therefore, the performance of the case company is directly reflected by the percentage of overdue and on-time jobs as shown in Figure 3-15. Overdue delivery date is illustrated from historical data excluding reworking jobs since 2012 to 2013. It clearly shows the percentage of overdue date around 55% of the total of 4,410 cars. The current performance is considered to be poor and inefficient due to a high percentage of overdue jobs when comparing to on-times jobs. Currently, due date given to customers at their arrival time is roughly estimated by expert's experiences based on due date

assignment policy that obviously leads to inefficient due date. The due date assignment policy of the case company is shown in Table 3-1.

Table 3-1 Current due date assignment policy of the case company

Severity Level	Price (Baht)	Due Date (days after arrival date)
Low	<=10,000	10-15
Medium	<=30,000	20-30
High	>30,000	30-60

Moreover, overdue delivery date can be classified into time interval as shown in Figure 3-16 to clearly show how many days late from the promised due date. The average tardiness time during 2012 to 2013 is approximately eight days. Most customers are able to receive their finished cars within five to eight days later than promised due date.

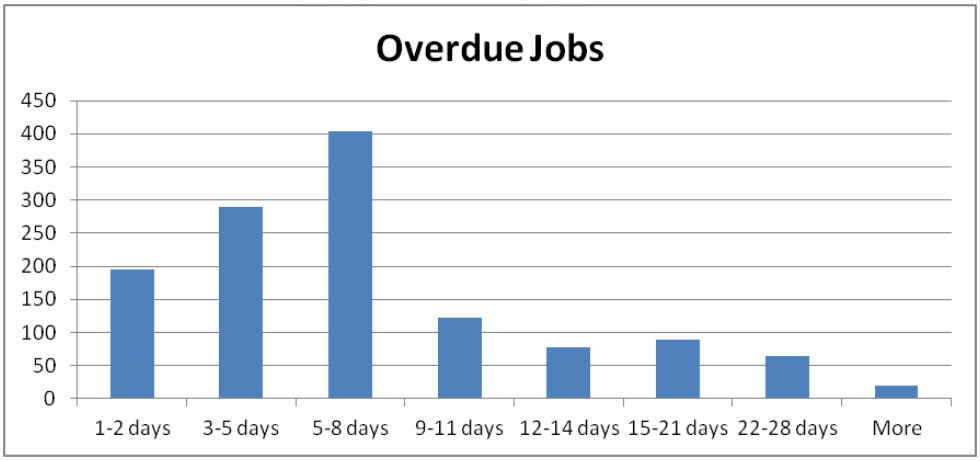

Figure 3-16 The overdue jobs categorized by range of late days

Since arrival jobs of the case company mainly have low severity level which is about 84% of total damaged cars. The due date assignment policy for low severity cars is

typically assigned at least ten days after arrival date. Hence, the average tardiness of eight days is considerably unacceptable.

Additionally, due date assignment policy leads to a problem as shown in table below:

Table 3-2 Examples of current job's problems

Job No.	Severity	Price (THB)	Arrival Date	Due Date	Due-date Lead Time (days)	Finished Date	Lead Time (days)
1	L	4,250.00	3/3/2014	15/3/2014	12	20/3/2014	17
2	L	3,506.25	1/4/2014	11/4/2014	10	23/4/2014	22
3	M	22,199.80	30/10/2012	20/11/2012	21	8/12/2012	39
4	M	15,587.30	4/1/2014	30/1/2014	26	20/1/2014	16
5	H	31,489.10	19/4/2013	31/5/2013	42	26/5/2013	37
6	H	50,616.65	26/3/2012	30/4/2012	36	20/4/2012	25

It is obviously seen that current due date assignment policy for all severity levels cannot provide a due date which nearly close to the actual lead time of the service. For instance, the cars with medium severity level are roughly assigned a due date within 20-30 days after arrival date. In fact, job no.3 had a late due date with 39 days lead time in the service, whereas job no.4 which has due date setting as 26 days could be finished before due date with only 16 days actual lead time. From this case study, car information; severity level and quoted price are definitely inadequate information for estimating due date. It also directly affects service reliability for delivering value to customers and operation performance of the case company.

Therefore, root causes should be critically analyzed in order to find the most suitable solutions to efficiently solve this problem. There are two possible causes that are explained as following:

3.4.1 Inefficiency of due date assignment policy

Current due date is decided by experts who are responsible for car inspection. They simply estimate due date by using car information which are severity level and quoted price. It can rewrite as a constant due date setting policy as below:

$$Due\ Date = Arrival\ Time + c$$

$$\text{Where } c = \begin{cases} 10-15, if\ severity = \text{light}, and\ price \leq 10{,}000 \\ 20-30, if\ severity = \text{medium}, and\ price \leq 30{,}000 \\ 30-60, if\ severity = \text{heavy}, and\ price > 30{,}000 \end{cases}$$

The problems of current due date setting policy can be concluded as following:

- Due date assignment is only based on inspector's experiences. Each expert can provide different due date within the range of indicated date duration as shown in Table 3-1.
- The sequencing order is not clearly identified. Senior operator can randomly select any damaged cars for operation executing. They sometimes decide to firstly choose low severity of car damage which takes a short time to finish. There is no appropriate sequencing rule for ordering cars into the processes.
- Current due date setting policy lacks of considering existing cars in the system. It is a major parameter for estimating a due date to customers in order to realize how much total time they need to wait for car repair. This parameter can properly improve due date estimation to be more realistic and help customers

to make a decision on whether to park a car and wait for service or come back again on its start date.

- There is no processing time included in due date assignment. Due to various car severity level and different required processes, each broken car is certainly executed with particular service time. Total processing time is significant car information that needed to be used in due date consideration.
- There is not information system for supporting reception in making a decision on job due date. Manual due date estimation probably leads to inefficient due date and job conflict from human error.

3.4.2 Inefficiency of monitor and control

Since current job control board of operation management system provides limited job information, reception and operation supervisor are not able to estimate start and finish time of a job order in each process. They only know basic job information and real-time status of job order without timeframe via job control board. Hence, job lateness cannot be properly foreknown and instantly notified to customers. In general, when some unexpected problem is immediate notified, customers are willing to understand and change their due date. Missed due date is considered to have more impact to service reliability than instant notification of due date postpone. Whereas job can sometimes be finished earlier than promised due date, customers will be early notified to pick up their car that definitely leads to increasing of customer satisfaction.

Furthermore, the action plan or job order planning is not included in operation management system. This action plan can be used to efficiently indicate the performance of workers since it will identify each ideal job's start and end time of every process. Therefore, the actual time of workers will be compared with action plan in order to measure personal performance for continual improvement.

3.4.3 Inconsistent and inaccurate due date assignment

At present, experts or senior workers play a significant role to estimate due date to customers. The problems of human error and emotional bias can occur because they have different level of experiences and skills. Inaccurate and inconsistent due date given to customers definitely affect to service reliability. Moreover, manual due date estimation usually consumes too much time depended on expert experiences. Therefore, IT support system can provide more accurate and consistent due date estimation. It will help operation working smoothly and faster.

3.5 Conclusion

To conclude, this chapter describes overview of the case company, current working processes including process workflow and IT supporting system. Then, current problem of overdue date is critically analysed in term of service performance. The case company is facing the high percentage of job lateness. The main cause is current due

date assignment policy which is only based on severity car, price and expert's experiences. These information are considered to be not enough for efficiently estimating due date given to customers. Moreover, there is no timeframe planning of each job order displaying on current IT supporting system. Job lateness cannot be foreknown by supervisors and notified to customers immediately. These problems are not only lead to missed due date to customers but also potential business losses in the future. Customers will disappoint with unreliable service and choose to go elsewhere.

Therefore, this research will emphasize to solve these problems by developing IT supporting system for assigning due date and monitoring and controlling every job order.

4 Design and Development of Due Date Assignment System

4.1 Introduction

In previous chapter, background of the case company, current operational workflow, and the problems that are currently facing are discussed. This chapter will focus further on due date assignment system that is developed for solving current problems as mentioned in the previous chapter. The overview of system is firstly explained to better understand the workflow of system. Then, the development procedures of each component will be properly described. Finally, user interface of due date assignment system will be shown along with the benefits of applying web-based information system.

4.2 System Overview

Due to current problems mentioned in previous chapter, due date assignment system aims to cope with overdue delivery date by applying IT system to assign efficient due date to customers. Since current due date assignment policy is based on expert's experiences, due date variation definitely occurs because each expert has different level of experiences and skills. Therefore, the design of due date assignment system mainly considers to systemize all support information used to assign an efficient due date. According to(Keskinocak and Tayur 2004), the flow time which has two components including job processing time and waiting time is considered to be

important for estimating due date. Job processing time refers to job information because it is depended on damaged parts with its severity level, and the number of required processes. Meanwhile, waiting time can be indicated from system information. There are information of service availability and existing jobs in the system. Job and system information are major factors for formulating due date assignment model.

In addition, regarding to working process of the case company (Section 3.3.2, Figure 3-5) in chapter 3, due date assignment system will be developed and installed to support the operation of reception and inspection. It will help inspectors to assign a due date to customers by considering damaged job information and system information at customer's arrival time. Hence, the processes of reception and inspection will be properly improved as it can provide better service due to more reliable due date and quick response to customers when they ask for their job status and expected finish time.

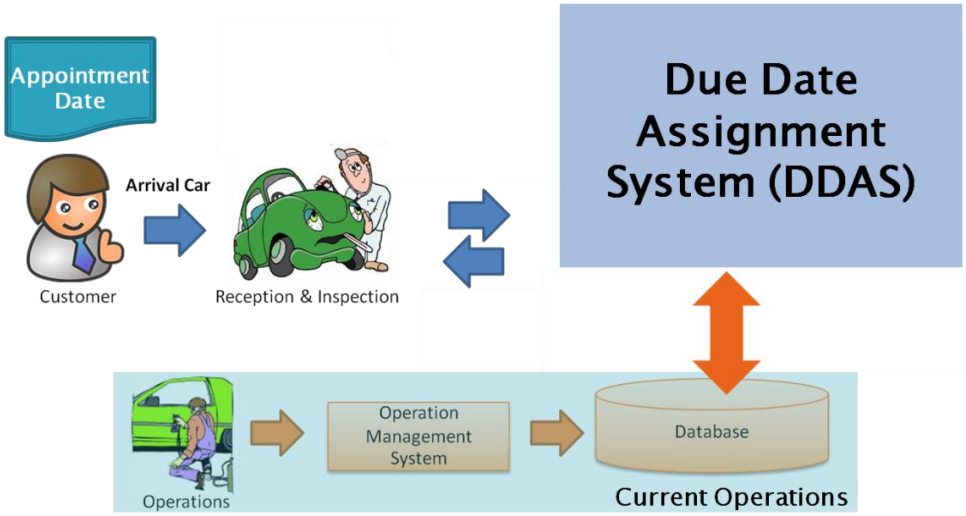

Figure 4-1 The information flow of due date assignment system

According to Figure 4-1, the system overview represents the interaction of due date assignment system (DDAS) with current operational workflow. It consists of reception and inspection, due date assignment system, electronic storage; database, operation management system. Firstly, arrival customers will contact receptionist at front to request a body repair and paint service. Receptionists have to send for inspecting damaged car from senior expert. The major factors of car inspection include damaged position, size, and severity level. These factors are needed to identify required processes, price quotation, and also due date estimation. After inspection, customers are required to approve repairing processes and quoted price. They are able to negotiate price and exchange damaged information with experts. Then, reception will entry a new job into a due date assignment system in order to issue appointment date to customers and create a job order to the operation level. Due date assignment system will support in estimation of appointment date by considering total service time of the damaged car and current available resources in the system. In order to indicate waiting time, the information of available resources including existing cars is definitely important. Hence, due date assignment system will query available resource information from database. Database which is considered to be a significant component will store all car information from operation management system. Workers have to input status of existing car into operation management system.

At operation level, the case company aims to develop operation management system to assist several internal processes as mentioned in the previous chapter and also to

keep job repair as historical records of the company. However, the current problem of overdue delivery date is a result from inefficient due date assignment policy with lacking of data consideration from operation level. Therefore, due date assignment system is developed to solve overdue date problem by developing new due date assignment policy and monitor and control platform. It will lead to the improvement of information utilization between administration and operation level. The detail of development of each component is described as following section.

4.3 Conceptual Design

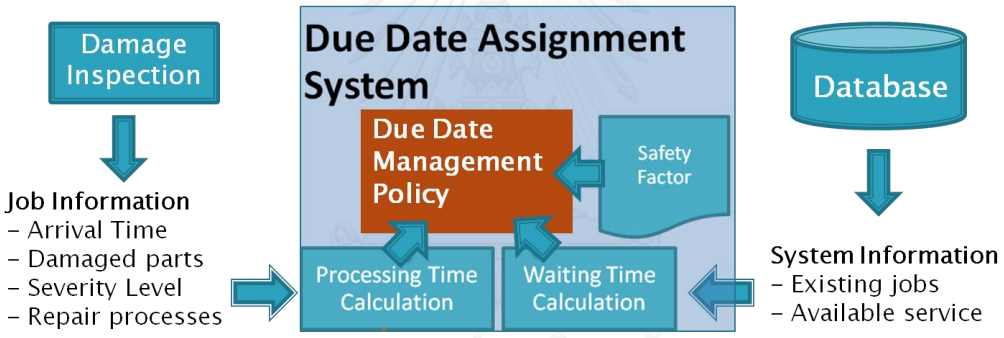

Figure 4-2 System overview of due date assignment system

Due date assignment system is a web-based information system developed for support in due date decision making. In general, customers need to know appointment date or expected finished date in order to bring back for personal utilization. Late due date can directly affect to service reliability and customer satisfaction. Therefore, due date assignment system will help to enhance service performance. This system will be used by reception where is considered to be the first contact point for customers. Arrival damaged car Information from inspection form will be an input. The system will

instantly provide an estimated due date at that arrival time of job. Moreover, due date assignment system has interested feature called action plan or job planning in order to improve the ability of monitor and control of the case company. For developing due date assignment system, due date management policy is important to be firstly developed. It refers to a logical module used to estimate due date.

4.3.1 Due Date Management Policy

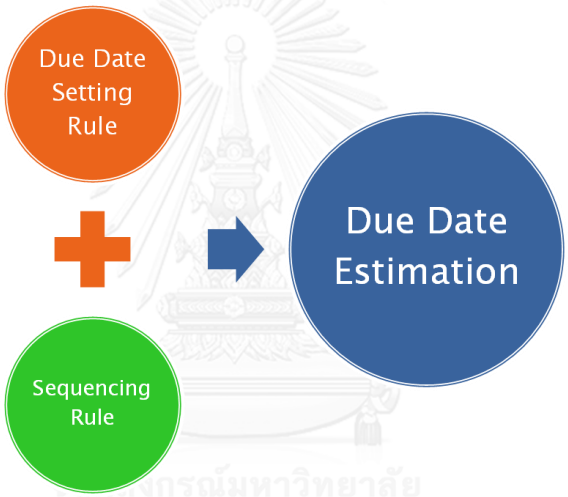

Figure 4-3 Relationship of Due Date Management Policy and Due Date Estimation

Due date management policy is an essential part for indicating how due date can be estimated. It consists of due date setting rule and sequencing policy. Due date setting rule mainly considers the flow time of a job. Since each job requires different processing time and waiting time to be repaired in processes, due date is efficiently estimated based on both time. For sequencing rule, it typically used to indicate how jobs will be input into processes. It is important for calculating accurate waiting time

of job which is also used in due date estimation. The appropriate due date setting rule and sequencing rule for due date assignment system as following:

- Due Date Setting Rule

  There are several factors used to estimate due date to customers at their arrival time. Since the case company has limited resources in term of number of server and workers. Also each arrival job has different required service time based on its severity level. Therefore, damaged car information gathered by inspectors and system information are required to estimate an efficient due date. The due date setting rule of the case company is shown as following:

$$DueDate = ArrivalTime + ProcessingTime + WaitingTime + SafetyFactor$$

  As the case company is considered to be online service model, arrival job date and time are uncertain. With different arrival date, each customer will have different due date. Service time also distinctly differs from others because each job has dissimilar damage characteristics and severity level. Service time consumption for each job must be obviously different. In term of waiting time, it can represent the current information of the system such as existing cars and resources in the system. In fact, there will be no waiting time when the operation resources are available to serve all arrival jobs. Lastly, safety factor

is considered as a spare time added to the overall service time. It is probably a significant factor when small error in service time estimation occurs. Customers are willing to get their jobs back on prior due date time rather than late time. Hence, adding suitable value of safety factor can protect the case company in term of service reliability and solve the overdue date problems.

- Sequencing Policy

Sequencing policy refers to the process to prioritize several jobs to be processed. Currently, sequencing policy of the case company is a random that jobs will be selected for processing by operation supervisors. This selection is usually based on their experiences and preferences. They may choose a job to be processed firstly due to shorter processing time or nearest jobs as it can be transferred easily. Since, there are many supervisors working depended on working shift, it probably leads to inefficiency in management and estimation of due date. Therefore, sequencing policy should be identified to enhance operation capability.

Auto body repair and paint service is considered to be time-consuming process. Operation process of the case company is also a sequential process. Job that needs to go back to previous processes is not allowed because each process of auto body repair and paint service is continual repairing processes; for example, painting can be performed when dent repair, panel repair and

primer spraying are totally completed. However, job with a small scratch needs a process only painting and polishing. The prior unwanted processes can be skipped.

In addition, due to online service model, the arrival time of jobs and required service time cannot be exactly known. Hence, jobs are difficult to be prioritized before inputting to repair processes. First-Come-First-Serve (FCFS) is appropriate sequencing policy used in the case company. It will help supervisors to prioritize uncertain arrival jobs for executing in each process. Job that comes earlier will be processed firstly. Moreover, FCFS is able to reduce some conflicts and errors from sequencing a job that may occur from human bias and personal preferences.

4.3.2 Processing Time

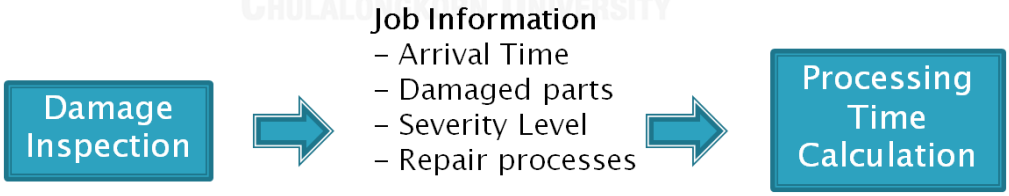

Figure 4-4 Major information for processing time calculation

Total processing time is considered to be major factor for estimating due date. Each job usually consumes different time in processes based on its damaged part, severity level, and repair processes. This job information can be gathered by reception and

damage inspection. The workflow of reception and inspection is clearly shown as flowchart diagram as following:

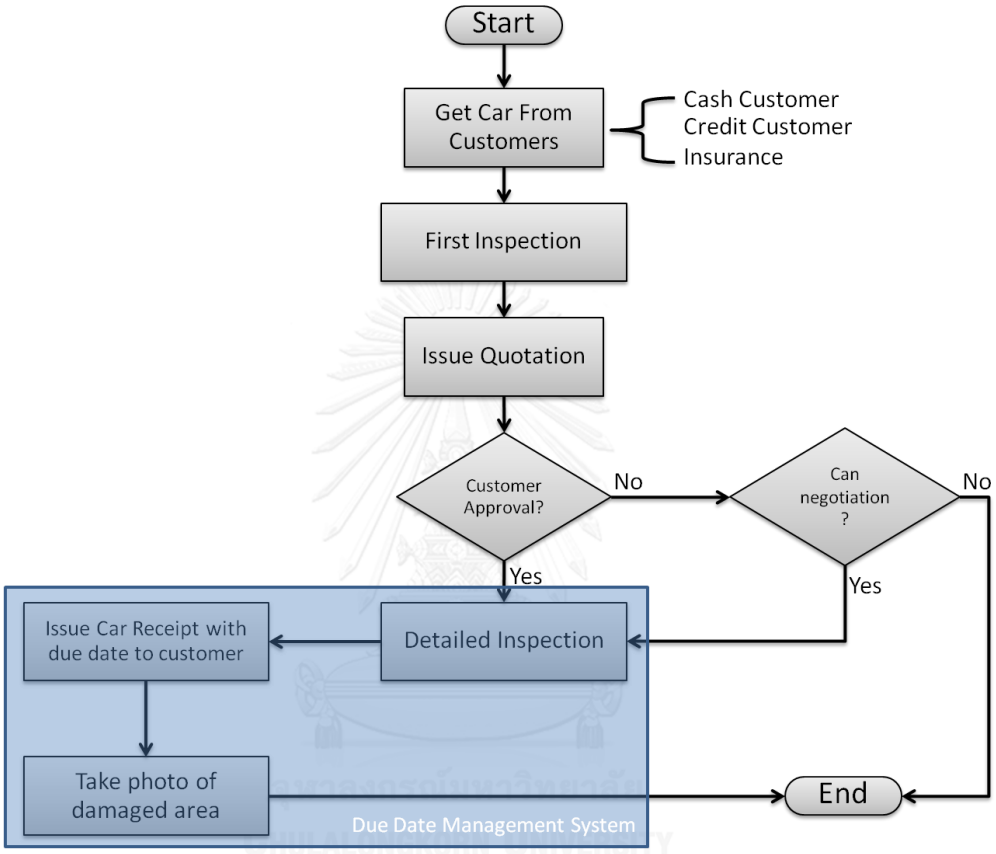

Figure 4-5 The flow chart diagram of reception with due date assignment system

Reception is the first contact point where every arrival customer requests for body repair and paint service. Reception of the case company called front desk is responsible for providing service information, serving what customers want, and following up a job for customers. Receptionist is considered to be a mid-person in order to communicate between customers and operation level. In the other words, some extra requirements that customer concerns such as part material, painting colour brand, or cleaning procedure should be totally transferred to operation workers.

Moreover, price quotation after expert inspection is issued by reception. Sometimes, customers need to negotiate a repair price. Hence, receptionist should have basic technical knowledge to quick response to customers and be good at negotiation skill to achieve acceptable profit along with customer satisfaction. After customer approval, damaged job will be critically inspected and its job information will be gathered to input into due date assignment system. An appointment date will be calculated and output as a receipt of car given to customers.

4.3.2.1 Inspection Policy

The damaged car is commonly a consequence from accidents and collision which can be divided into major and minor collisions. Each severity of collision can have different damage characteristics and severity. It may lead to major dent, unbalance of frame structure or only some scratch on painting colour. Therefore, experts who have long working-time and enough experiences are needed to carefully inspect damaged cars. The required processes for repairing will be identified and also repair price will be quoted.

For the case company, there are four main factors for damage inspection including characteristic, position, size, and severity level as following detail:

- Characteristic

  Due to different accidents, the characteristics of damaged car are totally different. The common damage characteristic includes dent, scratch, paint

repair, rust or corrosion, and replacement. Firstly, dent is typically occurred by major and minor collision between cars or any hard objects. Collision can cause dent on every part of auto body especially front and rear bumpers. Next, scratch refers to minor damage that does not affect the structure and body shape of car. It probably needs only panel repair based on damaged surface and painting process to repair. The third one is paint repair which generally results from low quality painting. For example, paint wave or unsmooth paint surface may occur due to inefficient painting color and drying procedures. Next, rust or corrosion usually spreads depended on time. Due to metal material, moisture in the air and water is main cause to encourage rust on old car body. Lastly, part replacement will be considered if a damaged car has heavy collision and major damage. It is too hard to repair dent and painting. Inspectors will suggest replacing with a new part from car manufacturers.

- Position

Most auto body have the same components which involves thirteen number of body parts as shown in Table 4-1. Shape and design may be distinctly different based on car models and brands. However, position of damage has direct impact to difficulty of operation. Some parts spend much time to access and repair damage; for example, if front bumper needs to be removed to repair its damage, both left and right fenders

must be removed firstly. It will take much time for working. Therefore, position of damages is important to be considered.

Table 4-1 Auto body components

Front	Rear
Front bumper	Rear bumper
Front hood	Rear hood
Front left fender	Rear left fender
Front right fender	Rear right fender
Front left door	Rear left door
Front right door	Rear right door
Rooftop	

- Size and Severity level

  In damage estimation of the case company, severity level can be divided into three levels including heavy, medium, and light. These levels are typically used to identify required processes, service time, and price quotation for operational workers and customers. Damaged size plays a significant role to indicate severity level as shown in figure below:

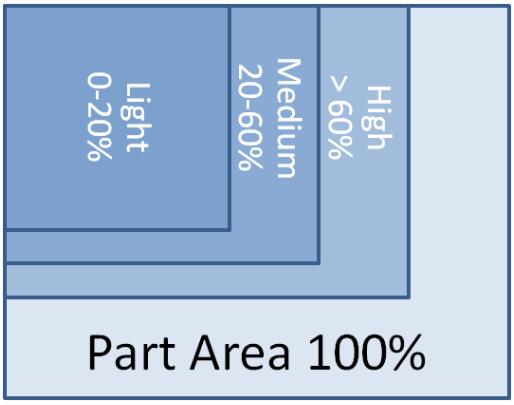

Figure 4-6 The criteria for classifying damage parts based on severity level

Regarding to Figure 4-6, heavy severity level refers to at least 60% of damaged part area. Medium severity level is approximately 20% to 60% of damage part area. While, no more than 20% of damaged area is considered to be low severity level. Although various damages may be differently occurred, these criteria can be standard reference for inspectors used to identify severity level of damaged car. And also it is useful for customers to claim for car insurance.

- Light severity level

  It refers to a damaged car which has maximum at 20% damage of its part. In general, scratch, abrasion, and small dimple are repaired without using specific equipment. Figure 4-7 shows an example of low severity of damage.

Figure 4-7 Examples of light severity level. Reprinted from (sbrand co., ltd, n.d.)

- Medium severity level

The part that is damaged around 20% to 60% of the overall area is considered to be medium severity level; for examples, deep abrasion rather than dimple and small impact dent. Furthermore, it includes damages that do not affect the structure and car frame. In the other word, a damaged car with no impact on safety driving and body structure balance will be categorized as medium severity level. The example of medium damaged car is shown Figure 4-8.

Figure 4-8 Examples of medium severity level. Reprinted from (sbrand co., ltd, n.d.)

- Heavy severity level

Heavy severity level refers to damaged area of more than 60%. It commonly needs heavy specific tools to help repairing back to its original shape or structure. Damage characteristic can make body frame and angle to be distorted shape. However, this heavy damage will not affect bearing area of car for safety driving. Otherwise, damaged car is not able to be repaired.

Figure 4-9 An example of heavy severity level. Reprinted from (sbrand co., ltd, n.d.)

- Replacement

Replacement is an important service for severe jobs. It refers to jobs that are difficult to be repaired. Most replacement jobs have damages more than 80% to 100% of total part area. Inspectors will suggest customers to replace spare part due to driving safety and utilisation.

Due to various major factors of damaged car inspection, inspection form is designed in order to assist inspectors to efficiently collect the job information to be the input of due date assignment system as shown in Figure 4-10.

Inspection form consists of basic car information and dimension of inspection factors. Since damage position and severity level are totally used to indicate required processes, inspection form is properly designed according to major related factors. Therefore, the dimension data structure in an inspection form will involve all body part's name with severity level and all processes. Inspectors can use this inspection form to estimate damaged car and then check into a blank space of what part needs to be repaired, how severe of a part, and also which processes are needed.

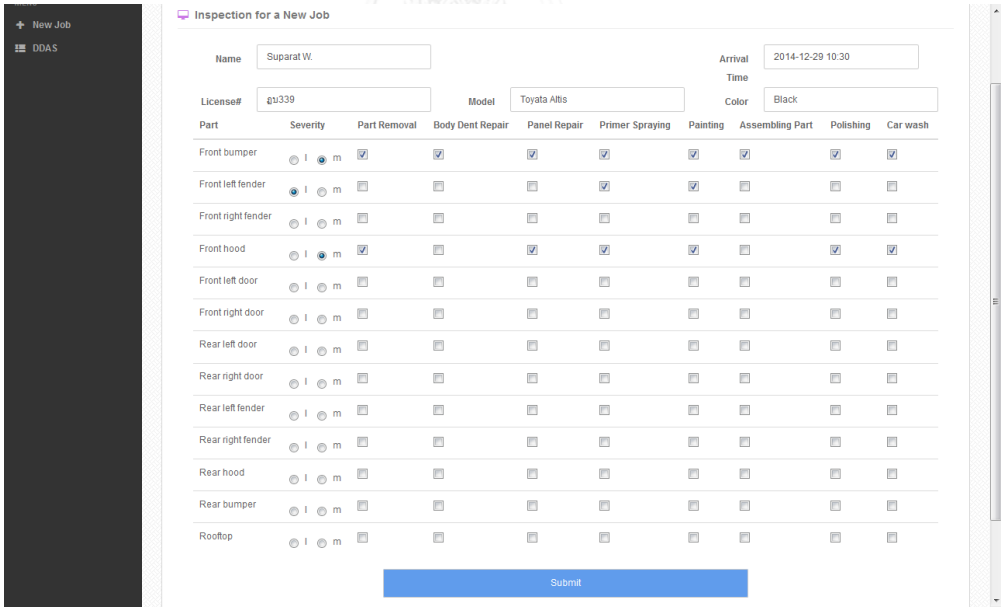

Figure 4-10 Inspection form of due date assignment system

Furthermore, there are many factors relating to each process for identifying standard processing time of a job. Therefore, processing time will be categorized in eight processes of auto body repair and paint service of the case company. The relationship

between processing time of each process and significant factors can be clearly represented as data structure in Figure 4-11.

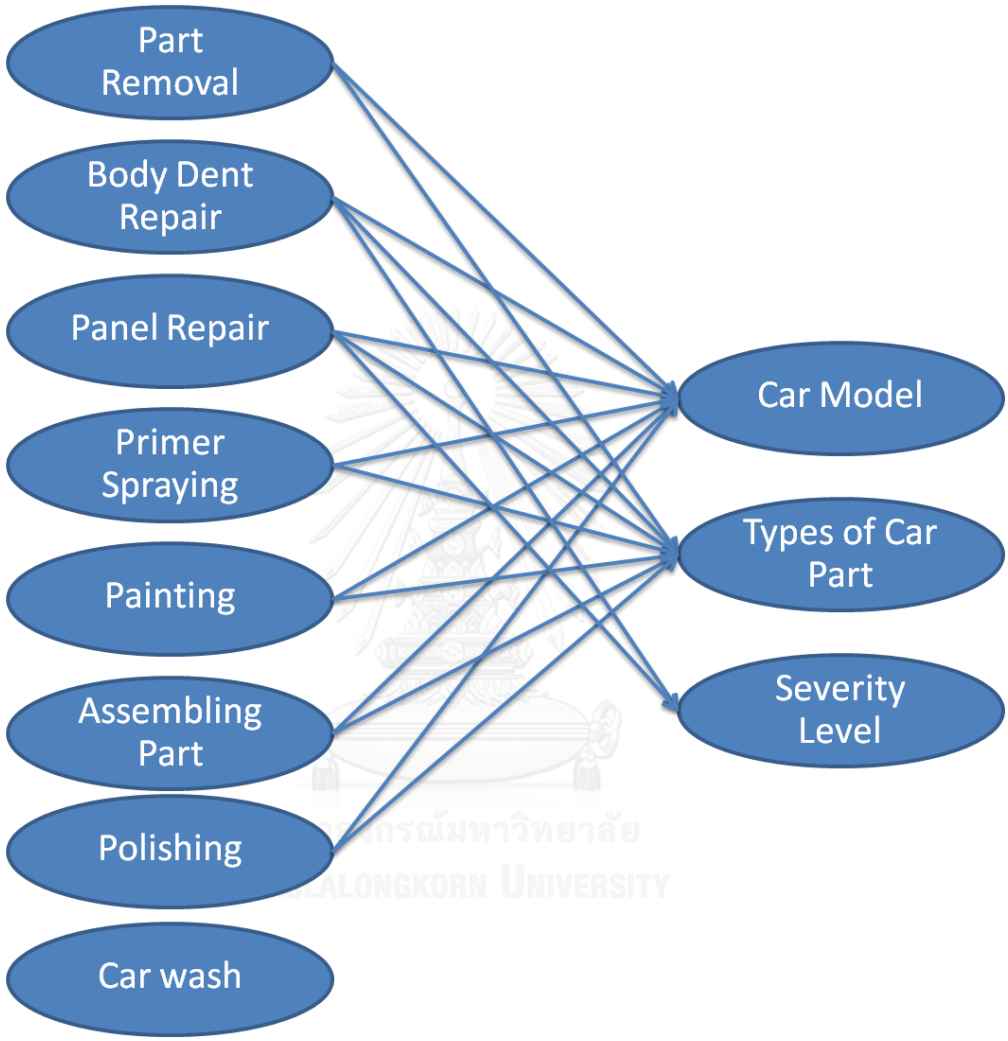

Figure 4-11 The relationship of factors affecting processing time in each process

- Part Removal

The first process of auto body repair and paint service is car part removal. Workers will remove both damaged parts for repairing and some accessories part for keeping in storage room. Moreover, parts that cannot be repaired will also be removed and threw away as a waste. There are totally

thirteen parts of car body. In order to remove each part, standard processing time will be used based on each type of car part and model such as front left fender of Toyota Vios model has standard time for removing as 23.5 minute. Hence, standard processing time should be carefully collected and analyzed by scientific method.

In reality, some parts are required to be removed together due to connected structure components. For examples, the damaged front bumper is able to be removed. Front left fender and front right fender must be removed firstly. At the same time, rear left fender and rear right fender are also needed to be removed before rear bumper. Therefore, standard processing time of removing bumper will be added up by removal time of both fenders. In order to better for understanding, dependency flowchart of related parts in part removal process can be shown as Figure 4-12.

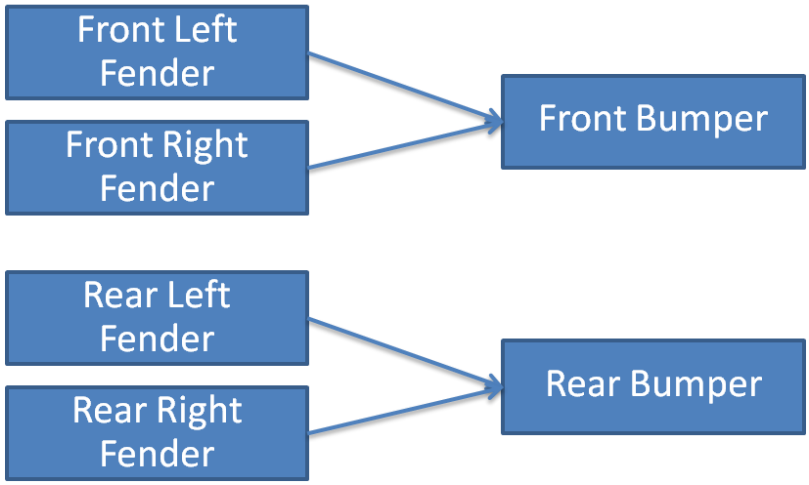

Figure 4-12 Dependency flowchart of relating body parts

- Body Dent Repair

In order to repair a dent, the major factor that can directly affect the processing time for repairing is damaged characteristics including damaged parts and size. It is generally used to indicate how difficult to repair a dent and estimated time used in a process. Therefore, the processing time of body dent repair is based on damaged parts and severity level. Since severity level of every job must be inspected and identified from expert at reception process. The severity level for the case company can be divided into three levels including heavy, medium, and light damaged parts. The major factors that can affect standard processing time of body dent repair are types of car part and its model, and three levels of severity.

- Panel Repair

Since the purpose of panel repair is to smoothen a surface by using specific chemical. The rough surface of damaged parts is too hard to be repaired by body dent repair equipments. Some chemical will be applied to nearly make it to be as part's original surface. Hence, the major factors indicating the standard processing time of panel repair process is similar to body dent repair. The type of body parts, model and severity level will be used to specify the standard processing time of panel repair process.

- Primer Spraying

In general, all processes relating to color painting of auto repair service will consider painting a new color on the whole damaged parts. As there may be some chance that the same color code of a car can be slightly different in term of shade and color pigment. Moreover, each manufacturing lot of auto color is able to be a bit different. Therefore, auto painting repair of all damaged parts will usually apply the new color all over the whole part in order to avoid being noticed even through the same color code.

Primer is a base color in order to help improving of the adhering and balancing of true color. It is necessary to spray on the whole damaged part before true color painting. Hence, the standard processing time of primer spraying process is based on types of part and car model.

- Painting

Painting is an important process in painting repair service. The repairing approach required specialized skills and long term experiences. Due to difference of color manufacturing lots, the damaged parts have to be painted over all surface area. Therefore, the major factor for indicating the processing time of painting is also types of part and model which is similar to primer spraying process. Each part requires different processing time to be overall painted.

- Assembling part

The factors affecting to the standard processing time of assembling process are similar to process of part removal which are types of part and car model. Furthermore, there are some parts that need to be continually assembled due to dependency chart as shown in Figure 4-12. For example, in order to assemble front left and right fenders, front bumper is required to be put in firstly.

- Polishing

After finishing all painting processes, polishing is needed to help removing of some dust and painting dirty. The body part surface will be more shiny and glossy. As painting color is needed to apply all over the damaged part, worker will also use sanding machine with some chemical to polish surface of the whole part. Hence, there is the type of part used to classify the standard processing time of polishing process as represented Figure 4-11.

- Car Wash

Car wash is final process of auto body repair and paint service of the case company. The case company aims to provide quick car wash service. The standard time of car wash is needed to be fixed as forty five minute for every car model. This time will include all standard cleaning steps of interior and exterior car wash. Workers should efficiently perform based on this standard time to provide quick service with high quality.

4.3.3 Waiting Time

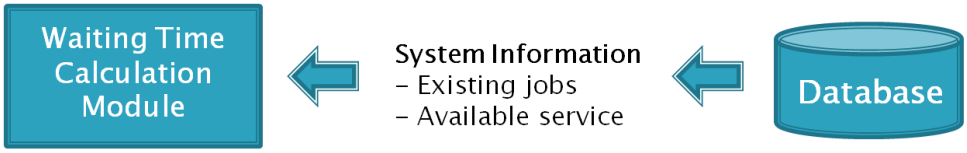

Figure 4-13 Major information for waiting time calculation

Waiting time is considered to be a significant factor for estimating due date to customers. Since required processes with processing time for each job order is totally different based on damaged parts and severity level, waiting time is also different. Each process has its own waiting line or queue before repairing in process. Waiting line typically occurs when there are jobs requesting for service operations more than available resources including labor and several facilities.

All new jobs are given a due date at their arrival time. Due date is properly estimated by considering both job information and system information. System information including the number of servers and existing cars in the same required processes for damaged repairing, for example, a new job needs reprocess of primer spraying, painting, polishing, and car wash. All current cars in these processes will be used to identify total waiting time of a new job. The sequencing policy of the case company is First-Come-First-Serve (FCFS) rule. This rule is used to prioritize job orders based on their arrival time. The job that has its arrival time later than other jobs needs to insert into waiting list for repairing in each process. Since each process has its own queue, total waiting time of a job will be the summation of waiting time in each process. In order

to represent the logical thinking of waiting time in each process, the flowchart diagram is used to better describe step by step as shown in Figure 4-14.

Firstly, when a new job has its required processes for repairing, the system will find a number of previous jobs that are equal to a number of servers in each process. For example, dent repair process has four servers. The system will find four jobs prior a new job. Secondly, the system will consider all finished time of the identified jobs that are equal to a number of servers. When there is some previous job that can finish before arrival time of a new job, the server will be available for repairing immediately at arrival time of a new job. Hence, start time of a new job will be equal to its arrival time at this process. Whereas, there is no any finished jobs at arrival time of a new job. The system will consider the lowest finished time from all identified jobs. Then, the start time of a new job will be set as the minimum finished time of one previous job. Finally, after start time of a new job can be identified, the system will calculate waiting time in this process by comparing between start time and arrival time. Waiting time typically occurs when arrival time is less than start time.

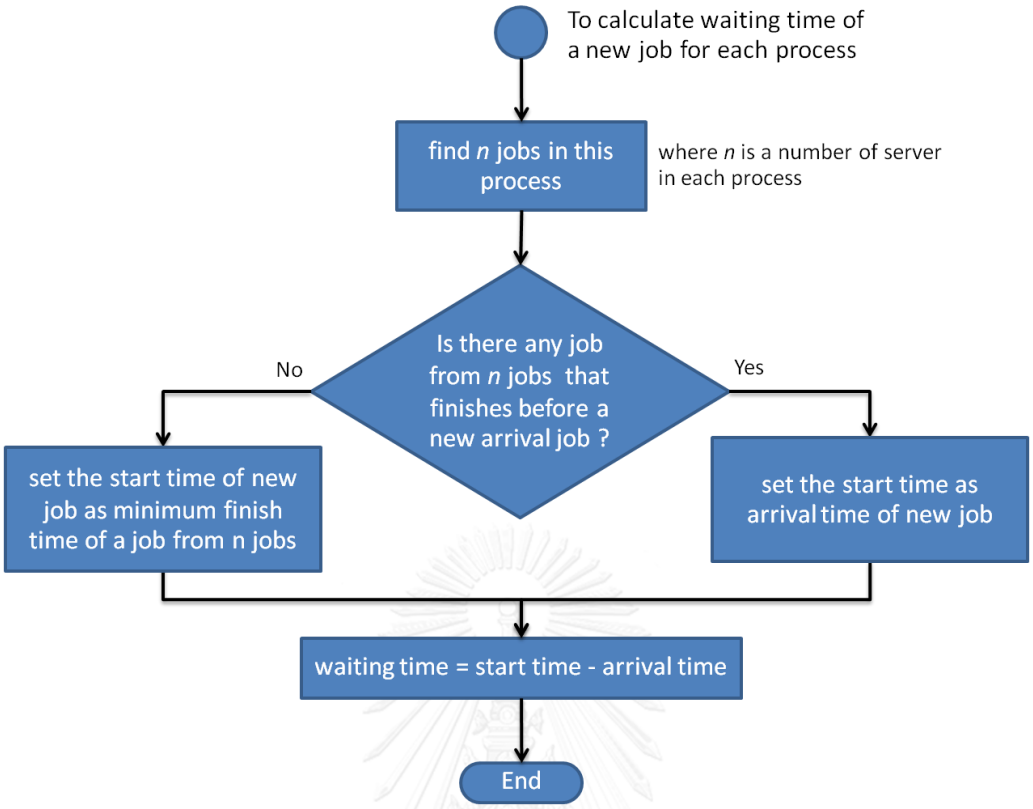

Figure 4-14 The logical thinking flowchart of waiting time

4.3.4 Numerical Example of Due Date Calculation

Since due date assignment system is able to provide due date as the receipt of car to customers at their arrival time. At the time of arrival, due date will be calculated by considering new job information and system information. The following example properly represents the calculation procedures for better understanding of due date assignment system.

Firstly, new damaged job asks for service at reception and inspection. The job information will be inspected and input into inspection form consisting of damaged parts, severity level, and repair processes as shown as following:

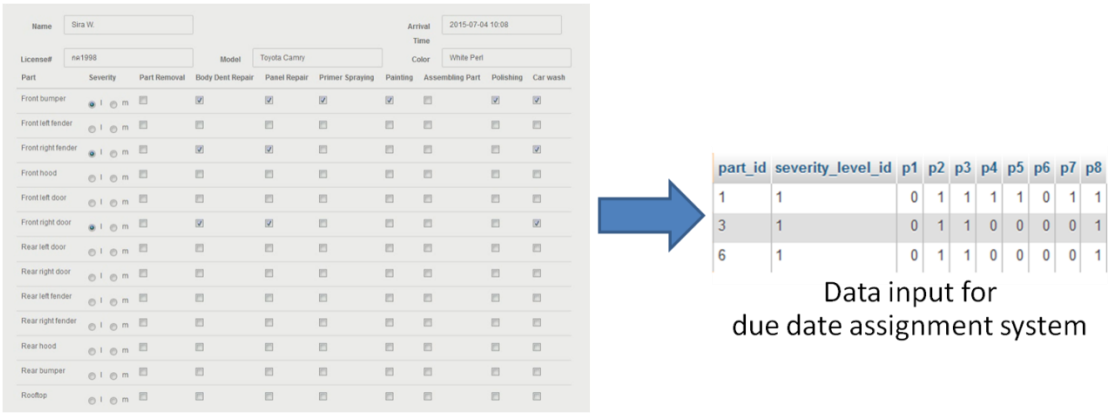

Figure 4-15 An example of data input

Secondly, in order to find total processing time of this new job, standard processing time for each repair process will be properly used which is based on damaged parts and severity level. In this case, the repair processes for part no. 1 are process 2, 3, 4, 5, 7, and process 8. Therefore, standard processing time is shown below:

service1	service2	service3	service4	service5	service6	service7	service8
0	379	636	227	140	0	107	45

Figure 4-16 An example of calculated processing time

Then, total waiting time is needed to be calculated. It sums up from waiting time from each repair process. Moreover, system information including existing cars in the same repair processes and available work stations or servers is important for estimating waiting time. For example, there are two existing cars in the system as shown as following job plan:

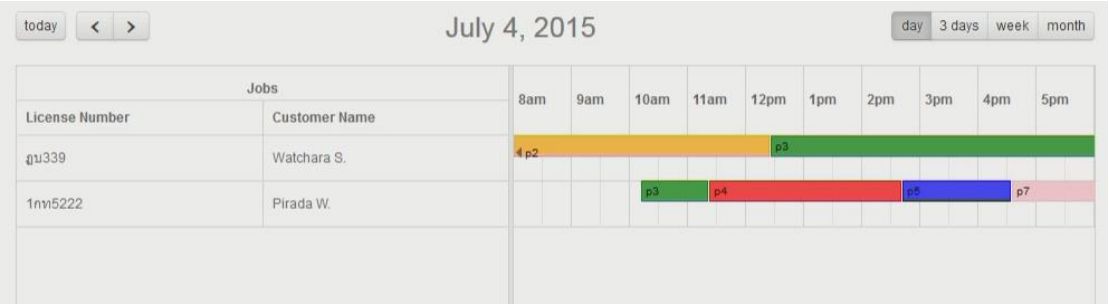

Figure 4-17 An example of job plan

In case of waiting time of process 2, the below logical flowchart is used to calculate waiting time of process 2 for this job example.

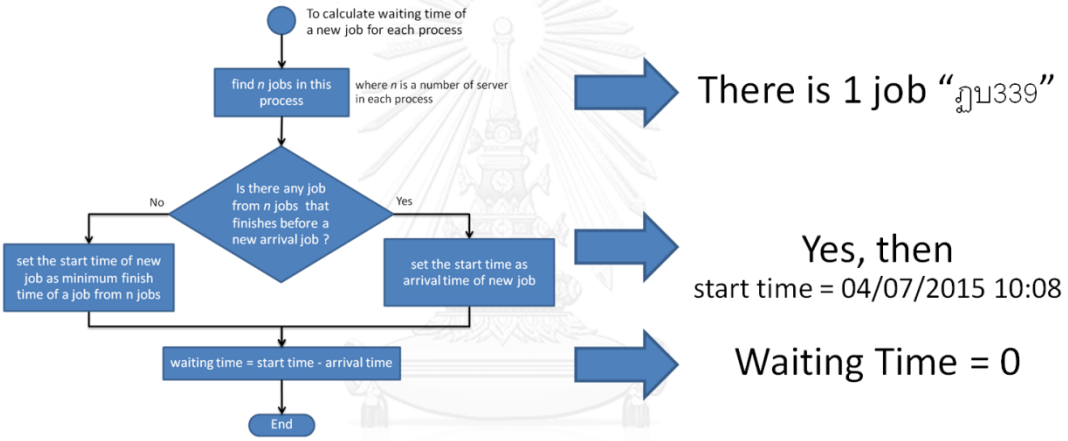

Figure 4-18 An example of waiting time calculation

It starts with finding the number of job as equal to the number of server in process 2. The result shows only one job in this process. Then, the system will check that "Are there existing jobs will be finished before arrival time of new job?" In this example, the answer is "Yes". It clearly means that there is currently available server in process 2 at the arrival time of example job. Finally, waiting time in process 2 of this example job will be zero. This job do not need to wait, it can be repaired in process 2 immediately. On the other hand, if the answer is "No", the system will indicate

minimum finished time of existing jobs in that process and set start time of new job as the soonest time of available server. Next, waiting time of the rest of processes will be calculated by using this logical flowchart as well.

After calculating total processing time and waiting time, due date assignment policy is required to estimate a due date.

$$DueDate = ArrivalTime + ProcessingTime + WaitingTime + SafetyFactor$$

Arrival Date and Time = 04/07/2015 10:08

Total Processing Time = 1534 mins. (26 hrs.) since 8 working hours, total processing time is approximately 4 days

Total Waiting Time = 0

Safety factor = 1 day

As a result, $DueDate = 09/07/2015$

4.4 System Development

4.4.1 Database Design

ER diagram is typically used to represent database structure. It consists of several database tables with their relationship. In case of due date assignment system, there are additional table including jobs_parts, standard_times, plans, and calculation_times. In each table, there are several attributes used for storing job data, standard processing time, and job's plan as shown in Figure 4-19. Since the case company has the database for supporting their current operations, these additional database tables can be added

to the existing one. The highlight of red colour in Figure 4-19 represents the existing database tables. These data are about the basic job information, body part name, and severity level categorized by the case company.

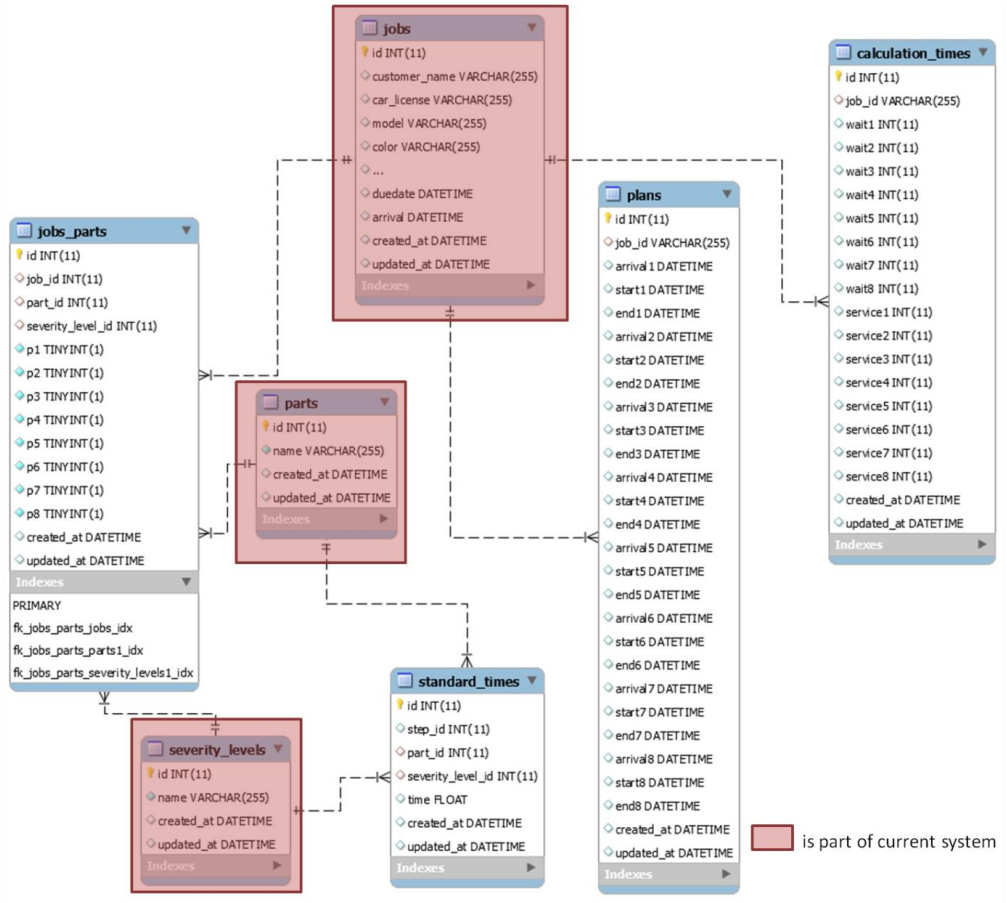

Figure 4-19 ER diagram of due date assignment system

According to Figure 4-19, the additional database table for using in due date assignment system consists of four tables. The database table of jobs_parts is mainly stored data of required processes for each part in a job. There are job_id, part_id, severity_level_id, and all eight required processes. Secondly, table namely standard_times focuses on keeping standard processing time of a job based on its parts, severity level, and major factors relating to each process. Next table is plans which will record the start and end

times of every process for a job. This data in plans is utilized to create the action plan for monitor and control. The last table called calculation_times will store times data such as waiting time and processing time for each process in order to sum up to be total waiting time and total processing time used in due date setting rule accordingly. The four additional tables are important parts for supporting data exchange with due date assignment system to run efficiently.

4.4.2 Monitoring and Controlling Platform

Since the major problem of the case company is that it is difficult to monitor and control each job order within the system. Current job control board of operation management system provides only the status of job order in a process without considering time. As a result, the planning of start and end time of all required processes of each job order cannot be identified. The expected time in process of a job cannot be efficiently monitored by supervisor. Workers usually consume too much time for executing each job without planned time control. It leads to inefficiency of worker performance measurement. Moreover, when late delivery of job occurs, the case company cannot foreknow and notify customers on time. Therefore, due date assignment system is designed to cope best with this problem. There is monitor and control platform providing visualization view of job planning. It is developed to be a guideline for tracking and controlling each job in a process. Participant workers are able to give a quick response to customers when they need to follow their job. Customers

will be satisfied with the improved service. Due date assignment system aims to monitor and control total service time of a job which is divided into start and end time of each required process. The start and end time of every required process will be planned at that time of due date estimation. Job will be input in a system with identified timeline. The action plan consists of required processes with the timeframe as shown in Figure 4-20.

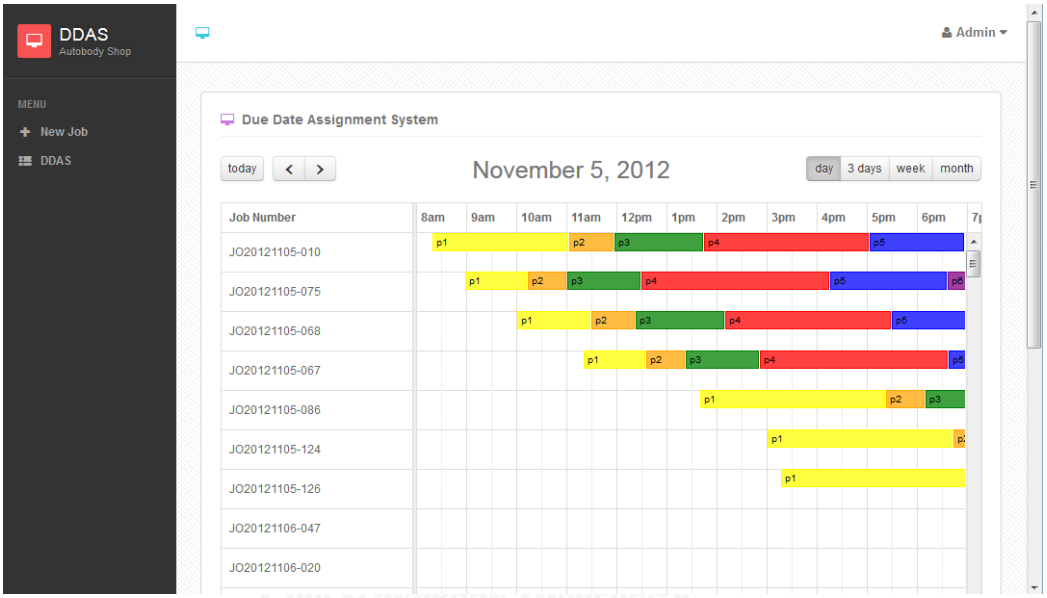

Figure 4-20 The action plan from due date assignment system

Figure 4-21 shows the user interface of monitor and control platform of due date assignment system. It includes all jobs in the system with their job order number and planned time in their required processes. At their arrival time of every job, receptionists will input new job information into due date assignment system in order to estimating due date given to customers. The system information such as existing cars and available resources are also used to calculate due date. Meanwhile, the start and end time of all required processes of a new job will be identified.

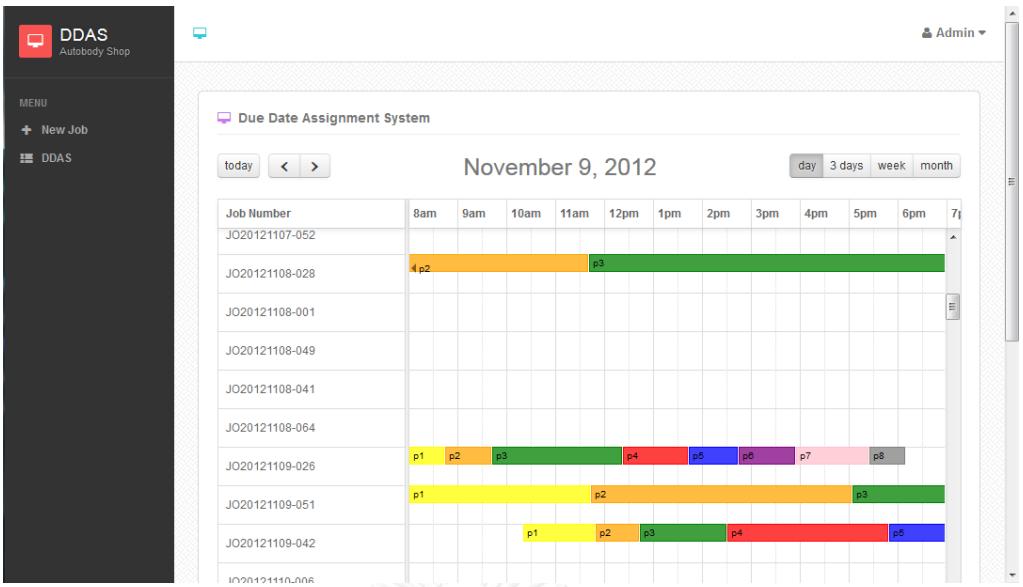

Figure 4-21 The user interface of monitor and control

In order to enhance the ability of monitoring tool, the monitor and control platform of due date assignment system provides boarder view of jobs as one day, three days, a week, and a month. The working time of the case company is eight hours per day starting from eight a.m. to five p.m. of Monday to Saturday. The major component consists of job identification number, timeframe of working time, required processes of each job with planned start and end time. In Figure 4-21, the repair processes for a job is represented as various colours and abbreviations as following:

- Part removal; p1 is represented by yellow
- Body dent repair; p2 is represented by orange
- Panel repair; p3 is represented by green
- Primer spraying; p4 is represented by red
- Painting; p5 is represented by blue

- Part assembling; p6 is represented by purple
- Polishing; p7 is represented by pink
- Car wash; p8 is represented by grey

In addition, the action plan of monitor and control platform can be exported as document soft file and also printed as a hard copy plan. Supervisor is able to use this printed plan for controlling worker performance in each process. As the time in process of each job is previously estimated, the actual time that workers use to repair a job can reflect their working performance. When the actual time of repairing a job is later than planned time, it definitely leads to missed due date. Job lateness will be foreknown and notified to customers in time. Postponement of due date is considered to have less impacts from customer dissatisfaction.

4.4.3 Benefits of Applying Web-based Information System

In order to gain the highest utilization of due date assignment system, web-based information system is considered to be practical approach for the case company to develop system. After developing of due date assignment system framework, it is practically implemented to be a web-based information system which properly connects with database of operation information. Due date assignment system is able to get data input from inspection through user interface of web application. Then, the system will perform due date calculation by gathering all related operation data from

database. Lastly, due date will be output that can be printed as job receipt to customers. Therefore, the benefits from applying web-based information system for the case company can be explained as following:

- Better utilization

  Since web-based information system provides user friendly interaction and simple utilization. All receptionists who are responsible for assigning due date can use the system via many well-known web browsers such as Firefox and Google Chrome. Hence, they can be familiar with the system and easy to understand how to efficiently use.

- Simple installation and troubleshooting

  The case company can simply install due date assignment system on server of the company at once. The system is able to be accessed by using network infrastructure. Therefore, several work stations that have authorized access can use due date assignment system instantly without installation on each work station. Moreover, when some errors occur, it can be easily found and fixed only on the installed server. Meanwhile, in case of system updating, the case company can also update new version of the system at one time on the server. This new version will be immediately updated on every work station through network. It definitely reduces time for information technology support.

- Remote management

Using of web-based information system provides efficiency in monitor and control of operation. In the other word, supervisors or managers can simply access this system at anytime and anywhere through internet network. It encourages working and managing internal operation on remote area. It can probably lead to improvement of operation capability and performance of the case company. Since monitor and control of due date assignment system aims to be as performance indicators for controlling workers performance. The action plan of each job will be identified since reception process. Therefore, the actual operation is able to be compared with expected plan in order to measure the performance of workers.

- Efficient data security

Data security is a significant issue to the case company because there are history record of job information, customer information, and also various confidential data. Due to stable infrastructure of web server and network, data is safely stored in server that can be accessed and used from every work station through network. Storage devices such as external hard drive and handy drive do not need to store data. It can reduce a chance of data loss and error. Moreover, web-based information system is directly connected to an electronic storage called database which is only installed on one server. Database is considered to be a powerful tool for keeping data in the form of data structure

and standard format. When there is a huge of data, it is easy to maintain and find out the problems.

4.4.4 Due Date Assignment System User Interface

After developing of due date assignment system by using web-based information system, user interface of the system is designed for enhancing the interaction between human and computer system. On the other hand, end user is able to input data and customize features of the system by using user interface. Moreover, user interface will present data output from system computation in the readable form. User interface of due date assignment system is shown as Figure 4-22.

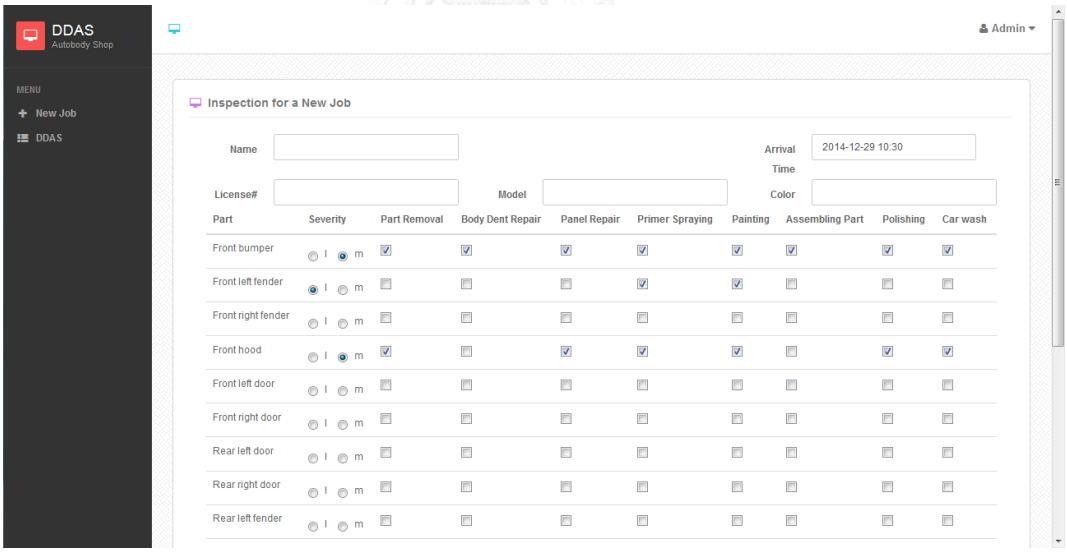

Figure 4-22 User interface of due date assignment system; inspection form

It is obviously seen that data input of due date assignment system refers to inspection form used by experts in process of inspection. Basic job information includes customer name, arrival date and time, license number of damaged car and other car information. Since inspection process needs specific job information for estimating due date, user

interface is designed to gather data of damaged types with its severity level as low or medium, and required processes.

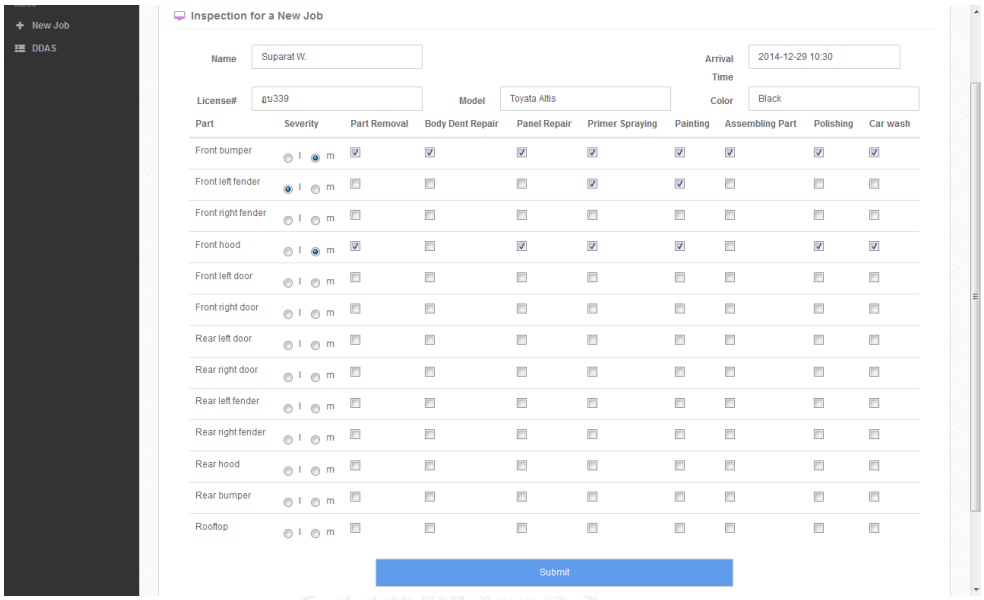

Figure 4-23 An example of inputting data into inspection form

After estimating damaged parts and check required information on the user interface, there is button to summit data into the system. The system will create a new job and store in the database for using in operation processes. Meanwhile, the system will compute and estimating due date by considering new job information and existing jobs in the system with their current status. As due date setting rule is based on information from arrival job for identifying required processing time and also information from existing jobs in the system for estimating waiting time. Then, the output of the system is due date given to customers at their arrival time. It is able to print out as hard copy to be the receipt of job. The output form of the system is shown as Figure 4-24. The information from the system includes job identification information with customer name, and estimated due date. Due date is important for service business because it

has an impact on service potential and reliability. Therefore, efficient due date estimated by due date assignment system considers both of job information and system information concurrently.

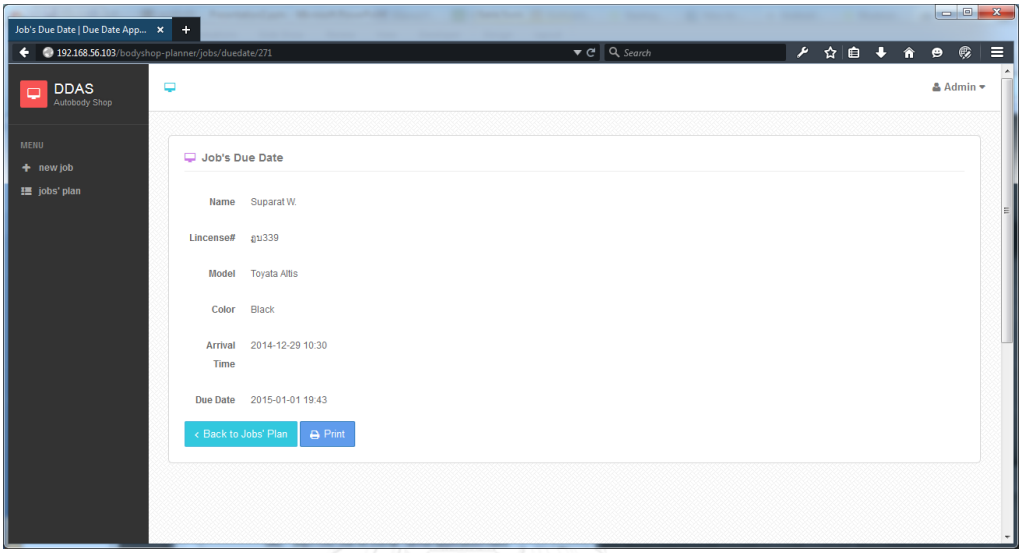

Figure 4-24 The output of due date assignment system; the receipt of car

In Figure 4-24, estimated due date from due date assignment system consists of appointment date and time for customer to pick up their car. Customers are able to decide to send their cars to repair service when estimated due date is satisfied. It properly leads to customer satisfaction because they can plan the usage of their cars. Additionally, due date assignment system has an important feature for monitor and control. The action plan for each job is produced in order to efficiently manage operations as shown in Figure 4-25 and Figure 4-26. The timeframe is used to represent required time used in processes for each job order. This timeline can be selected as one day, three day, a week, and a month to expand boarder view of status of current jobs in the system. Since the start and end time of each process can be identified, supervisor is able to monitor and control operations by considering the status of job

order with timeframe. Moreover, new arrival job will be given the start date of first required process. customers can decide either to send their cars waiting for the service or bring their cars back to use until the planed start date of service. It will increase car utilization instead of parking in a waiting queue. This monitor and control feature does not only satisfy customers in term of service flexibility but the case company can also reduce many parking spaces for waiting cars.

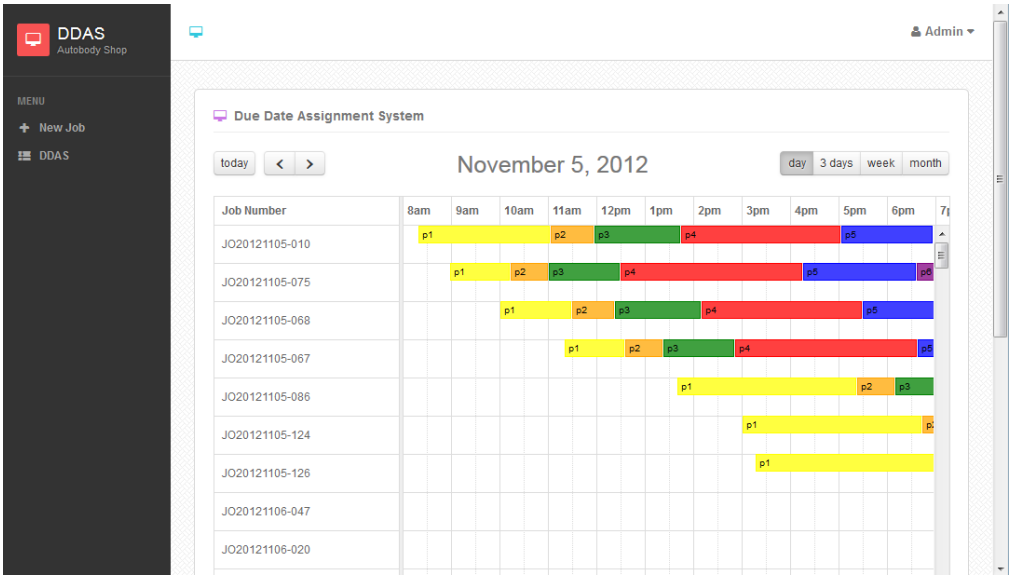

Figure 4-25 An example of the action plan

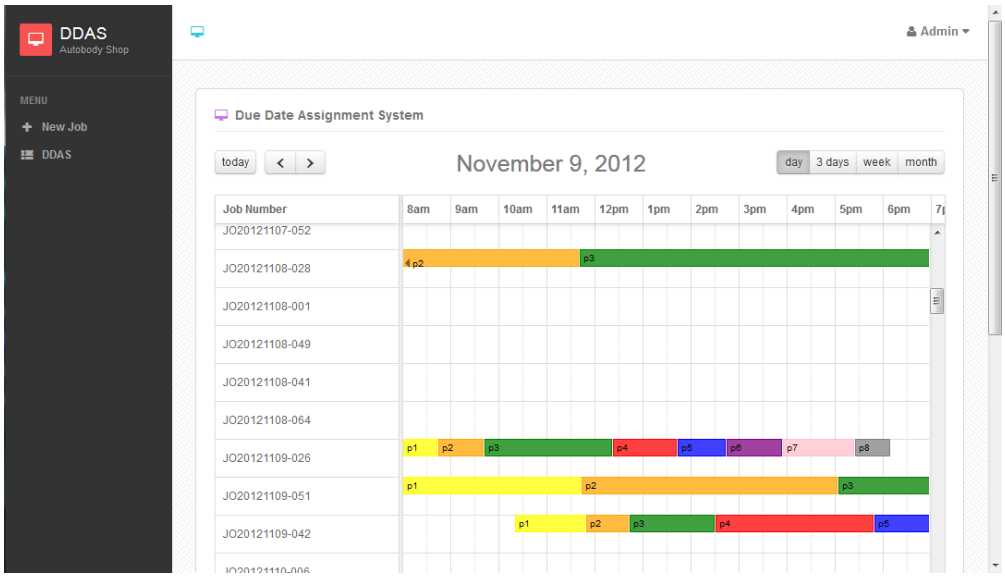

Figure 4-26 An example of the action plan

4.5 Conclusion

This chapter describes the overview of due date assignment system including the development of each system element. Firstly, reception and inspection process which is relating operation to directly use due date assignment system. The inspection form is developed for gathering the necessary information to be a system input. Then, the development of due date setting rule is clearly explained including job information and system information such as arrival time, total processing time, and total waiting time of each job. Moreover, the ER diagram of database connected to due date assignment system is next described. It is used to exchange some useful information for estimating due date. Although efficient due date is an output of the system, monitor and control which is an important feature can provide the action plan for each job used to control every job to go along with the plan. Lastly, the user interface of the system is illustrated for inputting data, displaying data, and printing out the action plan.

In addition, since web-based information system is a framework for developing due date assignment. The benefits of applying web-based information system for the case company are also described in this chapter.

5 System Evaluation

5.1 Introduction

This chapter focuses on evaluation of due date assignment system. It is developed as web-based information system for improving service reliability in term of efficient due date. The overview of evaluation in term of objectives and evaluation plan will be firstly concluded. Secondly, data preparation for system input will be described including necessary job information, system information, and appropriate input format. Then, various performance indicators are explained for measuring new due date performance comparing with an old due date. Next section will be simulation procedures with related development tools. Finally, simulation results will be analyzed and evaluated based on performance measures.

5.2 Evaluation Overview

After developing due date assignment system, the method of evaluation plays an important role to ensure the system improvement when comparing to current due date setting policy. In order to measure system performance of the new system, there are many indicators including mean tardiness and earliness to measure how reliable is both due dates, and mean absolute missed due date (MAMD) to indicate an error from due date estimation. The evaluation method for due date assignment system is using the simulation study. Since due date assignment system is a web-based information

system, the simulation study consists of simulation model developed by web programming, virtual database for exchanging some necessary data, and the simulation data. The 300 historical data of the case company during year 2012 is properly used in this simulation study. All data is firstly input into the new system at its arrival time. New due date will be estimated and the action plan of each job will be presented. At the end of the simulation running, new due date will be measured by various indicators and compared to old due date in order to analyse system improvement from the simulation result.

5.3 Data Preparation

The preparation of data is necessary before running simulation because data input of due date assignment system requires less information from existing database and specific input format. The simulation data from database needs to be extracted and transferred into appropriate format for inputting in due date assignment system. The required data includes arrival time, due date, finished time, damaged parts with its severity, and required processes. Therefore, procedure of data preparation is explained as following:

5.3.1 Query from existing database

There are various kinds of data filed from existing database. All data comes from operation management system that workers will create job information with its

required processes and update status of job during each process. An example of query data from existing database is shown as Table 5-1 for job information and Table 5-2 for damaged details. There are data field of JobNo ModelSize, PartId, SeverityID, Sum(TotalAmount), Arrival date, Arrival time, Finishdate, Finishtime, Appointdate, Appointtime, and also required processes which is represented as specific code number. The job data is totally gathered as 300 jobs observing from arrival date of job since 5 November of 2012 because this period properly provides complete data in every field of database.

Table 5-1 Examples of query data; job information

JobNo.	Total Amount	Finish Date	Finish Time	Due Date	Due Time	Arrival Date	Arrival Time
20121105-010	6380.95	12/11/2012	16:11	12/11/2012	15:00	5/11/2012	8:19
20121105-054	32181	24/11/2012	15:09	27/11/2012	17:00	5/11/2012	9:42
20121105-067	3959.3	8/11/2012	16:07	8/11/2012	16:00	5/11/2012	10:20
20121105-068	3431.45	9/11/2012	13:46	9/11/2012	13:00	5/11/2012	11:25
20121105-075	2697.05	8/11/2012	10:22	9/11/2012	14:00	5/11/2012	13:58
20121105-086	11796.3	19/11/2012	16:33	19/11/2012	14:00	5/11/2012	14:40
20121105-100	3729.8	17/11/2012	16:36	10/11/2012	11:00	5/11/2012	15:00
20121105-124	2065.5	7/11/2012	16:41	7/11/2012	10:00	5/11/2012	15:15
20121105-126	22051.55	24/11/2012	15:04	27/11/2012	9:00	5/11/2012	16:17
20121106-020	10297.75	15/11/2012	11:13	14/11/2012	15:00	6/11/2012	8:49
20121106-028	9123.05	15/11/2012	16:43	16/11/2012	16:00	6/11/2012	10:00
20121106-041	3213	10/11/2012	16:49	10/11/2012	17:00	6/11/2012	11:45

Table 5-2 Examples of query data; damage details

JobNo.	ModelSize	Severity	P1	P2	P3	P4	P5	P6	P7
20120105-045	L	L	1	1	1	1	1	1	1
20120105-046	S	L	0	0	0	1	1	1	1
20120105-047	S	L	1	0	0	1	1	1	1
20120105-048	L	L	1	0	0	1	1	1	1
20120105-049	M	M	0	0	0	1	0	0	1
20120106-009	S	L	0	1	1	0	1	1	1
20120106-017	XL	L	0	0	1	1	1	1	1
20120106-018	L	L	1	0	1	1	1	1	0
20120106-033	XL	M	1	1	1	1	1	1	1

In Table 5-2, the data of job processes stored in database is represented as 1 and 0 for necessary processes and unnecessary processes for a job respectively. Since the last process; P8 which is car wash is considered to be compulsory process for all jobs, it does not need to store in database. These process data is gathered from reception and inspection procedure.

After querying data from current database of the case company, these data will be extracted only necessary information to be data input for due date assignment system. The data input is typically divided into two categories which are job information and damaged inspection details.

- *Job information*: job number, date and time of arrival, appointment, and finish.
- *Damaged details*: part number, required processes and severity level.

5.3.2 Transfer data into compatible format

The extracted data from existing database needs to be transferred into compatible format for due date assignment system. Since these data is prepared for simulating in due date assignment system, training database has to be created in order to support data running and exchanging during the simulation period. Therefore, the format that is compatible for inserting into training database is considered to be SQL format. It commonly uses comma and quotation mark for representing data. An example of SQL format for training data is shown as following:

(, '20120105-001', '1700000146',0,0,1,1,1,0,1,1, 1, 1),

(, '20120105-012', '1700000061',0,0,0,1,1,1,1,1, 1, 1),

(, '20120105-012', '1700000726',1,1,1,1,1,1,1,1, 5, 1),

(, '20120105-015', '1700001912',0,0,0,0,0,1,1,1, 12, 2),

(, '20120105-015', '1700000558',1,0,0,1,1,1,1,1, 2, 2),

(, '20120105-021', '1700000970',1,1,1,1,1,1,1,1, 5, 2),

(, '20120105-021', '1700000029',1,0,0,0,0,1,0,1, 1, 2)

As there are two categories of data input including job information and damaged details, there are job identification number, part number, required processes of eight processes, part identification number and severity level. The number “1” means compulsory processes for each job from total eight processes. For severity level, the identification number “1” represents light and “2” represents medium severity level of repair.

5.3.3 Insert data into training database

Training database is specially created for running simulation of due date assignment system. Hence, all chosen data of 300 jobs used in simulation has to be firstly inserted into this database. The SQL command for inserting job data as shown as below:

```
INSERT INTO `repair_infos` (`training_job_id`, `partno`, `step1`, `step2`, `step3`,
`step4`, `step5`,`step6`, `step7`, `step8`, `part_id`, `severity_id`) VALUES
(, '20120105-001', '1700000146',0,0,1,1,1,0,1,1, 1, 1),
(, '20120105-012', '1700000061',0,0,0,1,1,1,1,1, 1, 1),
(, '20120105-012', '1700000726',1,1,1,1,1,1,1,1, 5, 1),
(, '20120105-015', '1700001912',0,0,0,0,0,1,1,1, 12, 2),
(, '20120105-015', '1700000558',1,0,0,1,1,1,1,1, 2, 2),
(, '20120105-021', '1700000970',1,1,1,1,1,1,1,1, 5, 2),
(, '20120105-021', '1700000029',1,0,0,0,0,1,0,1, 1, 2),
```

After data preparation of 300 jobs, the simulation of due date assignment system is able to be run in order to imitate working environment and job arrival of the system. Simulation study is significant technique for measuring performance of the new system before full implementation.

5.4 Performance Indicators

In order to measure the simulation result of due date assignment system, there are several performance indicators that can reflect efficiency of new system comparing with existing one. Due to overdue delivery date problem, the improvement of due date assignment of the case company requires more reliable due date given to

customers at their arrival time. Therefore, the indicators used for measuring system performance should rely on this objective. The better results of these indicators can lead to improvement of service reliability of the case company.

5.4.1 Mean Tardiness

According to(Ragatz and Mabert 1984), due date performance is commonly measured by mean tardiness of job and the proportion of tardy job. The average tardiness of all jobs will be used to indicate the performance of the due date. The jobs that are not late will be assigned as zero value during calculating mean tardiness. Moreover, the measure by the number of tardy job can also reflect the performance of due date. For better understanding of improvement, it is typically used to represent as the percentage of job tardiness comparing with current due date.

5.4.2 Mean Earliness

Although job earliness is considered to have less impact than tardiness because customers satisfies to get their jobs before due date, good due date assignment system should be able to provide due date that is close to the actual finish date of job. Mean earliness is important measure that is used to indicate the performance of due date. Furthermore, the number of early job will be measured to compare with current due date.

5.4.3 On-time Job

It refers to the acceptable range of due date considered by each company. The job that is able to finish within this acceptable range will be indicated as on-time job. For the case company, on-time job is +/- one day. It means that the finish time of job before one day and after one day of its promised due date will be defined as on-time job. Therefore, the number of on-time job can be used to measure the performance of due date.

5.4.4 Mean Absolute Missed Due Date (MAMD)

Regarding to(Ragatz and Mabert 1984), mean absolute missed due date (MAMD) is usually used to measure the average absolute difference between the actual finish time and promised due date. It can report an error in estimating a due date. Therefore, the MAMD value of due date assignment system is expected to be lower than current due date performance.

In conclude, all indicators are properly used to measure the performance of due date assignment system. The result of these measures will be compared with an existing due date in order to show how much improvement of due date assignment of the case company.

5.5 Simulation Model

The computer simulation model for due date assignment system is programmed by PHP: Hypertext Preprocessor 5.5 with framework of CodeIgniter 2.2.2. Since due date assignment system is developed to be a web-based information system, this simulation model will be run on the server. An operating system of a server is Ubuntu Server 14.04 LTS with the installation of web server of Apache HTTP Server 2.2. This server will connect and exchange data from the database of MySQL 5.6.24. Moreover, there is web browser of Chrome Version 42.0.2311.135 (64-bit) used as user interface for interacting with due date assignment system during the simulation.

In addition, the model consists of eight work stations or processes for auto body repair and paint service. Eight processes have the different number of servers which are three, four, five, five, four, four, four, and three servers respectively. All jobs will enter the shop randomly based on their arrival time. The number of required processes for each job is properly identified with its job information. The work stations are able to be skipped which is depended on required processes of a damaged job. However, the iteration of all processes does not allow. The processing time for each job regarding to damage parts will be directly retrieved from database. In case of waiting time, it will be calculated from all related time of each job with the sequencing policy. FCFS is a sequencing policy used to prioritize every job to be in operations. All processes also

have their own waiting line. Lastly, the transition time between processes of a job will assume to be null.

5.6 Experiment

In order to compare the performance between due date assignment system and current due date policy, the prepared data will be an input of the simulation model. There are 300 input data that comes from 5 November of year 2012 and the next consecutive days. However, the simulation results are observed after running of 120 data input because the simulation model is considered to become a steady state. Therefore, the performance of these two systems is observed from the total 180 of job orders.

Each data represented as a job order is retrieved from the training database row by row based on its arrival time. The simulation model runs due date assignment system in order to estimate a due date at arrival time of each job. Hence, there are 180 number of due date which are the output from due date assignment system. In order to measure the performance, the historical data of finish time and promised due date of every job are totally queried from existing database since data preparation. Lastly, the measures of average tardiness, average earliness, on-time jobs, and MAMD collected from the simulation of due date assignment system are well compared with the values of measures from current promised due date.

5.6.1 Estimating Safety Factor

Safety factor is an important factor for assigning a due date. It refers to uncontrollable time from unexpected situations that can be occurred during repairing processes. Moreover, since the processing time of due date assignment system properly uses the standard time of repairing for each auto body part, there may be some estimating errors based on different job orders. Therefore, safety factor will be added as a buffer time with the processing time and waiting time for every job.

An appropriate value of safety factor for due date assignment system is determined from experiment. As the objective of due date assignment system is to provide more reliable due date than current due date, the simulation is trying to adjust this buffer time in order to calculate an efficient due date. As a result, after running simulation, the best value of buffer time for due date assignment system is considered to be one day that can assign a due date as near as the finish time of 180 data input. Meanwhile, the system performance is able to achieve better result in various measurements.

5.6.2 Example of Experiment

There are totally 300 historical data used for system testing. They are queried from database consisting of basic job information and relevant time; arrival time, actual finish time, and current due date as shown as following:

Job Number	Arrival Time	Part	Severity	Process Number							
				1	2	3	4	5	6	7	8
20121105-010	05/11/2012 08:19	Front bumper	Light	x					x		
		Front left fender	Light	x	x	x	x	x	x	x	x
20121105-075	05/11/2012 08:58	Front bumper	Light	x	x	x	x	x	x	x	x
20121105-068	05/11/2012 10:00	Rear bumper	Light	x	x	x	x	x	x	x	x

Job Number	Actual finished date/time	Current Due Date
20121105-010	12/11/2012 16:11	08/11/2012 16:00
20121105-075	09/11/2012 13:46	07/11/2012 13:00
20121105-068	08/11/2012 10:22	07/11/2012 09:00

Figure 5-1 Examples of simulation data

In model testing, the 300 job information is gradually input into due date assignment system (DDAS) in order to mimic as arrival jobs into the service. Then, due date calculated from DDAS will be an output of the system as shown as example output:

Job Number	Due Date from Proposed DDAS
20121105-010	12/11/2012 15:48
20121105-075	09/11/2012 13:16
20121105-068	09/11/2012 09:33

Compare to actual finished time

Job Number	Actual finished date/time	Result
20121105-010	12/11/2012 16:11	On-time
20121105-075	10/11/2012 13:46	On-time
20121105-068	08/11/2012 10:22	On-time

Figure 5-2 Examples of system testing

Due date from DDAS will be compared with actual finished time of historical data. In order to show the improvement of proposed due date assignment system, due date from current policy also will be compared with actual finished time. Several performance indicators are used to measure the performance of both due dates (for more details in section 5.7.

5.7 Evaluation Result

The result from simulation can lead to efficiency of due date assignment system and also the improvement of service performance when comparing to current due date assignment policy. Various measures are used including average tardiness, average earliness, on-time jobs, and mean absolute missed due date. The measurement results are clearly shown as following table:

Table 5-3 Evaluation result of due date assignment system.

Due Date Assignment	Tardy Jobs (unit)	On-time Jobs (unit)	Early jobs (unit)	Average Tardiness (hr.)	Average Earliness (hr.)	MAMD (hr.)
Current Due Date Policy	82	65	33	247.5	81.29	188.18
Proposed Due Date Assignment System	43	128	9	171.57	83.2	114.55

Regarding to Table 5-3, it is obviously seen that the number of on-time job significantly improves from 65 jobs of current due date policy to 128 jobs of proposed due date assignment system. In contrast, the number of tardy jobs and early jobs decrease 39 jobs and 24 jobs respectively. Since the average tardiness is considered to have direct impacts to service performance of the case company. The proposed due date assignment system is able to reduce the average tardiness time from 247.50 hrs. to 171.57 hrs. Meanwhile, the average earliness is quite similar to the current due date policy. Moreover, the value of mean absolute missed due date (MAMD) of the new due date assignment system also decreases to 114.55 hrs. It properly means that the average error in assigning due date of the new system can be better than the current one.

For better understanding, the result of simulation can be represented as a liner graph in order to clearly show the comparison and improvement of both system performances.

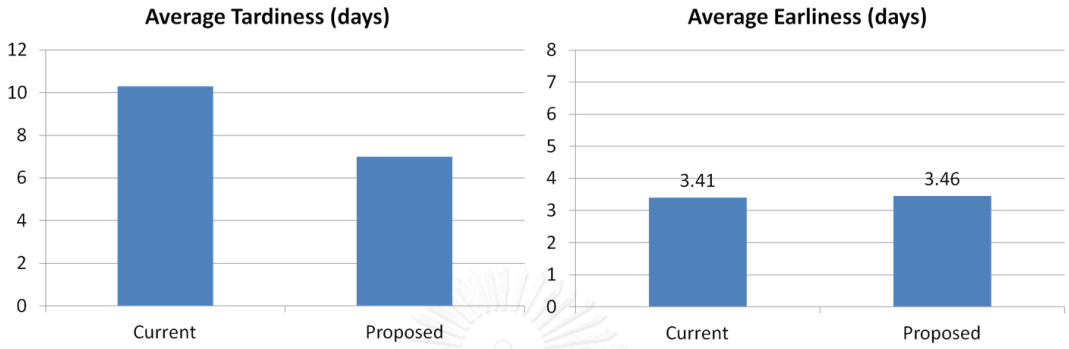

Figure 5-3 Average tardiness and earliness of due date assignment system (proposed) compare to the current due date policy (current).

According to Figure 5-3, it clearly shows the improvement of new due date assignment that can achieve better result in seven days of average tardiness day. In case of average earliness, although it does not distinctly change from the old due date performance, the result is still satisfactory for the case company to assign due date after the actual finish date to their customers.

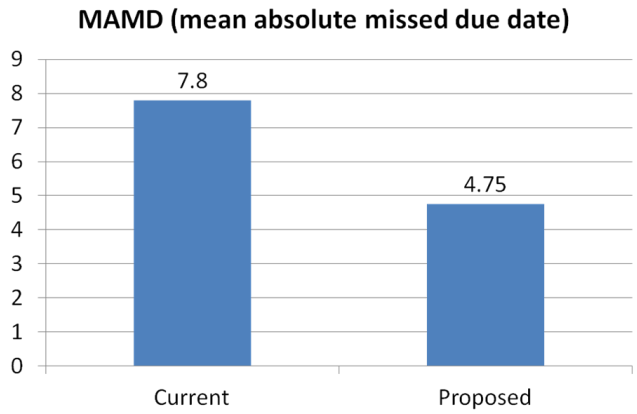

Figure 5-4 Mean absolute missed due date of due date assignment system (proposed) compare to the current due date policy (current).

Figure 5-4 illustrates the result of MAMD that measured between the current due date performance and new one. The result is notably different in term of inefficiency in due date performance. Due date assignment system is considered to be more efficient for estimating a due date than current due date policy with an ineffective MAMD of eight days.

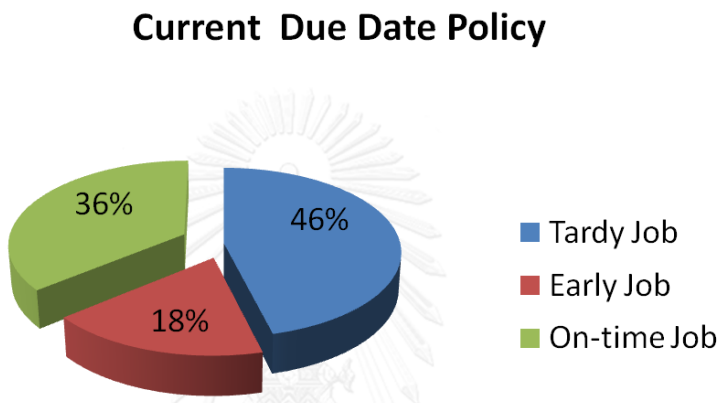

Figure 5-5 The percentage of tardy jobs, early jobs, and on-time jobs of current due date policy.

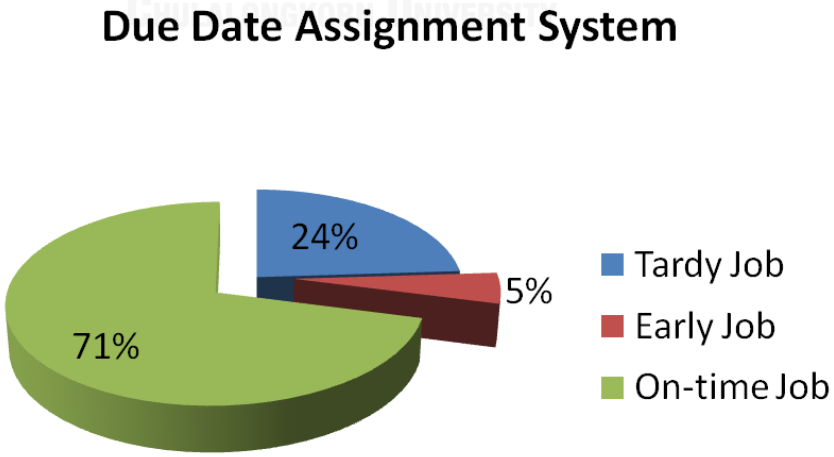

Figure 5-6 The percentage of tardy jobs, early jobs, and on-time jobs of due date assignment system.

In addition, the proportion of tardy jobs, early jobs and on-time jobs of both due date performance are obviously represented as the percentage value as shown as Figure 5-5 and Figure 5-6. The due date performance of new due date assignment system is better than the current due date policy. It can reduce the percentage of tardiness from 46% to 24%. At the same time, the percentage of early job also decreases to only 5%. Furthermore, the due date assignment system can achieve 71% of on-time jobs, while only 36% is obtained by the old due date. The percentage of on-time job is able to indicate the performance improvement when comparing two due date. As a result, the performance on assigning due date using due date assignment system is properly improved by 35%

However, there are still some tardy jobs from due date assignment system simulation. These tardy jobs are deeply analyzed to find their job information and reasons why they are still late. The examples of tardy jobs from due date assignment system are shown as following table:

Table 5-4 Examples of tardy job from due date assignment system

jobNo	Current System			DDAS
	Total Amount	Arrival Date	Finish Date	Due Date
20121119-114	฿642.60	19/11/2012 15:07	17/12/2012 11:51	21/11/2012 14:00
20121120-082	฿2,228.00	20/11/2012 9:00	3/12/2012 10:20	21/11/2012 12:55
20121122-036	฿3,075.30	22/11/2012 10:21	24/12/2012 15:20	23/11/2012 23:58
20121208-017	฿2,655.00	8/12/2012 9:34	25/12/2012 11:15	10/12/2012 9:10
20130102-004	฿7,643.20	2/1/2013 9:13	31/1/2013 13:42	4/1/2013 11:13

Table 5-4 shows tardy jobs that are late from promised due date approximately twenty to thirty days even though these jobs are inspected to be low and medium severity level. From interviewing with supervisor of the case company, most jobs have

unexpected problems in spare parts inventory. Hence, these jobs are needed to wait for their spare parts. Some model part is suddenly out of stock that can lead to longer time to be ordered and restocked. Moreover, some painting colour is from specific brand and texture which is another reason for taking too much repair time than usual situations. When this system is implemented on the case company, due date assignment system has a feature of monitor and control designed to handle with unexpected situations. Since some job is facing with problem that affects promised due date. Supervisor is able to foreknow and notify to change to a new due date on time. It can avoid overdue job problem and reducing of service reliability.

5.8 Conclusion

This chapter presents about the evaluation of due date assignment system through simulation study. Historical data for simulation which is retrieved from existing database is well prepared. The necessary data used to be a system input includes damaged parts, all operation times, severity level, and required processes. Then, the simulation model is totally explained with brief procedures and tools. Various indicators efficiently measure new due date performance estimated by due date assignment system and compare with the current due date performance. As a result, new due date is able to achieve better performance than the old one with 35% of improvement and 71% of on-time job. In the next chapter, the conclusion and discussion of this research including further studies will be properly described.

6 Conclusion, Discussion, and Further Studies

Conclusion

The objective of the thesis is to develop due date assignment system for the case company that is currently facing with a problem of overdue delivery date to customers. Due to service business, appointment date is considered to be a major factor for customer satisfaction in term of service reliability. Therefore, this thesis develops due date assignment system with appropriate due date setting policy by applying web-based information system. Due date assignment system can estimate reliable due date to customers at their arrival time by considering both job information and system information such as existing jobs. Since due date assignment system is developed by web-based information system, it can enable the case company for easy data accessing and simple system maintenance. It can also support current operation to work efficiently in monitor and control. As due date assignment system provides monitor and control feature for providing the action plan of each job.

The due date assignment system is divided into four main parts which are due date calculation module, the standard processing time of each body part, waiting time logical module and monitor and control. Moreover, this system is properly connected to database that plays an important role to exchange job and system data used in due date calculating module. Due date assignment system will mainly support reception

and inspection process because due date has to be given to customers at arrival time. Firstly, the damaged car is needed to be inspected by inspectors in order to identify severity level and required processes for repairing each car. After inspection, the new job will be created by inputting into an inspection form via web user interface of due date assignment system. It consists of basic job information, damaged parts with its severity level, and processes that should be repaired. Then, the due date calculation module consisting of due date setting rule and FCFS sequencing policy will be executed. The system will consider total processing time based on job's damaged parts and severity level. It also retrieve all existing jobs information from database whose their processes are similar to this job's processes for identifying a total waiting time. Lastly, promised due date will be estimated and displayed via web user interface as the system output. The output form with a promised due date is considered to be a receipt of car printed to customers. Additionally, there is monitor and control which is important feature of due date assignment system. The action plan is used to evaluate the performance of operations and workers. Supervisor is able to monitor and control operations to go along with the action plan for each job. Hence, a job that is predicted to be late can be foreknown and notified to customers in order to modify due date on time.

In order to measure performance of the new due date assignment system, several indicators are properly used. There are average tardiness, average earliness, on-time job and mean absolute missed due date (MAMD). The simulation is developed to

simulate virtual environment of the case company. The 300 historical data of job order are queried from existing database in term of arrival time, finish time, promised due date, damaged parts with its severity level, and required processes. Each job is input to the simulation one by one based on its arrival time. After running the simulation, only 180 jobs are observed because the system is considered to be in the steady state. As a result, due date assignment system provides more efficient due date than the current due date with 71% of on-time jobs. Meanwhile, the percentage of tardy job reduces to 24% from 46% of current due date. In case of MAMD, new due date obviously performs better than current due date with the average missed due date of four days. Due to overdue date problem of the case company, due date assignment system is developed to cope best with this problem by estimating efficient due date. It can definitely lead to higher service reliability and customer satisfaction.

6.1 Discussion

Although many measures of due date assignment system indicate better performance than old due date, there are some result variations due to incomplete data and external factors.

Firstly, since data input used in due date assignment system simulation is historical data from 2012, all jobs are totally finished and their information are stored into database of the case company. However, some information such as required processes and standard processing time are not well recorded. The information of required

processes usually occurs from untrained workers and operation mistakes to efficiently keep job information. In case of standard processing time of each body part, it typically takes too much time and specific approaches to gather a lot of information and make as a standard time. Hence, participating persons and experts of the case company plays an important role to reasonably estimate missed information.

Another point is that due date assignment system is developed under the assumption of no external factor and job interruption affecting the action plan of each job. In reality, there may be some unexpected situation. For examples, cancel of job during processes, disapproval of insurance customer and urgent job interruption. It cannot be denied that several uncertain situations usually occur in service business. In order to gain customer satisfaction, these unexpected situations should be considerably handled. The case company should instantly adjust planning, notify customers before their due date and provide them an optional solution.

When first implementing of due date assignment system, the case company should establish training programs for participating workers to make them to be familiar with the new system. Moreover, all system documents should be distributed to supervisors and related operations including user manual and simple troubleshooting system problems.

Finally, the operation problems and any defects that may occur from actual system implementation should be documented. These problems can be used to improve the system to be more efficient. It definitely leads to continual improvement.

6.2 Further Studies

There is future works relating to this research that can be continual developed. Firstly, further study is to expand the standard processing time covering other fields such as car model with its manufacturing year. Since each car model may have different details in body parts, conducting of standard processing time for particular body parts can lead to more accuracy in due date estimation.

Second issue of further studies is real-time notification in monitor and control of due date assignment system. The system should automatically compare between the actual time from operation data and the action plan provide by due date assignment system. In case of predicted lateness of job, the system should be able to real-time notify participating workers via user interface. This feature will reduce some problems before they occur due to human error.

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