

การออกแบบระบบติดตามพื้นที่การผลิตในอุตสาหกรรมเครื่องนุ่งห่ม



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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาการจัดการทางวิศวกรรม ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต

คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2550

ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

501841

SHOP FLOOR MONITORING SYSTEM DESIGN
FOR THE GARMENT INDUSTRY



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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Engineering Management
The Regional Centre for Manufacturing Systems Engineering

Faculty of Engineering
Chulalongkorn University
Academic Year 2007

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ที่ระพล ทัศนพงศกร : การออกแบบระบบติดตามพื้นที่การผลิตในอุตสาหกรรม
เครื่องนุ่งห่ม. (SHOP FLOOR MONITORING SYSTEM DESIGN FOR THE
GARMENT INDUSTRY) อ. ที่ปรึกษา: ผศ. ดร.เหรียญ บุญดีสกุลโชค, 198

วิทยานิพนธ์ฉบับนี้มีจุดมุ่งหมายที่จะออกแบบระบบเพื่อใช้ในการนำข้อมูลในพื้นที่การผลิตของแผนก
เย็บในอุตสาหกรรมเครื่องนุ่งห่มมาวิเคราะห์แล้วรายงานความก้าวหน้าการผลิตไปยังแผนกควบคุม
การผลิต เพื่อให้แผนกควบคุมการผลิตได้ทราบความก้าวหน้าและปัญหาในพื้นที่การผลิตได้อย่าง
ใกล้ชิด ในการรายงานความก้าวหน้าการผลิตวิทยานิพนธ์ฉบับนี้ใช้เทคนิค Line of Balance (LOB)
ในการช่วยแสดงผลและเตือนปัญหาแก่ผู้ใช้ในกรณีที่เกิดการผลิตในสายการผลิตคลาดเคลื่อนจากแผนที่
ได้วางเอาไว้

นอกจากนั้นระบบยังมีการนำข้อมูลที่ได้จากพื้นที่การผลิตไปวิเคราะห์และปรับค่าประสิทธิภาพของ
พนักงานอย่างต่อเนื่อง ทำให้ฝ่ายวางแผนการผลิตมีข้อมูลที่แม่นยำมากขึ้นในการวางแผนการผลิต

การพัฒนาในระบบในวิทยานิพนธ์ฉบับนี้ถูกพัฒนาตามรูปแบบ Adapted Waterfall System
Development Life Cycle และ ใช้ Methodology เพื่อพัฒนาแต่ละขั้นตอนของวงจรแบบ Structured
Design ในการพัฒนาระบบ

ศูนย์วิทยทรัพยากร

ภาควิชา.ศุนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต...ลายมือชื่อ.....
สาขาวิชา...การจัดการทางวิศวกรรม..... ลายมือชื่ออาจารย์ที่ปรึกษา.....
ปีการศึกษา....2550.....

##4771635021: MAJOR ENGINEERING MANAGEMENT

KEY WORD : SYSTEM DESIGN / SYSTEM ANALYSIS / SHOP FLOOR MONITORING /
SHOP FLOOR CONTROL / GARMENT / LINE OF BALANCE / LEARNING CURVE

PHEERAPHOL PATTANAPONGSAGONE: SHOP FLOOR MONITORING SYSTEM
DESIGN FOR THE GARMENT INDUSTRY: THESIS ADVISOR: ASST.PROF. REIN
BOONDISKULCHOK, 198 pp.

This research aims to design the system to collect production data from shop floor in sewing section of garment industry and use that data for analysing and reporting to production control section, which helps to identify progress and problem in shop floor. To report progression in shop floor this research applies graphical technique "Line of Balance (LOB)" for reading the progress in shop and warning for problem when process at any review point misses the target.

In addition, this system also takes shop floor data to calculate and update worker efficiency continuously, which will help production planning to get more reliable and accurate worker information to plan target.

The design of system in this study is developed follow the Adapted Waterfall System Development Life Cycle, and uses Structured Design methodology to develop the life cycle.

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Academic year...2007.....

ACKNOWLEDGEMENT

The author would like to dedicate this research to all of those who supported him along the way. First of all, the author would like to express his deepest gratitude to his mother and family who provided all kind of supports and encouragement; he could have never done this without them.

The author would also like to express his sincere thanks to his thesis advisor, Asst. Prof. Rein Boondiskulchok, for his helpful guidance, commitment to student, kindness, and valuable suggestions all the time throughout this entire process.

Grateful thanks are also conveyed to the rest of thesis committees, Prof. Sirichan Thongprasert, Asst. Prof. Manop Reodecha, and Asst. Prof. Paveena Chaovalitwongse for their helpful comments and extensive supports.

The author wishes to thank for all instructors both from Chulalongkorn University and Warwick Manufacturing Group (WMG), University of Warwick who provide valuable knowledge to author to done this research.

Finally, the author would like to show appreciation to SAM-g2 project team and all interviewees who helped to make this work successful.



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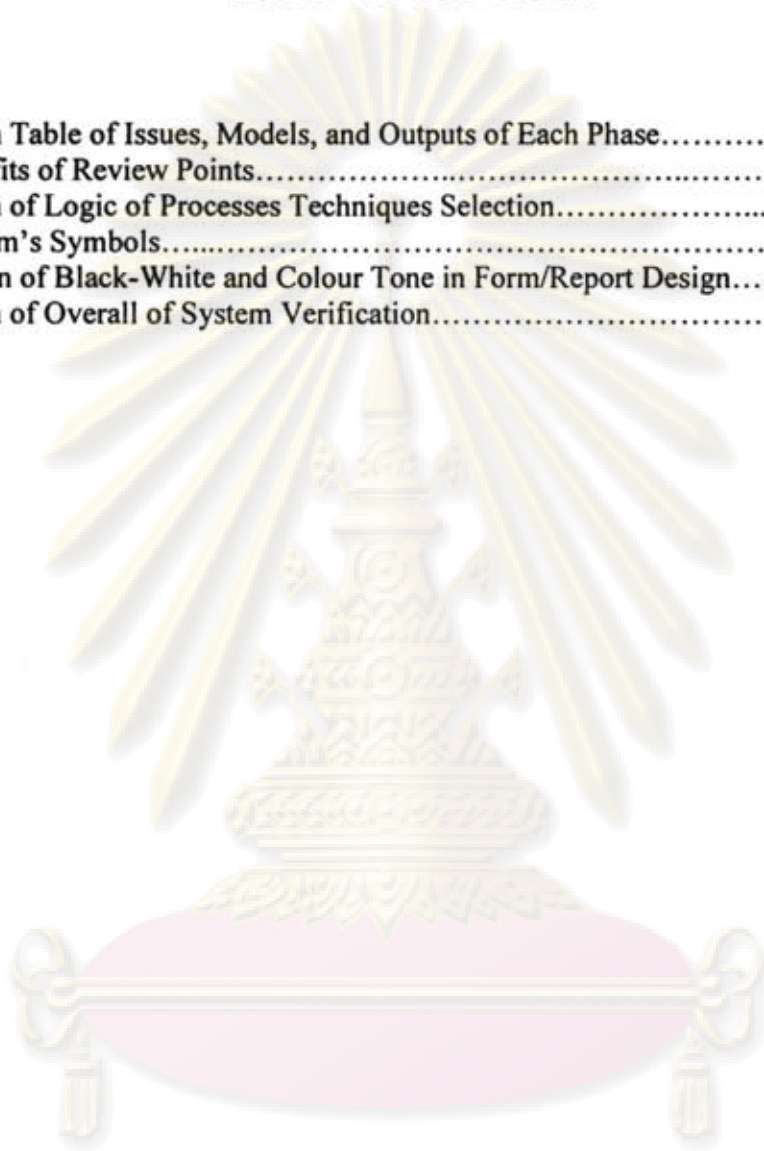
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CHAPTER I

INTRODUCTION

1.1 Thailand's Garment Industry Business Environment

Garment and textiles industry is one of the most important economic drivers of Thailand. According to information of The Office of Industrial Economics [1], garment and textile industry employ over 1.08 million people and gain income for country more than 5,000 million US. dollars a year (5,800 million US. dollars, 2004). Main garment and textile export markets of Thailand are United States, EU, Asian, and Japan; respectively [1].

Typically, garment and textiles industry can be categorised into 3 generic groups including;

- Up steam industry; including fibre and spin fibre.
- Middle steam industry; including weave, knitting, and wash-dry.
- Down steam industry; including garment.

According to information of The Office of Industrial Economics [1], garment industry has the highest employment rate up to 77.6% while second (weave and knitting) is 10.9% and third (spin fibre) is 5.7%. In addition, export volume of garment industry is about 50% of total Thailand's garment and textiles export volume. Obviously, refers to three generic groups of garment and textile industry above, the most important group of Thailand's garment and textile business is down steam industry which is garment industry. As a consequence, this study aim to improve and try to design system that enables manufacturers to solve some current problems in garment industry which is one of the key important businesses of Thailand.

At the present, Thailand is number 10 of global garment exporter [2]. The competitive advantages of Thailand are low cost, good quality and pool of skillful garment worker place. Nevertheless, in current global environment even Thailand can export high volume of garment a year, but most of products are relying on sub contract order from aboard customers. Therefore, it can say that most of export volumes in Thailand are original equipment manufacturers (OEMs) product not original brand manufacturers (OBMs) product. Even many Thailand's manufacturers are trying to create in-house brand in order to build barrier against bargaining power of customers and to response

with competitors' pressure. Thailand's brand is still unsuccessful to stand in fashion world like leader garment fashion in Europe says France, UK, and Italy.

When considers business environment through Porter's five forces model [3], now Thailand is being forced by two main business pressures including competitors and customers. Competitors nearby like Laos, Vietnam and especially China have advantage on price because they have lower cost. Under this high competition degree, therefore customers have many choices for them which they can switch from Thailand to use those suppliers anytime.

Consequently, to survive in this environment Thai garment manufacturers are forced to strengthen its potential by reduce some costs, increase productivity, and try to remain customer loyalty by providing satisfactory service, which this research tries to find the way to cover these issues.

1.2. Rational of Research

As described previously, now Thai garment manufacturers are being forced by many pressures like customers and competitors, so to survive in this business circumstance Thai garment manufacturers need to improve its performance, try to reduce costs, and maintain customers by providing satisfaction.

However, it appears that many times garment manufacturers deliver customer's orders behind their objective schedule which causing them to pay extra cost for rush shipment, overtime (OT), and also decrease customer's satisfaction. Sometimes it also makes them to pay penalty cost for delay or in the worst case they may lose customers. The major causes of delay problem mainly come from low efficiency production planning and control. So, this research tries to explore an opportunity for Thai manufacturers to solve problems in these issues.

One of important sources of delay production which this research tries to focus is shop floor monitoring and production control system. Because garment manufacturing is unlike other industries, output of production mostly relies on performance of worker which has high variation. So, productivity of shop floor always misses the plan and bottleneck also occurs simultaneously. But, now shop floor monitoring system in many garment manufacturers has low efficiency communication system which cannot report actual progress in shop floor to production control. Therefore, when output missed the target production control of many manufacturers sometimes spends long time before

recognises it and takes corrective action. Furthermore, many times they do not know where corrective action should be taken place because they do not have enough information to make decisions on it. These problems occur due to the lack of efficient tool to monitor progress in shop floor. Therefore, this research tries to improve shop floor monitoring system in garment industry, which can help them to able to better recognise progression in shop floor, able to response with problem earlier, increase productivity, and reduce some extra costs.

Another issue that is focused in this research is problem in production planning. Again, normally characteristics of garment industry are different from others, because this industry is labour intensive, which has high affect from issue of learning curve, so it is hard to make output constant all the time like automobile production. In recent study, Heizer, Render [4] argued that for stable, standardized, and labour intensive products and processes, the learning curve trends to have higher effect than others.

The production output of each day week or month is always unpredictable and miss objective plan due to learning issue. For this reason, it makes major mistake to production planning when makes planning because mostly, still ignore issue of learning curve, while in fact it can take highly effect to output of the plant. Even learning curve is recognised as a big problem for this industry, but now most of Thai garment manufacturers have not properly considered learning curve in recent production planning method. Therefore, if planning does not consider learning curve issue, it is possible that this can be cause of bottleneck and can effect to planning schedule miss its objective plan.

As reasons stated, therefore this study aims to cope with these problems by design system that can manage data in shop floor to improve shop floor communication system. The research also consider learning curve issue that tries to help production planning calculate target and plans production plan with more accuracy. Nevertheless, this study focuses only on sewing section of garment industry because sewing process is a core manufacturing process of garment industry and consumes the longest time in garment manufacturing processes [5]. In an addition, bottleneck of production line always occurs in sewing section [5].

1.3. Concept of Research

The system design in this research is a part of project "SAM-g2" (Standard Allowance Minutes-garment industry. SAM-g2 is a system that helps and supports production

planning and control in garment industry. As interviewed and analysed data collected from many factories in garment industry, the work flow diagram processes focused in SAM-g2 can be drawn as Figure 1.

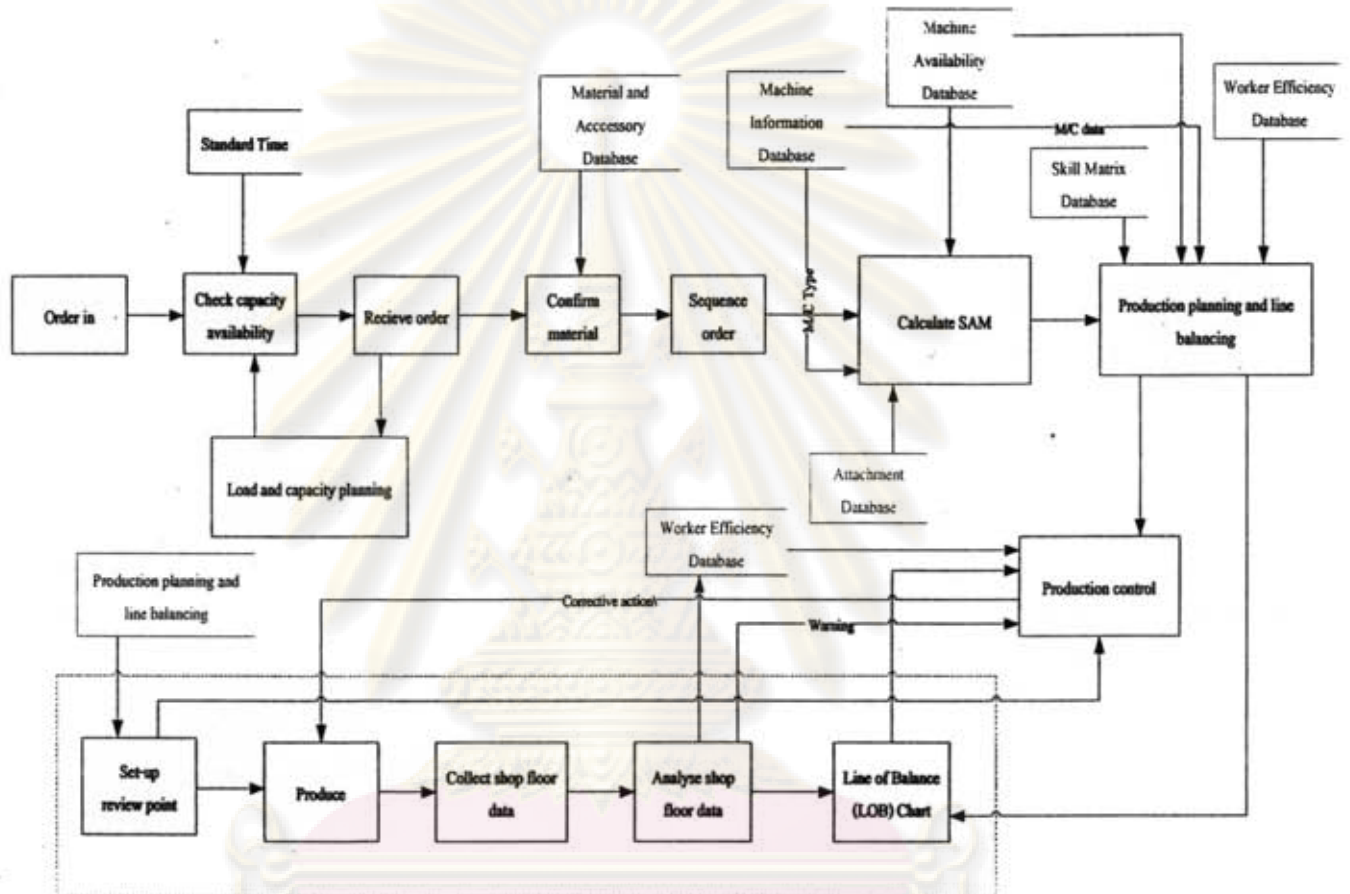


Figure 1. Overview Work Flow Diagram of SAM-g2

This work flow diagram shows some key processes of garment production that project SAM-g2 focus. The processes start when order in until production plan is applied in shop floor which includes process of receiving data from shop floor and feed back to production planning. However, the detail of each process is clarified in following issues.

- **Order in**

This process is about business negotiation. Function that handles this process is marketing or merchandiser or sale. The process starts when customer contacts company and brings sample order to discuss details with marketing. But, the

company usually does not receive order in this process because company need to check availability of capacity before.

- **Check capacity availability**

Once the marketing recognised demand of customer, then marketing sends inquiry to load and capacity planning in order to check availability of capacity in company. In addition, different factory may use different capacity counting unit such as time unit or basic product unit.

- **Load and capacity planning**

This process shows all capacity of factory comparing with used capacity to see remain availability capacity in order to support marketing function to make receive or reject decision. Detail of capacity can show range from monthly to weekly and data used to analyse this process come from 3 sources including 1. Customer's purchase order 2. Output from production planning and line balancing 3. Daily output

- **Receive order**

In this process, marketing needs to make agreement with customer in details in order to confirm to produce that purchase order. However, in this process details can be changed a bit in future. Details of agreement included purchase order number, type of product, style, materials used, quantity, packaging, and delivery date.

- **Confirm material**

This step is about confirming material. Company can check materials requirements and its availability.

- **Sequence order**

Normally, there are many orders in the plant, so this step is about sequence those orders in production schedule like shop floor planning. The criteria of sequencing depend on each company such as early due date and first-in first-out (FIFO).

- **Calculate SAM**

This process belongs to production planning's (Industrial Engineer) responsibility. Main jobs relate to planning and sequencing of operations, allocating attachment, allocating machine, and material resources planning. The information needed in this process including 1. Machine database 2. Attachment database 3. Materials and accessory database. The output of this process is very important and will be used to set review point which will be used to monitor production in shop floor.

- **Production planning and line balancing**

Production planning division uses output that planned from manufacturing and standard allowance minutes (SAMs) to calculate work load for each operation by using following equation;

$\frac{\text{Standard time of operation}}{\text{Summation of all standard times of product}} \times \text{Number of workers in group}$
--

Once workload finished determine workload, some operations that have workload lower than 1 are combined together in order to make production line as balance as possible. In this process also includes worker allocation for each process. However, because each worker has different skills and skill levels, so this process needs information from skill matrix to support. The skill matrix databases that record worker data in main frame including skills and % cumulative efficiency of worker in each skill. Moreover, these data will be updated simultaneously by using data that collected from shop floor. When line balancing arrangement is finished, then user measures result of line balancing. If the result is unacceptable, planner may back to determine and make line balancing again.

- **Set-up review point**

When shop floor planning allocates processes and workers used in each order company can set the processes that want to monitor in shop floor in this step. The review points that are selected will bring to collect shop floor data in later step.

- **Produce**

This process is about producing process of sewing section.

- **Collect shop floor data**

When orders started production shop floor supervisor will collect shop floor data in this step in order to monitor the progress in shop floor closely. The processes that are collected data in this step are the processes that set as review points in set-up review point step.

- **Analyse shop floor data**

Data that gained from shop floor will be analysed in this process. The output of this analysis will be used to update worker efficiency in worker efficiency database, draw Line of Balance (LOB), and report to production control.

- **Line of Balance (LOB) chart**

This process helps users to monitor processes in production line. It can show progress of production and shows variation of output comparing to target. Line of balance also helps production control to recognise problems in production line and encourage production control to know where corrective action should be taken. Data needed in this process including 1.Data from line balancing 2. Data from shop floor.

- **Production control**

Production control will control about shop floor production. Duty of this function may be handled by low to high level of management depends on each company, for examples, shop floor supervisor, production planning, production control, or top management. However, this research will call function who responsible for this duty "Production control" entire of this paper.

From overview of SAM-g2 project, the project is separated into 4 main modules in order to make it easy to design and reduce complexity of work. Each module includes;

1. Employee Database System; this system is database management system that acts like database to record factory data and worker data (e.g. name, position, id., efficiency, etc.) in order to support production planning function and other functions in the company.
2. Capacity and Load Planning System; this system helps to control and monitor capacity of the plant, for example, when marketing negotiates order with customer company can check capacity availability and quickly response to customer from this system.
3. Shop Floor Monitoring System; this system is the study scope of this research, it supports production control able to monitor progression in shop floor efficiently and effectively.
4. Production Planning System; this system supports production planning and shop floor planning functions to create production plan, for examples, target planning, line balancing, worker allocation, and machine layout design.

These four modules are concurrent developed and all of these called project "SAM-g2" system. Even this study focuses only on "Shop Floor Monitoring System", which is number three, but all modules in the project are linked together, so some data of system design in this research may be linked and transferred from another three modules. The scope of this study is in the dot line box in overview chart of SAM-g2 in Figure 1.

Concept of this research aims to design the system that collects production data from shop floor and brings data to analyse and report back to production control, which helps production control able to recognise progress and problem in shop floor closely.

When production misses the target, system will send warning to warn production control and indicate the problem process, which helps production control can correct problem earlier before it becomes big problem. Nevertheless, system in this research is just a tool that can warn company when production misses the target, but it does not indicate action to response with it. The system will provide shop floor information such as progression of each process, which if there is any problem in production line production control can take corrective action to solve the problem by using this shop floor information to make decision.

To report progression in shop floor the research applies graphical technique which is called "Line of Balance (LOB)" in this system, which helps production control can read the progress in shop floor easier and clearer. Furthermore, using LOB helps user to see hidden problem and can bring information from LOB to make corrective action.

Furthermore, because learning curve is such a big problem that makes production plan always miss the objective plan. When time has passed efficiency of worker can change but many manufacturers do not update worker efficiency continuously because they overlook issue of learning. Therefore, this research also brings shop floor data to calculate and send to update worker efficiency continuously. Hence, when production planning uses this worker efficiency to plan target, they will get the number that has higher accuracy.

In an addition, design of system in this research also includes a part that user can input shop floor problems, which when time has passed they can print report of those problems to analyse and improve shop floor performance.

1.4. Problem Statement

1.4.1 Problem in production planning

As interviewed from a number of garment factories, mostly is not satisfying with their current production planning performance, which always miss target and sometimes vary significantly. Miss production target can damage company because most of orders are belong to foreigner clients, so delay of production force companies to pay for extra cost like overtime (OT) and rush shipment like air freight instead of sea freight, which is much

more expensive. Moreover, in the worst case companies may also have to pay for penalty or lose their customers.

Generally, garment industry is labour intensive therefore productivity always related to worker performance more than machine. This reason effects the output of factory to always unpredictable and miss objective plan, because efficiency of each worker can increase or decrease all the time rely on many factors, for instances, learning issue, health condition, emotion condition, and work place environment.

Even that, most of garment factories plan its production by ignore issue of learning curve. Production planning of many garment manufacturers uses unreliable and out of date worker efficiency to plan target. Many of them use testing method as measurement system for grading their worker efficiency. The test is always set ranging from 1 to 3 times a year rely on company. Furthermore, some plants also do not have any measurement system. They rely on shop floor supervisor to classify their employee efficiency from experience, which always absolutely miss the actual number. These two methods are inefficient to make precise plan. When time has passed efficiency data from test may be out of date and when production planning uses it, the target always misses the actual output.

Actually, typical characteristic of garment jobs are repetitive jobs, so it has very high opportunity that learning curve has high relation to worker performance and this can be the main cause of miss production planning if manufacturers use unreliable or out data information to make production plan.

Furthermore, the learning curve of each process is different. Obviously, the harder process, workers need longer time to learn job. Therefore, using worker efficiency from test method to make production plan, the line balancing that balance in early day can be vary and unbalance when time has passed. This can be cause of bottleneck because workers who do easy process may have much higher productivity while workers who do hard and complex process may have about same output.

1.4.2 Problem in shop floor monitoring and production control

Even learning curve is applied in production planning but human performance can vary all the time, so it still able to miss target as well. As described before, the productivity of garment industry appears very fluctuate. Because, each activity in the chain of production is essential link of each other, and product is not complete until all individual activities in the chain have been completed [6].

So, once the output has high variation, it often that bottleneck occurred in the line. Efficiency of human cannot fully forecast. It can be dropped significantly and vary all the time. Therefore, it is essential that when shop floor output misses target, production control needs to response with situation quickly, because it might be the cause of delay in next processes.

But, it appears that production control of many manufacturers always do not recognise progress and problems in shop floor as they should know. Once problem is recognised there is less time left to take corrective action. Now, there is insufficient linkage and bad communication between shop floor information and production control in many companies. Shop floor monitoring system in current days cannot help to see problems in shop floor as it should be. Many times they do not have enough information to indicate source of problem and do not know where corrective action should be taken place.

Even garment factories have its current shop floor monitoring and control system but mostly are still unreliable and always depend on individual skills according to supervisors' experience. Some companies use supervisor to walk along the plant finding work-in-process (WIP) or problems and solve it by supervisor itself, but this method inadequate to see hidden problems. Many factories have no standard methods or tools to help supervisor monitor processes. In addition, some factories did not record the problem in the line which in fact it very useful for productivity improvement in future.

1.5. Objectives of Research

To design system for the garment industry that can manage and use shop floor data helping to monitor progress in shop floor.

1.6. Scope of Research

- Sources of information used in this project are collected from 4 Thai garment manufacturers (two manufacturers are listed companies), asking experts and from public information including journals, books, dissertations, and internet.
- This project focuses and studies only on sewing function of garment industry in Thailand.
- This design of system in this project may not appropriate for every garment manufacturers, so manufacturers that need to apply this system in practice may

have to adjust some contents in system in order to fit with individual business processes.

- This design of system does not include programming and software part. It just designs of user interface and logical structure that can be developed to practical software.
- This design of system is evaluated by asking experts in system development and target users in industry.

1.7. Methodology

1.7.1 Collecting relevant data

First of all, before formulates the system; characteristics of garment industry should be clearly understood in order to generate system that align with industry and worker needs and behaviour in current industry circumstance. In addition, theory and concept used in system also collected in this process. The information is gathered by 2 methods including:

- **Interview**

The interview focuses on supervisors, managers and experts in garment industry. There are 4 garment factories in interview which two of these are listed companies. The topics of discussion related to situation of present jobs, overview of garment industry, and problems occurred in production planning and control. The interview does not scoped only in sewing department, but also included every functions entire factory since receive order to packing.

- **Public information**

The public sources are including journals, books, dissertations, and internet. The information is not scoped only in engineering academic but also included knowledge of garment industry, garment manufacturing processes, garment business situation, and system development knowledge.

1.7.2 Analysing problems and requirements

After collected information from industry, problems occur in shop floor monitoring are analysed in this step in order to clarify jobs and industry's requirements that this research trying to focuses.

1.7.3 Considering system concept

This step is about finding methods and theories to plan concept of system to solve problems and requirements in previous step. All methods and theories applied in the

project are carefully selected, studied and analysed in order to achieve feasible and correct concept before develop the system.

1.7.4 Developing system

After problems, requirements and concepts are clarified, the design of system in this research is developed based on information from those steps. The system in this project is related to workers in the shop floor, so it has high probability that these workers have very low IT skills. Therefore, it is important to study system development knowledge in this step and design system that easy to use.

1.7.5 Verifying system

Once design system is developed it is verified by asking experts and target users in garment industry in order to check that system can answer concept and users' requirements or not, checks feasibility of system, and ease of use.

1.7.6 Modifying system

After design system is verified by asking experts in system development and users in industry, some recommendations are used to modify system in order to increase system performance and block weaknesses. The system that is modified will be sent back to verify and edit again and again until got the satisfied version, which users in garment industry and experts in system development accept it.

1.8 Expected Benefits

This research contributes design of system that helps production control to monitor and control production line by enable production control to recognise progression and problems in shop floor. The research also contributes the design of system that prepares information to support production planning when make production plan.

1.9. Expected Results

- The design of system that can receive and manage data from shop floor which can help to monitor and report progress in production line.
- The design of system that can warn user to when production misses the target.
- The design of system that uses data collected from shop floor to analyse and prepares worker efficiency information for production planning.
- The design of system that can collect problem data from shop floor, which manufacturers can bring to analyse and improve productivity.

CHAPTER II

LITERATURE REVIEW

2.1 Manufacturing Processes of Garment Industry

According to Promlarwan [5], garment industry in Thailand was first official supported by government in 1967, but that period Thailand was unsuccessful in business because Thailand had major weakness in quality which unacceptable in world market.

However, at the present, garment industry of Thailand is accepted worldwide because low manufacturing standard and quality problem is improved so far.

Generally, garment manufacturing system tries to separate one product into many sub-components because it can contribute better quality and higher productivity [5]. The typical manufacturing processes of garment industry can be generically separated as following:

1. Design

Because garment industry is about fashion products, so the style of each batch usually differently especially women's clothes. Now, there is limit of fashion designers resources in Thailand even government is trying to promote fashion industry in this country. Therefore, most of export orders are designed from customer.

2. Size

Normally, when customers give drawing of design to manufacturers, it always includes dimensions of each size in drawing. According to Promlarwan [5], the size of products in this industry may use alphabet to be code, for examples, S, M, L, and XL. Similarly, customer may use number to be code, for examples, 8, 10, 12, 14,..., and 22 for children's clothes and 30, 32, 34, 40,..., and 44 for adult's clothes.

3. Pattern

Once design and size are confirmed, the pattern is drawn either in computer or hand writing.

4. Maker

When finished creating pattern, the patterns are put on fabric in order to find the most appropriate position of each pattern that minimise lose of fabric because it can save cost of materials [5].

5. Spreading

After finished maker process the maker will be put on fabric in order to prepare fabric in many layers before sending to cutting process because when fabric is folded in many layers the worker can cut many pieces of work at a time.

6. Cutting

According to Promlarwan [5], cutting process is important process that highly affect to the quality of product because the higher accuracy cutting, the higher neatness of product. Moreover, good cutting process also reduces defect and waste.

7. Sectioning

Once fabric is cut into many sub-components, sectioning process tries to separate fabric into group of each size, colour, and purchase order and also inspects defect such as cutting defect. After that bundles of fabric are sent to sewing section. According to Promlarwan [5], sectioning process also needs to sequence and control distribution of fabric on basis of shop floor plan.

8. Sewing

Sewing is the process that sews pieces of fabric together to become each sub-component, for examples, body, arm, and collar. Furthermore, sewing process also includes assembling process that sews all sub-components to be product like shirt, jacket, dress and etc. Sewing process is a core manufacturing process of garment industry [5]. It consumes the longest time in garment manufacturing processes. Because of this reason, therefore bottleneck of production line always occurs in sewing section.

Productivity of sewing function mostly relies on worker performance. Therefore, to get high productivity manufacturers have to provide appropriate attachment that enable workers work faster and have high efficiency planning method. According to Promlarwan [5], because there are numerous sewing methods which require different sewing skills, therefore each sewing operation is sectioning by skill requirement and difficulty of each operation. It have to allocate into appropriate worker that qualified for each job in order to get high productivity, minimise defect, and avoid bottle neck.

9. Quality control

Normally, good quality control of garment industry has to cover three main areas including materials, manufacturing, and final output.

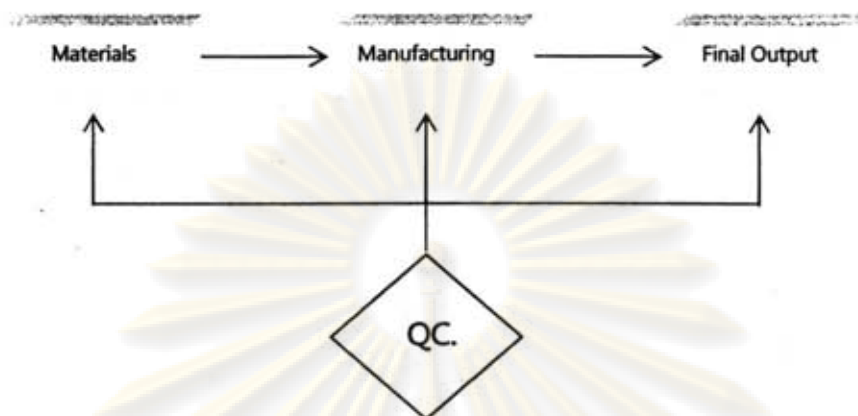


Figure 2. Quality Control in Garment Industry

10. Packing

Packing process is the last process before shipment to customer. Once finished inspection, products have to be ironed and washed before be contained in package. This process uses simple operations and requires simple skills, so it is easy to sectioning job and also easy to allocate workers in this process.

The manufacturing value chain of garment industry is illustrated in Figure 3.

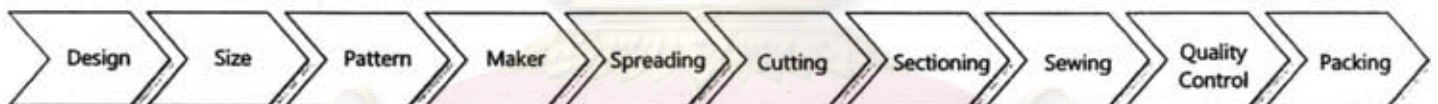


Figure 3. Manufacturing Value Chain of Garment Industry

2.2 Learning Curve

When production planning plans jobs, allocate workers, scheduling production, and planning capacity, it is important to know that what productivity can increase during production through learning curve consideration [7].

The concept of learning curve was generated during World War II in aircraft industry and became an empirical theory in 1925 [8]. The learning curve was first found by T.P. Wright, he observed that when output of aircraft industry was doubled, the labour used decreased by approximately 20 percent and performed like this simultaneously [8]. Wright's learning curve model is $y = ax^{-b}$ which is log-linear model [9]. y represents the

average cost or time of x^{th} units, x represents number of units, a represents time or cost of first unit, and b represent learning rate which is constant number [9].

Learning curve concept is based on idea that when workers doing repetitive job for amount of time, they gain experience in and become better at their job, so their productivity is slightly increasing continuously[7][8][10][11][12]. Hence, it means that the more unit workers produce, the lesser cycle time and resource will be used. The learning curve provides information that valuable for decision making, for instances, cost/price estimation, labours allocation efficiency variance analysis, production planning, capital investment, standard time and etc [8][10][12]. The sample figure of learning curve is showed in Figure 4.



Figure 4. Learning Curve Graph

In recent study according to Towill's research, it found that when separated order of batch production into 4 batches, production time increase round 40 % due to learning effect [13]. Furthermore according to Camm [14], learning curve also has relative with cost of unit which always did not take into consideration. Camm [14] argued that if manufacturers produce any product from such amount of time cost per unit can definitely decrease.

To increase productivity, Anzanello, Fogliatto [15] argued that if company assigns same product family which has similar work methods on the same team of workers, it can help worker can learn job continuously and reduce production time of that product.

There are amount of synonyms for learning curve may found in different academic works from various academic experts including manufacturing progress function, cost-quality relationship, cost curve, product acceleration curve, improvement curve, performance curve, efficiency curve, and experience curve [8].

Learning curve model based on non-linearity while uses of traditional liner models can effect to significant planning errors and absolutely non-optimal solutions, so it means that non-linearity that wildly used in present learning curve consideration is better and has higher precision [8]. The learning curve does not considered only in labour-intensive, but it also has correlation in others types of industries like capital-intensive, machine-intensive, job shop production, and even in continuous production line such as petroleum and chemical industries [8]. According to Chase [10], the learning curve can also be separated into two parts including "individual learning" such as people and "organisational learning" such as department and production line.

The learning curve theory has been various introduced in a number of models from a variety of academic experts. But, mostly have same parameters which are input resources and learning rate. Some famous models are showed as follow [8];

- The log-linear model
- Pegels's exponential function
- Levy's adaptation function
- The Stanford-B model
- Dejong's learning formula with an incompressibility factor
- S-curve
- Glover's learning formula with a work commencement factor

From various models Mohamed, Kher [16] argued that even there are many learning curve models have introduced, but the most widely accepted model is Wright's model which; a log-linear model.

Nevertheless, it should bear in mind that different industries, different companies, or even different products may have different learning curves, so analyst should find the suitable model or learning curve that match with individual[7][8][10][11]. Moreover, another issue should be careful which Smunt, Watts [17] also argued that the high level of data variance can reduce decisions maker confidence of learning rates estimation.

2.2.1 Factors affect to learning

There are many factors can affect to the performance of learning for examples;

- **Complexity of job**

The complexity of job can be categorized in 3 types

- A. Length of cycle time- Typically, the longer cycle time, the higher complexity because it has more chance that worker can forget previous job element.
- B. Non repetitive movement job- The job that has low repetitive motion is likely to take longer time to remember more than repetitive job. Therefore, the workers always need more time to learn and improve their efficiency.
- C. Length of training-Apparently, the job that consumed more time to learn whether working with machine or not it is classified as higher complexity task.

- **Worker condition**

- A. Age of worker
- B. Historical data of learning curve in record
- C. Health condition of workmen

- **How worker learn job?**

As described before, complexity of job can affect to performance of learning ability, and complexity stays around range between 88%-92% of learning curve differently relies on instructor performance.

- **Experience of worker**

The engineer should aware of this issue when conduct the experiment because different experience workers may consume different time to learn, which can make the experiment result error.

2.3 Forgetting Curve

Previously, the issue of learning curve is explored in detail to show that workers can increase their performance when they do repetitive task for amount of time, conversely when interruption occurs and workers stop doing that job for amount of time, it can also be cause of forgetting [7] [18]. It means that if workers do not work in that task for a long time, they may switch to do the new task that significant different from previous task. This case workers can forget method to work in previous task and when they come back to work again their efficiency can decrease from last result.

In recent issue research of Towill [13] also supported that due to the lapse time between the previous batch and next batch, the forgetting factor can make affect to production time of manufacturing. Furthermore, Anderlohr [19] and Globerson [20] proposed that

company may lose productivity approximately 50 % of lot size has lapse time round 3-6 months and 75 % in a year.

However, even efficiency is decreased for some numbers or totally forget but when workers back to work in that task again workers can learn quicker than first time [21]. In recent study Martinich [7] argued that the rate of recovering of skill depends on how long the interruption is and what activities the worker performs in the meantime. And, according to Jaber, Kher, Davis [22], there are another two important factors which are level of experience that workers has before be interrupted and learning rate of that task.

2.4 Line of Balance (LOB)

Sometimes actual production may not match with the planned delivery schedule, and once management recognise the problem many times corrective action may be late [23]. Therefore, manufacturers need tool to monitor and control all production steps [23], which in recent study line of balance (LOB) is applied to solve this problem.

Line of balance is production control technique that uses graphical aids helping to monitor and measure progress of operations though comparison of actual progression and target.

The LOB technique was originated by the Goodyear Company in early 1940s [24] and was developed by U.S. Navy during World War II in early 1950s [5][24][25]. It was first applied to manufacturing and production control to attain or evaluate progress of production line [24].

Schonberger [26] argued that manufacturing process that appropriate for line of balance technique should be large-scale of items. If quantity is too small, the production may be over before the LOB can fully operate.

The LOB technique includes of 4 main components:

1. Objectives chart

Objectives chart shows objectives of project in term of unit of quantity per time unit (e.g. pieces/month). According to Riggs [25], it represents graph that shows expected completion schedule and the actual completion rate.

2. Programme plan

Programme plan is slightly same as operations process chart. It shows all activities in the process, time consumption of each node, and lead time that each activity must finished before due date. Example figure of program plan is showed in Figure 5.

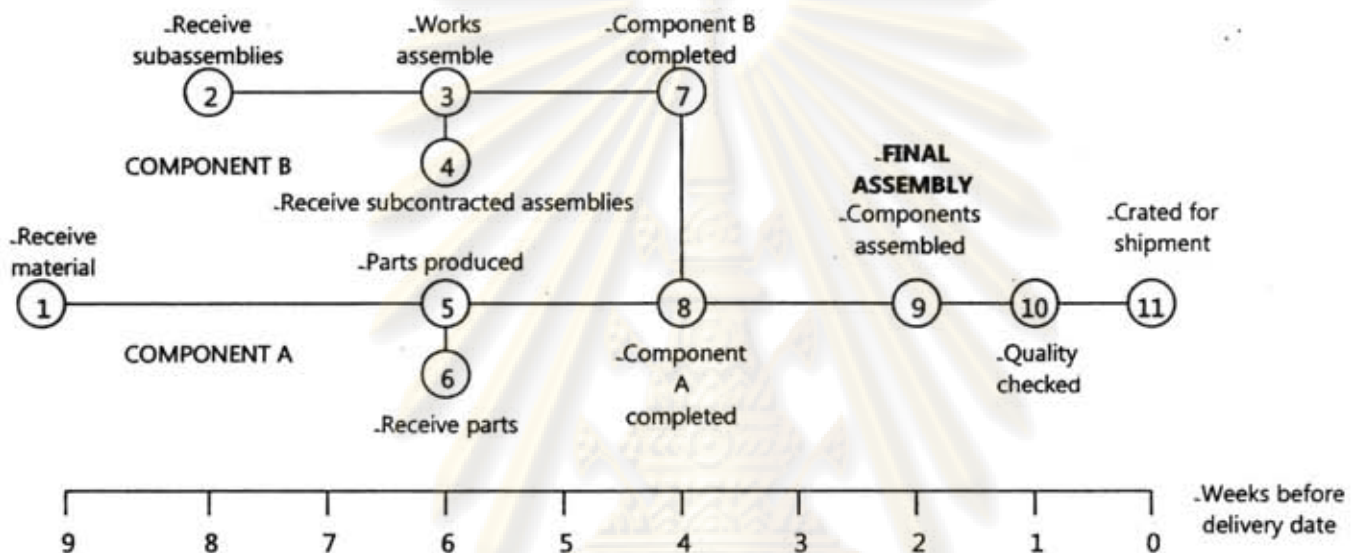


Figure 5. Example of Program plan
Source: Riggs [25]

3. Progress chart

Progress chart represents progression of programme which can be done in actual production. The vertical bars show amount of units, parts, components, materials, or products that have been produced in each review point at each time.

4. Line of Balance (LOB)

Line of Balance (LOB) is comparison tool between actual production in progress chart and target in objectives chart. According to Riggs [25], it is plotted from the objective chart crossing along the vertical bars in progress chart. The bars that exceed the line of balance means those activities have been done over expected volume. On the other hand, bars that lower than line of balance means those activities are running behind the schedule and need corrective action to fix.

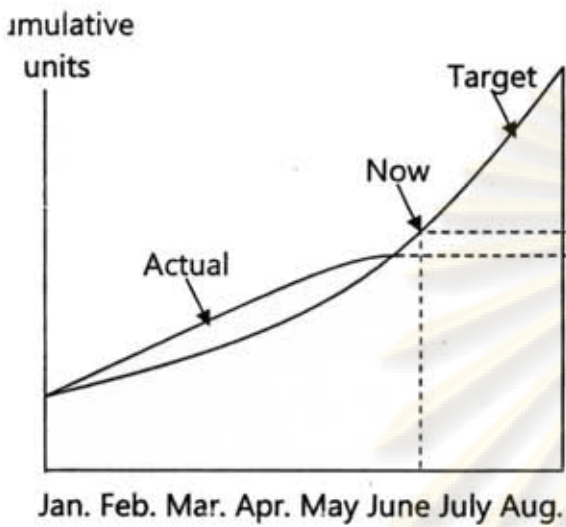


Figure 6.Objective Chart

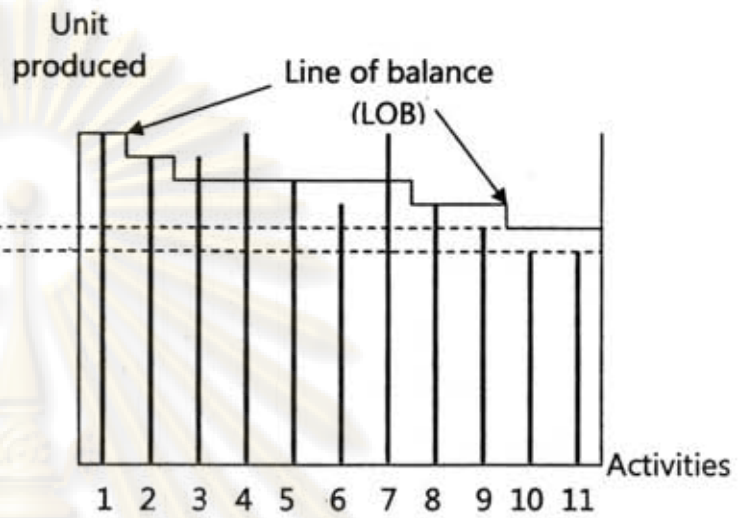


Figure 7.Progress Chart

Source: Riggs [25]

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จุฬาลงกรณ์มหาวิทยาลัย

CHAPTER III

SYSTEM DEVELOPMENT LIFE CYCLE

3.1 System Development Life Cycle (SDLC)

In present day, system developer may create and develop system in many different ways. But, all of it have same objective that is to maximize efficiency of System Development Life Cycle (SDLC). According to Avgeron, Cornford [27] the information system can be either new system development or improvement of existing system to meet with dynamic of companies' requirements. However, this research focuses to develop new system to use to solve problems in garment industry.

Generally, information system can be developed for three main reasons; to solve a specific problem, to respond with pressures (e.g. competitors' force), or to exploit an opportunity [27]. The system development in this research focuses on first and second reasons that are to develop the new system to solve current problem in shop floor monitoring system and strengthen garment manufacturers performance against with business environment by increases its productivity and decreases costs. It also contributes benefit to third reason which helps garment manufacturer increases an opportunity to get more orders and profits.

Basically, SDLC consists of 4 main phases including planning phase, analysis phase, design phase, and implementation phase [28]. However, there are many SDLCs that have different advantages and disadvantages depending on project's characteristics and requirements. However, advantages and disadvantages of each SDLC model on this research are described in following issue.

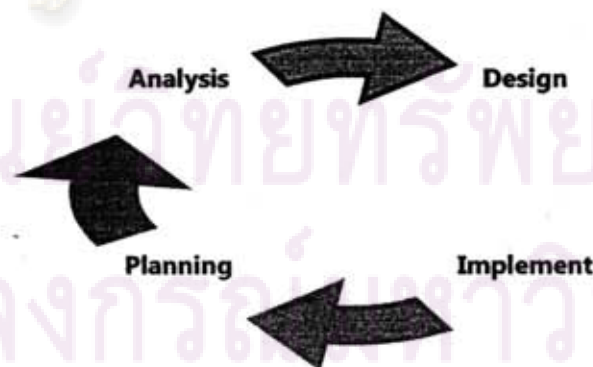


Figure 8.Four Main Phases of SDLC

3.1.1 SDLC selection

As stated previously, there are a number of SDLCs have been used in system development in present days. This issue will show some main SDLCs and show how to select the most appropriate SDLC to use for developing the system in this research. The advantages and disadvantages of each model on this research are clarified in following categories.

- **Waterfall SDLC**

Waterfall SDLC is step by step system development. Project in each step of waterfall SDLC must be fully completed before go to the next step because system developer cannot go back to edit the previous step. And, because it cannot go back, so the advantage of this model is system developer can control resources and time used in project precisely, which helps company to meet its initial target.

But, this SDLC is inappropriate for this research because each garment manufacturer may have different business processes and infrastructures, which the system that satisfies company A may not appropriate for another company. So, the system in this research is verified by end user of several garment manufacturers from time to time during system is being developed, and may need to adapt some components in system from time to time in order to make it align with actual practice in industry.

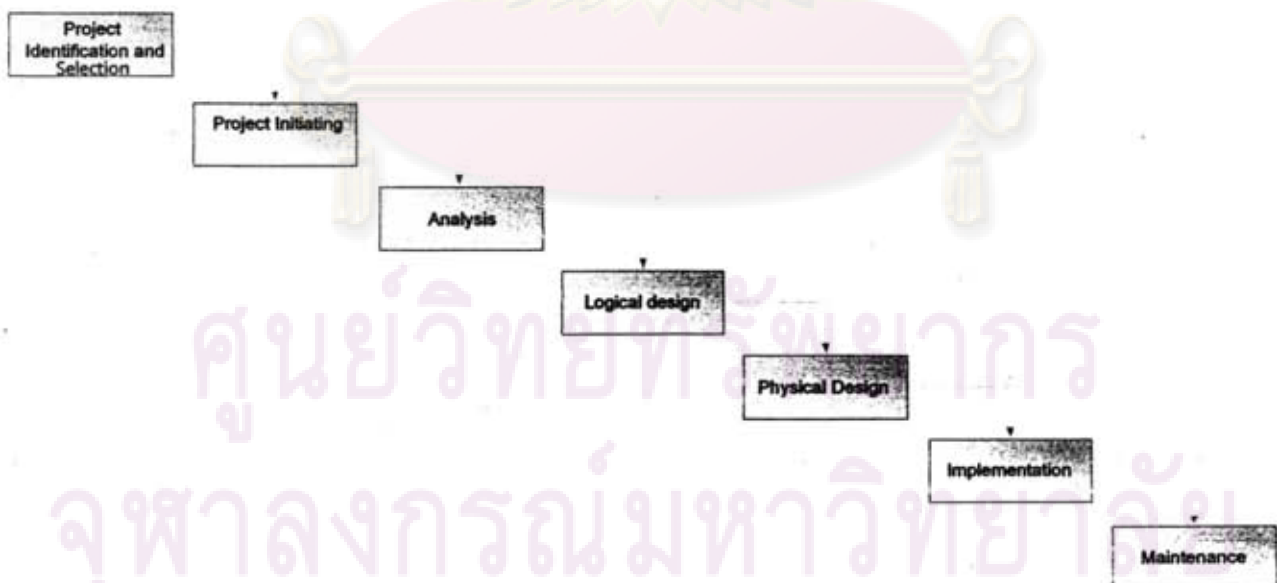


Figure 9. Waterfall System Development Life Cycle (SDLC)

- **Adapted waterfall SDLC**

Adapted waterfall SDLC is very similar to waterfall SDLC, but adapted waterfall SDLC can go back to any step in SDLC to correct some problems or change some properties in previous steps. This model is the most suitable SDLC model for this research because garment manufacturers can change the design of system in any step that does not align with their organisation. Moreover, this design of system may change from time to time because this research brings end user to involve in system to give suggestions. So, the design may be edited simultaneously to meet users' recommendations, which using this SDLC helps system designer able and easily to edit the system during system is being developed.

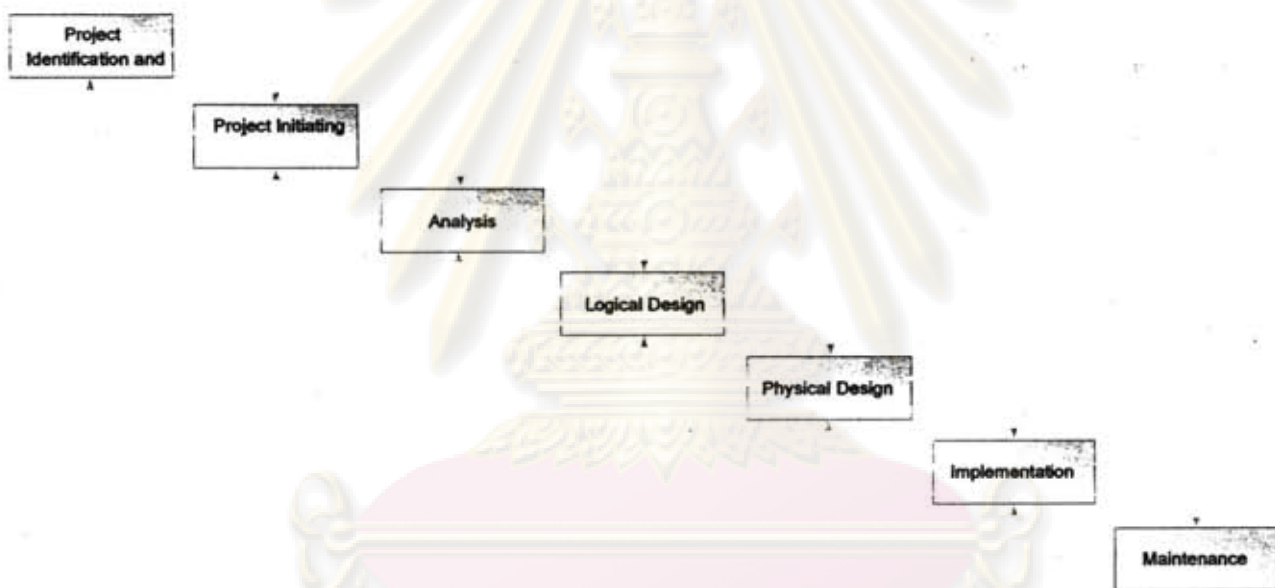


Figure 10. Adapted Waterfall System Development Life Cycle (SDLC)

- **Evolutionary SDLC**

Evolutionary SDLC concept is cycle that tries to develop product in first version and then upgrading the first version to second, third, and so on until the company satisfies in system. This SDLC may develop system at small area at version 1 and expand to bigger area in version 2 and 3.

However, this SDLC is inappropriate for this research because this design of system is not planned to upgrade the version until got the final product. Even some components in this design of system can be changed to align with

individual firm, but it may not support the version upgrading system which sometimes may require major change in the programme. In an addition, evolutionary SDLC needs the prototype of in each version to test and find weak points before move to next version, which this research is just the system design that does not include the prototype making.

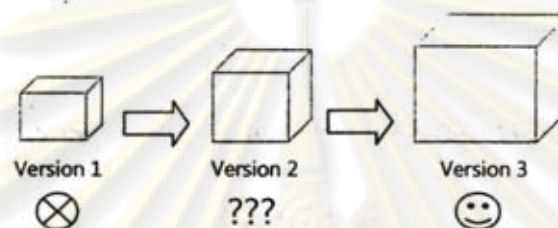


Figure 11. Evolutionary SDLC

- **Incremental SDLC**

Incremental SDLC is slightly same as evolutionary SDLC that is develop the first system and then expand to bigger and bigger system, but incremental SDLC will develop the system as module by module. For an example, company may develop system to use in merchandising section, and after that company may continue to develop system in production planning, production control, or others sections of business in later stages. In addition, normally when all modules are finished all parts or some parts of incremental SDLC can be integrated.

This SDLC is very interesting tool. It has benefit on step by step development, which reduces chance of many problems instead of big step improvement, for instances, technology conflict, employee resistance, resources constraint and bugs in the programme. Moreover, to develop the system as module by module enables company to reduce its possibility of project failure.

Nevertheless, incremental SDLC is not appropriate for system development in this research because this research is concurrent system development, which developing many part of business at a time.

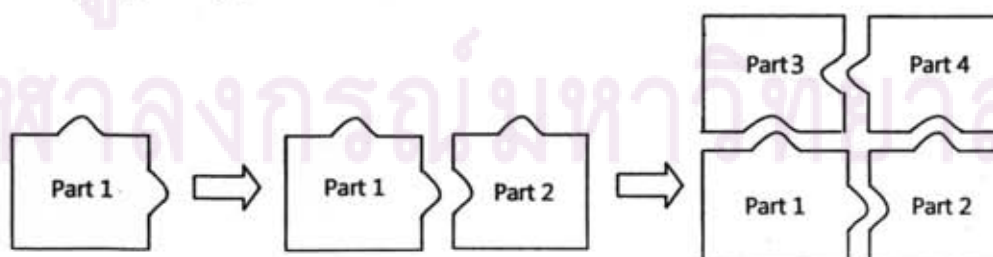


Figure 12. Incremental SDLC

- **Spiral SDLC**

Spiral SDLC is system development that trying to develop the system as the cycle. The spiral SDLC has 4 basic phases including analysis, design, implementation, and testing. The SDLC starts at planning then go to analysis, design, and implementation. After completes implementation if company find some weak points company may start to run cycle again which is planning, analysis, design, and implementation.

Advantage of this SDLC is it forces company to review the system from time to time, which increases a chance to find bugs and weak points, because all phases in system must be repeated and verified again and again until company satisfies in the system.

Again, this SDLC is not suitable for this study, because spiral SDLC need to implement and test system again and again until developer satisfied, which this research does not include the implementation and testing phases. It only focuses on analysis and design phases.

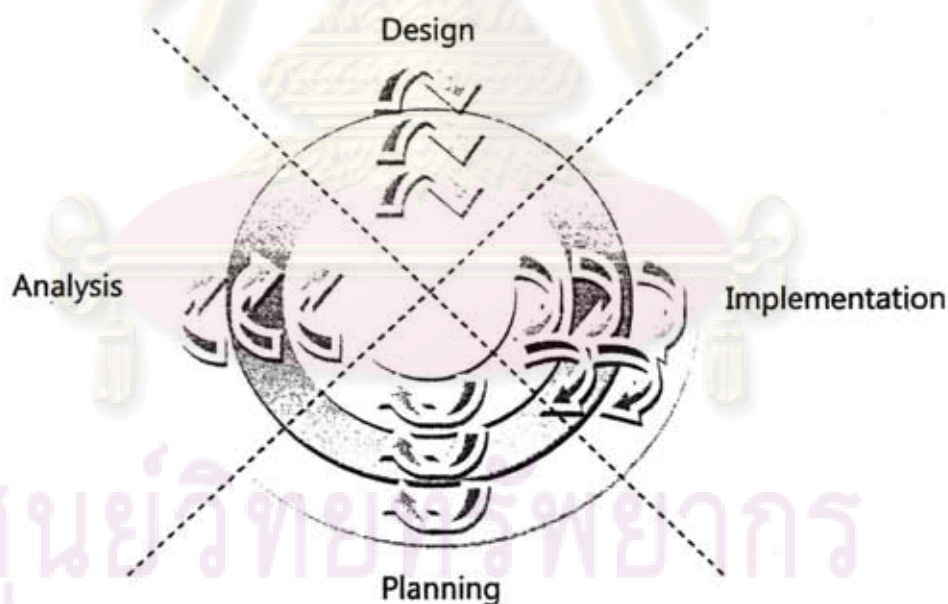


Figure 13.Spiral SDLC

In conclusion, the system development life cycle that most suitable for this research is "Adapted Waterfall", because it provides a chance for system developer to edit the

system in any phase of the life cycle which is important for this study as described before. Moreover, although there are many interesting SDLCs such as incremental SDLC, those models always require the implementation phase to review the system occasionally, which this research is just a design of system that does not include the implementation phase in the study. So, many interesting SDLC models may not align with this study.

3.1.2 System development life cycle (SDLC) of research

As clarified earlier, the most appropriate SDLC for this research is adapted waterfall SDLC. The adapted waterfall SDLC used in this research has 4 main phases, which also can be categorized to 7 steps, and the illustration of SDLC of this research is showed in Figure 14.

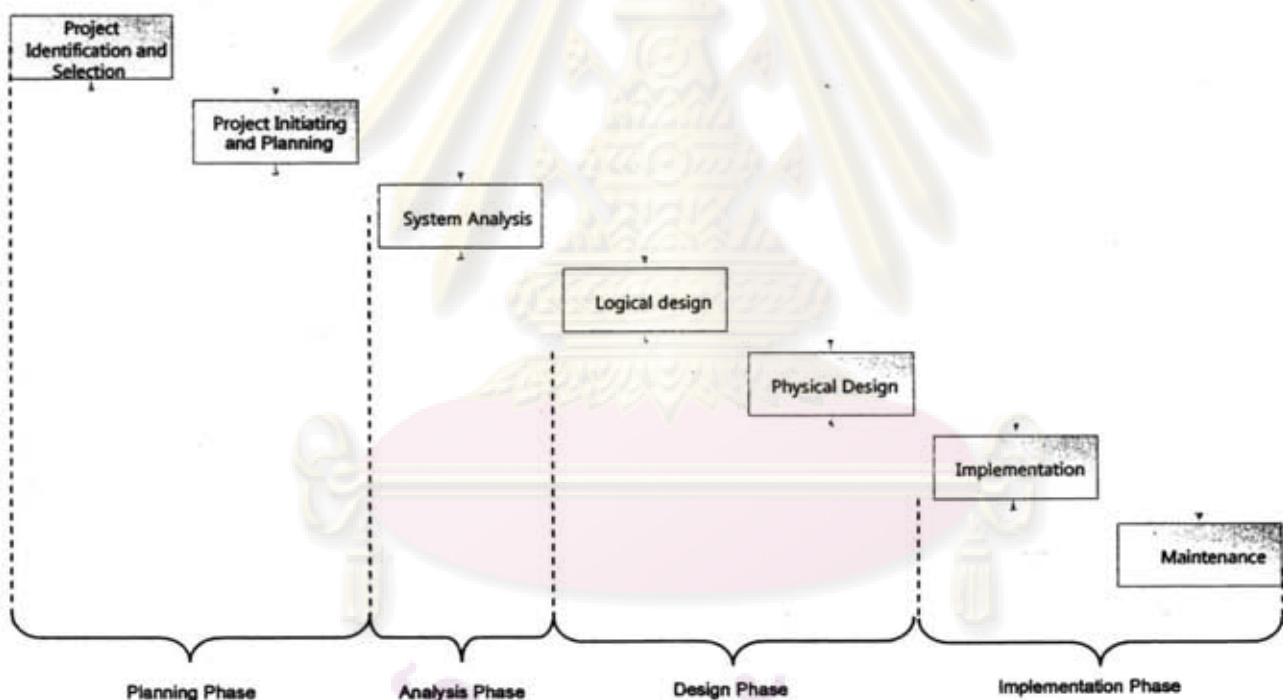


Figure 14. Adapted Waterfall System Development Life Cycle (SDLC) of Research

However, as seen in figure it may not clearly understand job of each step, so details of each step is described in following categories.

- **Step1 Project identification and selection**

Project identification and selection step is first step of SDLC. The objective of this step is to identify the problem and area that company needs to improve and develops system. It also includes project selection because actually there may be many parts of business that need to be improved, but in case of resources constraint company may need to select the most value for money project that gives the highest return of investment (ROI) or benefits for company.

- **Step2 Project initiating**

After project is identified and selected this step is to plan the team that responsible for project. It also includes project feasibility analysis, plans target, and resources planning.

- **Step3 System analysis**

This step is to analyse problems and requirements of system in order to get the design of system that meets company's objectives. This step also includes analysis of work flow and data flow of system to recognise flow of data, processes, and relationship of all related functions in project.

- **Step4 Logical design**

Logical design step is design of system appearance. It includes report of system, user interface, and data base design.

- **Step5 Physical design**

This step indicates the physical requirements of system such as hardware and software used to develop system, and local area network (LAN).

- **Step6 System implementation**

After system is completed company needs to implement it into business processes. The implementation may be either upgrading old system or implementing new system. In implementation step, company may found some bugs of programme that needed to be fixed. In an addition, it often found that many companies fail to implement its new information system and technology. Company has to confront with many problems, for examples, employee resistance, technology conflict, resources constraint, and etc. So that, one better solution are company should implement new system step by step instead of whole enterprise implementation and tries to communicate with workers.

- **Step7 System maintenance**

Obviously, after implementation, company has to maintain its system and pay some expenses for recovery and system updating from time to time. Moreover, company may found some conflicts in system, so that maintenance step also includes bugs correction and system improvement.

As described, project identification and selection helps to identify the problems and areas that company needs to improve and develops system in order to increase company's competitiveness because in fact company may have many problems that need information system to help. But, different companies may have different problems and requirements, the shop floor problem that is considered in this research may be the big problem in company A, but can be a little issue for company B. Therefore, project identification and selection steps in SDLC should be considered individually, which this research does not include this step in the study.

For project initiating step, this step is about resource planning, project feasibility, and target planning. Again, obviously different companies may have different resources, different financial statuses, and need different targets. Therefore, this step should be explored individually, so this research does not include this step as well.

For step 5 which is physical design step, this step is related to hardware and software selection and Local Area Network (LAN) design. Again, Scope of this research is design of system which does not identify hardware and software used to develop and used in the system. Companies can bring this system design to write up with any software. Moreover, different companies may have different LAN system and security, so this system design also does not identify and design LAN system in the study.

For step 6 and 7 which are system implementation and maintenance steps, these two steps are final steps that bring the system to use in practice. However, this study is just a design of system which does not include implementation and maintenance steps, if any company interested to bring this design to use, company can explore these two steps and bring to use in practice individually.

Consequently, this research focuses only on step 3 and 4 which are system analysis and logical design steps in system analysis and system design phases, which are designed to provide information to support programmer easily to write up programme with unidentified software and hardware. The system analysis phase is clarified in Chapter 4 to understand what the system should do [28][29], while system design phase in Chapter 5 specifies in detail about components of information system such as user interface and report design[28][29]. The issues of each step are showed in Figure 15. And, the conclusion of issues and models used for each phase and output that this research provided for software developer is showed in Table 1.

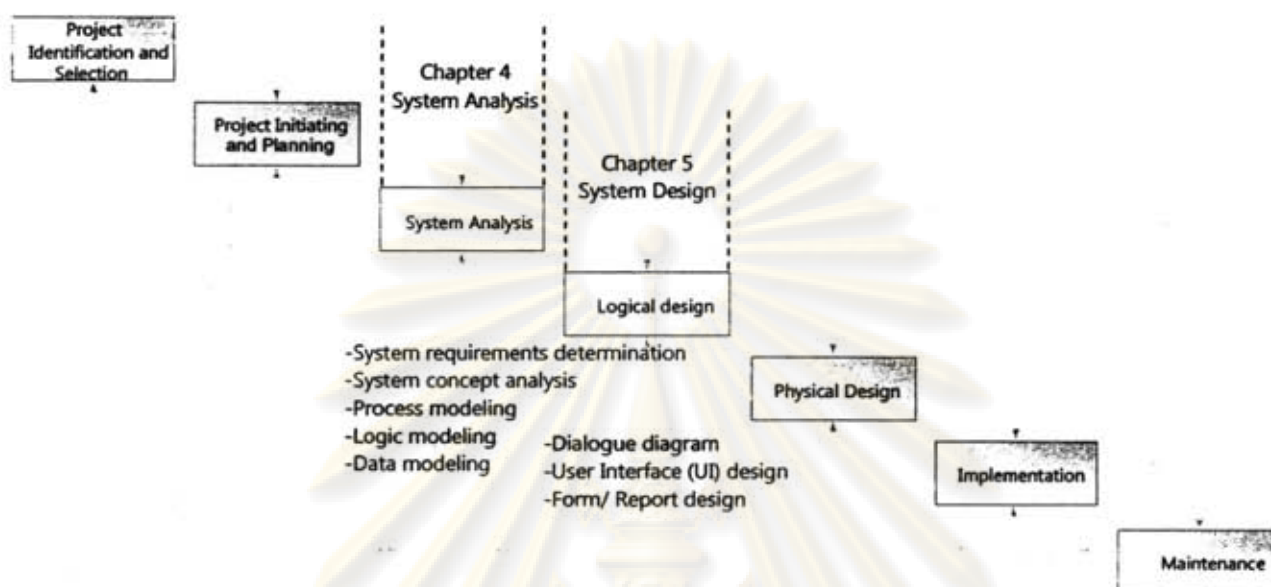


Figure 15. Issues of Each Step in This Research

Phase	Issue	Model	Output (For Software Developer)
System Analysis (Chapter 4)	System Requirements Determination	-	Requirements of System
	System Concept Analysis	-	System Concept
	Process Modeling	Work Flow Diagram Context Diagram Data Flow Diagram	Work Flow Diagram Context Diagram Data Flow Diagram
	Logic Modeling	Flow Chart	Logic Flow Chart
	Data modeling	Entity Relationship Diagram (ER-Diagram)	Entity Relationship Diagram (ER-Diagram)
System Design (Chapter 5)	Dialogue Diagram	-	Dialogue Diagram
	User Interface (UI) Design	-	User Interface (UI) Design
	Form/Report Design	-	Form/Report Design

Table 1. Conclusion Table of Issues, Models, and Outputs of Each Phase

However, there are many methodologies that can be applied to use to develop system in SDLC, but the methodology that is used in this research is Structured Design methodology because it is step-by-step phase-by-phase approach which suitable for Adapted Waterfall SDLC [29][30][31][32][33].



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CHAPTER IV

SYSTEM ANALYSIS

As stated before, this research focuses only on system analysis and system design phases in system development life cycle (SDLC). The system analysis is clarified in this chapter to analyse problems and requirements of shop floor in "System Requirements Determination" and then the research will propose the concept used to solve with those requirements in "System Concept". After that research will analyse flow of work and data in system, logic in system, and database in system in "Process Modeling", "Logic Modeling", and "Data Modeling", respectively.

4.1 System Requirements Determination

There are many technologies to be applied to increase firm's competitiveness and each firm should develop the technology that align with business and corporate strategy and to response with current business environment[24].

In addition, according to Hill [35] most companies often purchase new technology by base on high flexibility for high range of product and low order-quantity requirements instead of focus on assessment of business needs. Indeed, investing in technology the company should understand what is current business needs in order to eliminate unnecessary flexibility and excessive cost. Hill [35] also argued that investment in technology strategy can be divided into two main types including push and pull strategies. Push strategy means most process technology comes from technology base arguments, while pull strategy means technology that based on what business needs and business trend.

According to previous paragraphs, therefore before design the system this study concentrates on pull strategy which tries to clearly understand system requirements of actual needs and problems of garment manufacturers in order to design the system that align with current garment's business needs, strategies, and environments.

System requirements determination is in the phase of system analysis. It enables organisation to clearly understand the actual problems and what the business requires from the system [36], which analyst can bring this analysis to design the system that aligns with users' needs. This part is critical to success of the project [28][29][36] because it helps organisations to do not waste subsequent time on the wrong problem [28][29].

Data used to determine system requirements in this research is gained from many sources including documents of garment manufacturers, public presses, observation, and filed interview. After collected data from factories, some problems and requirements of shop floor are clarified in following categories.

4.1.1 Production control cannot recognise progress and problem in shop floor

In recent issue Dilworth [37] argued that good production control depends on good communication about the actual progress of each job and about shop floor situation. But, now it is found that production control cannot recognise the information in shop floor as they should know. Some manufacturers recongnise the condition in shop floor or problems when time has passed for 3 or 4 days, which make them get lesser time left to react with situation once they recognise the problem. The problem can affect them to close the order behind the objective schedule, which creates some following extra costs.

There are a lot of manufacturers that still do not have efficient shop floor monitoring tool and system to monitor and report progress and problem in shop floor. Many manufacturers still too much dependent on shop floor supervisors' skill to monitor progress in production line and make decision, which is unreliable and the late due date still happens occasionally.

4.1.2 Insufficient shop floor data to take corrective action

Normally, when production does not achieve the target production control needs to take corrective action to solve problem. But, at the present it is often found that when production control need to fix problem they do not know where corrective action should be taken place. This situation occurs because data collected from shop floor is too rough, which manufacturers cannot track the source of problem when bottleneck occurs in the production line.

The common way that wildly used in garment industry is to collect shop floor data at final process of each production line, which is too rough to track back and finding bottleneck process and unable to identify work in process (WIP). Present solving method is too much relies on shop floor supervisors to make corrective decision with his or her experience. The common method is to use shop floor supervisors walking along the production line and trying to seek the station that has high WIP (Work-in-Process) then they manage it with their experience, for examples, relocate worker, add resources, or pick those WIP to other stations.

Obviously, just relies on eye control and supervisors' experience cannot see hidden problems for an example in Figure 16. In Figure 16 assumes that every line produce different parts which finally every parts will be assembled in assembly line. As see in the figure, it appears that Line D can produce Part D much behind the expected target. On the other hand, although Line C can produce parts much higher than level it should be, but the exceeding units of Part C cannot be assembled at assembly station as well because assembly station has to wait for Part D.

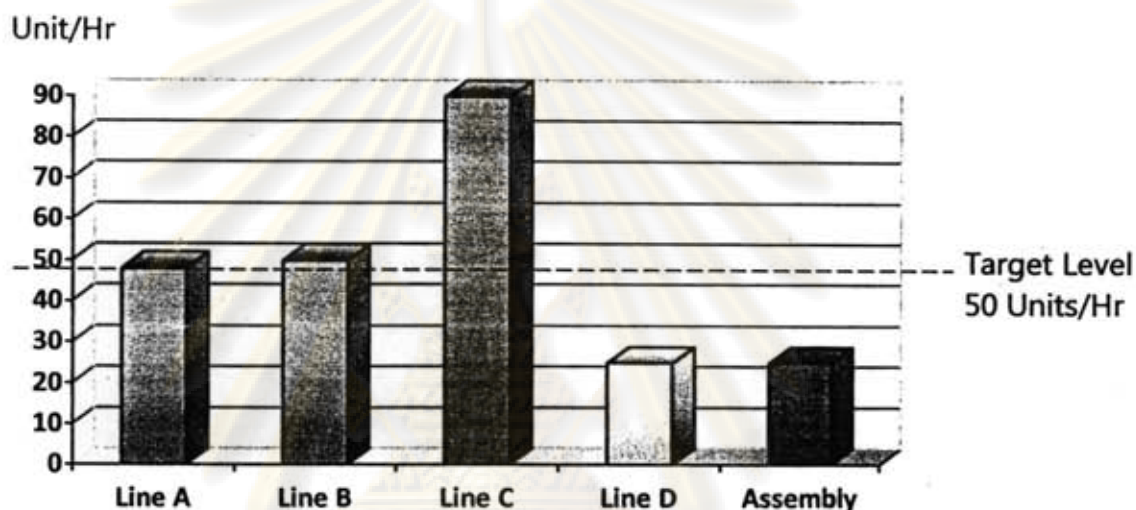


Figure 16. Example of Hidden Problems in Shop Floor

As showed in this case, one possible corrective action is to transfer resources from Line C to Line D in order to encourage Line D to meet balancing level. Therefore, if shop floor collects data only at assembly station and ignores to collect data from line A to D, production control may has inadequate information to balance the line and take effective corrective action, because they may not see the information of other Lines, which is such an important information.

4.1.3 Efficiency of worker are unreliable and out of date

As described, garment industry gets high effect from learning curve especially in sewing function because most of processes are labour intensive. However, although learning curve is such an important thing, it appears that many garment manufacturers still ignore this issue. Once they make the production plan, they do not consider the learning curve issue in its planning and control method.

The actual production rate of workers can increase continuously when company has run the production for amount of time. On the other hand, if workers do not operate in any

job for such a long time they may forget, and efficiency of that job may reduce. Even many manufacturers have their information about working efficiency of each worker, but many of them use testing method as a measurement system for grading their employee efficiency. The test is always set ranging from 1 to 3 times a year relies on each company.

Furthermore, some plants also do not have any measurement system. They stand on shop floor supervisor to classify their employee efficiency from experience, which always miss the actual number. These two methods are inefficient to make precise planning because when the time has passed worker efficiency can change, therefore the target can miss the actual output if production planning bring that data to use.

4.1.4 Problems in shop floor are not recorded properly

Now many garment manufacturers have widely used computer and software in their company for manage information gained from shop floor. Many factories record and keep production information in their system for use to analyse and improve its productivity. However, many garment manufacturers still do not interest to record problems in shop floor, while actually those problems always occur every day and also decrease productivity of the production line.

Problems that occur in shop floor are always fixed by production control or worker itself. But, when problem has already fixed many manufacturers mere to record those problems properly, which make them do not have enough information when they need to make productivity improvement in shop floor.

4.2 System Concept

This research tries to solve problems which are described previously in "System Requirements Determination". Although there are many possible solutions can be applied to solve those problems, only some tools, theories and methods are selected to use in this research, which it might not be the best optimal solution. But, this research tries to seek better possible solutions that garment manufacturers can apply to use and align with their current manufacturing system.

As described, now production control always cannot recognise progress and problems in shop floor as they should know. Therefore, when problem occurs in shop floor or when actual output misses the plan, it takes long time before production control recognises and fixes it. Therefore, the concept of this system is to design the system that

collects production data from shop floor and brings data to analyse and report back to production control which helps production control able to recognise progress and problem in shop floor.

The system will show the progress in shop floor which helps production control able to recognise the status of production line all the time. The system also includes warning system to indicate the process that miss the target, which helps production control can recognise the bottleneck and source of problems in shop floor immediately.

This system just one such tool that provides information to production control like shop floor progress and problems, and warns user if there is any process in shop floor miss its target. But, it does not indicate the solution to solve the problem, so it depends on production control to make decision on it. Nevertheless, the processes that this system focuses are show in the dot line box in Figure 17.

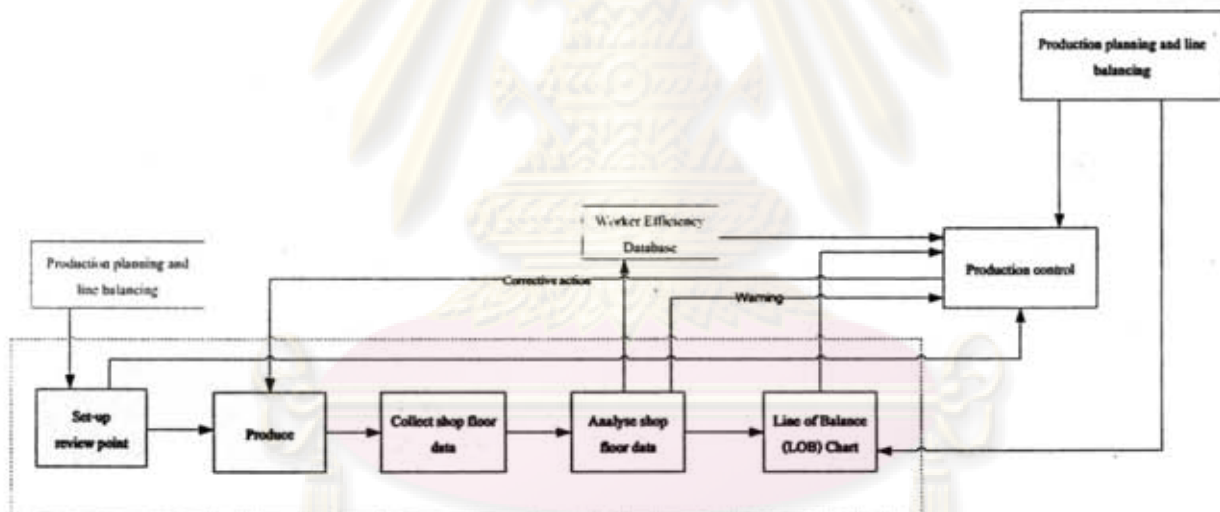


Figure 17. Processes Related in the System

For briefly introduce concept of work in this system, from the figure the process of this system starts at "Set-Up Review Point" process. User can create review point by selects processes in production line that wants shop floor supervisor to collect data. After that, when production line starts to produce order then shop floor supervisor will collect the production data and problem data from the review points that are selected in this process.

The problems data will be recorded in database which company can use to analyse and improve productivity in shop floor. The production data will be used to draw Line of Balance (LOB) to show progress in shop floor. If production data at any review point below the expected target, the system will also send warning to warn production control in order to recognise the problem immediately and make corrective action on it. Moreover, production data is also sent to calculate worker efficiency and transferred to update worker efficiency in database, which will provide more reliable and accurate information for production planning to plan target.

Furthermore, even this research focuses on system design and analysis to develop software used to improve monitoring system in garment manufacturers, but this software system design is only a tool that brought to encourage garment manufacturers managing its data easier, faster, and cheaper. However, without software that is designed in this research, ideas of solution and system concept that are described in this research can be implemented to increase shop floor monitoring and production planning and control performance as well. Companies can bring these concepts to apply and use with simple tool such as collect shop floor data by paper form instead of using computer.

However, there are some details of concept that are used to design system in this research, and those details are described in following issues.

4.2.1 Increase review points in shop floor

As stated earlier, many garment manufacturers do not pay attention in its shop floor monitoring system and method. They always set the review point at the final process of part or product which effect them to recognise the problem longer than it should be and also unable to indicate the process that occur the bottleneck.

A solution for this problem in this research is to increase number of review points in shop floor. Even the more review points, the more monitoring cost (e.g. counter cost) company has to pay, but there are many benefits that company will get. In the production line that has more review points it helps production control to recognise the problem faster and also get narrow range of problem.

For example in Figure 18 and 19, assumes that it is line production, and as illustrated in these two figures Figure 18 company sets review point only at final process which widely used in present garment shop floor. But, Figure 19 company decides to set review point more frequently. Figure 18 shows that production control has to wait the problem run

until final process before they recognise it. Furthermore, once they get the information they cannot indicate the bottleneck process, and if they want to know the source of problem it also has wide possible problem range which takes times to find out. Conversely, for Figure 18 production control can recognise the problem faster since process 7, so they can make reaction immediately. Moreover, production control also gets narrow possible range of problem which they can easier to find source of problem and able to react with problem quicker.

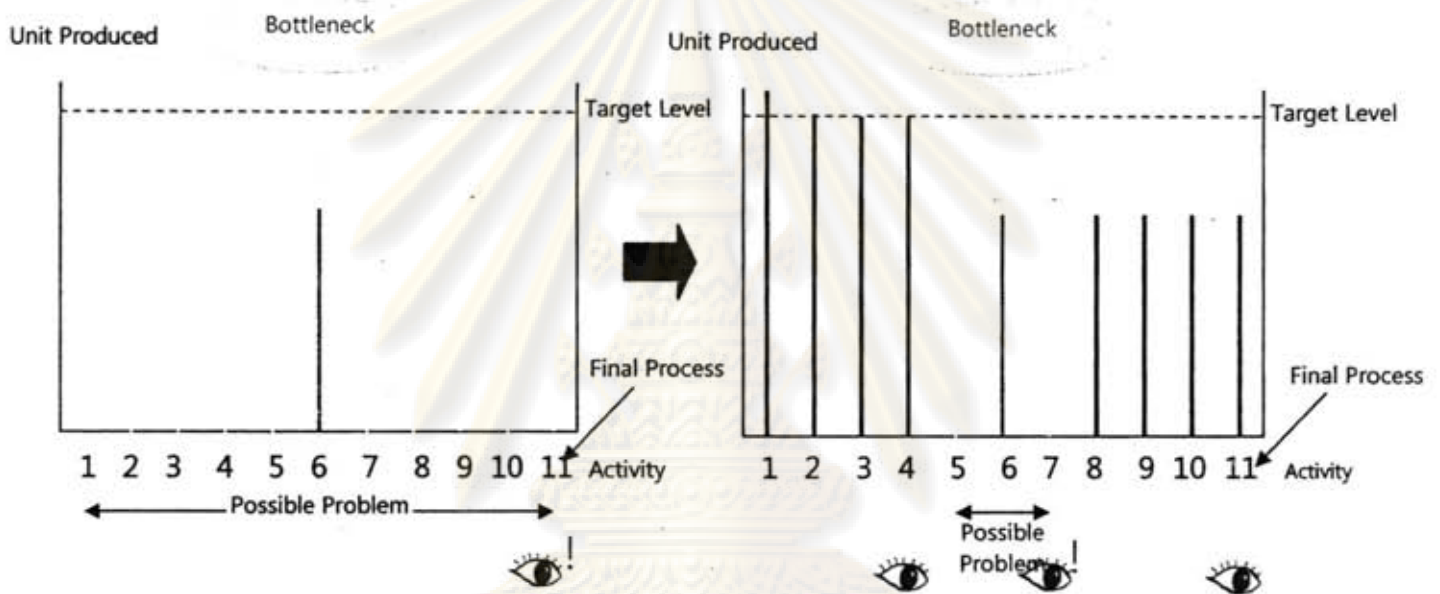


Figure 18. Example of One Review Point

Figure 19. Example of Many Review Points

If production control can react with the problem faster, it will help company achieve its production plan which can reduce penalty cost, extra rush shipment cost, increase customer satisfaction, remain customers loyalty, and reduce Over Time (O.T.). In an addition, it also increases productivity which helps company to get more profit.

However, there are some disadvantages of having many review points. Firstly, company may pay extra cost for hire counter to count units at review points or if uses worker to count worker may loss working time to check units, which is non-value adding activity. So, this issue depends on company to determine and find reasonable review points of each production line.

The suggested solution is to set about 3 review points for each sub production line such as body, arm, collar, and assembly line or at the line that has high bottleneck rate. In

In addition, normally some garment manufacturers always pay for employee by unit. Many of them use coupon system to indicate output of each employee. Each coupon will tell the number of unit that each worker produced. Therefore, company may bring data from the payment system such as data from coupon to update data in system in order to reduce time and cost.

Secondary, company may have to confront with employee resistance because employees in this industry are always paid by units. To count the units they worked may consume employees' time and effect to their payment. So, the suggested solution is to use supervisor instead of worker itself to count the unit, and company also needs to have well communication with supervisors to encourage them to understand benefits of this action.

Nevertheless, conclusion between cost and benefits of having several review points is showed in Table 2.

<u>Cost</u>	<u>Benefits</u>
-Need to pay some extra costs (e.g. cost for counter)	-Reduce penalty cost
-Increase non value adding activity	-Reduce extra rush shipment cost (e.g. air freight)
-Cause of employee resistance	-Increase customer satisfaction
	-Reduce Over Time (O.T) payment
	-Increase productivity

Table 2. Cost/Benefits of Review Points

4.2.2 Monitor shop floor more frequently

Now system that is widely used in most of garment manufacturers is barcode system. Some factories use barcode system as real time information which provides high efficiency monitoring system. Disadvantage of real time barcode system is time consuming because workers have to spend their working time to scan every unit or bundle.

In real work condition, most of factories use barcode system in their system but data from barcode is not read as real time. Mostly, read data once per day at the end of the day, and many companies may read this data two or three days per time. Actually, data from shop floor should be updated immediately like real time system. But, the real time

system may consume time and cost to implement and operate, so most of garment manufacturers are not willing to implement it.

Therefore, another one possible solution which is proposed in this system is to monitor shop floor data more frequently such as every hour or at least every half of the day. Higher monitoring frequency helps company recognise its condition of shop floor continuously, which if there is a problem or bottleneck occurs in the line; production control will know and can take corrective action immediately. Waiting for two or three days until recognise the problem may damage the company and finally production control may unable to take corrective action in time.

Nevertheless, the more frequently of data collection, the more complexity and cost, so many companies may not want to do this. Therefore, this system provides a chance for user to select review frequency as they want. The suggested solution is to set high frequency of data collection like every hour or at least every half of the day at only the core process such as end of assembly line and end process of every part.

4.2.3 Update worker efficiency continuously

Many garment manufacturers do not pay attention in learning curve issue. When time has passed, efficiency of worker can change significantly, so if company uses old worker efficiency to plan target they may miss the actual production rate in the latest condition.

For an example, company may calculate target from old information, which actually worker may be able to produce higher than the expectation. In this case, it seems no suffer will be received from this circumstance, but in another point of view company may lose its opportunity to get more purchase orders. On the other hand, if company does not update efficiency of worker continuously and their efficiency has dropped sharply. The actual production may not reach the plan which makes company to pay for extra cost like OT. or rush shipment to catch up with due date. The example of this case is illustrated in Figure 20.

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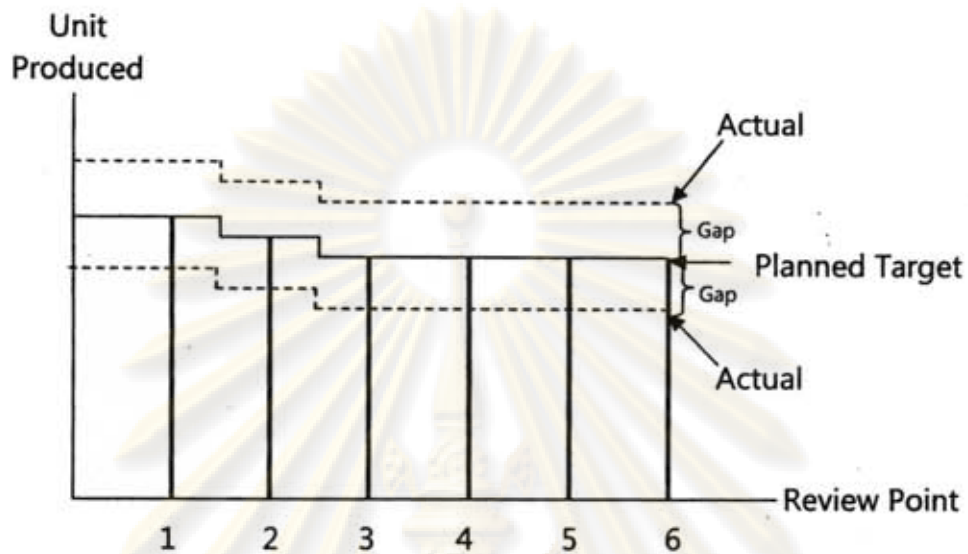


Figure 20. Learning Effect in Shop Floor

The concept in this system for this problem is to keep collecting and updating worker efficiency continuously. Once, the company uses the latest worker information it can increase production planning performance. Production planning can plan the production plan closer to real output. It helps to reduce gap between planned target and actual production in real condition and enables company to allocate resources efficiently.

By the way, another following question is how to collect employee efficiency? Company can collect efficiency data for many types ranging from plant efficiency, section efficiency, team efficiency to employee efficiency. Absolutely, the more detailed of data means the higher accuracy, for example if company collect data as team efficiency it will exactly contributes higher accuracy than section efficiency. Likewise, if company collects data as employee efficiency it will contribute higher accuracy than team efficiency.

Although collecting efficiency of every employee enables company to plan the target really close to real output, garment manufacturers who have many employees in their plants, they may lose high amount of resources to do this non value adding activity. Therefore, one better rational choice in this system is to collect data same as payment system, for example if company pays for employee by team, so company may select to collect data as team efficiency, which this information can use for both in payment system and update efficiency of worker as well.

For the payment system that pays by team, when the production planning creates the production plan it can use team efficiency to plan team target, or if company wants to allocate person target, production planning can estimate that every employee in the team has same efficiency and use that efficiency to allocate person target. Likewise, for the company that collects data by person as it pays by person, planning can use efficiency of worker to plan person target directly, but if planning needs to plan the target by team, they can use summation of all workers efficiency in team and find average value of team efficiency to make the team target.

However another question is, should company collect data as skill or process? The skill in this terminology means group of process which combine many processes that have similar characteristic. Group of processes or skill can be grouped by many criteria which the criteria are being used differently in garment industry, for examples, to group processes that use same machine, to group processes according to similar work method, or to group processes that have similar complexity level of work. The sample figure of skill and process is showed in Figure 21.

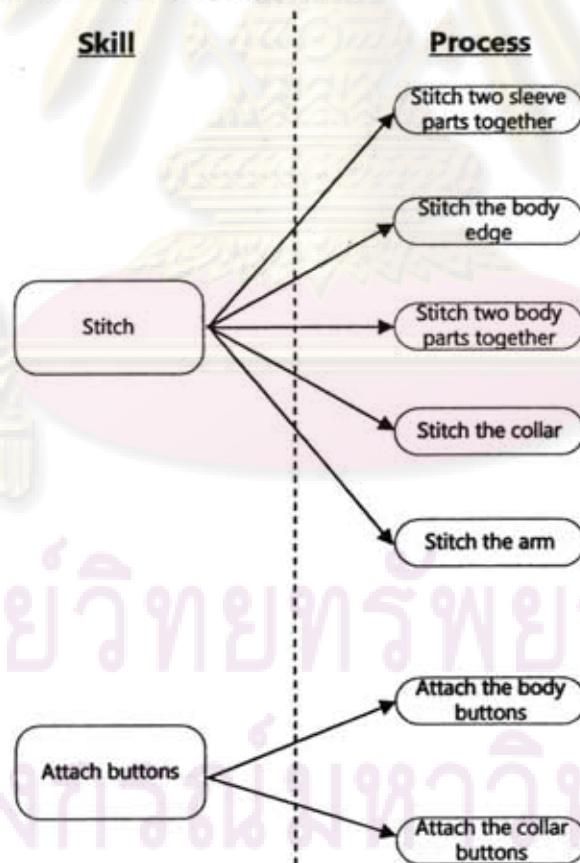


Figure 21. Sample Figure of Skill and Process

Either collecting data as skill or process both of them have upsides and downsides differently. Collecting data as process has advantage on higher accuracy when plans target, but for downside processes in garment industry has many hundred processes such as 100-300 processes or more, which very hard to manage and collect data. In addition, processes of work are always changed simultaneously when starts new purchase order. Therefore, data of process that is collected on month 1 may be used again when the time has passed for very long time such as 3 or 6 months, which efficiency of worker at that month possible to change from month 1 significantly. On the other hand, if company collects data as skill it has much more chances to update worker efficiency continuously and also helps to reduce size of data needed to collect from such as 100 processes to 20 skills.

Consequently, the suggested method is to collect employee data to update efficiency and efficiency as skill despite it gives lower accuracy than collecting data as process, but company can easier to collect data and more practical. For an example, the efficiency of stitch the collar process will be stored as stitch skill's percent efficiency that can also use to plan target in other stitch processes. In addition, the other stitch processes can use to update efficiency of stitch skill continuously which has higher reliability than update it for many months per time if company collect data as process by process.

Nevertheless, this system does not indicate the criteria used to group the processes, company can use own criteria to group processes in each skill. But, one suggested criteria is to group the process that has similar work method, because it always has similar pattern of learning curve.

4.2.4 Use LOB (Line of Balance) to show progress in shop floor

Line of Balance (LOB) is another type of graph technique that helps shop floor to see its progress efficiently and clearly. It helps production control able to clearly see problem in shop floor, and in addition it also shows the trend of each station which enables company to detect problem before it occurs. Moreover, LOB in this system design also includes warning issue which will warn user by appears red line on the process that being behind expected target. LOB tool can indicate the source of problem clearly that helps production control able to take corrective action at the right place with the right time, for an example in Figure 22.

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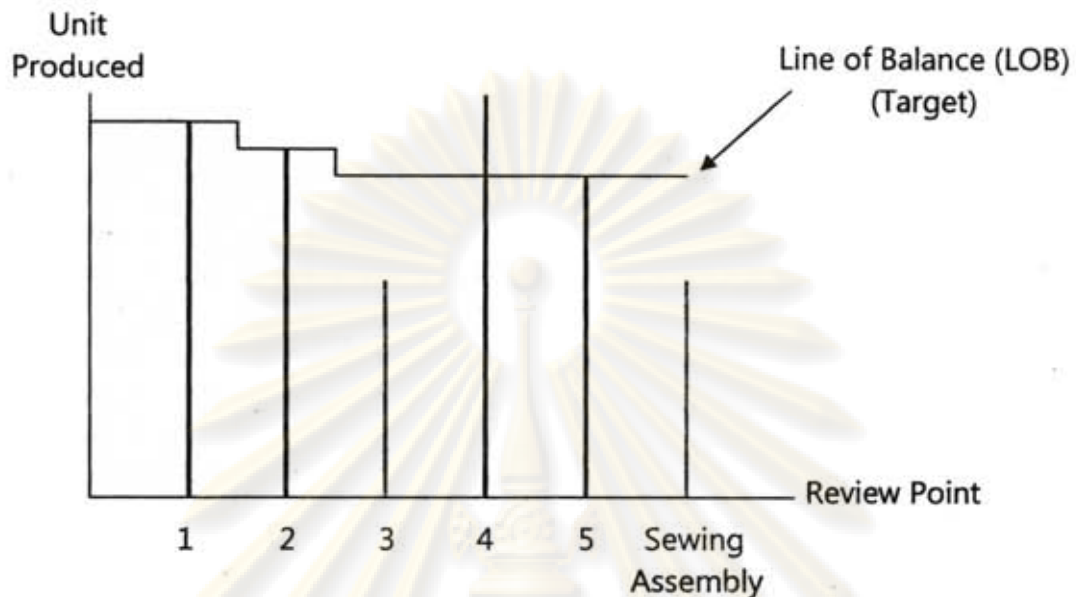


Figure 22. Example of LOB

From Figure 22, this Line of Balance (LOB) shows that there is a bottleneck at review point 3, which affects sewing assembly to be behind its schedule because it needs to wait for components of review point station 3. If production control sees this LOB, they can recognize the problem easier and clearer than views from the data table. Moreover, this LOB also encourages production control to be able to make corrective action decisions with an appropriate approach. For an example, from this figure, production control can know the bottleneck point and when seen at review point 4, it shows that the process in review point 4 can produce units beyond its target. So one possible corrective action is that the company may transfer resources from the process in review point 4 to review point 3 in order to balance the production line, which can increase the productivity of the sewing assembly station as well.

In addition, this system also provides another Line of Balance (LOB) which is the LOB that considers the learning curve issue as shown in Figure 23. The LOB that considers the learning curve is illustrated in a dot line in the figure. Normally, at the day that production planning plans the target, if worker efficiency is 60%, they will use this 60% of efficiency to calculate the target from day 1 to the end of the order, which means that the target will be similar every day. But, in fact, when running production for a certain amount of time, worker efficiency can increase, so the output of the worker may miss the planned target. In this circumstance, the line that balances may become unbalanced when time has passed, because normally, different skills always have different learning rates, so some processes may be able to produce much higher than others.

Therefore, this system provides another target line which is LOB that considers changing rate of worker efficiency to compare on the graph. The learning curve LOB brings the data that collect from shop floor to update efficiency of worker in database day by day and also uses it to draw new target line. So it means that, the learning curve LOB will show the target line that closer to actual than typical LOB target line, which helps company to make better decision.

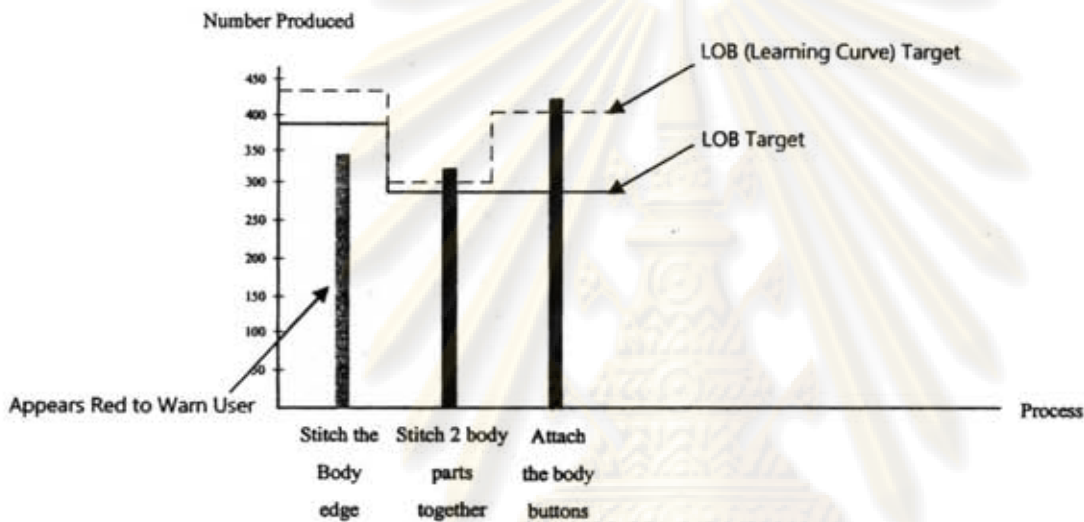


Figure 23. Line of Balance (LOB) with Learning Curve

The learning curve LOB target line helps to explore hidden problem and helps shop floor supervisor or production control able to manage resources and correct problem in shop floor correctly and efficiently. For an example from Figure 23, at start date attach the body buttons process has normal target when compare with other processes, but when sees in learning curve LOB it shows that worker who is operating in that process can improve efficiency so far when compare with normal target line. Therefore, from this learning curve LOB it can tell that the action company may take is to relocate resources from this process to the process which can produce units behind the schedule like stitch the body edge process. Likewise, another decision is production control may input more resources in other processes to catch up with attach the body buttons process in order to avoid bottleneck in shop floor.

4.2.5 Collect shop floor problem

Gathering problem data is worthwhile because company can recognise source of problem and truly know what is the issue and position that should be fixed? If company

record problems data properly when time has passed and company need to improve the productivity, company can bring those problems to analyse and fix it.

Therefore, this system also provides a part that shop floor user can input shop floor problem into the system. The system allows user to create problem pattern as cluster before use it in shop floor. So, problem from shop floor will be kept as cluster which much easier to analyse than scatter data that being used in many manufacturers in present days.

When time has passed, company can choose to print shop floor problems of the department that company wants to improve. Then the report will show frequency of each problem in that department, which helpful for analyst to know what the problem that should be concentrated.

4.3 Process Modeling

After requirements and solution of system are identified, process modeling helps analyst to understand work flow and data flow in the system, because normally there is a lot of data in and out in the system, which sometimes it is very complex and hard to analyse. If system is analysed by non systematic tool, it has high possibility that the analysis may miss some important issues or data. Furthermore, in recent issue Kendall [29] argued that the determination of work flow and information requirements also enables system developer to see particular users and functions in company that involved in the system.

Actually there are many process modeling models used in a variety of purposes, and three such important models that are used in this research including work flow diagram, context diagram and data flow diagram (DFD), consequently. The reason of using work flow diagram, context diagram, and data flow diagram (DFD) in this section is because these are simple tools, which are widely used in system development and easily to understand. Moreover, these models can clearly show relationship with many external agents of this system.

This research selects to use work flow diagram to analyse the overview of project before go to explore more details with context diagram and data flow diagram, because it helps system developer can clearly understand all main operations and all flow of work in the system before go to analyse it in detail. The system developers may unable to create context diagram and data flow diagram efficiently and correctly if they are still confuse in the project that they are working. Work flow diagram always not go in depth

in details like data flow diagram, but it encourages developer to see the overview, relationship of each process, and all relevant issues of project.

After completed analysing work flow of the system, the context diagram will be created in order to scope jobs of system, clarify all relevant external agents that involve in the system, and briefly illustrate data flow between external agent and the system. After that, the data flow diagram (DFD) model will be analysed to clarify more details of system, for instances, processes in system, relationship between data store and system, data flow, and all data required.

In an addition, in fact, there are a variety of tools that can use to design process modeling, for instances, PowerDesigner, Visble System, Rational Rose, and Visual Basic. But, one such tool used in this research to draw work flow diagram, context diagram, and data flow diagram (DFD) is Microsoft Office Visio 2007 as it is simple, has high availability, and adequate to cover all important functions.

4.3.1 Work flow diagram

Work flow diagram uses to help analyst to clearly understand the overview and flow of work in project. The objective of work flow diagram does not focus on flow of data, but it focuses on flow of processes in the system. Therefore, data that flow between process and process is not important to show in this step. Overview of project is always showed in level 0 of work flow diagram. And, the work flow diagram can be decomposed to many levels to show more detail in deeper levels says level 1,2, and 3, because just level 0 may inadequate to clearly show all flow of system. If system developer tries to show all details of work flow in the first level it will be too much complicate for software developer to understand.

By the way, the work flow diagram level 0 of this research is illustrated in Figure 24.

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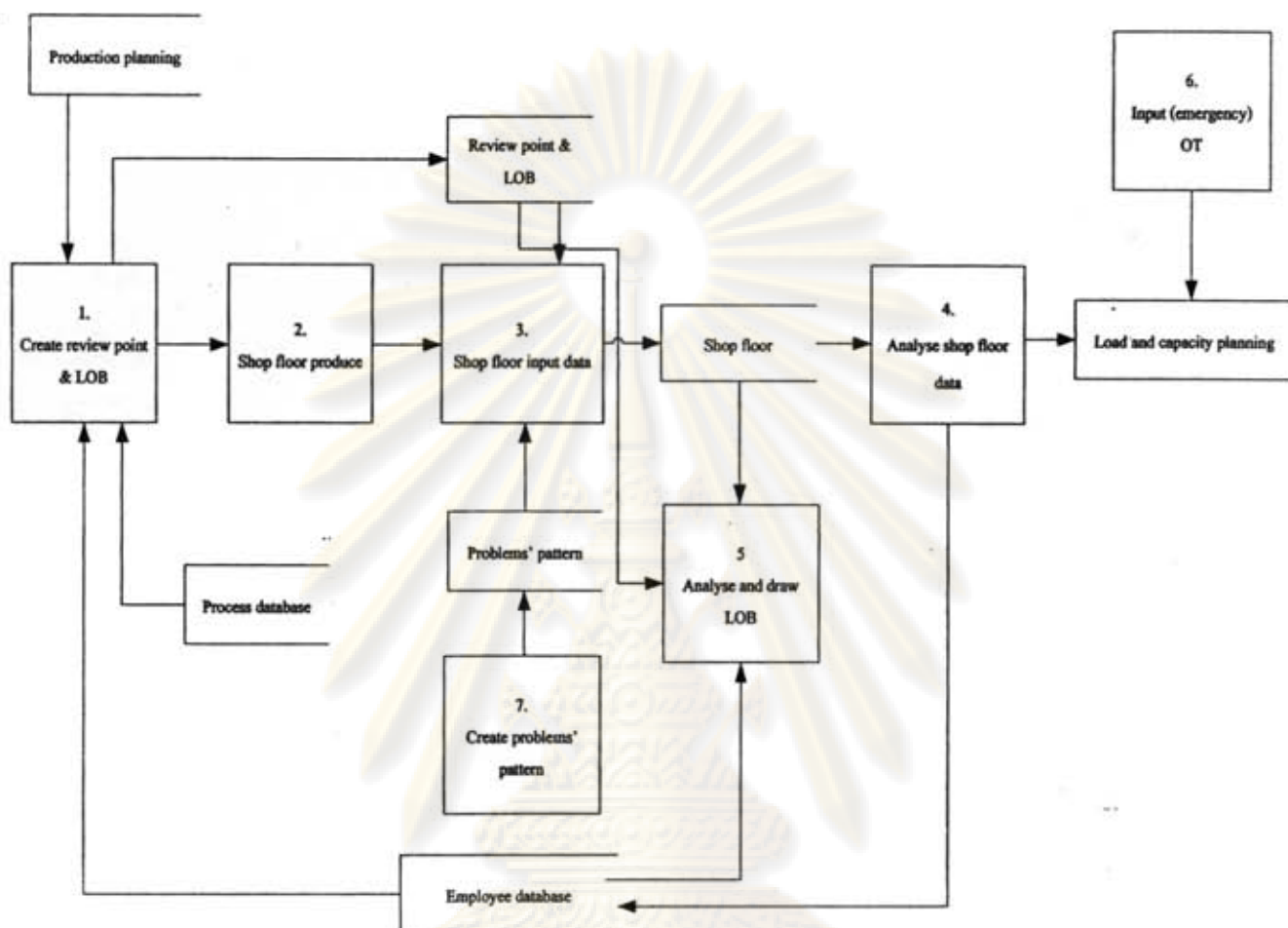


Figure 24. Work Flow Diagram Level 0

As showed in work flow diagram level 0 in Figure 24 the flow of work in system starts at user creates review point and Line of Balance (LOB) in system at process no.1. Then when line production starts to produce product at process no. 2, review points that are created in first step will be brought to gather shop floor data by shop floor user at process no.3.

Data from shop floor which is inputted at process no.3 are production data and problems in shop floor. Problems that used to select in shop floor in process no.3 are created by user in process no.7 as problems' pattern. So, it means that when shop floor user wants to input problem into system at process no.3, user can select the name of problem that was created before at process no.7 immediately.

After user has inputted data, the data from shop floor will be sent to analyse in order to calculate for percent efficiency at process no.4 before sent to store and update skill efficiency of each employee in "Employee Database".

Furthermore, system also provides Line of Balance (LOB) function for user to see progression of shop floor, which is process no.5 in work flow diagram. At this process user can select purchase order that wants to monitor the progression, then system will bring data from shop floor to draw LOB and shows it to user.

Last process; process no.6, when production in shop floor misses the plan and company wants to increase overtime period user can input team and number of hours that is going to do overtime in system. Then system will send data to load and capacity planning data store in order to check that this overtime do not repeat with planned overtime. And, it is also sent overtime period to database to protect capacity planning or shop floor open overtime period of that team exceeds the legal allowance in future.

However, work flow diagram in Figure 24 is showed only level 0 of the system, which cannot include some important details of system, so the next levels of work flow diagram are also analysed and showed in Appendix A in order to describe more detail about each process in deeper levels.

4.3.2 Context diagram

Although work flow diagram encourages analyst to recognise and clearly understand flow of processes in project and helps analyst to know what is the point that the project wanting to deal, it does not separate the external agent from the system. Hence, the analyst cannot clearly indicate the scope of the system that is going to be developed.

Therefore, this research uses context diagram in this step in order to help to separate all relevant external agents that interface with the system from the system that is going to be developed. Additionally, context diagram not even enables analyst to know the scope of system, but it also shows the top level of data flow, which system participates with external agents. The figure of context diagram is show in Figure 25.

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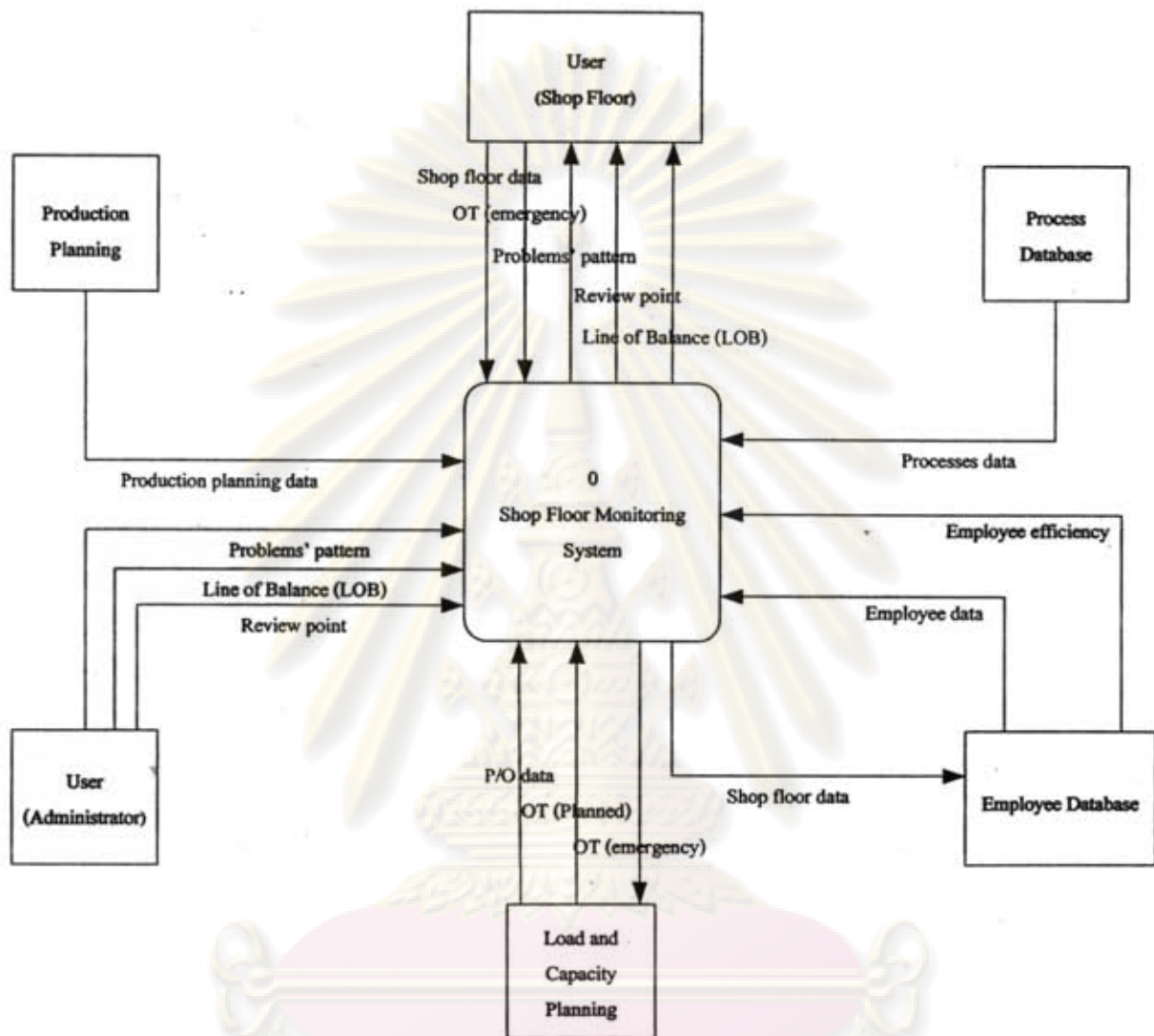


Figure 25.Context Diagram

From context diagram in Figure 25, there are 6 external agents interfere with the system. First; user who is administrator, the administrator acts like the user that sets everything in this system including sets problems' pattern, creates review point, and creates Line of Balance (LOB), which all of these will be used in shop floor. This part responsible by different function depends on each company says production control, top management, production planning, or shop floor supervisor.

Second; production planning, to create review point and Line of Balance (LOB) the system requires some data from production planning to run the system such as

operation processes flow of each purchase order. This data is important to use to select review point and LOB by administrator.

Third, shop floor user, shop floor user acts like the agent that input data from shop floor into the system. Main two data that is inputted by shop floor user are problem in shop floor and production data. Problem in shop floor is collected to use for productivity improvement, while production data from shop floor is collected to monitor the shop floor production closely which benefits of these are stated earlier.

Fourth; process database, process database is the data store that gathers all processes data such as process name and id., which this system requires these data to use to create review point and Line of Balance (LOB).

Fifth; employee database, the system uses some data from employee database to operate the system especially when user choosing the process to be the review point and when shop floor user inputs data in shop floor. If shop floor user does not know the team and name of worker who responsible in each process, shop floor user may unable to find the station that want to collect data in shop floor. Data required from employee database such as employee infrastructure in order to know name of worker and the section and the team that each worker staying.

Lastly; load and capacity planning, load and capacity planning in this system is the section that handle for manages the capacity in the plant. Accept or reject decision of every purchase order has to confirm from this section. This section in each plant can vary differently, and as collects information from garment industry the section that responsible for this duty can be including production planning, capacity planning, merchandiser, marketing and customer relationship. Because this external agent takes care about purchase order in and out, so system requires purchase order data from this agent.

Moreover, when production misses target and shop floor control wants to increase overtime, the system needs to check with capacity planning that the overtime that shop floor going to do repeat with overtime that capacity planning planned or not. If overtime does not repeat with overtime from capacity planning, system will send team and number of hours that the overtime is going to open to capacity planning in order to add overtime period in database to protect capacity planning or shop floor open overtime period of that team exceeds the legal allowance in next time.

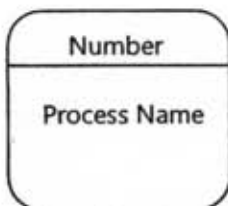
Nevertheless, even context diagram helps to clearly analyse the scope of project, separate between external agents and system, and shows top level of data flow, but it does not show the processes inside the system. Therefore, data flow diagram is brought to analyse in next step in order to explore in depth in details about processes and data flow in the system.

4.3.4 Data flow diagram (DFD)

After analysed work flow diagram and context diagram, this research uses data flow diagram (DFD) in this step to analyse in depth in details about system and also indicates data input and output of each process. To analyse data flow diagram the work flow diagram and context diagram from previous steps are brought to help analysing in detail in this diagram.

Data flow diagram (DFD) is a model that shows flow of data in the system such as data input and output in each process. It helps system developer enable to clearly understand data needed in each operation and indicates the place that data should be stored. Moreover, DFD also shows the relationship between each operation in system or between external agent and system.

The common symbols used in DFD including;



This symbol is "Process" which represents for the process in system. The process includes all actions occur in the system including process by human, system itself, machine, and etc. General rules of process in DFD are clarified in following issues.

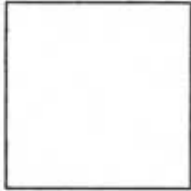
- All processes must have data in and out.
- Input data must be adequate to create the data out from the process.
- Name of process has to be verb such as "create review point".



This symbol is "Data Store" which represents for the data storage in system. General rules of data store in DFD are clarified in following issues.

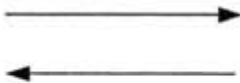
- Data cannot flows between data store and data store, it must pass through any process before go another data store.

- Name of data store always be noun such as "review point data".



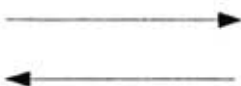
This symbol is "External Agent" which represents for external agent relating in system but not a part of system. External agent can be some functions in company, supplier, customer, and etc. that have data interaction with the system. General rules of external agent in DFD are clarified in following issues.

- Data cannot flows between external agent and external agent, it must pass through any process before go to another external agent.
- Name of external agent always be noun such as "customer" and "user".



This symbol is "Data Flow" that represents for the flow of data run in system, which the way that arrow points is a destination of data. General rules of data flow in DFD are clarified in following issues.

- Name is just a name of data in the flow, which does not need to explain its operation. The name should be concise, which the description of its properties can be clarified in data dictionary.
- Name of data flow should be noun such as "shop floor data".
- Each data flow must have the start and destination point.
- Data cannot flow between external agent and external agent.
- Data cannot flow between external agent and data store.
- Data cannot flow between data store and data store.



This symbol is "Request" that represents for the request action, for example, if user needs to see Line of Balance (LOB) from the system user needs to send request to system and then system will send data that user requests to show.

First of all, the DFD in this research is developed the first level of diagram, which always called "DFD level 0" in order to show the top view of the project and all relationships in the system before go in deeper levels. Because, this project has high complexity that cannot be clearly clarified just in DFD Level 0, so the DFD is also decomposed the first level to next levels deeper and deeper in order to see more details of system until the

system cannot be decomposed anymore, which the deepest level always called "Primitive DFD".

By the way, the data flow diagram level 0 of this research is illustrated in Figure 26.

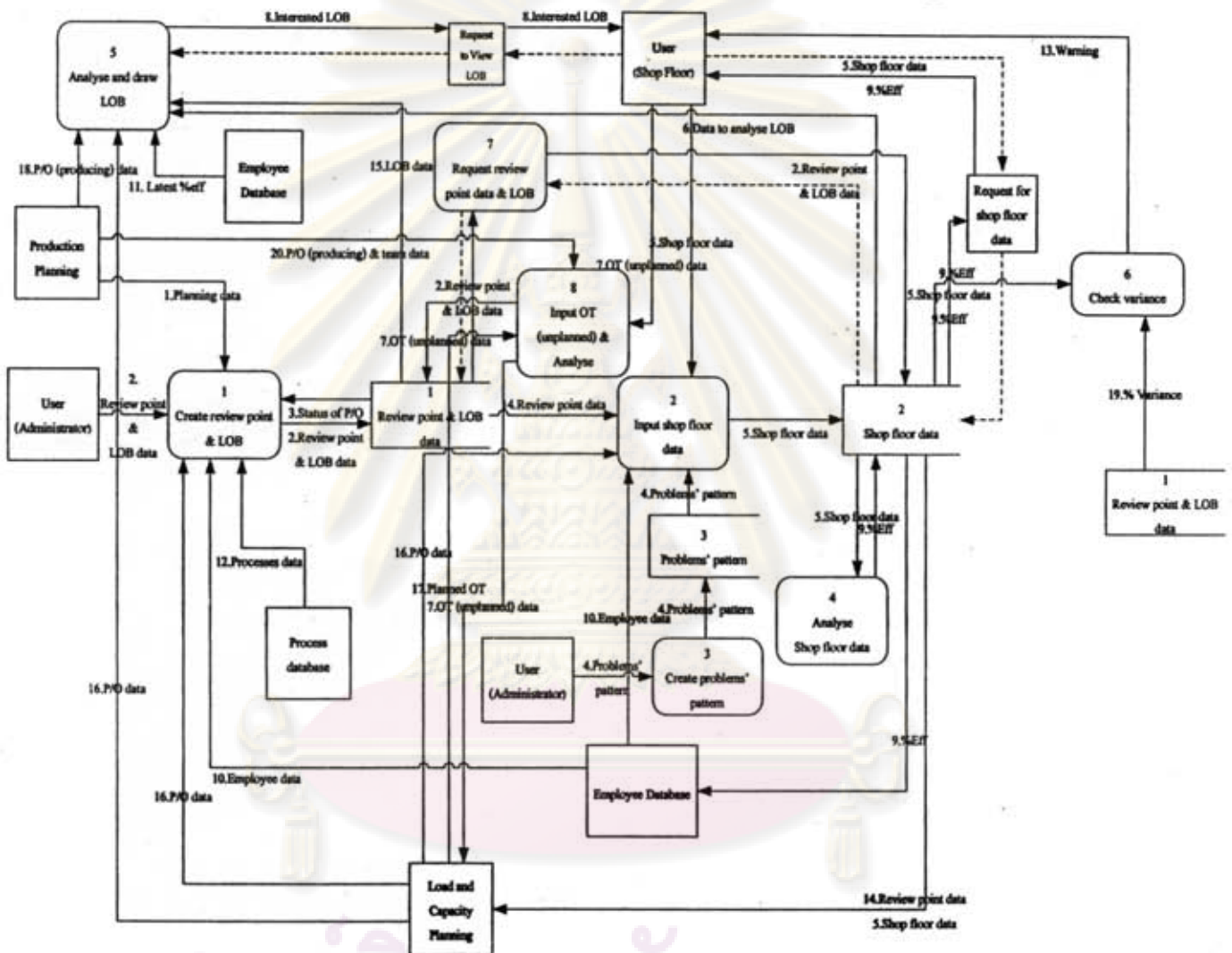


Figure 26. Data Flow Diagram (DFD) Level 0

From Figure 26, the system starts at administrator creates the review point and Line of balance (LOB) in process no.1. Then process no.1 sends the review point and LOB that administrator created store in database no.1. When shop floor user needs to input data in the system as in process no.2, the system will call data from database no.1 to use for select the purchase order (P/O) and review point that shop floor user need to input data.

In shop floor, user can input data as 2 types including production data and problem in shop floor. For problem data, the pattern of problem is created by administrator in process no.3 in order to use to quick select when problem occurs in production line. For production data, when shop floor user inputs data, it will be analysed in process no.4 to calculate percent efficiency of worker before send to store in external agent at "Employee Database". Furthermore, production data from shop floor is also sent to check the variation of production in process no.6 and if the variation exceeds the rate that is set by administrator in process no.1, the system will send the warning to user.

The system also provides an opportunity for user to monitor the progression of production line through Line of Balance (LOB) technique, which is process no.5 in DFD. The process no.5 starts when user selects the LOB that user wants to view, which is created by administrator in process no.1. After user selects LOB, the system will analyse and draw LOB by using data from database no.1 and production data from database no.2. In addition, if user wants to consider learning curve in LOB, the system will use the latest percent efficiency from "Employee Database" to draw another line in LOB that user can use to compare and make decision.

Sometimes when production does not meet its target, the company may increase overtime (OT) in that day which is not planned before. But, the company needs to know the team and number of hours of that OT, because it will be used for calculate target and used to check the maximum OT with "Load and Capacity Planning Section" in order to make sure that company does not violate the Labour Laws. Therefore, the system also provides a chance for user to input OT that will be increased in each date in process no.8.

However, the data flow diagram showed in Figure 26 is just the DFD level 0, which may not clearly describe all details for each process in the system. Therefore, the next levels of DFD of each process are also provided in this research in Appendix B in order to explain the flow of system and data in more details.

4.4 Logic Modeling

Logic modeling or logic of processes is in analysis step of system development. Logic modeling chart described the flow of operation in system and shows how it works step by step, which used to develop the user interface, report and data base in later stages. Processes logic is not similar to work flow and data flow analysis, because even work flow diagram shows flow of system and data flow diagram shows all flow of data, but

DFD and work flow diagram do not clarify flows how each process work and flow of it step by step in the system.

Logic modeling analysis focuses on how each process in DFD runs and it also includes calculation logic in some processes. In logic of processes analysis DFD is an important tool that uses to analyse the logic. It is not important to describe all processes, but for some processes that complicate which cannot clearly understand from DFD are clarified it working and processing steps in this logic analysis.

However, there are amount of techniques can be brought to analyse logic of processes which each technique has upsides and downsides differently rely on using purposes. The techniques selection for design of system in this research is described in next issue.

4.4.1 Logic modeling techniques selection

- **Structured english**

Structured English techniques uses text to describe the working steps of each process in data flow diagram (DFD). The Structured English has three main types including sequence, conditional or decision structure, and iteration or repetition. The sample figure of Structured English technique is showed in Figure 76.

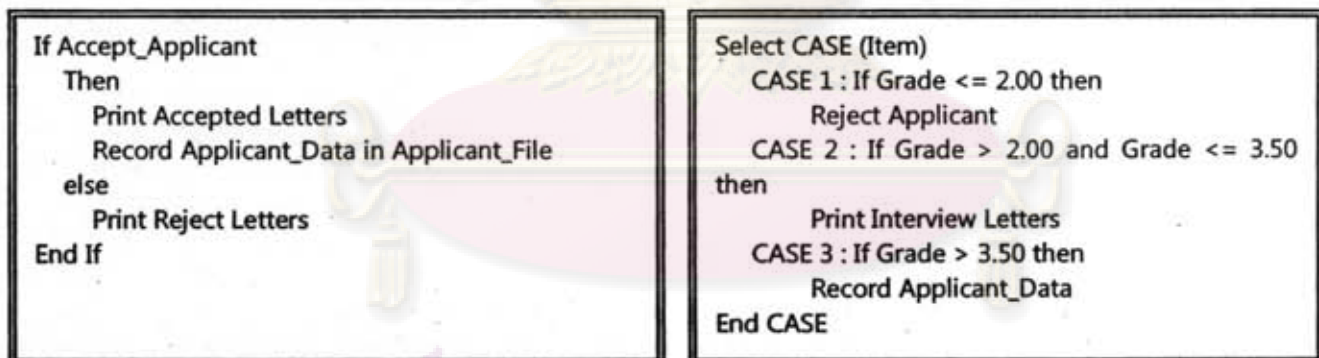


Figure 27. Example of If-Then-Else case in Conditional Structured English

Source: Pakdeewattanakun, Panichakun [38]

Structured English technique is not appropriate for this study, because this study has many logics of processes in system, so using this technique is quite complicate and hard to understand. Furthermore, this technique does not

support system developer to see the relationship of each operation in the process, which is an important point of this research as it needs to be related with many functions inside enterprise and interfaced with other sub-systems that is developed together.

- **Decision table**

Decision table technique is description of process that is very complicate. The table shows conditions, actions, and rules. The example of decision table is illustrated in Figure 28.

Conditions/Cause of Action	Rules					
	1	2	3	4	5	6
Employee type	S	H	S	H	S	H
Hours worked	<4 0	<4 0	40	40	>4 0	>4 0
Pay base salary	x		x		x	
Calculate overtime				x		
Produce Absence Report	-	x				

Figure 28. Example of Decision Table
Source: Pakdeewattanakun, Panichakun [38]

Decision table technique is not appropriate for this research, because it is not sufficient to show relationship with other functions. This technique is suitable for complicate logic of process that is too complicate for this design as logics in this design do not have high complexity.

- **Decision tree**

Decision tree shows the decision of process or decision point by node and description of each node is described separately in "Legend". The first node always called "Root Node" which is the starting point of the process. Decision can be more than two ways and the action of decision is always showed in "Oval"

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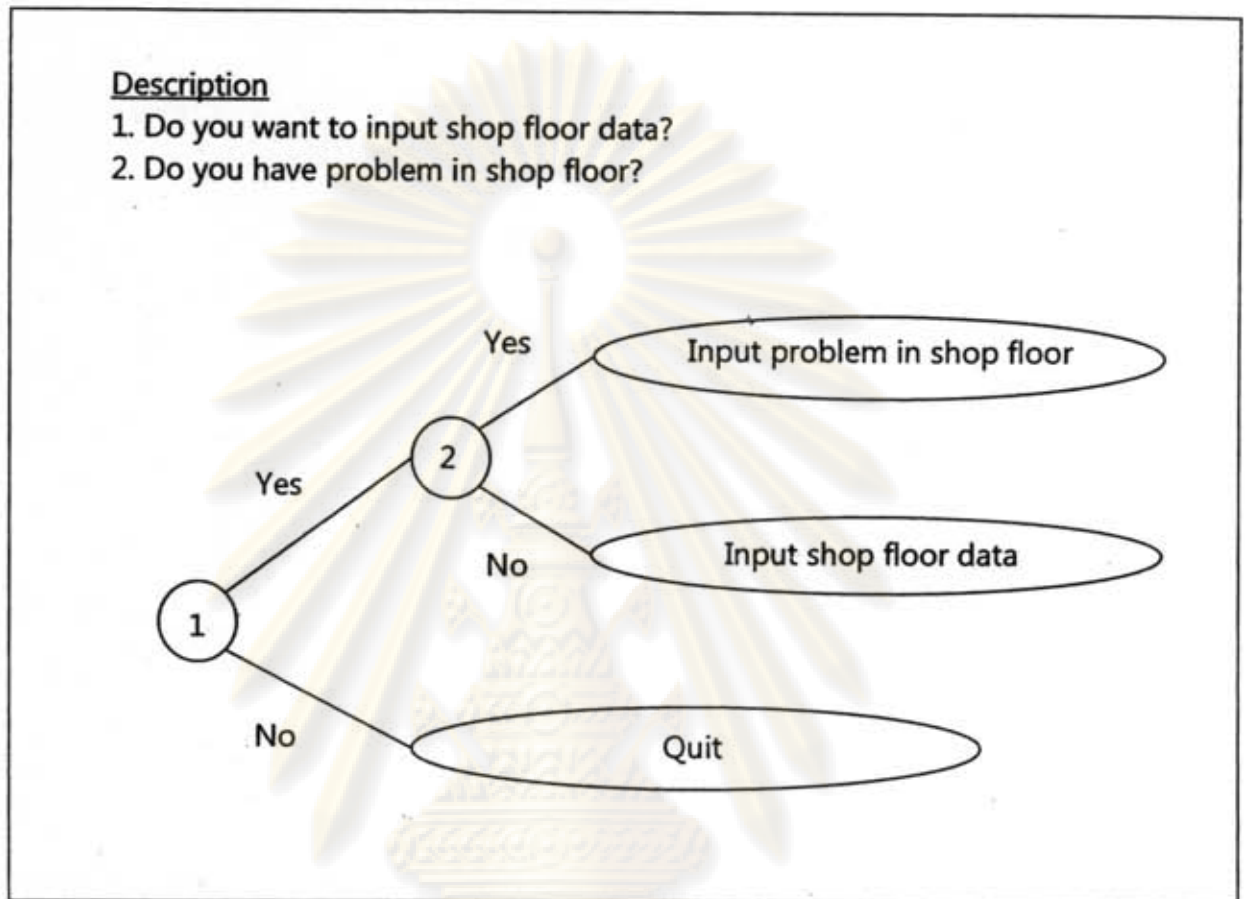


Figure 29.Example of Decision Tree

Decision tree is easy to understand and clearly states the decision determination of process, which is very interesting tool for this study. But, according to work flow diagram and data flow diagram there are not many decision points in system, so it may unnecessary to use this technique.

- **Flow chart**

Flow chart is a simple technique which easily to use and understand. It can show the flow of process clearly. The process is showed in rectangle and the decision point is showed in diamond. If the process cannot be described in one page, user can create the chart in another page and link it with pentagon symbol, and the circle symbol represents to the linkage in same page. Furthermore, the flow chart also includes data store that relates to each action in process. The example illustration of flow chart technique is illustrated in Figure 39.

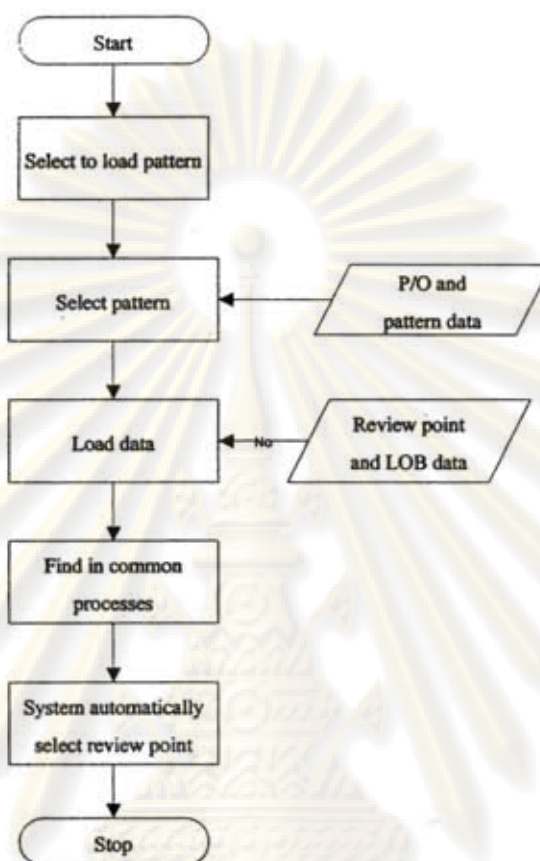


Figure 30.Example of Flow Chart

Flow chart technique is the most appropriate technique for this research, because it is a simple tool which easily to use and understand. Although this technique cannot clearly describe very complicate action and decision, it is adequate for this study because most of processes and actions in this study are not too much complicate. So, it is not necessary to use complicate tool like decision table and Structured English. In an addition, flow chart can show relationship with each action very well and also able to show data store involves in the process properly.

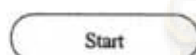
In conclusion, even there are many techniques can be applied to analyse logic modeling in this design of system, but one such appropriate tool that used in the research is flow chart. Although some tools able to describe the logic which finally the output is the same, those tools are too much complicate that unnecessary to use. Therefore, this research tries to keep it simple by using flow chart diagram which encourage programmer easily to understand. However, the conclusion table of technique selection of logic modeling selection analysis of this research is showed in Table 3.

Criteria	Structured English	Decision Tables	Decision Trees	Flow Chart
Clearly describes the decision	8	9	9	7
Clearly shows flow of process	4	4	8	9
Easily to check correction	7	5	9	9
Systematic thinking tool	9	8	9	8
Clearly shows relationship	4	4	7	10
Shows data store interfere	-	-	-	9
Ease of use	4	6	8	9
Easily to understand	7	5	8	9
Total	43	41	55	70

Table 3. Conclusion of Logic of Processes Techniques Selection

4.4.2 Logic modeling of research

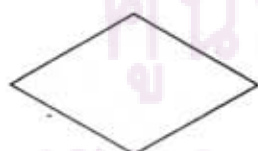
As clarified before, flow chart is the most suitable tool to describe logic modeling of this system. The symbol used to show logic of processes in this research including;



This symbol represents to starting point of logic.



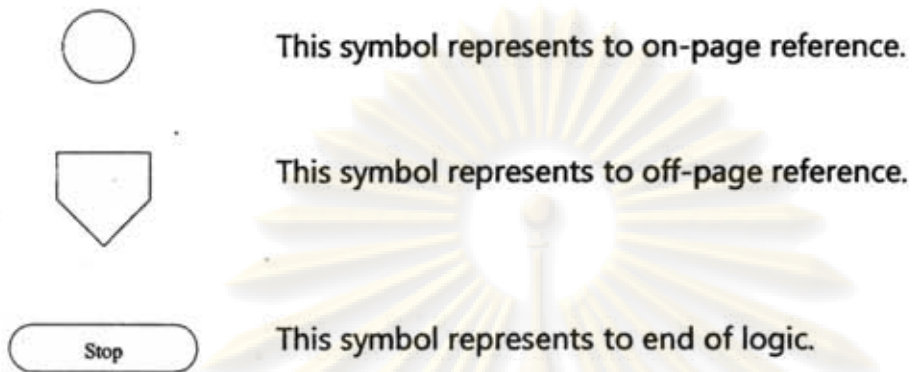
This symbol represents to process.



This symbol represents to decision point.



This symbol represents to data store.



Moreover, the tool used to create logic of processes in this research is Microsoft Office Visio 2007 as reason stated earlier, and all logic of processes in of this research are showed in following numbers.

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1. Logic of create review point process

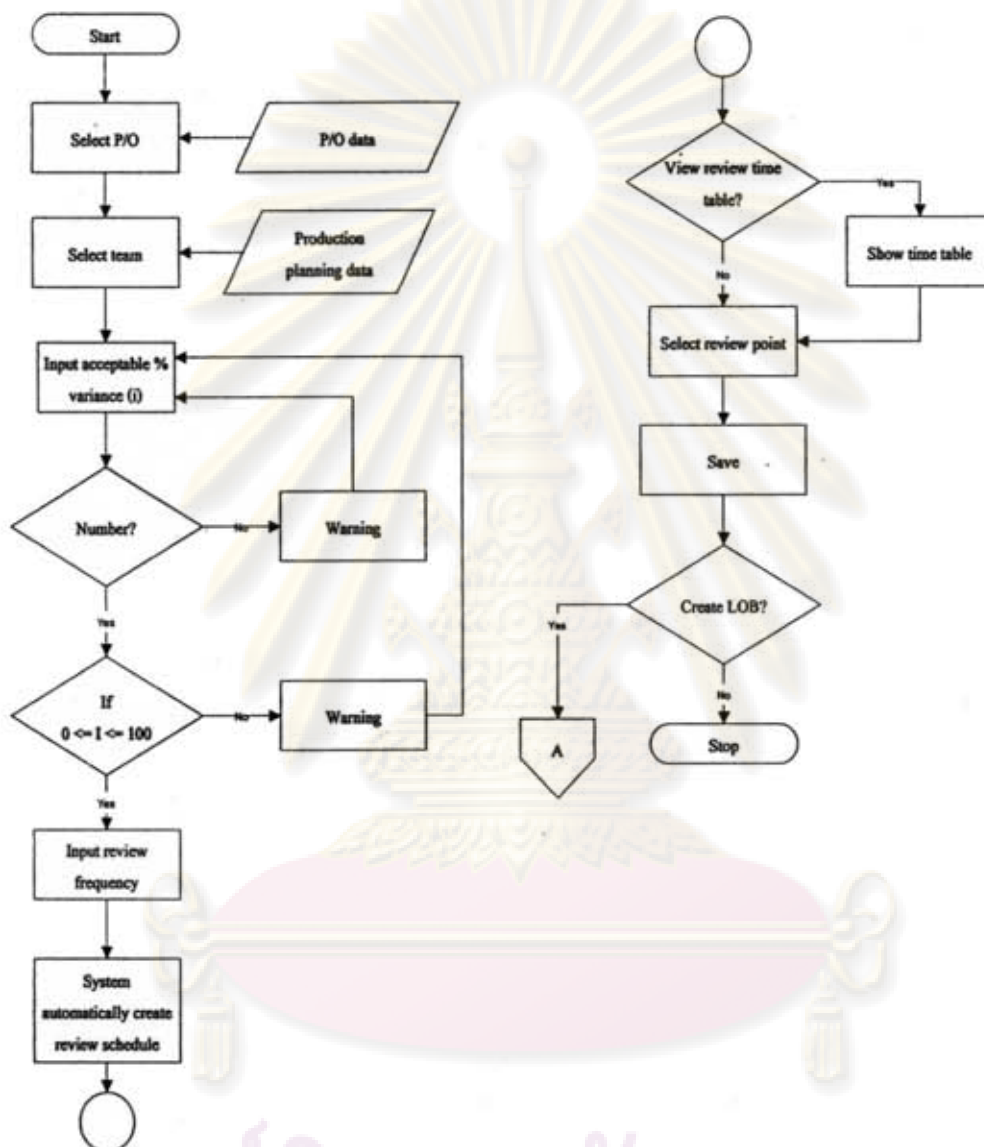


Figure 31. Logic of Create Review Point Process

To create review point and Line of Balance (LOB) process starts when user selects purchase order (P/O) and team that wants to input data. Then user inputs percent acceptable variation in system. The system will check that percent variation about, is it a number or not? If it is not number system will send warning to user, but if it is a number system will check that percent variation about, is it stays between 0 to 100 or not. Because if the % percent variance is lower than 0 % or exceeds 100%, the system will get error.

Then next step is to input review frequency in system, in this step system will generate review time schedule automatically, which user can select to view review time table from system as well. In the end, system will ask user that user wants to create Line of Balance (LOB) or not. If user selects to create LOB system, the system will go to "logic of create Line of Balance (LOB)" which is showed in next logic. Or, if user chooses to stop the system will stop this process and quit to main page.



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2. Logic of create Line of Balance (LOB) process

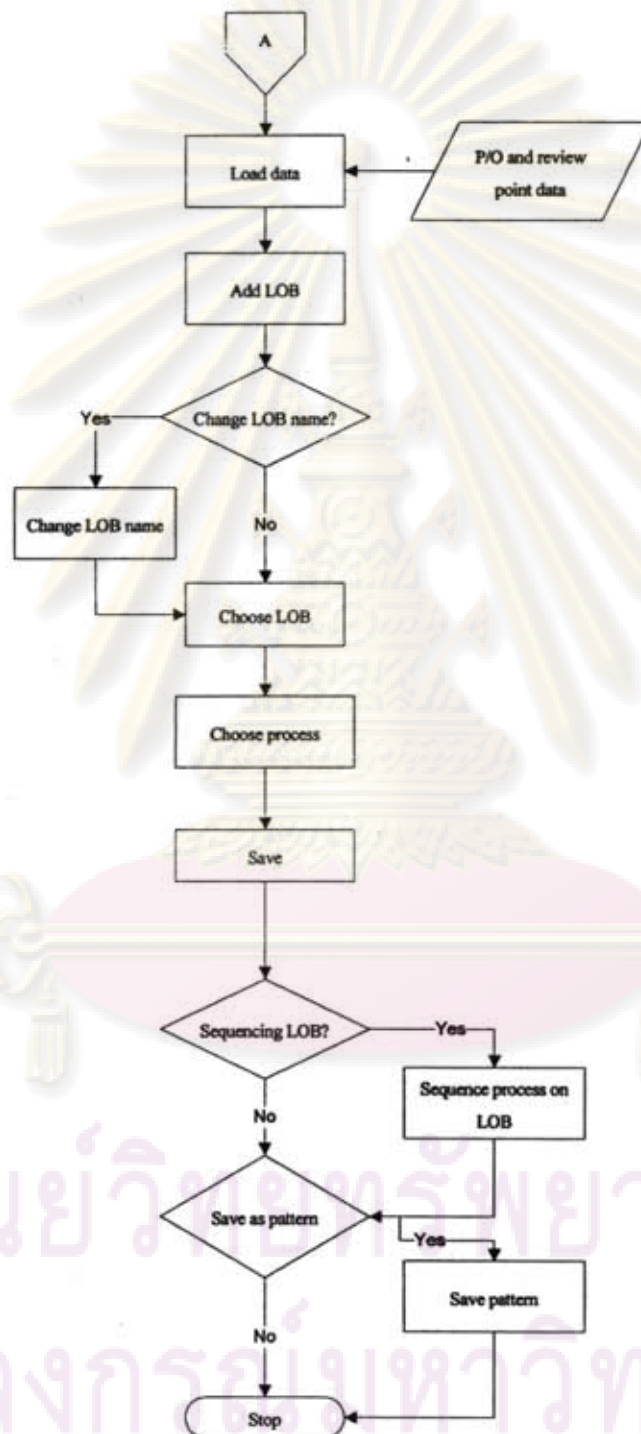
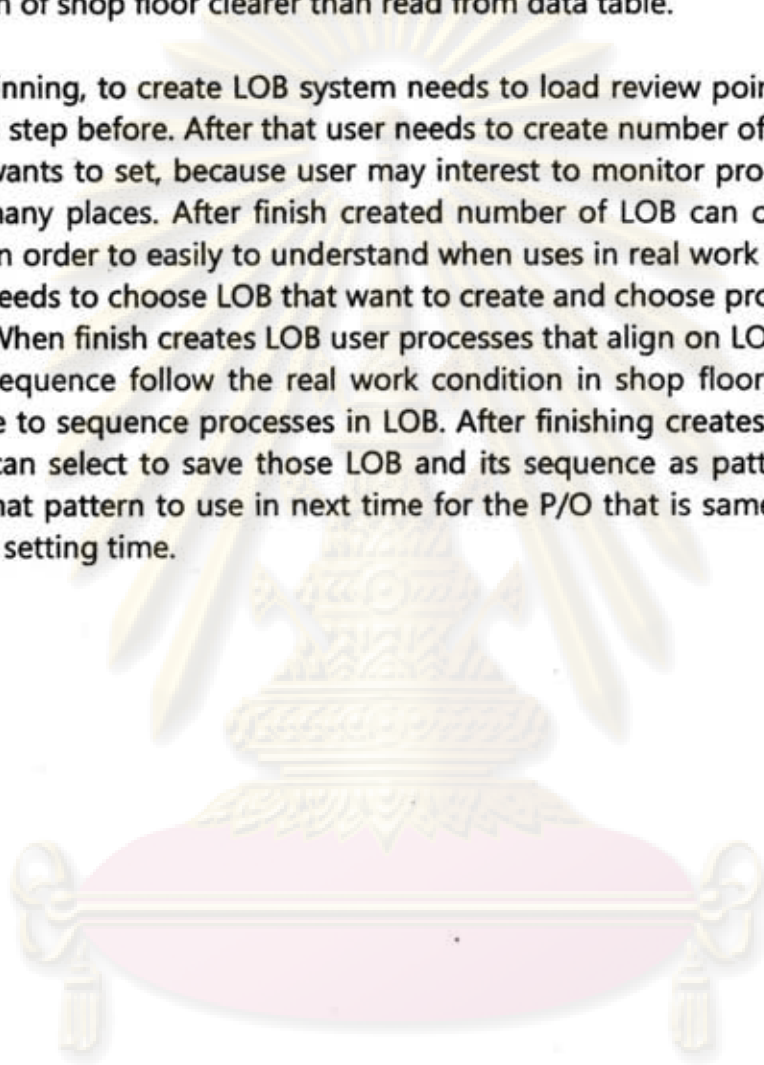


Figure 32. Logic of Create Line of Balance (LOB) Process

After finished create review point, user can bring those review point in previous step to create Line of Balance (LOB), which helps shop floor supervisor can see progression of shop floor clearer than read from data table.

In the beginning, to create LOB system needs to load review point that user sets in previous step before. After that user needs to create number of Line of Balance that user wants to set, because user may interest to monitor production in shop floor for many places. After finish created number of LOB can change name of each LOB in order to easily to understand when uses in real work condition. After that user needs to choose LOB that want to create and choose process to place in that LOB. When finish creates LOB user processes that align on LOB may not have the right sequence follow the real work condition in shop floor, therefore user can choose to sequence processes in LOB. After finishing creates and sequences LOB user can select to save those LOB and its sequence as pattern, which user can load that pattern to use in next time for the P/O that is same product name in order to setting time.



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3. Logic of review point and LOB pattern loading process

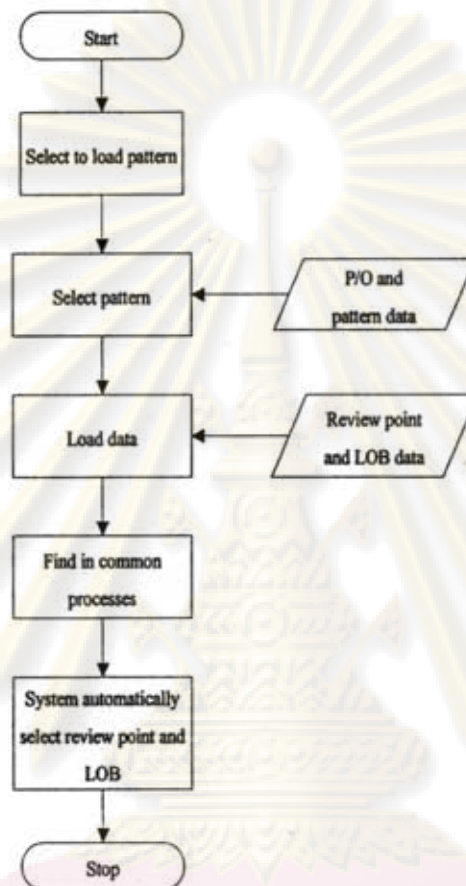


Figure 33. Logic of Review Point and LOB Pattern Loading Process

In logic of processes 1 and 2 user can select to save review point and LOB as pattern in order to load for use when new purchase order has same product name as the pattern that is saved. The logic of process of this step starts at user selects to load pattern from system and then user has to find the pattern that wants to load from system. Then after user selected pattern that wants to load, system will select the process of new purchase order that has same process id. with process in review point in pattern. Moreover, it will choose and sequence Line of Balance as same as the pattern that is saved.

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4. Logic of set problems process



Figure 34.Logic of Set Problems Process

This is the logic of process of problems setting. The problems that are set in this part will be used to select in shop floor when problem occur. Logic starts at user has to add problem, fill problem's name and fill problem's description, consequently. After that user can also add picture and clip into the system in order to help shop floor user uses to make decision when wants to select problem.

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5. Logic of shop floor input process

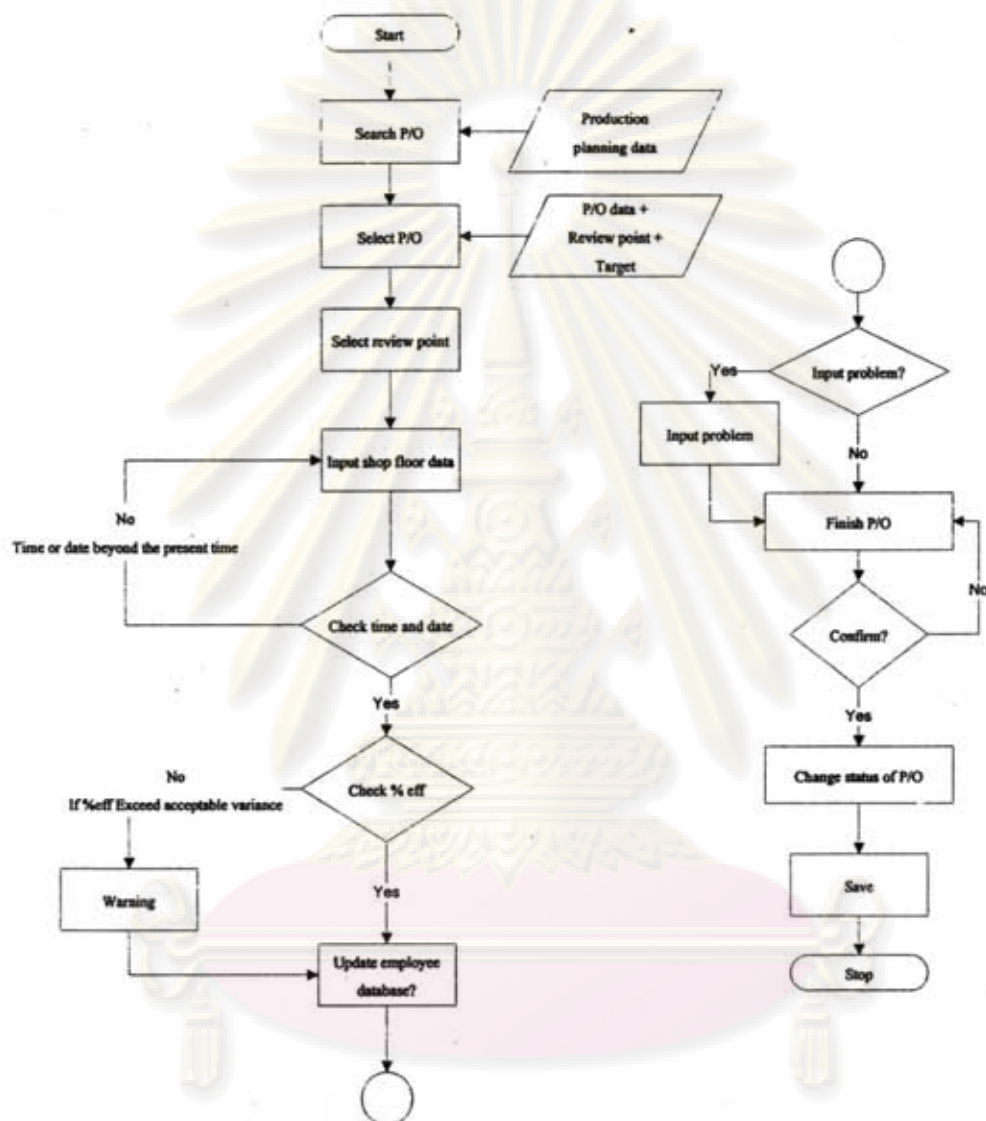


Figure 35. Logic of Shop Floor Input Process

Logic of process of shop floor input starts at shop floor user searches and selects purchase order (P/O) that wants to input data. After that user has to select review point and input shop floor data. In this step system will check time and date that user input in order to protect human error that user may input the data in text box that beyond the time at present. The data from shop floor will be sent to calculate for percent efficiency of worker and if percent efficiency below the

target system will send warning to user. Moreover, this step percent efficiency is also sent to update employee database in order to adjust percent efficiency of each worker in skill matrix as learning curve consideration. In addition, shop floor user can input problem in this step into system by select the problem that was set before in previous logic at logic of process number 4. Lastly, when purchase order is finished producing user can confirm to close order to eliminate data of this P/O from the system.



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6. Logic of show line of balance (LOB) process

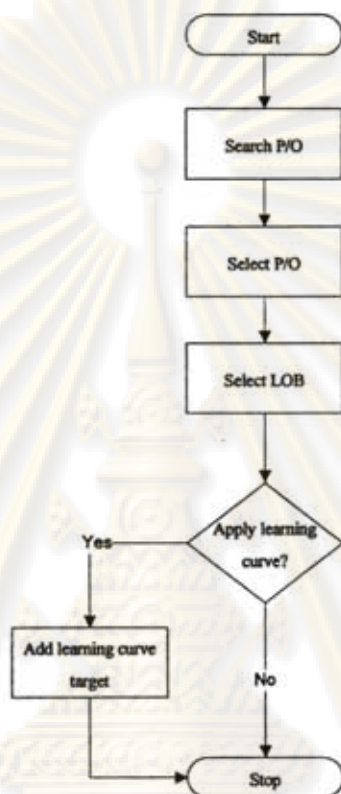


Figure 36. Logic of Show Line of Balance (LOB) Process

The logic of show Line of Balance (LOB) process starts at user searches and selects purchase order (P/O) and then user needs to select LOB that wanting to see. After that, user can choose to apply learning curve issue on the LOB, which system will add another target line that is learning curve target.

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7. Logic of input unplanned OT process



Figure 37. Logic of Input Unplanned OT Process

The logic of input unplanned OT process starts at user searches and selects purchase order (P/O) that wants to input overtime. Then user needs to choose team and number of OT hours. After that, system will send data to check data that the OT that is inputted repeat with planned OT or not, if OT is not repeat with planned OT system will allow user to add OT in the system.

4.5 Data Modeling

Data modeling in this research uses Entity relationship diagram model to analyse database in system as it is widely used and easily to understand. The Entity relationship diagram or ER-diagram is the diagram that shows relationship between data. ER-diagram consists of two main parts which are entity and attribute. The entity is box of

data which combines the data that is the same group, and the data inside entity is always called attribute.

There are many models can be brought to create ER-diagram such as Chen model and Crow's foot model, which its application just a little bit different. However, the model used in this research is Crow's foot model because this system design has many attributes in some entities, which Crow's foot model is easier to create and understand than Chen model. The common symbols used in this research are show in Table 4.

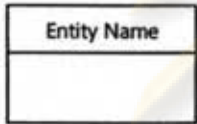

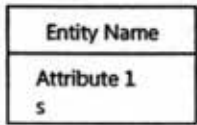
Crow's Foot Model	Meaning
	<u>Entity</u> Entity represents to name of data group which includes many attribute inside it.
	<u>Relationship Line</u> Relationship line represents to relation between entity and entity.
	<u>Attribute</u> Attribute represents to characteristic of data in each entity.

Table 4.ER-Diagram's Symbols

The ER-diagram of this system design is illustrated in Figure 38.

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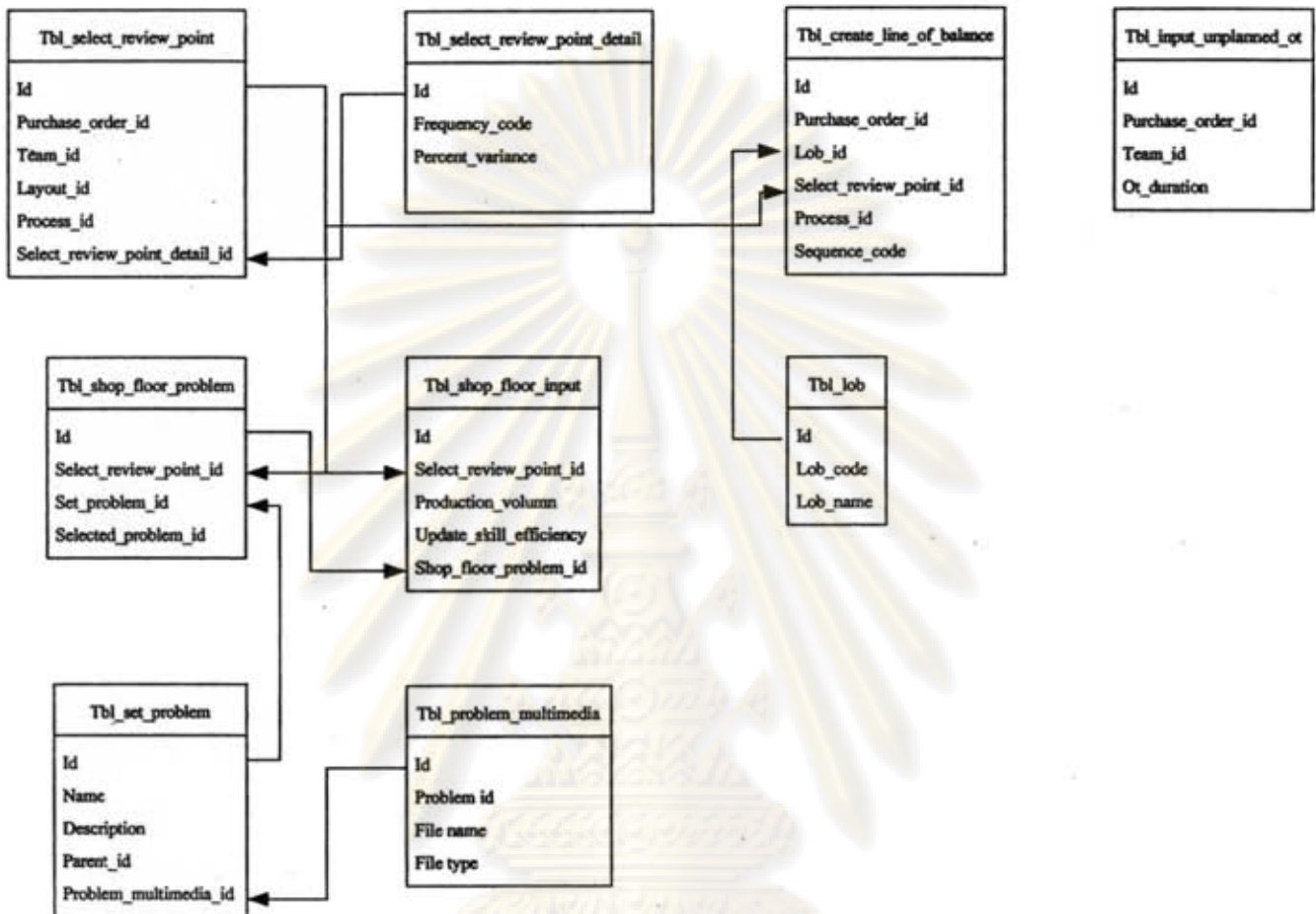


Figure 38.ER-Diagram

According to Figure 38, there are 9 entities in this ER-diagram. The process starts at "Tbl_select_review_point" entity. Once user creates review point in system, things system has to record are purchase order, team, layout, and process that user selected. In addition, the detail of review point including review frequency and percent acceptable variation are also transferred from "Tbl_select_review_point_detail" to record in this entity as well.

After user finishes select review point, user can go to create Line of Balance (LOB) in next step. Data in this step mainly shows in "Tbl_create_line_of-balance" entity. Attribute in this entity includes purchase order and LOB name that user wants to create. The LOB name is transferred from "Tbl_job" entity. The processes that are showed to select LOB are only processes that have already selected to be review point which this information

is transferred from "Tbl_select_review_point" entity. After that when user selects any process those processes and its sequence will be recorded in this entity as well.

Another important part before go to shop floor is problem setting. User has to set problem to use in shop floor, which entity that combines this group of data is "Tbl_set_problem". This entity combines all problems in company including problem name, description, parent of each problem, and multimedia files.

After finishes create review point, LOB, and problems, user can bring those things to use in shop floor. First step in shop floor is to input data into system which is "Tbl_shop_floor_input" entity. Attributes in this entity includes review point that user selects to input data, production volume that company produced, decision that user selects to send data to update skill efficiency or not, and lastly problem in shop floor. The problem in shop floor is inputted in "Tbl_shop_floor_problem" entity. Furthermore, another important thing in shop floor is to view Line of Balance (LOB). When shop floor user calls to view LOB system will bring data from "Tbl_create_line_of-balance" entity to create the graph and shows it to user.

Lastly, when production misses the plan and user needs to add unplanned overtime (OT) data that user wants to input unplanned OT will be recorded in "Tbl_input_unplanned_ot" entity, and attributes in this entity including purchase order and team that user wants make OT and duration of OT in each team.



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CHAPTER V SYSTEM DESIGN

5.1 Dialogue Diagram

Dialogue diagram shows relationship between one user interface (UI) and other user interface. It tells the step of work of each UI in the system and describes the relationship of that UI with other UI such as origin UI page that performed before and destination UI in next UI page.

Dialogue diagram in this research is built before going to create user interface in next step, because it helps to recognise all user interface needed to be created, relationship of each other, and its sequence. Furthermore, it also provides chance for system developer to eliminate unnecessary UI pages in the system.

Normally, there are 3 main parts of symbols in dialogue diagram as showed in Figure 39. The top part shows user interface's number of that page. Middle is name of that user interface. The bottom part is user interface's number of previous page and the number of next page.

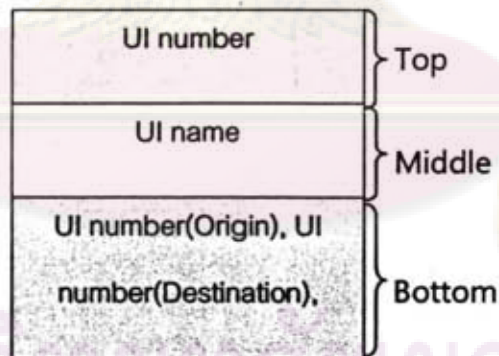


Figure 39. Symbols of Dialogue Diagram

Source: Prakdeewattanakun, Panitchakun [38]

The tool used to create dialogue diagram in this research is Microsoft Office Visio 2007, and the dialogue diagram of this research is illustrated in Figure 40.

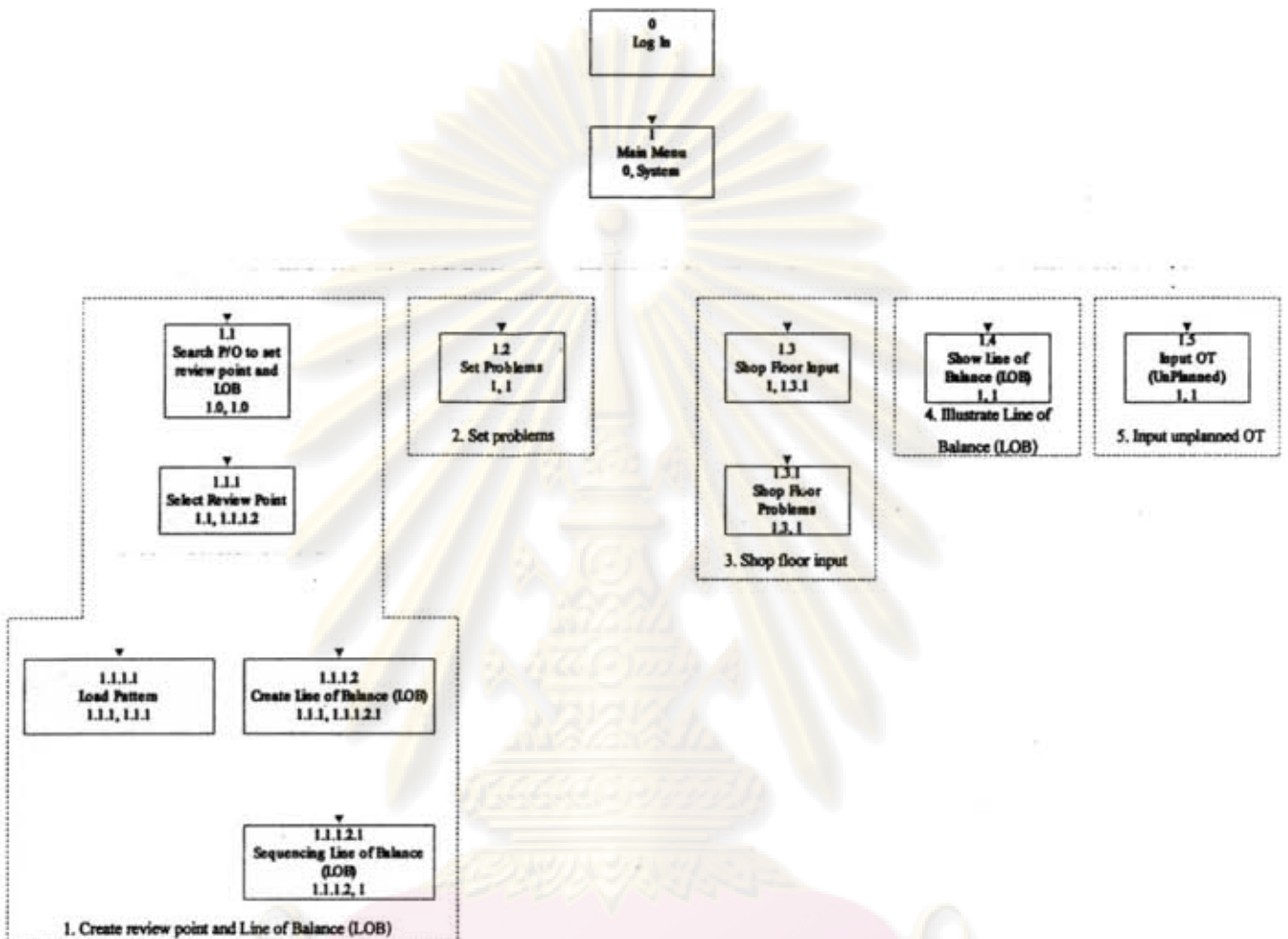


Figure 40. Dialogue Diagram

As showed in Figure 40, the process starts from log-in and select user interface from main menu. Dialogue diagram in this design of system can be separated into 5 main steams; 1.Create review point and Line of Balance (LOB) 2.Set problems 3.Shop floor input 4.Illustrate Line of Balance (LOB) 5.Input unplanned overtime (OT). And, each steam is described in following issues.

5.1.1 Create review point and Line of Balance (LOB)

For this first steam; create review point and Line of balance (LOB), because the more review points, the higher cost, therefore user needs to set only necessary review points instead of checking every processes in production line. To set review points, process steps start at UI 1.1 to find purchase order that user wanting to set review points. After

user selected the purchase order that wants to review, system will go to UI 1.1.1 which user can select all review points in that purchase order, or if that purchase order is slightly same as older order user can go to load old pattern of review points in UI 1.1.1.1 in order to save operating time. When finishes creating review points in UI 1.1.1, user can go to select some review points to create Line of Balance (LOB) in UI 1.1.1.2 in order to illustrate progression of those review points in graphical technique, which is clearer than view from data table.

In addition, after created LOB this system also allows user sequencing those review points in each LOB in UI 1.1.2.1, because those review points on each LOB may have wrong sequence, which do not match with actual work condition in shop floor.

5.1.2 Set problems

Second steam; set problems, actually problems in shop floor always occur again and again which can be categorized into 4 main categories including man, machine, material, and process. And, collecting problems as categories encourages company easier to analyse the data than analyse from spread data. Therefore; this steam which is UI 1.2 provides an opportunity for user to create problem's categories and its child as pattern for shop floor user uses to select when problem occurs in shop floor.

5.1.3 Shop floor input

Third steam; shop floor input, objective of this steam is for collect data from shop floor including production data and problems. Production data is used to update labour efficiency in order to provide up to date information for production planning, while problems in shop floor can be used to analyse and improve productivity. This steam starts at UI 1.3 to input production data into system, and if there is any problem occur in production line user can input that problem in UI 1.3.1.

5.1.4 Illustrate Line of Balance (LOB)

Fourth steam; illustrate Line of Balance (LOB), after production data in shop floor is collected, shop floor user can open this UI 1.4 to see progression of shop floor with LOB illustration technique in this UI. This UI helps production control able to monitor condition in shop floor closely which encourages them able to response with problems correctly and quickly.

5.1.5 Input unplanned OT

Last steam; input unplanned OT, the unplanned OT is always recognised at that individual day. It is different from planned OT, because planned OT is always included in

production schedule. It is important to recognise amount of hours and team required to do OT because system wants this data to calculate OT target to monitor production data in OT period. If system does not record amount of production produced in this unplanned OT period, it will affect number of cumulative production produced to miss the real number. Therefore, objective of this UI 1.5 is designed for collect team and time required doing OT in each day in order to send this data to other parts of the system.

5.2 User Interface Design

User interface (UI) is a part of this system that directly interferes with end user. This research selects to use "graphic user interface" to create interface with user as it is widely used, easy, and save time to input data. User that mostly related to this system may possible to have low information technology skill. Therefore, user interface in this research tries to specially concentrate on ease of use as well as its functionality.

User interface in this research is one such computer system tool that helps manufacturers able to monitor shop floor production easier, faster, and cheaper. It uses information from system analysis to design the system including work flow diagram, context diagram, data flow diagram (DFD), and logic of processes. It also uses dialogue diagram to clearly analyse the flow of UI and objective of each UI.

Even UI in this design is graphic user interface, but actually user interface is unnecessary to be graphic user interface, garment manufacturers can also bring concepts of this design in Chapter 4 and graphic user interface in this chapter creating system to improve its shop floor monitoring efficiency as well by using hard copy user interface like paper form to run the system.

By the way, there are many of user interface's principles in this design, and main important principles of UI design of this research are explored in next categories.

5.2.1 Focus on ease of use

As stated earlier, users of graphic user interface in this system are workers who have low computer skill. Therefore, ease of use becomes one of the most important issues in this design. Some important issues that this design considered to help the UI becomes friendly including;

- Apply tree node instead of complicate search boxes.
- Try to use table and graph instead of plenty of text content.

- Try to design every user interface with same pattern (e.g. positioning, wording, fonts) to avoid confusion.
- Adequate to cover all important functions.

Graphic user interface in this design tries to keep everything short and simple and eliminates all unnecessary functions and complicate functions. The user interface in this system tries to design to encourage user able to understand and uses, even they do not be trained before.

5.2.2 Use clear wording

Even this system focuses only on garment industry, but it appears that words that used in each company can be differently. Therefore, if analyst uses word that does not widely used in industry, user may confuse and miss understanding the content. Hence, this system also carefully selects word to use in the system by use clear wording that wildly used in industry.

5.2.3 Minimise operating time

Some user interface in this system consume amount of time to operate, which user may unsatisfied with the system, therefore this system design tries to minimise time used in each UI by;

- Eliminate unnecessary things on UI.
- Use search box _____ in UI instead of complicate search option.
- Provide menu tree for user which user can go directly to the page that user wanting to use instead of passing through many UI.

5.2.4 Adequate to cover requirements

Even user interface in this system focuses on ease of use and tries to eliminate some functions, features, and data from system, but it also remains all important things in system. Therefore, user can use the system easily, while it also covers all important functions, features and data.

5.2.5 Provide flexibility for user

Another important thing is flexibility of user interface. Because different company may require different usage, so system also tries to make it flexible enough to support various types of usages and requirements. However, because the more flexibility the more complexity of system, therefore all user interface pages are designed to meet the balance point between flexibility and ease of use.

5.3 System User Interface

Again there are many tools that can be applied to create user interface, but the tool that is used in this part to create illustration of user interface is Microsoft Office Visio 2007. First of all, the system starts at log-in page in Figure 41 to input user name and password before open the system.

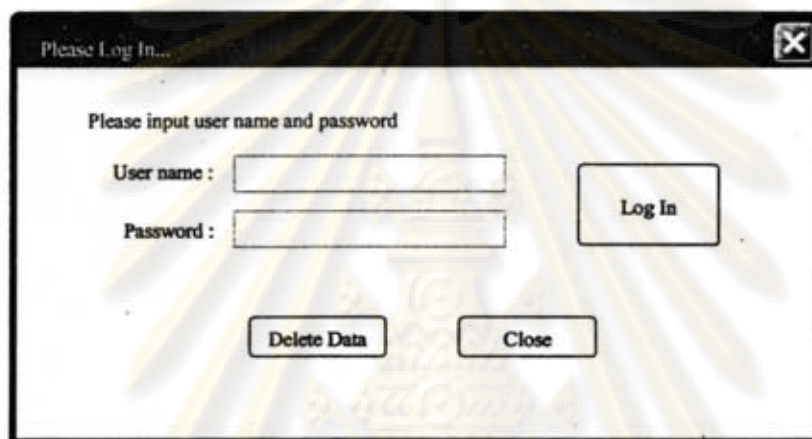


Figure 41.Log In User Interface


The log-in page helps company to increase security of information. In this UI if company wants to delete all data in system, company can choose this button  to reset everything. But once user selects this button, system will ask to input password again as following figure to protect unintended action.



Figure 42.Delete Data User Interface

Another common thing of UI in this system is appearance. This system design separates the UI into 3 main parts as showed in Figure 42. Part 1; main menu, every UI has the

Main Menu

- ☰ 1.1 Search P/O to Set Review Point and LOB
- ☰ 1.2 Set Problems
- ☰ 1.3 Shop Floor Input
- ☰ 1.4 Show Line of Balance (LOB)
- ☰ 1.5 Input OT (Unplanned)

same main which is . Most of user interface in system are designed to be linked directly from this main menu in order to minimise operating time. Part 2; search and tree diagram, this part is provided for locate tree diagram and search option in order to choose and find the thing that user wants to set. Part 3; operate, after user selected thing that wants to set from part 2, user can operate or input data in this part.



Figure 43.Appearance of System User Interface

By the way, user interface of this system are showed as follows.

5.3.1 UI 1.1 search P/O to set review point and LOB

The screenshot shows a web application interface. On the left is a 'Main Menu' with the following items:

- 1.1 Search P/O to Set Review Point and LOB
- 1.2 Set Problems
- 1.3 Shop Floor Input
- 1.4 Show Line of Balance (LOB)
- 1.5 Input OT (Unplanned)

The main content area contains a search form with the following elements:

- A 'Select' button.
- A 'P/O status' dropdown menu with the text 'Please Select P/O Status'.
- A label 'Please input producing time range'.
- A 'Please input producing time range' dropdown menu.
- A 'Search' button.

Below the search form is a table with the following columns: P/O, Customer, Job, Product Type, Product Name, Style, Producing Date, Status, Latest Updated, and Sample Picture. The table contains one row of data:

P/O	Customer	Job	Product Type	Product Name	Style	Producing Date	Status	Latest Updated	Sample Picture
ABC 2007-1	ABC	ABC 2007	Shirt	Short Sleeve Shirt	Slim Fit	13/1/07	-	-	View

Below the table, there are several 'View' buttons, one for each row of the table.

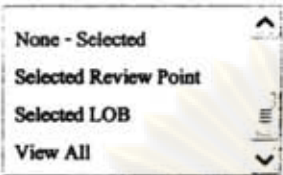

Figure 44.UI 1.1 Search P/O to Set Review Point and LOB

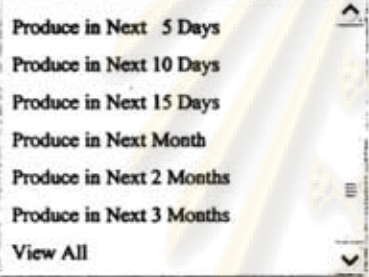
- **Objective**

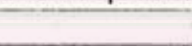

The objective of this UI is for search for purchase order that user wants to create review point and Line of Balance (LOB). Purchase order that shows on this page is focused only on the purchase order that has already passed the production planning process like worker allocation, method design, and line balancing. All purchase orders on this page need to pass production planning process before, because this information is important to use for create review point and LOB in later processes.

- **Description**

The processes start at user selects the searching criteria to find the purchase order that user wants to set review point. First criteria is purchase orders status , when user clicks on this drop down system will show

status including . "None-selected" means user wants system to show purchase orders that have never been set review point and Line of Balance (LOB) before. "Selected Review Point" means the purchase orders that have already selected review point, but have not been selected LOB. "Selected LOB" means purchase orders that have been set both review point and LOB. And, finally "View All" means user wants to see all status. Another criteria is producing time range , this criteria uses to scope the time that P/O going to produce ranging from 5 days to 3

months .

After user finish selecting criteria the purchase orders that match with criteria will show in table which showed in next page. And, if user wants to select any P/O user can double click on that row. Furthermore, in the table it may has many P/O in the list which hard to find the purchase order user wants to set, so system also provide this search box  which located on top of the table to key the words want to find. In an addition, if user wants to see product picture of any P/O user can click view button  to view product picture as well.

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P/O	Customer	Job	Product Type	Product Name	Style	Producing Date	Status	Latest Updated	Sample Picture
ABC 2007-1	ABC	ABC 2007	Shirt	Short Sleeve Shirt	Slim Fit	11/11/07	-	-	View
									View
									View
									View
									View
									View
									View
									View



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5.3.2 UI 1.1.1 select review point

Load Pattern Create LOB Save Save Pattern Preview Diagram Print

Please input review point information

Acceptable % Variance % Review Frequency Review Time Table

Please Select Review Point

Line Balance	1	2	3	4
	SN1	SN2	CV1	IL3
	Select Properties	Stitch the collar edge Mr.Paid Abornal		

Summary Table

<input type="checkbox"/> Delete All <input type="button" value="Delete"/>	Process	Team	Process ID.
	Short sleeve shirt (Assembly)	4	-
	Fuse and stitch the collar edge	1	1220
	Stitch the sleeve edge	2	1750
	Stitch 2 sleeve parts tog Delete	2	2500
	Stitch the body edge	3	3000
	Stitch 2 body parts together	3	3200
	Attach the collar buttons	1	400
	Attach the body buttons	3	570

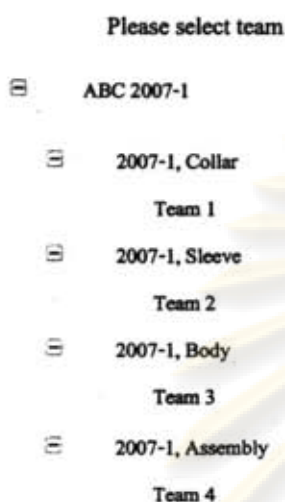
Figure 45.UI 1.1.1 Select Review Point

- **Objective**

The objective of this UI is for select the process that user wants it to be the review point. Besides that it also used for input acceptable variation percentage and input time schedule that user want shop floor to review processes in shop floor.

- **Description**

The processes start at the tree diagram on bottom left of the



UI . This tree is used for select the team that user wants to set review point. After use selected the team, the machine layout of that team will appear of right side of the UI as follows.

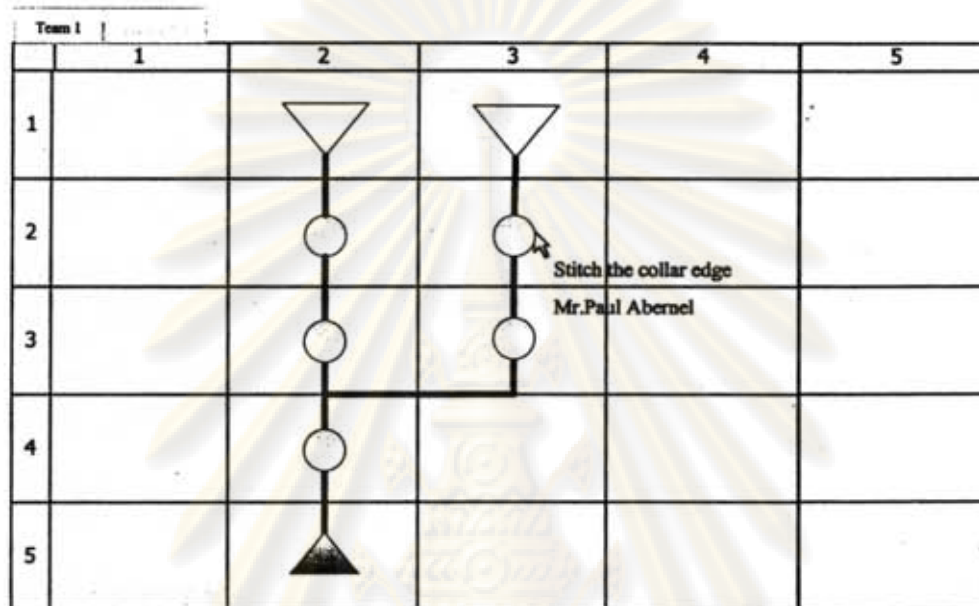
Please Select Review Point

	Line Balance			
	1	2	3	4
1	SN1	SN2	OV1	IL3
2	Select Properties	Stitch the collar edge Mr.Paul Abemel		
3				
4				
5				

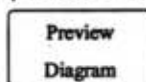
In this step if user points mouse on any block, its properties will show which including process name and worker who responsible that process. Then if user wants to select any process to be the review point, user can right click and then chooses select or double click on the layout.

Moreover, on the top of layout there are two tabs Team 1 Line Balance provided for switches to see operation process chart of that team in order to help user enables to select review point correctly because in lay out user may does not see the flow

of operation in actual work condition. If user clicks on team name at the tab, the operation process chart of that team will show as following figure.



Furthermore, if user wants to view all processes of this P/O user can also press on



this button which is located on the top right side to go to see whole operation process chart of this P/O.

When user selects any process in the layout, the process that user selected will show in this summary table.

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Summary Table

<input type="checkbox"/> Deselect All <input type="button" value="Delete"/>	Process	Team	Process ID.
	Short sleeve shirt (Assembly)	4	-
	Fuse and stitch the collar edge	1	1220
	Stitch the sleeve edge	2	1750
	Stitch 2 sleeve parts together	2	2500
	Stitch the body edge	3	3000
	Stitch 2 body parts together	3	3200
	Attach the collar buttons	1	400
	Attach the body buttons	3	570

After user has got all review points, user has to set the % acceptable variance
 Acceptable % Variance % If actual production in shop floor exceeds this percentage the system will warn production control to recognise the problem in order to response with it immediately.

Moreover, user also has to set the frequency of time that wants to review the production in this drop down , and frequency

- Every 1 Hr.
- Every 2 Hrs.
- Every 3 Hrs.
- Every Half of the Day
- Every End of the Day

that system provides including . Additionally, after chose review frequency user able to see review time table by clicks on this

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button **Review Time Table**, then system will generate review time table automatically

Period	Start	End
1		
2		
3		
4		
5		
6		
7		

and shows on the pop-up as following figure

Lastly, when user finishes setting this UI user has to click on create LOB button

Create LOB

in order to proceed to next UI to create Line of Balance (LOB). And, if user wants to save this pattern of review points to use with next order that has

similar processes or product, user can click on this button

**Save
Pattern**

to save these review points as pattern. Next time when user wants to load the pattern user can

Load Pattern

click on this button, which system will go to "UI 1.1.1.1 load pattern" to find the pattern that user wanting to load.

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5.3.3 UI 1.1.1.1 load pattern

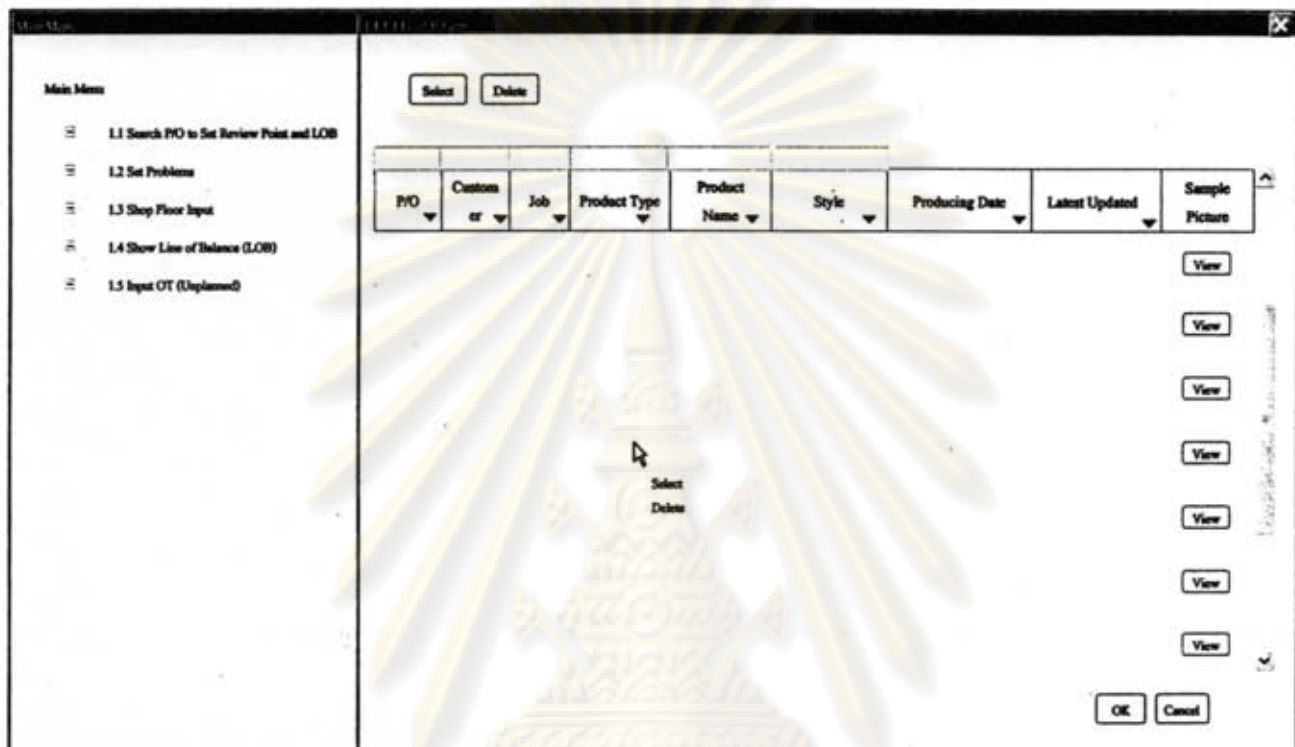


Figure 46.UI 1.1.1.1 Load Pattern

- **Objective**

The objective of this UI is for load review points and Line of balance (LOB) data from old data in database that has similar product name or similar operation processes in order to reduce time to create the review point and LOB for new P/O.

- **Description**

This UI is linked from previous UI "UI 1.1.1 select review point" in order to select the pattern of review point. Actually, there may be many patterns of P/O in this table therefore system provides this search box for user to key the keywords in order to search for that pattern that user wants. For an example, if user wants to find the pattern of product name short sleeve shirt user can key "short sleeve shirt" in the box of product name column then all patterns that has product name short sleeve shirt will show in the table.

However, when time has passed there may be many patterns of review points from several P/O in the table, which some of them may be outdated, so this UI provides opportunity for end user to delete any pattern by right click then chooses delete or click on delete button . Moreover, the system also provides view button for user when user wants to see picture of product.



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5.3.4 UI 1.1.1.2 create Line of Balance (LOB)

Main Menu

- 1.1 Search P/O to Set Review Point and LOB
- 1.2 Set Problems
- 1.3 Shop Floor Input
- 1.4 Show Line of Balance (LOB)
- 1.5 Input OT (Unplanned)

Buttons: Save, Save Pattern, Preview Diagram, Print

ABC 2007-1

Customer : ABC Job : ABC 2007 Product Type : Shirt Product Name : Short sleeve shirt Style : Slim fit Product Code : SM01
 Producing Date : 13/11/07 Finish Date : 21/11/07 Due Date : 25/11/07 Shipment Date : 30/12/07 Quantity : 5,210
 Producing Day : 5 days

LOB1

<input type="checkbox"/> New at	<input type="checkbox"/> Deleted at	Process	Time	Process ID.
<input type="checkbox"/>		Short sleeve shirt (Assembly)	4	-
<input type="checkbox"/>		Press and stitch the collar edge	1	1220
<input type="checkbox"/>		Stitch the sleeve edge	2	1750
<input type="checkbox"/>		Stitch 2 sleeve parts together	2	2300
<input checked="" type="checkbox"/>		Stitch the body edge	3	3000
<input checked="" type="checkbox"/>		Stitch 2 body parts together	3	3200
<input type="checkbox"/>		Attach the collar buttons	1	400
<input checked="" type="checkbox"/>		Attach the body buttons	3	370

Tree Diagram:

- ABC 2007-1
 - LOB 1
 - LOB 2
 - LOB 3
 - Delete
 - Rename

Figure 47. UI 1.1.1.2 Create Line of Balance (LOB)

- **Objective**

The objective of this UI is for bring the review point that is selected from UI 1.1.1 to select review points that user want to locate on each Line of Balance (LOB).

- **Description**

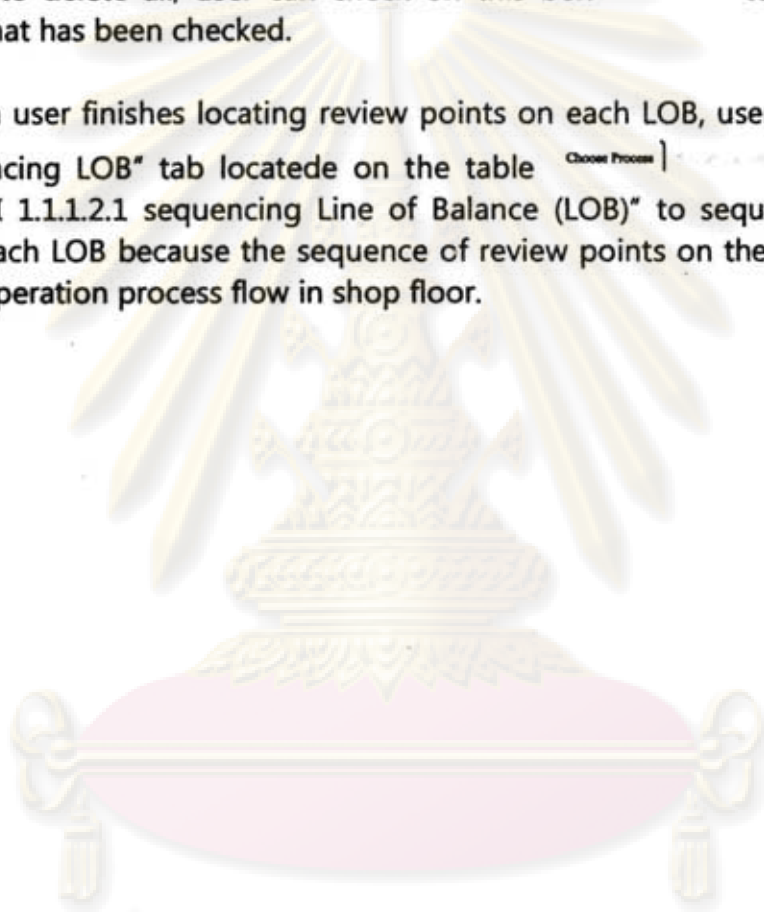
The operations of this UI start at bottom left of the UI at tree diagram. The tree diagram used for select the LOB that wants to set. Firstly, user needs to add number of lines that wants to set and user may change its name by right click and chooses rename. Once user wants to set any LOB, user can click on that LOB and set it in the right side of UI.

On the top right hand side of UI is properties of that P/O. The below table is list of processes that user selected as review points at "UI 1.1.1 select review point". If user wants to locate any review points on the Line of Balance (LOB) user can check on this box which located in front of each process. Or, if user wants to select all processes user can check on this box Select All. On the other hand, if user wants to delete all, user can check on this box Deselect All to delete all of processes that has been checked.

Lastly, when user finishes locating review points on each LOB, user may click on the "sequencing LOB" tab located on the table

Choose Process

 in order to swap to "UI 1.1.1.2.1 sequencing Line of Balance (LOB)" to sequencing review points on each LOB because the sequence of review points on the LOB may not align with operation process flow in shop floor.



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5.3.5 UI 1.1.1.2.1 sequencing Line of Balance (LOB)

The screenshot shows a software interface for sequencing Line of Balance (LOB). On the left, there is a 'Main Menu' with options: 1.1 Search P/O to Set Review Point and LOB, 1.2 Set Problem, 1.3 Shop Floor Input, 1.4 Show Line of Balance (LOB), and 1.5 Input OT (Deployment). Below the menu is a tree view showing 'ABC 2007-1' with sub-items 'LOB 1' and 'LOB 2'. 'LOB 1' is selected, and there are 'Add LOB' and 'Delete' buttons. The top right of the main area has buttons for 'Save', 'Save as Pattern', 'Preview Diagram', and 'Print'. Below these buttons, the product information is displayed: 'ABC 2007-1', 'Customer : ABC', 'Job : ABC 2007', 'Product Type : Shirt', 'Product Name : Short sleeve shirt', 'Style : Slim fit', 'Product Code : SM01', 'Producing Date : 13/11/07', 'Finish Date : 21/11/07', 'Due Date : 25/11/07', 'Shipment Date : 30/12/07', and 'Quantity : 5,210'. Below the product info, the 'Sequencing LOB' tab is active, showing a table with three columns: 'Process', 'Time', and 'Process ID'. The table contains three rows of data:

Process	Time	Process ID
Stitch the body edge	3	3000
Stitch 2 body parts together	3	3200
Attach the body bottom	3	370

Figure 48. UI 1.1.1.2.1 Sequencing Line of Balance (LOB)

- **Objective**

The objective of this UI is for provides an opportunity for user to sequencing the review points on each Line of Balance (LOB), because review points that are located on the LOB may not match with the flow of processes in actual work.

- **Description**

When user clicks on "Sequencing LOB" tab ^{Sequencing LOB} in previous UI, the table on right side of UI will change to table showed in this UI. This table will show only processes that are selected on each LOB from previous UI. When user wants to sequence processes on any LOB, user can choose LOB that wants to set at tree diagram on the bottom left. Then review points on that LOB will show on the

table, which user can sequencing it by click on this arrow



in order to move the process up or down.



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5.3.6 UI 1.2 set problems

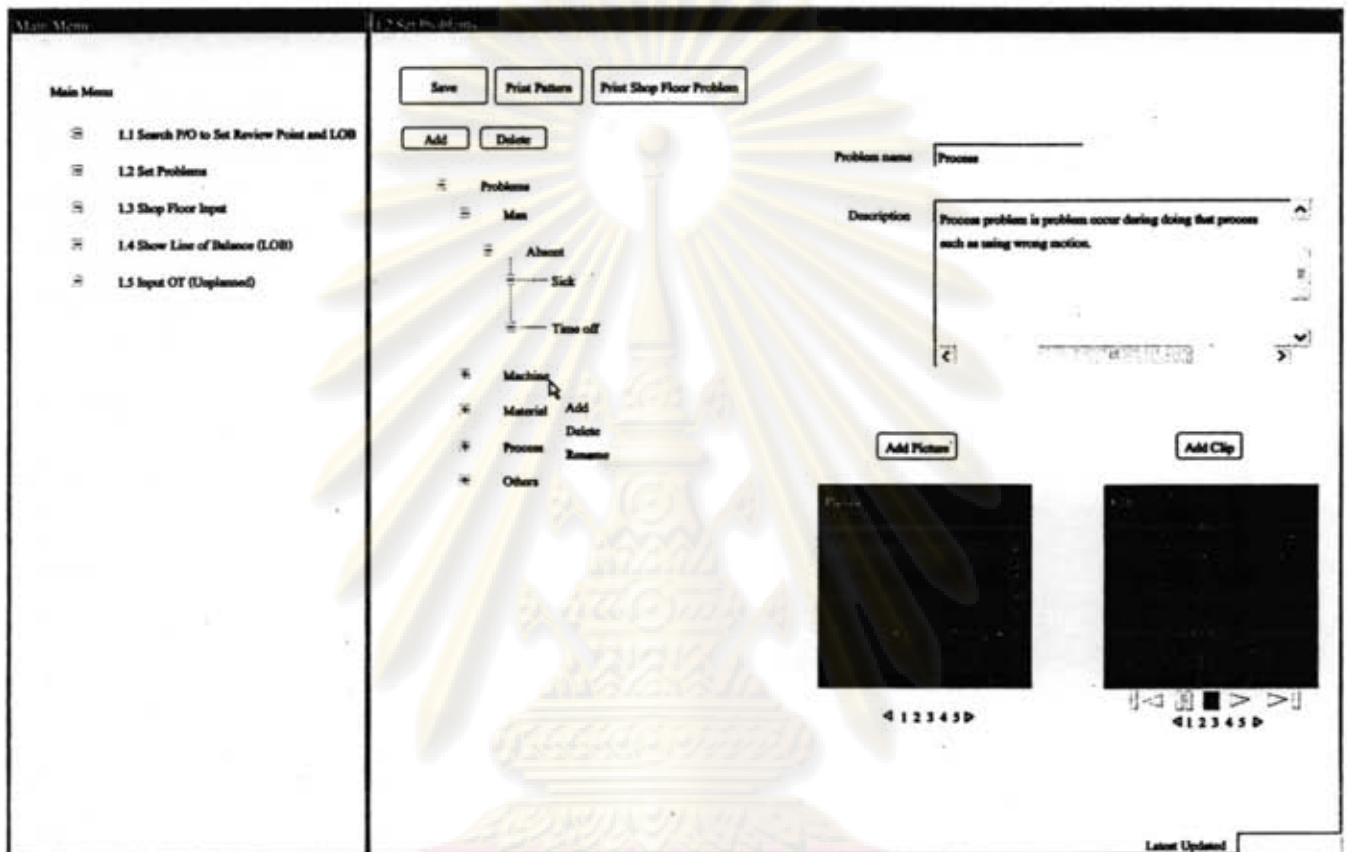


Figure 49.UI 1.2 Set Problems

- **Objective**

The objective of this UI is for set group of problems and its child that shop floor user can use to select when problem occurs in shop floor. It helps company to keep the information as cluster which much easier and better for analyst to use. In an addition, this UI also provides an opportunity for user to print out the shop floor problems report which company can bring to analyse and improve productivity in shop floor.

- **Description**

The operations start at tree diagram on the right side of UI. The tree diagram is problem tree diagram which categorises problems as groups. The default groups of problem in the system have 4 main default groups including man, machine, material, and process. But, actually the group of problems can be more than this

depends on each company, therefore system also provides flexibility for user to create and edit group of problem or its child as company wants.

To create problem user can click on any problem and then click add its child. For instance, if user clicks on man group and clicks the system will create child of man group which user can edit name and add description on the right side of the page in these two boxes.

Problem name

Description

Additionally, user can add picture and clip video for each problem, which shop floor user can use to see when needs to select any problem at "UI 1.3.1 shop floor problems". And, when user clicks on or button, the pop-up below will show for browse the file to insert into the system.

Insert File ✕

Please insert the file.



File 1:

File 2:

File 3:

File 4:

File 5:

Lastly is the print function. Report that can be printed from this UI includes two types of report. First; is problem pattern report , this report will show problem categories and its child that user set in this UI. Second; is shop floor problem report , this report will show shop floor problem that collected from shop floor which company can use this report to analyse and improve productivity of production line.

Moreover, to print shop floor problem this UI also provides print option to enable user to choose time range and department that user interested and wants to it show in the report, which the print option is showed in Appendix E.



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Please select P/O

Job	P/O	Product Name
ABC 2007	ABC 2007-1	Short Sleeve Shirt
		Properties

User can search for the P/O that wants to set by using this search box _____ to key the words that want to find.

Once user selects on any P/O, the page on right hand side including review points and review time table will appear as user set for that P/O before. This step user has to choose the review point that wants to input data from the following table by clicks on the row of that review point.

Review Point	Process	Responsible Position			
		Department	Section	Team	Worker
1	Short Sleeve Shirt	1	2	4	-
2	Fuse and stitch the collar	1	2	1	Mr.Paul Abernel
3	Stitch the sleeve edge	1	2	2	Mrs.Cristina Lobanson
4	Stitch 2 sleeve parts toge	1	2	2	Ms.Anna Rose
5	Stitch the body edge	1	2	3	Ms.Lolita Defry
6	Stitch 2 body parts togeth	1	2	3	Mrs.Coco McAnderson
7	Attach the collar buttons	1	2	1	Mrs.Celine Dior
8	Attach the body buttons	1	2	3	- Ms.Jessica Bonds

When user clicks on the row of any review point the following table will appear, which user can input data into this table.

Period 6 14.00 pm - 15.00 pm	Target	50	
	Produced	50	
	%eff	100%	<input type="checkbox"/> Don't Use
	Problem	Problem	
Period 7 15.00 pm - 16.00 pm	Target	50	
	Produced	10	
	%eff	20%	<input checked="" type="checkbox"/> Don't Use
	Problem	Problem	
Period 8 16.00 pm - 17.00 pm	Target	50	
	Produced	50	
	%eff	100%	<input type="checkbox"/> Don't Use
	Problem	Problem	
OT 2 Hrs. 17.00 pm - 19.00 pm	Target	100	
	Produced	100	
	%eff	100%	<input type="checkbox"/> Don't Use
	Problem	Problem	
End of Day	Target	400	
	Produced	350	
	%eff	87.5%	<input checked="" type="checkbox"/> Don't Use
	Problem	Problem	

↔

Day 1/5 (13/11/07)

The table will tell time schedule that shop floor user has to review production in each period and also shows target of each review point. Once user inputs data in the box, system will calculate the percent efficiency automatically and if efficiency of any review point below the % acceptable variation system will warn user by change the percent efficiency to red colour.

In addition, in shop floor sometimes there may be some circumstances that can interrupt the working condition of each review point such as accident or worker in that review point may be relocated to help another station. This situation can affect the company to get the error data and miss actual production rate which inappropriate to use this data to update skill efficiency of worker. Therefore, system provides this check box Don't Use to mark the data that user does not want sent to update efficiency and record into database. Furthermore, if user wants to view previous data of each review point user can click to go back to

↔

Day 1/5 (13/11/07)

view old data from this arrow

During each period there may be some problems occur in shop floor, so user can click this button to go to input shop floor problem at "UI 1.3.1 shop floor problems" which will be described in next UI.

On the top of right side page system also provides link button to view Line of Balance (LOB) of that P/O at "UI 1.4 show Line of Balance (LOB)" from this button . And, when production of P/O end shop floor user has to confirm the end of P/O at this button to eliminate data of this P/O from system and also makes other parts of the company to know that this P/O has finished all sewing processes.



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5.3.8 UI 1.3.1 shop floor problems

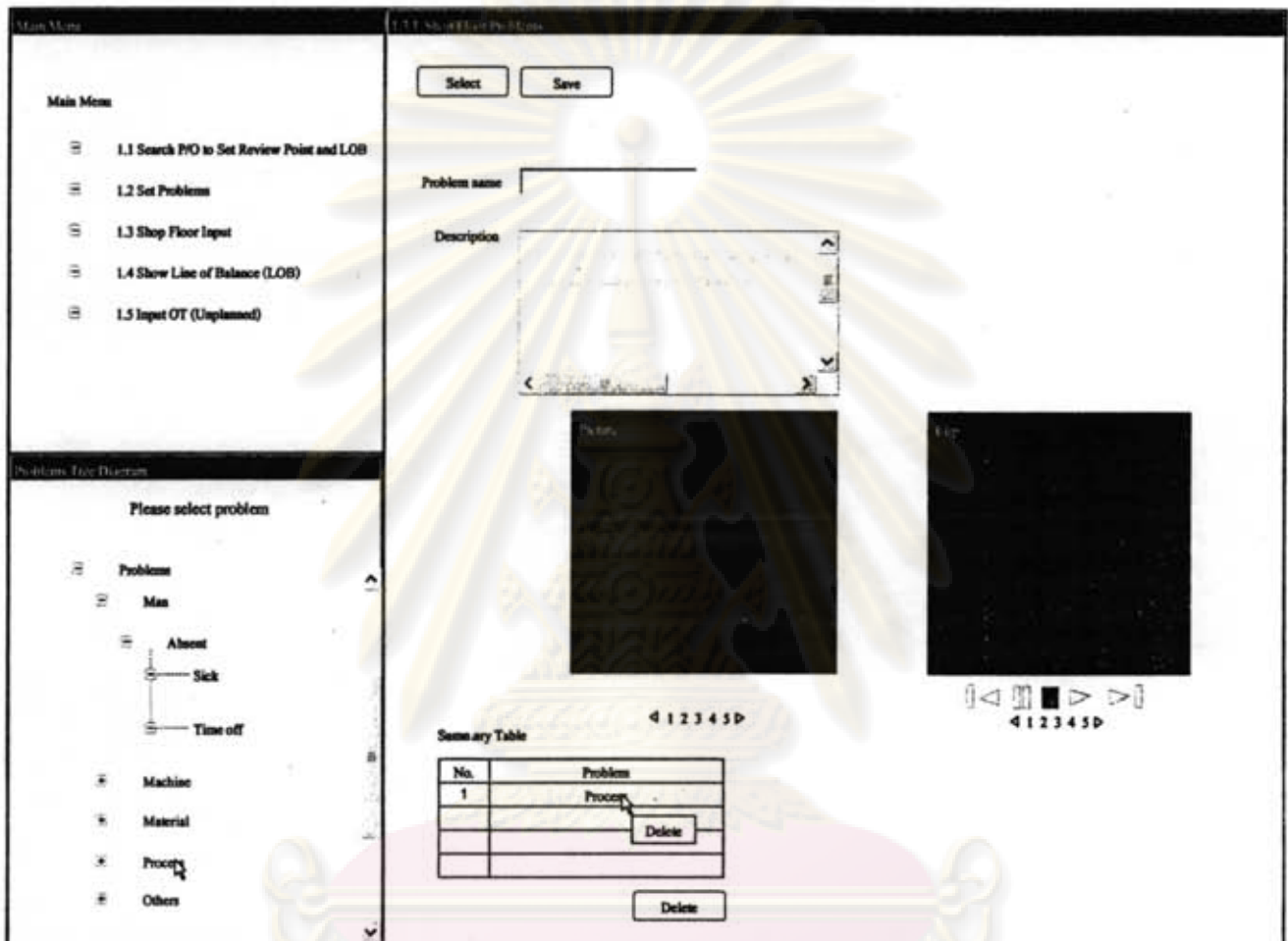


Figure 51.UI 1.3.1 Shop Floor Problems

- **Objective**

The objective of this UI is for collecting shop floor problems that occurs in shop floor, which company can bring this data to analyse in detail when needs to do productivity improvement.

- **Description**

This UI is linked from previous UI "UI 1.3 shop floor input". At first, user has to select the problem from tree diagram on the bottom left of UI by double click or click on the problem then presses select button . Once user clicks on any problem its name and description will show on the right side of UI and when

user selects any problem, problem that is selected will show in summary table. In an addition, system also provides pictures and clips of problem for user to view in order to use it to make selective decision.



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5.3.9 UI 1.4 show Line of Balance (LOB)

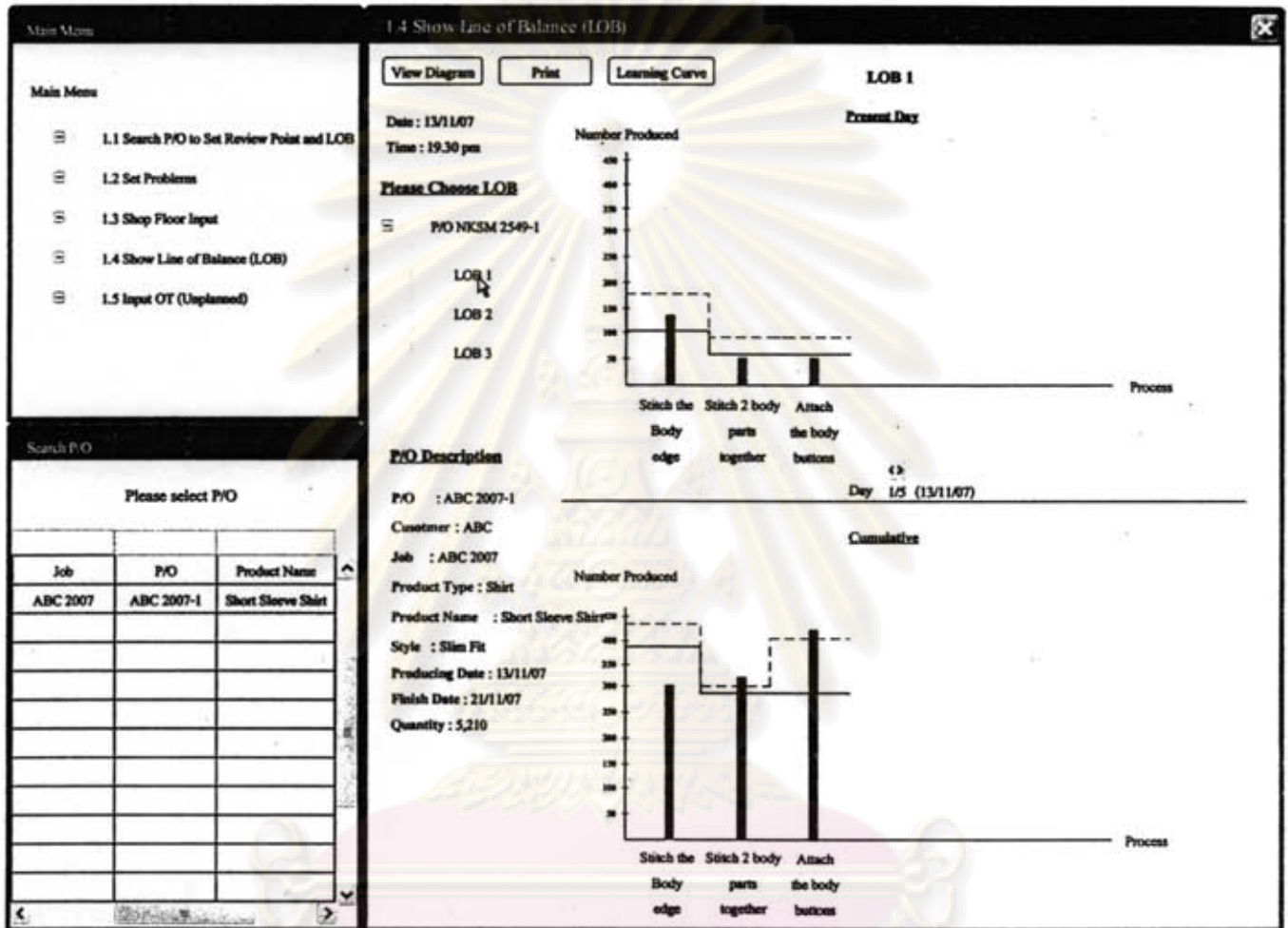


Figure 52.UI 1.4 Show Line of Balance (LOB)

- **Objective**

The objective of this UI is for show the progression of production line as graphical method by Line of Balance (LOB). The LOB technique enables production control to monitor its shop floor efficiently, because it is better show hidden problems, can indicate real source of bottleneck, and much easier to read than data table. Besides that, this LOB also includes warning system that will warn user to know process that misses the target by appear red bar on the UI.

- **Description**

The operations of this UI start at search part at bottom left of UI. If this UI is linked directly from main menu, this step user has to key job number, P/O number, or product name to search for the P/O that wants to view Line of Balance (LOB) in this search box _____ . However, if this UI is linked from "UI 1.3 shop floor input" the P/O that is showed on the UI will be the same P/O of UI 1.3.

After chose P/O user has to select the LOB that user wants to view in this tree

Please Choose LOB

☰ P/O NKSM 2549-1

LOB 1

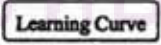
LOB 2

LOB 3

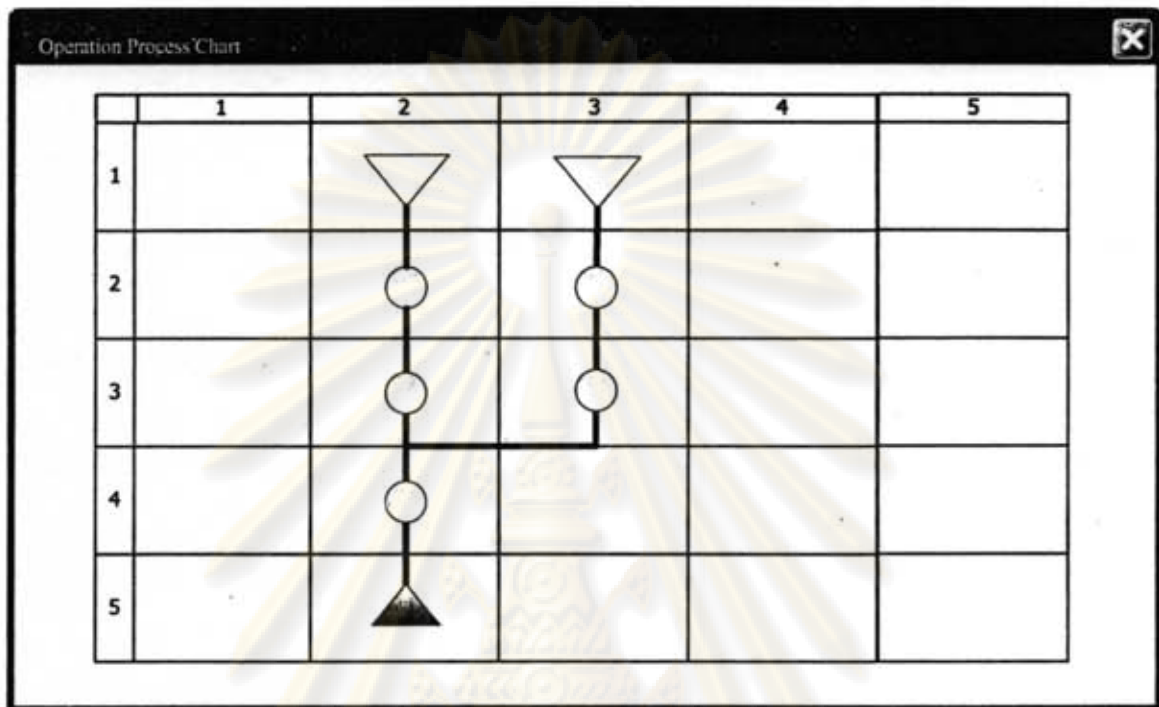
diagram

Once, user clicks on any LOB the graph of that LOB will show on the right side of UI. There are two types of LOB showed on this UI including present day LOB and cumulative LOB. The present LOB is the LOB that shows only production data of that day, while cumulative LOB will show production data that is cumulated since open the order till today. Each graph represents thing differently, present day LOB can tell progression of that day which helps production control able to see problem and take corrective action quickly and correctly. On the other hand, cumulative LOB helps production control can see the top view which can indicate that since order has started until now the output meets its plan or not.

Moreover, this LOB also includes warning system that will warn user to know process that misses the target by appear red bar on the UI.

Another important function of this UI is learning curve function. This function is activated by this button  . Once user click on this button, the LOB will has another addition line which is dot line of the Figure 52. This line represents to the target that has already considered learning curve issue, which normally it always closer to real output than normal target.

Lastly is view button  , this button used for open this pop-up



that shows all operation process chart of this purchase order.

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click this drop down on the team that wants to input OT and the

alternatives of OT hours includes

5.4 Form and Report Design

Form and report is another important part of system. Form and report interfere with user directly, so if form is too complicate to understand, user may fill wrong data in it and finally it will affect system to error or run inefficiently. Likewise, if report is too much complicate, user may confuse and miss understand its meaning, which can effect to wrong decision making.

Even this design of system selects to use "graphic user interface" in computer system to receive data from user, but it also provides a chance for user to print the paper form in "UI 1.3 Shop Floor Input" to get data from shop floor including production data and problem before inputs into system.

As stated earlier, this design of system mostly relates to shop floor employee, which many of them may unable to understand technical terms and complicate form and report. Therefore, form and report in this research tries to aware those issues and important things of form and report design in this system which this design tries to consider including;

- Use clear wording that users can understand its meaning in the same content..
- Keep it simple and short.
- Emphasise important words.
- Try to use table, list, graph and illustration instead of text.
- Try to balance position of content.
- Try to design every page as the same pattern (e.g. positioning, wording, fonts).
- Try to eliminate unnecessary content.

In addition, another important issue of form and report design is colour. There are 2 main types of colour in form and report including black-white tone and colour tone,

which each of it has both upsides and downsides. Main advantages and disadvantages between these two reports on this system are clarified in Table 4.

Colour Tone	Black – White Tone
<p><u>Advantages</u></p> <ul style="list-style-type: none"> - Able to use colour to emphasis content - Help user easier to understand complicate content - User can easily see warning - Appropriate for high graphic resolution 	<p><u>Advantages</u></p> <ul style="list-style-type: none"> - Colour blind user can understand the content - Save printing cost - Reduce error from printer's colour varaince -Wildely used in garment industry
<p><u>Disadvantages</u></p> <ul style="list-style-type: none"> - Not appropriate for colour blind user - Higher cost - Colour variance from printer may make user miss understand content -Not wildly used in garment industry 	<p><u>Disadvantages</u></p> <ul style="list-style-type: none"> - Harder to understand complicate content - Warning word may not be seen - Not appropriate for high graphic resolution

Table 5.Comparison of Black-White and Colour Tone in Form/Report Design

As show in Table 5, it can be both advantages and disadvantages of each tone, but the most appropriate one for garment industry is black-white tone because it is cost cheaper and wildly used in garment industry in present day. Therefore, form and report in this system design are design based on the black-white tone.

In an addition, form and report of this system design are created by simple tool which is Microsoft Word 2007, because it is simple, has high availability, and adequate to cover objective. However, a sample of form and report are show in Figure 53, and all forms and repots are showed in Appendix D.

Date.....Time..... Page ..

Latest Updated.....

Company Name

Line of Balance (LOB) Producing Date 3/5

ABC 2007-1

Customer: ABC Job: ABC 2007 Product Type: Shirt Product Name: Short sleeve shirt
 Style: Slim fit Product Code: SM01 Producing Date: 13/11/07 Finish Date: 21/11/07
 Due Date: 25/11/07 Shipment Date: 30/12/07 Quantity: 5,210 Producing Days: 5 days

% Acceptable Variance : 15% Review Frequency : Every 1 hour

LOB 1 (Normal Target)

Present Day

Sequence	Process	Target	Produced	%Variance	Meet Target
1	Stitch the body edge	100	140	0 %	✓
2	Stitch 2 body parts together	60	50	17 %	✗
3	Attach the body buttons	60	50	17 %	✗

Cumulative

Sequence	Process	Target	Produced	%Variance	Meet Target
1	Stitch the body edge	390	375	4 %	✓
2	Stitch 2 body parts together	290	320	0 %	✓
3	Attach the body buttons	290	430	0 %	✓

User Name:.....

Figure 54.Example of Report

CHAPTER VI

SYSTEM VERIFICATION

System verification is another important part of this design of system. It is necessary to verify system because system that is developed may not match with business processes in actual working condition. Moreover, design of user interface (UI) and report in this system design may too much complicate to use and understand which can affect user to confuse, or if some pages in system are not included important data and functions user may unsatisfy with it, which all of these can lead the project to failure.

Therefore, some parts of system including user interface (UI) and report in this research are verified from time to time during system is being developed by expert in system development and people in garment industry especially the end user of each UI and report. And, because this system design is verified simultaneously, so some comments from interviewees are brought to improve and block weaknesses of system and bring new version to ask interviewees again and again.

However, detail of verification methods of this research are explored in following issue.

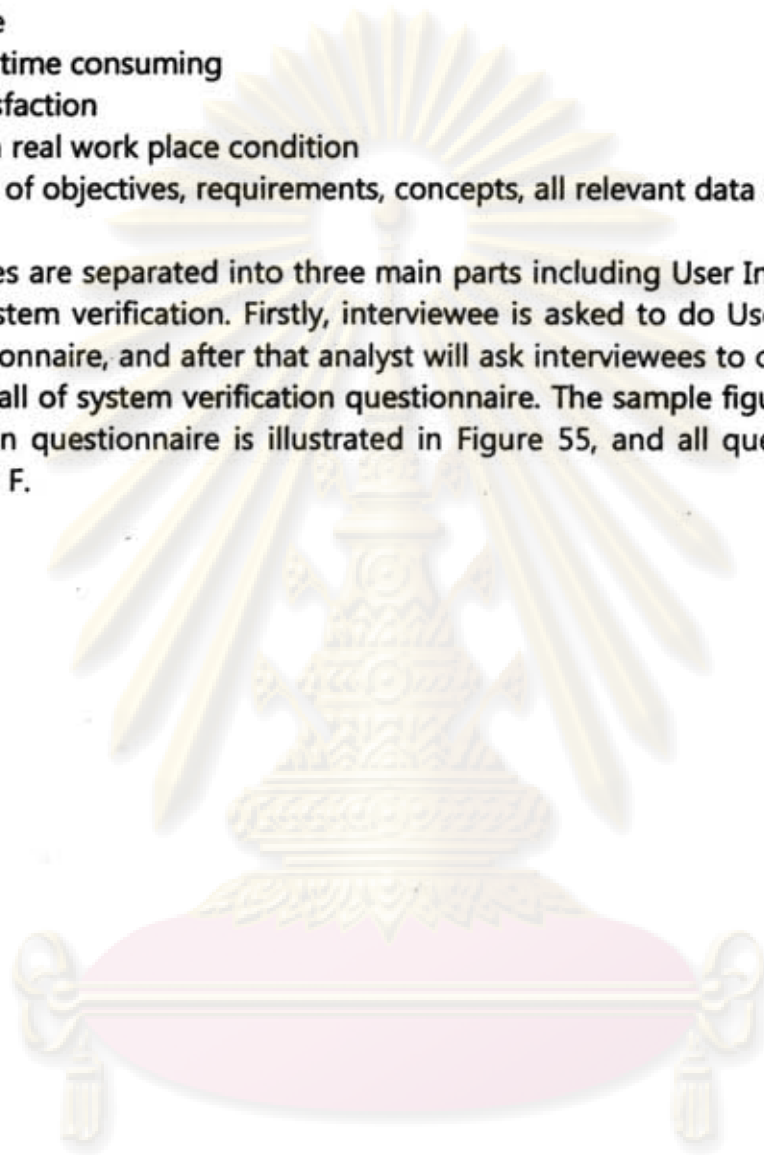
6.1 Verification Methods

The verification of this research uses questionnaires and interview methods to check the system. The interview and questionnaires conducted in the verification are focused on expert in system development and end users in garment industry. First of all, the verification of this system design is verified by experts in system development. However, comments from system development experts are limited only in technical knowledge in system development, which inadequate to point out the problems in real work condition in garment industry. Hence, after that the system is also brought to interview the person in garment industry who is direct user of each UI and report says shop floor supervisor, production planning engineer, and production control engineer.

Before starts interview, each UI and report is clearly described to interviewee about its objectives, functions, requirements and concepts of system that this design of system trying to solve. The topics in interview and questionnaire are mainly focused on some important issues that are;

- Ease of use
- Operating time consuming
- User's satisfaction
- Usability in real work place condition
- Fulfillment of objectives, requirements, concepts, all relevant data and functions

The questionnaires are separated into three main parts including User Interface, Report, and overall of system verification. Firstly, interviewee is asked to do User Interface (UI) and report questionnaire, and after that analyst will ask interviewees to conclude overall of system in overall of system verification questionnaire. The sample figure of overall of system verification questionnaire is illustrated in Figure 55, and all questionnaires are showed appendix F.



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Questionnaire of Overall of System Verification

Name: Position:

Reaction with Requirements and Concepts

1. Does this system can warn you to know shop floor problem quicker?

Very Bad	Bad	Fair	Good	Very Good
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comment:

.....

.....

.....

2. Does this system can help manufacturer to better recognise progress in shop floor?

Very Bad	Bad	Fair	Good	Very Good
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comment:

.....

.....

.....

3. Does Line of Balance (LOB) provided in this system can help user to clearly see progress and problem in shop-floor?

Very Bad	Bad	Fair	Good	Very Good
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comment:

.....

.....

.....

4. Does worker efficiency provided in this system can help production planning able to plan target closer to actual output?

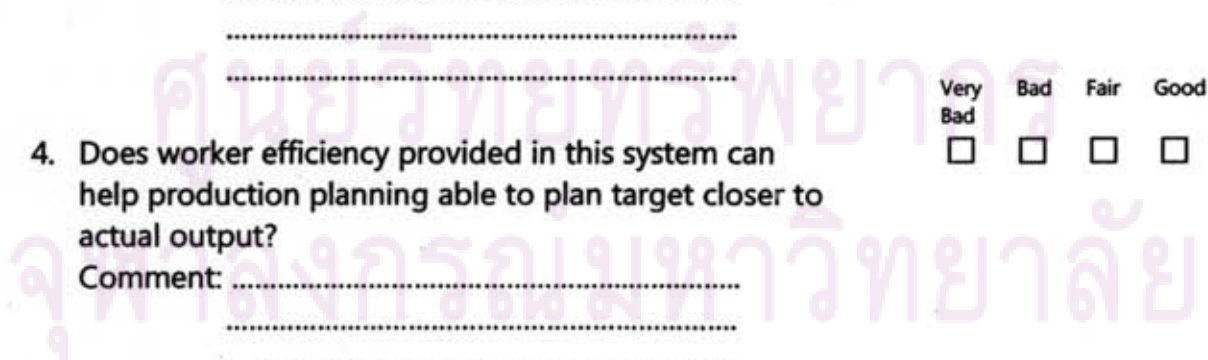
Very Bad	Bad	Fair	Good	Very Good
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comment:

.....

.....

.....



- | | | | | | |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| | Very
Bad | Bad | Fair | Good | Very
Good |
| 5. Does shop floor information provided in this system adequate for production control to make corrective decision? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Comment:

.....

.....

.....

.....

- | | | | | | |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| | Very
Bad | Bad | Fair | Good | Very
Good |
| 6. Does information of shop floor problem that collected and reported in this system useful for you to make productivity improvement? | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

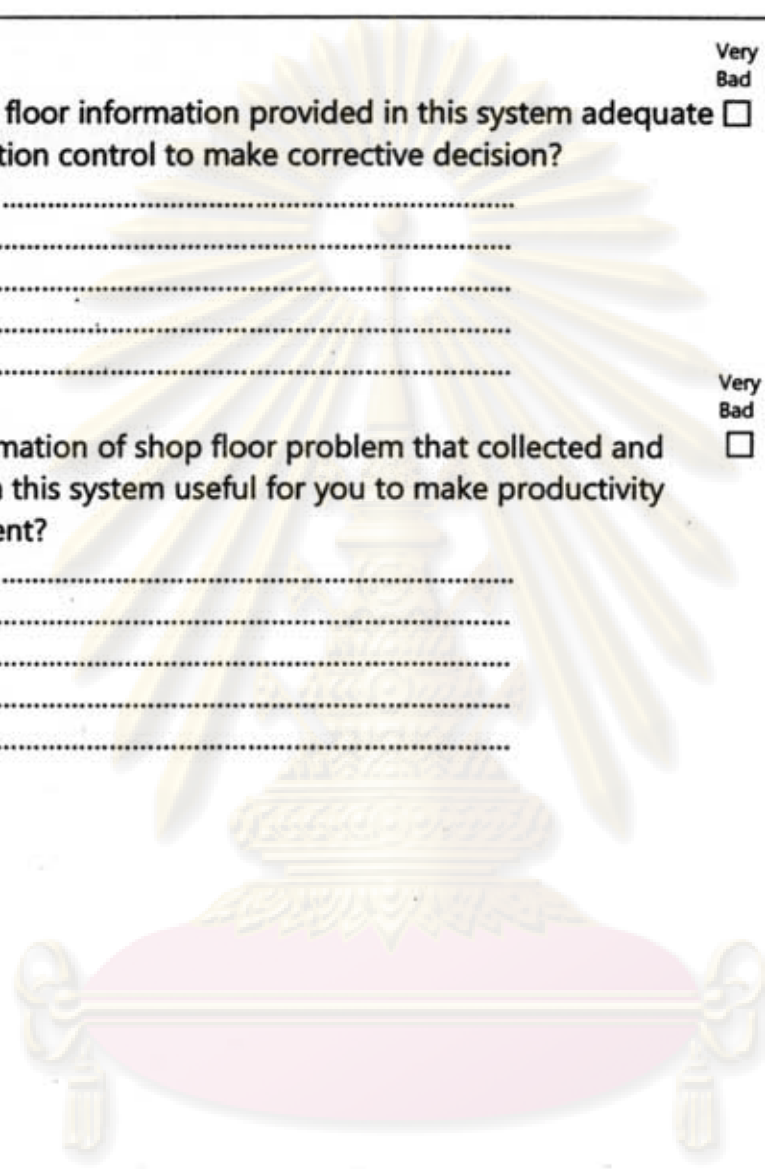
Comment:

.....

.....

.....

.....



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Conclusion		Very Bad	Bad	Fair	Good	Very Good
1. Does this system can implement to use in your company?		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Comment:						
2. Does this system easily to use?		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Comment:						
3. Does this system can fulfill your expectations and requirements?		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Comment:						
4. Does this system can improve your production control and monitoring performance?		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Comment:						
5. Do you satisfy with this system?		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Comment:						

Figure 55.Overall of System Verification Questionnaire

Absolutely, it is hardly to fulfill all requirements and comments, because different people may have different point of view and requirements which unable to apply all of it into system. For examples, some recommends may appropriate for company A but may not align with company B and C, some may good but can effect to other modules of SAM-g2, and there many interesting issues but cannot bring into system as limit of resources such as time and people. Therefore, some comments from interview and questionnaire are brought to improve the system again and again, but some of them are not applied into system due to some reasons and constraints as described. So, the method used in this system design is trying to eliminate all severe problems and comments, and for non severe issue the system is designed to seek the balance point that tries to fit with overall of industry.

Nevertheless, some interesting comments from system development experts and end users in user interface and report verification are described in following issues.

6.2 User Interface Verification

User interface (UI) is crucial important for success in this design of system. The complicate UI may make user confuses and leads the project to failure. Likewise, confusion UI may also affect them to miss understanding the objective or functions of UI, which make them put wrong information into the system.

The user interface in this design specially focuses on ease of use, because end users of system have high possibility to have low technology skills. The verification criteria of UI are as same as verification criteria of report which are described before says ease of use, operating time consuming, user's satisfaction and etc. But, one thing differently from report verification is logic of process. To verify UI the logic of process is also added into interview because there are many logics in system, which some of them may not align with present working condition of industry. Hence, to verify user interface logics of each UI become another crucial part. The illustrations of questionnaire used in interview are showed in Appendix F.

However, some interesting comments from interview are described in next issues.

6.2.1 Difference of terminology

In garment industry even some technical terms and wording are same, but there are many words which are used differently. For an example in shirt production, when manufacturers produce shirt they always break down the product into many sub parts

like arm, body, and collar, and take these sub parts to produce in sub production lines such as body production line and collar production line. The problem is garment manufacturers call those sub production lines differently; some companies may call those sub production lines "section", while others may call "department" or "team". To response with this problem this system design tries to use terminology that wildly used in this industry in the design.

Even that many terminology still used differently, so there are two such possible solutions for this problem. First, company may change their terminology in work place to align with terminology in the design. Unfortunately, downside of this action may affect employee to confuse and becomes cause of resistance because employee may familiar with those old words for such a long time and do not want to change to the new one. Second solution is to change wording in the design to align with company before implement the system. This solution helps company to reduce employee confuse and resistance, but for downside company may waste time and cost to change words in design.

Whether using first or second solution this design of system can support both of it, but one recommended solution is second solution, because it can reduce employee confusion and resistance. Even it consumes some resources to do such as time and money, but making worker confuse may lead the project to failure, so when compares cost and benefit it is better to pay some resources to fix this issue before implementing the system.

6.2.2 Flexibility of system

Absolutely, different firms may have different requirements even those firms are playing in the same industry. Therefore, there are many comments from users that want the system fully support their requirements and manufacturing processes. For example in shop floor, manufacturers may assign target by team or by person depend on their payment system or production planning method. Therefore, target of each review point is relied on type of worker assignment. Solution for this problem in this design is to provide flexibility for many types of usage. For example, whether team or person assignment this design of system can support calculation of target for both of it.

Another comment is about review frequency, because some companies do not want to waste their time to review production every hour while some companies require reviewing production as much as they can. Likewise, even in same company users also require flexibility of the system to choose review frequency as they want. Because some

companies may give more important to review production every hour only in main production line such as assembly line and for others they may prefer to review only once or two times per day. Therefore, this design of system also provides flexibility for users to choose range of time to review the production as they need.

Another important issue is difference of monitoring tool and method in shop floor. For technology leader they may use real time data gathering application such as RFID (Radio Frequency Identification) or barcode tool to get data from shop floor as real time information system. But, typical garment manufacturers may use supervisor to count the production from time to time and record it into soft copy like paper before send to central database or production control. Hence, this system is also designed to support data from wide range of tools including RFID, barcode, and direct input from worker whether it is real time information system or not.

In conclusion, there are many different requirements from users that want the system to flexible enough to support their business processes, which this design tries to provide flexibility for users to fit with their requirements. However, the greater flexibility, the greater complexity of system, therefore this design of system trying to design system that meet the midpoint between flexibility and ease of use.

6.2.3 Consume amount of time to operate

Even this design of system tries to eliminate all unnecessary processes in each UI, but there are some UI in the system that have many processes cannot be eliminated, which make that UI pages require quite long time to operate. For an example in UI 1.1.1 "Select Review Point", this UI consumes amount of time to operate because users have to select the each review point by themselves. And, the problem is they have to do in every purchase order. The solution for this problem in this system design is to try to reduce unnecessary processes in that UI and provides functions to reduce repetitive works. For example in UI 1.1.1; "Set Review Point", users do not need to waste time to create new review points for every purchase order, because system provides pattern of review points to load if product or processes of that order similar to previous order.

Another interesting comment from interviewees is time used to get into destination UI. Many of them claim that some UI in design need to pass through many UI before reach the UI that they want to use, which waste their time to operate the system. Solution for this problem in this system design is to encourage users to get to target UI as fast as it can be by provides linkage to almost UI from tree diagram in main menu. Hence, users can go to their destination UI page immediately by choosing that UI from menu.

However, for some UI pages which require operation from previous UI before users can operate UI they want, users still have to do follow the steps. For example; UI 1.1.1 "Select Review Point", users have to go to choose purchase order that they want to set review points in UI 1.1 "Search P/O" before pass through to set review points in UI 1.1.1 "Select Review Point" and "Create Line of Balance (LOB)" in UI 1.1.1.2, consequently.

6.3 Report Verification

The verification of this research does not focus only on User Interface (UI) but it also giving important for report. The verification criteria of report are as same as verification criteria of UI including ease of use, speed of operation, and user's satisfaction. But, one thing differently is report of this system add legibility issue in the verification because some reports of this system are used to make the decision, so if it is difficult to read users may get the wrong information and affect them to make the wrong decision which can harmful the company. Nevertheless, some interesting comments from interview are described in next issues.

6.3.1 Legibility of report

Legibility of report is crucial important for this system design. As described, difficult report can lead the user to miss understanding the information and leads them to make inappropriate decision. Initially, there are many comments from interviewees about the legibility of report. Many of them claim that some reports are too much complicate to read and also include irrelevant information. Therefore, solution for this problem in this system design is to try to use table, list, graph and illustration instead of text to describe the content in report. In addition, it also tries to focus only on important data and eliminate all irrelevant data. These can help user easily to understand content and also legible.

6.3.2 Flexibility of print option

Because some reports in this system design has many types of illustration in one UI. For an example; UI 1.4 "Line of Balance (LOB)", this UI can print two types of report including report that shows graph Line of Balance (LOB) and data table of that LOB. These two reports represent the same thing which is progression of production in shop floor compares with target. However, objective of each type of report is used differently, for graph it cannot show in depth detail about that LOB such as number when compared with data table, but for upsides it is much easier and legible to read.

Therefore, when users need to print out the report of this UI they may not want to waste resource to print out both types of it. So, they require the system to provide the print option to select type of report they want.

Moreover, even some reports has only one type of report to select, but it may has many illustration types in that report, for instances, tree diagram, picture, text, and table, which this system design also provides flexibility in this point by giving a chance to select types of illustration before prints the report out.

In conclusion, from these problems, so this system design tries to response and solves it by adds printing option in some UI for user to select thing that user wants before print out the report in order to reduce printing cost and time. Report print option illustrations are showed in Appendix E. However, the samples figures of report type and report illustration selection of print option in this system design are showed in Figure 56 and Figure 57.

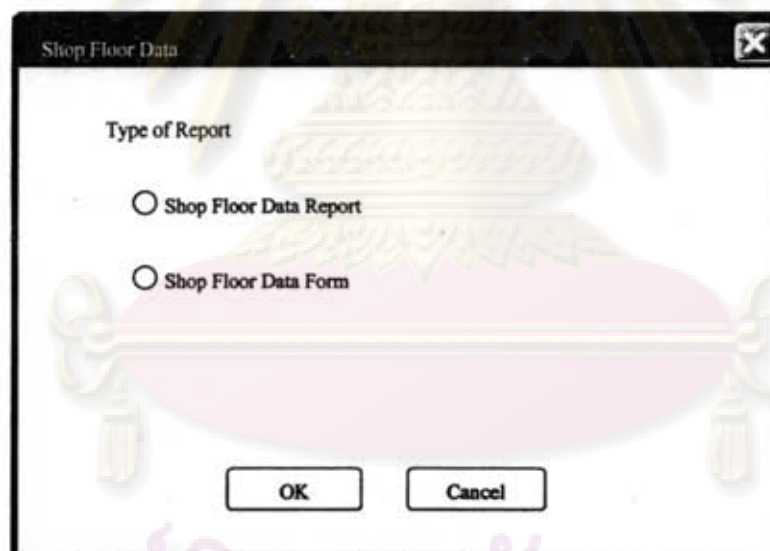


Figure 56. Sample Figure of Report Type Selection



Figure 57. Sample Figure of Report Illustration Selection

6.4 Conclusion of System Verification

Even different companies have different requirements and comments, many of those requirements and comments have been brought to improve the system especially some severe issues, for examples, conflicts between system and real work condition in industry, flexibility of system, wording in UI, and legibility of report. Comments from interviewees are applied in this system design until interviewees satisfy in the system.

And, consequently in the latest version as interviewed from 10 interviewees, which are users and experts in system development most of them agree that this system can react with requirements and concepts that stated in this research with average satisfaction score 4.78 (Max. =5). Furthermore for conclusion of overall of the system, the average satisfaction score is 4.7 (Max. =5), most of them satisfy in the system and confident that the system can be applied to use in their companies. When compares with present production control and monitoring method their confident that it able to improve their production control and shop floor monitoring performance.

However, the conclusion table and average score that interviewed from interviewees in overall of system verification of the latest version is showed in Table 6.

No.	Question	Average Score
Reaction with Requirements and Concepts		
1.	Does this system can warn you to know shop floor problem quicker?	4.8
2.	Does this system can help manufacturer to better recognise progress in shop floor?	4.8
3.	Does Line of Balance (LOB) provided in this system can help user to clearly see progress and problem in shop floor?	4.7
4.	Does worker efficiency provided in this system can help production planning able to plan target closer to actual output?	4.8
5.	Does shop floor information provided in this system adequate for production control to make corrective decision?	4.6
6.	Does information of shop floor problem that collected and reported in this system useful for you to make productivity improvement?	5
		4.78
Conclusion		
1.	Does this system can implement to use in your company?	4.6
2.	Does this system easily to use?	4.6
3.	Does this system can fulfill your expectations and requirements?	4.7
4.	Does this system can improve your production control and monitoring performance?	4.8
5.	Do you satisfy with this system?	4.8
		4.7

Table 6.Conclusion of Overall of System Verification

**Note: Very bad = 1 point and Very good = 5 points

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CHAPTER VII CONCLUSION

7.1 Conclusion of Research

The objective of this research is to design system for the garment industry that can manage and uses shop floor data helping to monitor progress in shop floor. Finally output of research includes;

- Design of system that garment manufacturers can create review points and collect production data from those review points in order to reports to production control, which helps production control able to recognise progress and problem in shop floor.
- Warning system that warns production control when any review point miss the target and also indicates the problem process, which helps production control can recognise and correct problem earlier before it becomes big problem.
- Design of system that brings shop floor data to calculate and sends to update worker efficiency continuously, which helps production planning gets reliable and up to date information to plan target.
- Design of system that helps garment manufacturer to collect and manage problem data from shop floor, which manufacturers can bring problem data from this system to analyse and improve productivity when time has passed.

During system in this research is being developed, it is verified by experts in system development and people in garment industries especially end user of each UI. Comments of interviewees are applied into system to develop new versions again and again, and from the interview of the latest version most of them agree that this system can properly react with requirements and concepts that stated in this research with average satisfaction score 4.78 (Max. =5). Furthermore, for conclusion of overall of the system, most of them satisfy in the system and confident that the system can be applied to use in their companies and able to improve their production planning and control and shop floor monitoring performance with the average satisfaction score 4.7 (Max. =5).

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7.2 Research Problems

7.2.1 Conflict between system and real working condition

As stated before, different company may have different business processes, so one big problem that always found in this study is conflict between system and actual working condition. It always appears that the system that aligns with business processes of company A may not be able to apply in company B. However, to handle with this problem the system design in this research tries to find the midpoint and design the system that flexible enough to support various types of business processes.

7.2.2 Limit of business and technology knowledge

Another problem in the study is constraint of business and technology knowledge. Despite analyst of this research studies about business knowledge in garment industry and some basic technology and system development knowledge before design this system, but sometimes those knowledge still inadequate to cover all things that are needed to use in development.

Absolutely, no one can know and be expert in everything, so sometimes the design of system cannot be applied in actual working condition. The limit of business knowledge makes the design of system does not match with actual business processes in workplace. Likewise, limit of technology knowledge makes the analyst unable to know that what technology can do or cannot do.

However, to response with this problem the study gets both people in industry and experts in technology and system development involve in development by using interview and questionnaire to verify system and bring their comments to improve system.

7.2.3 Low commitment of interviewees

As stated, this research brings user in industry and expert tem development to help to give suggestion. But, sometimes those people have to work with their job which some of them may not be pleased to spend their time to give information and help to verify system.

7.2.4 Complicate collaboration between the system and other modules

Because this system design is a module of the project "SAM-g2", hence many data and parts of system have to interfere with other modules in the project. So, it increases complexity of this project because analyst has to clearly understand the job of other

modules and clearly knows what data system needs from them and what data they need from this system.

7.3 Suggestions

7.3.1 Pre-consider project identification and selection and project initiating

This research does not consider step 1 and 2 in System Development Life Cycle (SDLC) which are project identification and selection and project initiating before creates the system. But, actually these two steps are important for company. In fact, it is better if company considers these two steps in order to make sure that company gets in the right track and has high chance to succeed the project.

Project identification and selection step helps to identify problems and selects the most suitable project for each company. Absolutely, different company may have different problems and requirements, and sometimes it is impossible to do all of it. So, company should find the project that able to response with current severe issue and contribute the highest return on investment (ROI).

For project initiating step, this step is about resource planning, project feasibility, and target planning. It often occurs that many information systems cannot contribute the benefits that management team expects. And, many information system projects fail because company's resources inadequate to draw the project to the end. Therefore, after company decides to work on any project company shall take in depth analysis about its feasibility, return of investment (ROI), and resources. These considerations help to make sure that the project is worthwhile to do and company has potential enough to do that project in order to reduce project failure chance.

7.3.2 Use joint application development (JAD) technique in development

Joint Application Development (JAD) is a technique that tries to get all related functions in company to join in the development project, for examples, top management, system developer, IT manager, manager of department that project focuses, and end user. According to Hoffer [22], JAD helps to reduce several months of data collection to 5 or 6 days meeting.

JAD provides opportunity for all related participants able to propose ideas in project which can broaden development team's viewpoint and explores hidden problems. Development team can recognise resources constraint from top management,

recognises technical limit from IT manager, and actual problems from department manager.

7.3.3 Increase communication between system designer and software developer

Even this research is the design of system which garment manufacturer can bring to develop in practice in term of commercial software. But, actually although this system design is included many important issues, for examples, process modeling, logic of processes, UI and report design, and ER-diagram which all of these are designed to support software developer easily to write up the software, it is better if software developer has a chance to communicate with system developer directly or if this system are co-developed by both system developer and software developer.

7.3.4 Collect efficiency of every process

In this system design shop floor user can input shop floor data only at the process that is set as review point, but for the process that is not set as review point user will lose a chance to input data into this system. But actually, company it is better to collect data of every process to update worker efficiency continuously which production planning can bring this data to plan the target and production scheduling that close to actual.

Therefore, it is suggested that company should collect data to update efficiency for every processes. Although this system does not support to input non-review point data, user can input data collected from shop floor directly into employee database system which is one module of this "SAM-g2" project. In an addition, to collect data of every process may consume many resources; therefore company may use data that collected for payment system to update efficiency of worker in order to reduce cost. Or, likewise company may apply current system such as coupon system to update data in employee database as well.

7.3.5 Data integrity

This system design is designed to receive data directly from user which it might be direct input by hand, bar coding, or optical scanners. But, key problem in this issue is data inaccuracy. Workers may make error counting or mere to input data into system or supervisor switches to work another job. When these occur, data in the system are wrong, which affect to incorrect production decisions [29]. Results of this problem are excess inventory, stockout problems, miss due date, and inaccurate cost estimation [29]. Therefore, company should beware of this source of problem by trying to communicate workers in order to make them understand damage of this problem.

7.4 Further Research

7.4.1 Make information system implementation strategy

Implementation strategy is one such critical success factor of project. Most of human resists change especially thing that relates to technology. Even the best system if company overlooks this issue the company may has high chance to be failure. Therefore, further research may study to plan the implementation methodologies and strategy of this system. The implementation shall start from small to large like from instead of entire enterprise implements. The study may also focus on change and risk management and hardware requirement system implementation. The strategy may also include issues like resources planning, time target, financial analysis, and maintenance.

7.4.2 Design system to analyse and manage shop floor problem

Actually, even shop floor problem in garment industry occurs every day simultaneously, but it appears that there is limit of software which specifically focuses on this issue. Although this system design provides a part that supports garment manufacturers to collect problem in shop floor and store it systematically, the system does not provide pattern of garment's shop floor problem as a guideline for user to collect it effectively. Furthermore, this system design also does not include problem analysis that can help to analyse and identify the point in shop floor that should be corrected.

Indeed even different company may have different problem, but most of problems in garment industry that occur in shop floor are always same. Therefore, the future research may study to collect shop floor problem in garment industry and design the cluster of shop floor problem for garment industry which can be used to manage this data efficiently and effectively. The system may cover the part that helps company to analyse shop floor problem and able to identify the part of company that company should take corrective action. Furthermore, if the study also includes solution guideline to solve each problem it will be very useful. In an addition, from all of these the future research may study to design expert system that can identify problem that should be collected and find the most appropriate solution to solve that problem automatically.

7.4.3 In-depth study learning curve in production planning

Although this research considers and uses learning curve to develop shop floor monitoring system and provide information for production planning, the learning curve in this research is just used to show the change of worker's skill when time has changed and update worker efficiency all the time to use to calculate new target which can support top management to make the better decision and plan better target.

Nevertheless, it appears simultaneously that the learning issue is still the biggest issue that affects production planning in garment industry to always miss the plan. Even this system design supports manufacturer to collect worker efficiency and update it all the time, which helps production planning able to plan the production schedule that closer to the real output. But, for long production in big lot size like 15 days or a month the worker efficiency of first date and complete date can be much significantly different. So, it means that the longer production time, the higher variation of plan. Therefore, one better solution suggested herein is to find the way to predict the increasing rate of worker skill and bring that information to plan the dynamic production plan which has different target when time has passed. For example, target of day 1,2, and 3 may be increasing rate like 10 units, 15 units, and 20 units, respectively instead of flat rate like 10 units every day.

Hence, another interesting application of learning curve that can help to improve production planning performance is to apply learning curve theory in the production plan. The further research may study to find learning curve model or method to predict future output that closing to the real. The method shall able to calculate the target of each process and can estimate number of required production days more correct even efficiency of worker trend to increasing every day.

However, there are many learning curve models from various academic experts, for examples, log-linear model, exponential model, and Stanford-B model, which different industry even different company may suit with different model. So that, one thing that further research shall be very careful is to find the model that can align with characteristic of garment industry.

7.4.4 Find the most influence learning factor

However, there is another such interesting learning issue which is the learning factor. In actual there are many factors that can affect to learning rate of worker, for examples, task complexity, length of process, and type of machine. As stated before in Chapter 3 the system design in this research suggests company to collect efficiency of worker as skill to use for calculate production plan and target. This means that the learning curve of this research is considered as skill by skill as well. So, the same skills are assumed that it have the same learning curve.

Unfortunately, this research does not identify the most influence learning factor that should be used as the issue to group those skills. It just allows user to group processes as skill by themselves because at the present most of manufacturers have their own

grouping method. But, in actual the method that those manufacturers are using may inappropriate for this industry. Therefore, the further research may study to find the most influence factors that can affect to worker efficiency and learning curve and bring those factors to find the appropriate ways to group the skill.

7.4.5 Design shop floor monitoring system for other sections

Even the most important section of garment manufacturing processes is sewing operation, but the future research may bring concepts and design of this system to modify and apply to use in other sections in the plant such as cutting and packing sections.

7.4.6 Design shop floor monitoring system for leather industry

Actually, the production of some leather products such as hand bag, wallet, and shoe, has many characteristics similar to garment industry. Moreover, many garment manufacturers also produce leather products in their plant because many know how can use interchangeably. In addition, the main process of leather production is similar to garment which is sewing process. Therefore, further research may study to modify and apply this system design to use in leather industry as well.



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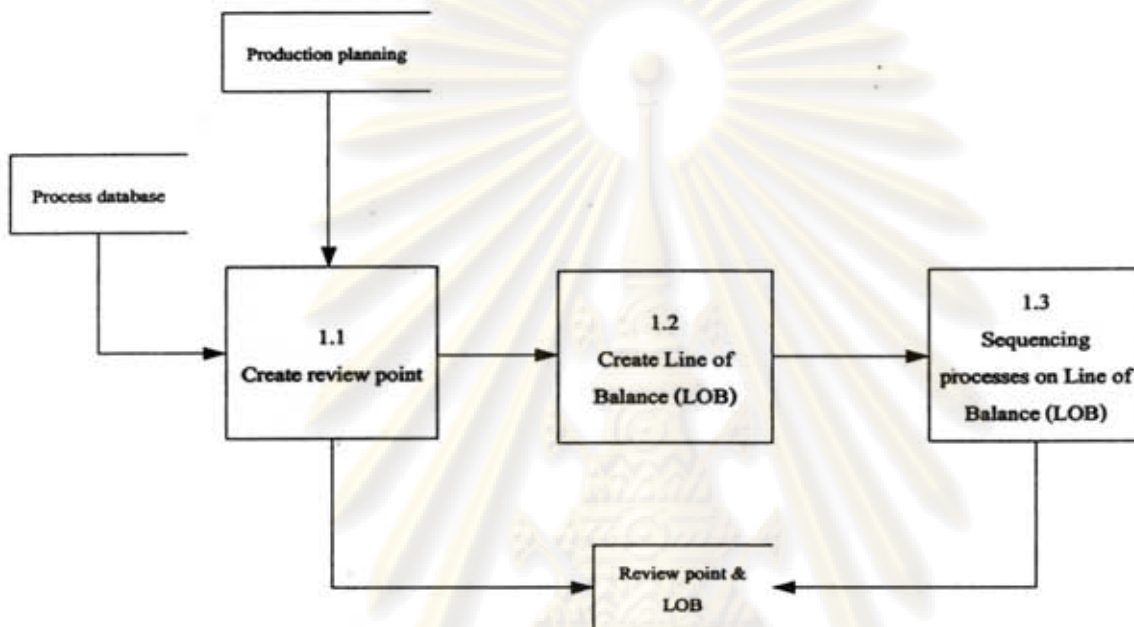
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APPENDIX A
WORK FLOW DIAGRAM

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Level 1 of process 1

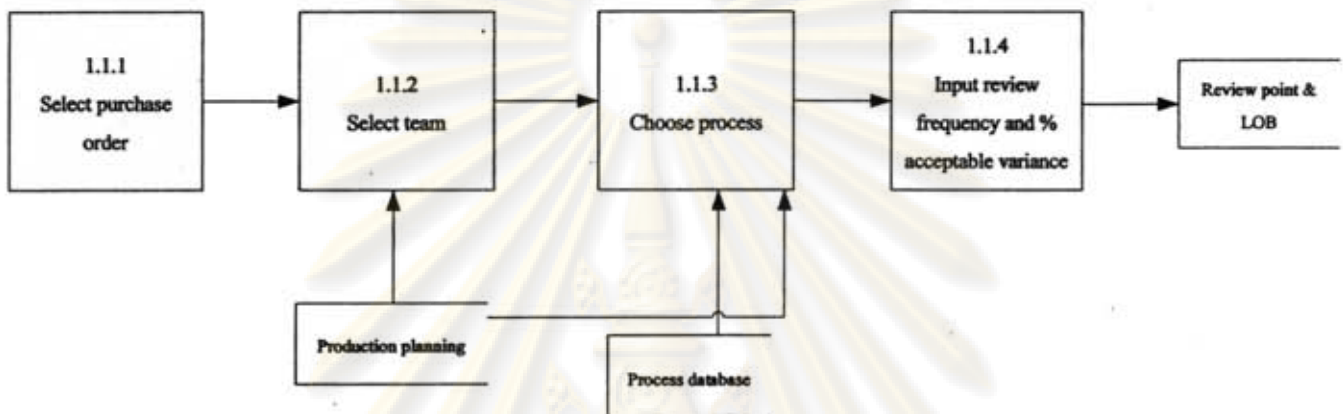


This process concerns about creating review point and Line of Balance (LOB). The process starts at user select process to be review point. To select process system requires information from production planning in order to know that what purchase order has already finished production planning process, because the purchase order that going to be set review point must be only the order that has been planned by production planning before. When administrator user wants to select review point system will bring process data to show all processes used in each purchase order from process database and production planning database, and then user needs to select the process that wanting to set as review point. After finishes creating, review point the review point that user selected will be stored in database "review point & LOB".

Another step is to create LOB. The review points that are selected in previous step will be brought to create LOB in process 1.2 and get into sequencing process at process 1.3 before send back to store in database.

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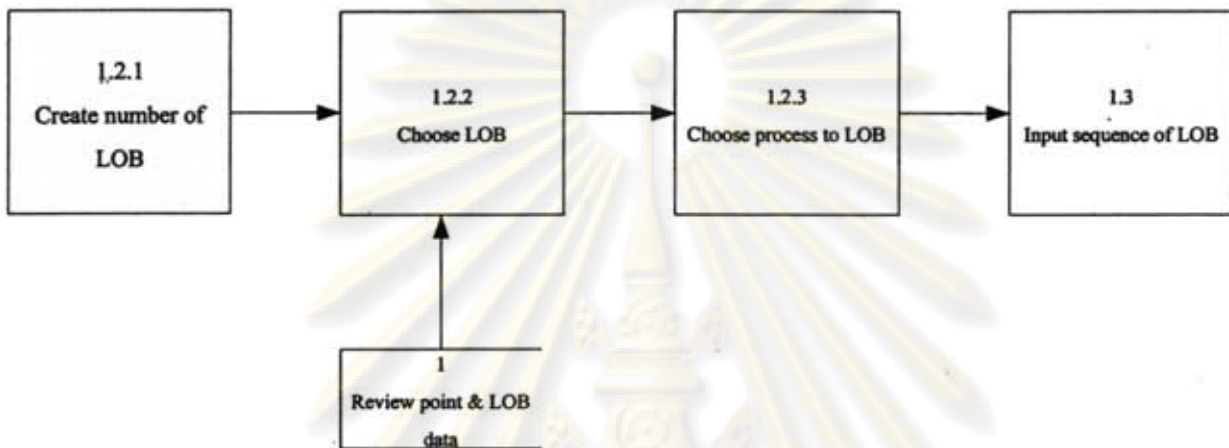
Level 2 of process 1.1



This is deeper level of work flow diagram of process 1.1 "create review point". To operate this step user needs to select P/O and team that wants to create review point at process 1.1.1 and 1.1.2, respectively. Then, user has to choose processes that needed to set as review points. After that, user also has to choose review frequency and percent acceptable variance, then review point and its details that user set will be stored in "review point & LOB" database.

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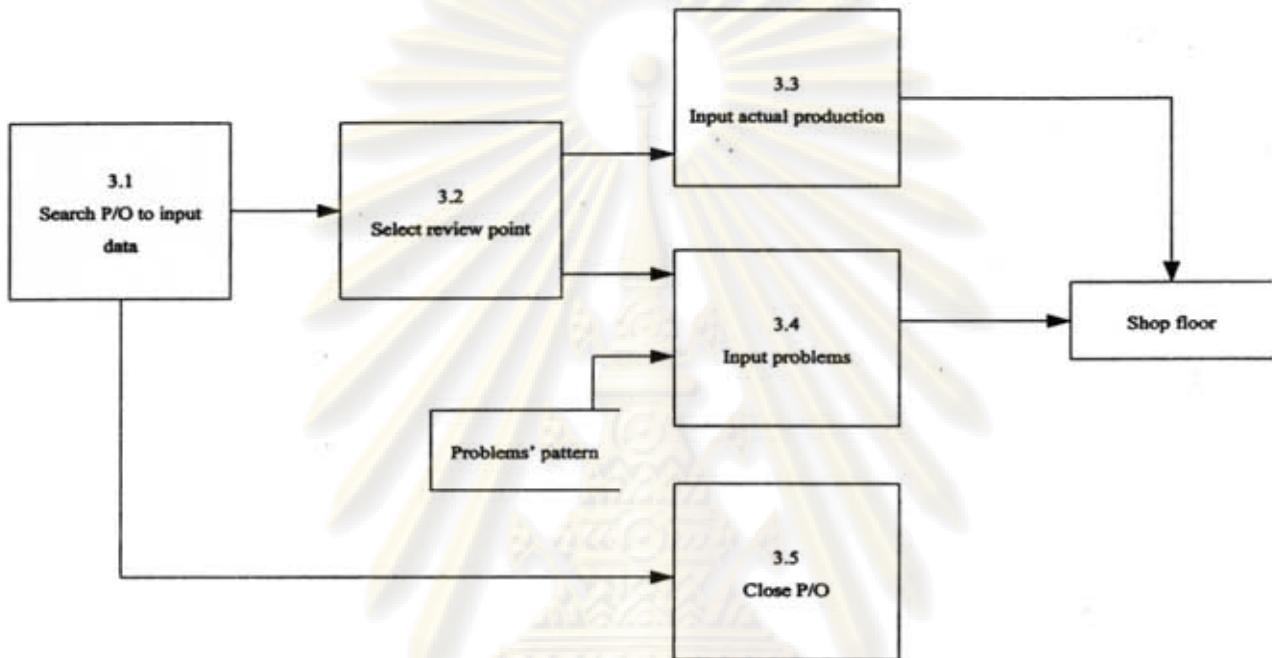
Level 2 of process 1.2



This is deeper work flow diagram level of process 1.2 "create Line of Balance (LOB)". Process starts when user sets number of LOB and names it in process 1.2.1. After that user has to choose LOB that wants to setting at process 1.2.2 and choose process to locate in each LOB in process 1.2.3. Lastly, user can also rearrange sequence on LOB in process 1.3 in order to make it align with real operation process flow in shop floor.

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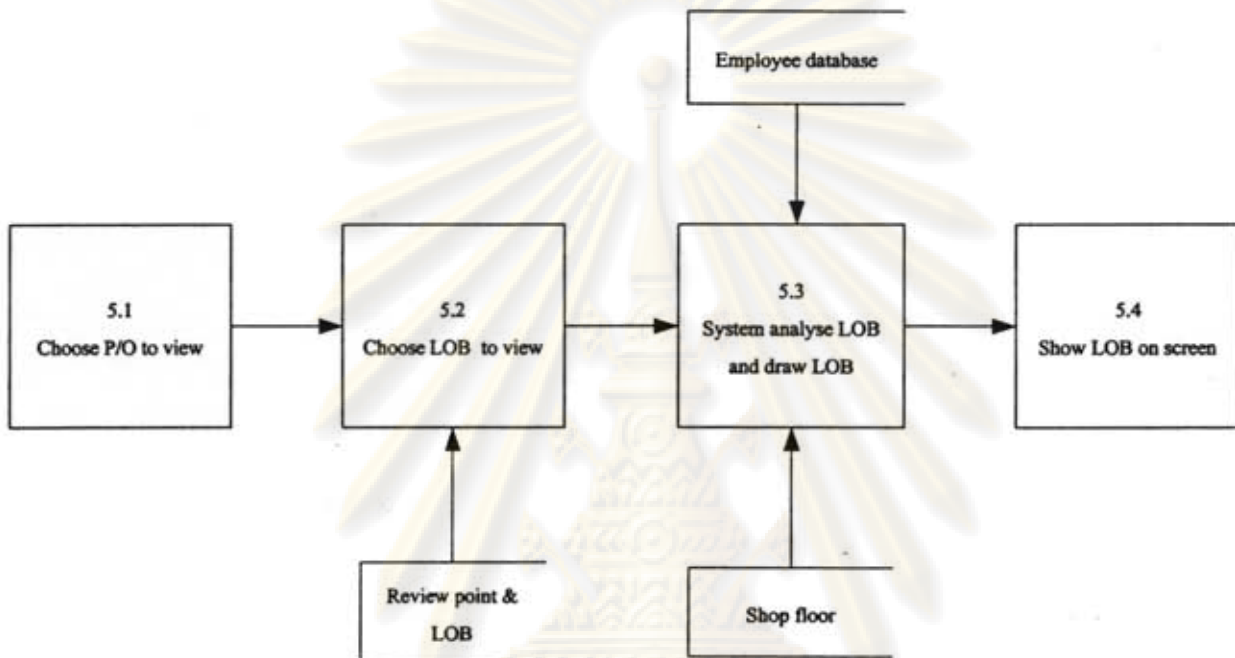
Level 1 of process 3



This process concerns about inputting data in shop floor. The first procedure of this process is to search P/O to input data at process 3.1. Then user has to select review point which wants to input data at process 3.2. After user selected review point user can input data into system. The data that user can input including actual production and problem. The actual production is inputted in process 3.3, while problem is inputted in process 3.4. These two data will be stored in database 2. In addition, when any purchase order is finished user can also confirms to close that order at process 3.5.

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Level 1 of process 5

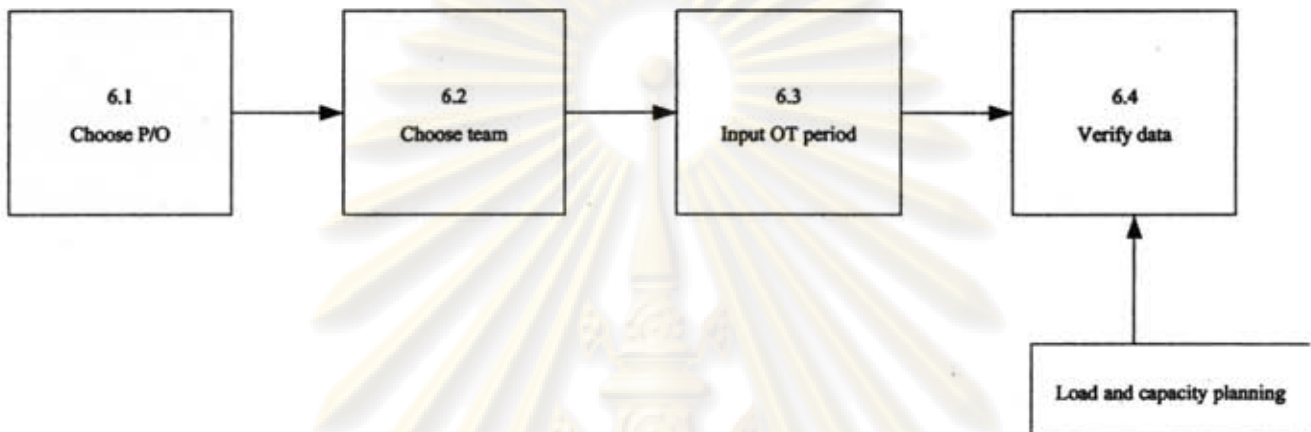


This process concerns about analysing and creating Line of Balance (LOB) to monitor progression in shop floor closely. First step starts at user choose the purchase order wants to analyse and see LOB at process 5.1. One thing important in this step is purchase order that showed on this UI must be only the purchase order that is producing on shop floor. Therefore, the order that has not started production yet or already closed order will not be showed on this process.

After user has got the purchase order user has to choose the LOB that wants system to analyse and draw which is process 5.2. Once user select any LOB the system will transfer that LOB data from database and uses shop floor data from database 2 to analyse and draw LOB at process 5.3.

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Level 1 of process 6

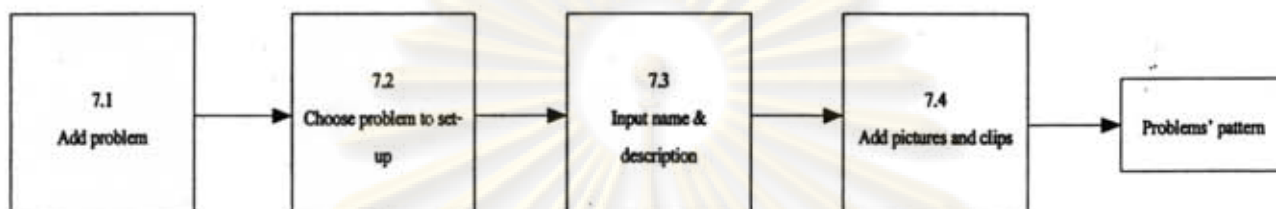


This process concerns about in inputting unplanned overtime in shop floor. To operate this process first of all user has to choose the purchase order and team that wants to add overtime period at process 6.1 and 6.2, respectively. Again, in this step the purchase order that showed on this process must only be the purchase order that is producing in shop floor. The order that has not stated production yet or already closed order will not be showed on this UI.

After user has selected purchase order and team that wants to add overtime period, the following step is to input overtime duration at process 6.3. This step once user inputs data into system, the system will send the duration to verify with "Load and Capacity Planning" agent at process 6.4 in order to check that the duration of this unplanned overtime is not repetitive with planned overtime.

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Level 1 of process 7



This process concerns about creating problems' pattern to use in shop floor. First step administrator user has to add new problem in the group at process 7.1. After that administrator user needs to choose the problem that wants to set-up at process 7.2. After selected problem user can input problem name and description at process 7.3 and adds multimedia file at process 7.4. And, finally all data will be stored in database to use in shop floor in later step.

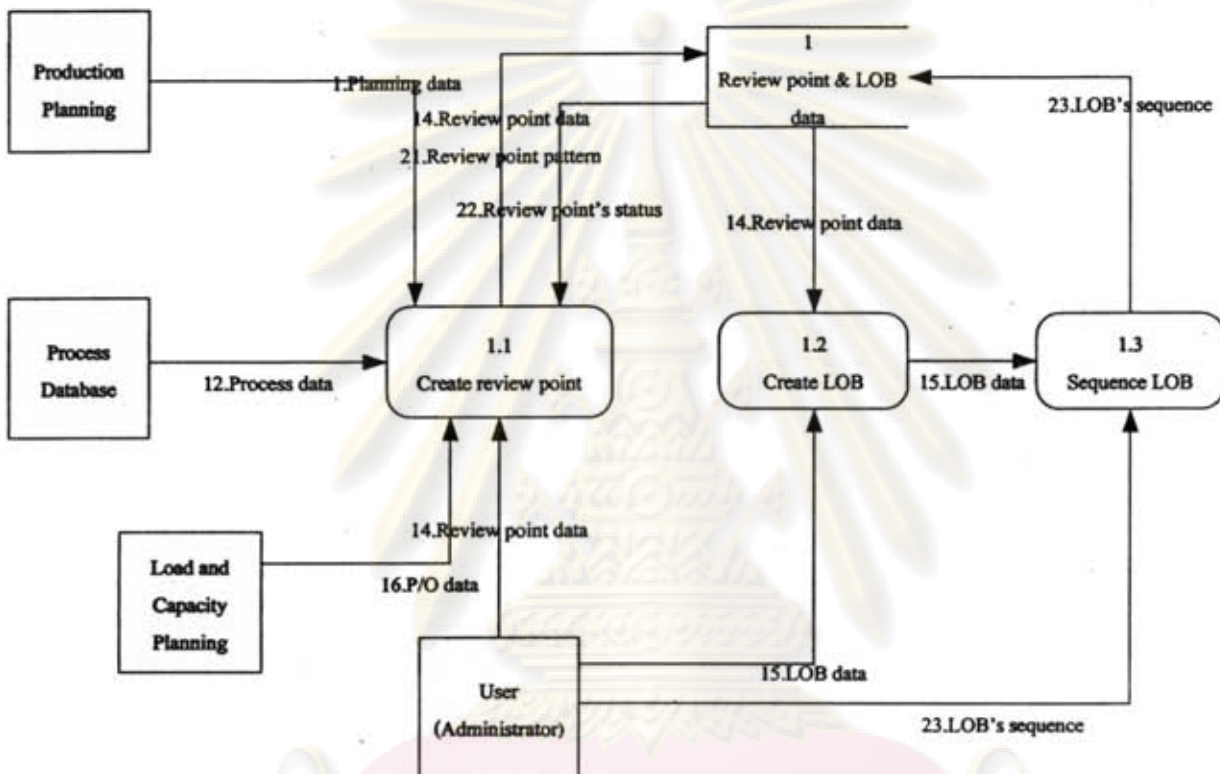
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APPENDIX B
DATA FLOW DIAGRAM

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Level 1 of process 1



This process concerns about creating review point and Line of Balance (LOB). The process starts at administrator user selects review point in system. To select review point system requires information from "Production Planning" in order to know that what purchase order has already finished production planning process, because the purchase order that going to be set review point must be only the order that has been planned by production planning before. And, when administrator user wants to select review point system will bring process data from "Process database" to show all processes used in each purchase order and then user needs to select the process that wanting to set as review point. Moreover, the purchase order data is also brought from "Load and Capacity Planning" to show the properties of each order.

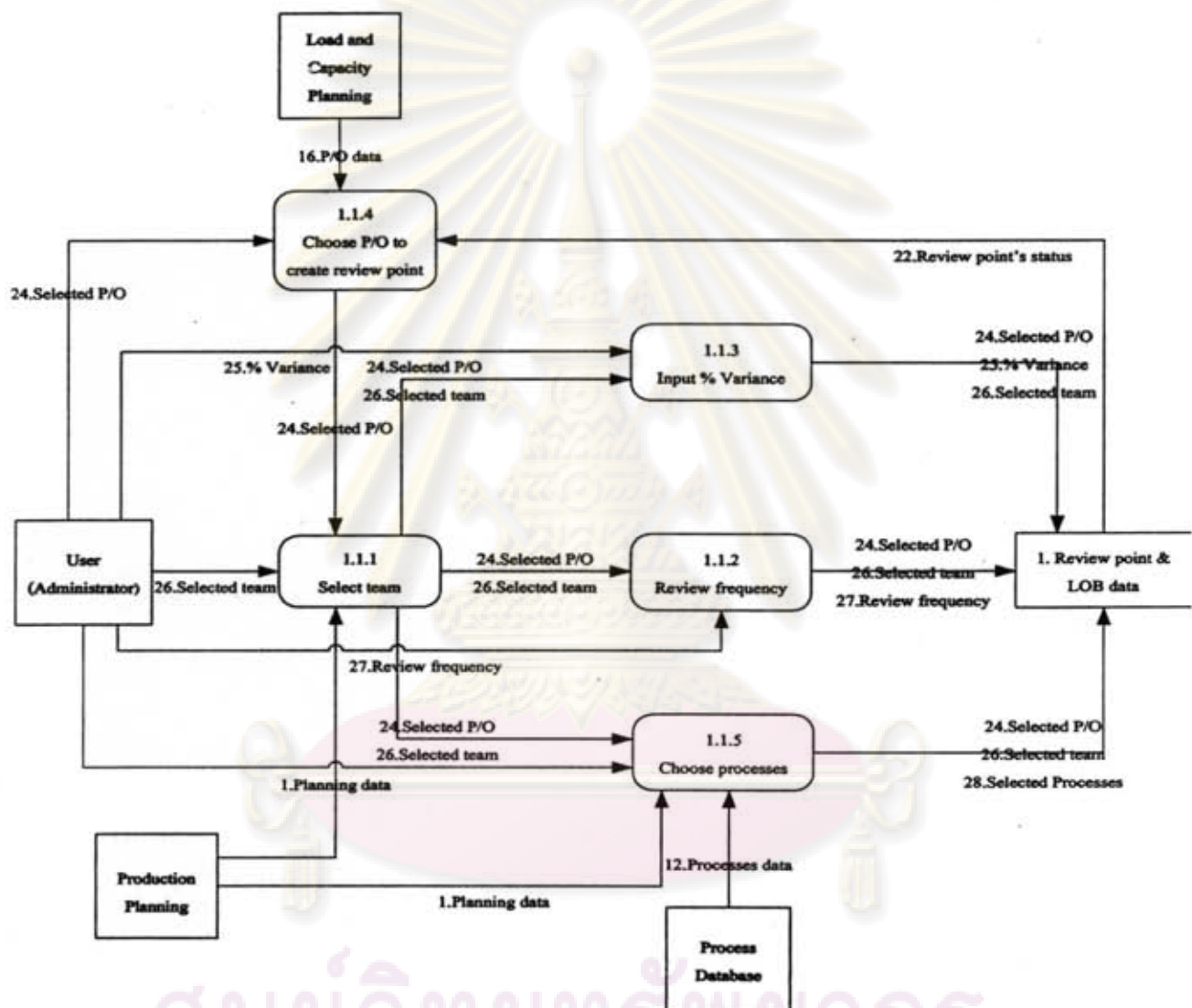
After finishes creating review point, the review point that user selected will be stored in database 1 "review point & LOB data". And if, user wants to save these review point as pattern to use again review point pattern will be stored in this storage as well.

Next step is to create LOB. The review points that are selected in previous step will be brought from database to create LOB in process 1.2 and get into sequencing process at process 1.3 before send back to store in database 1.



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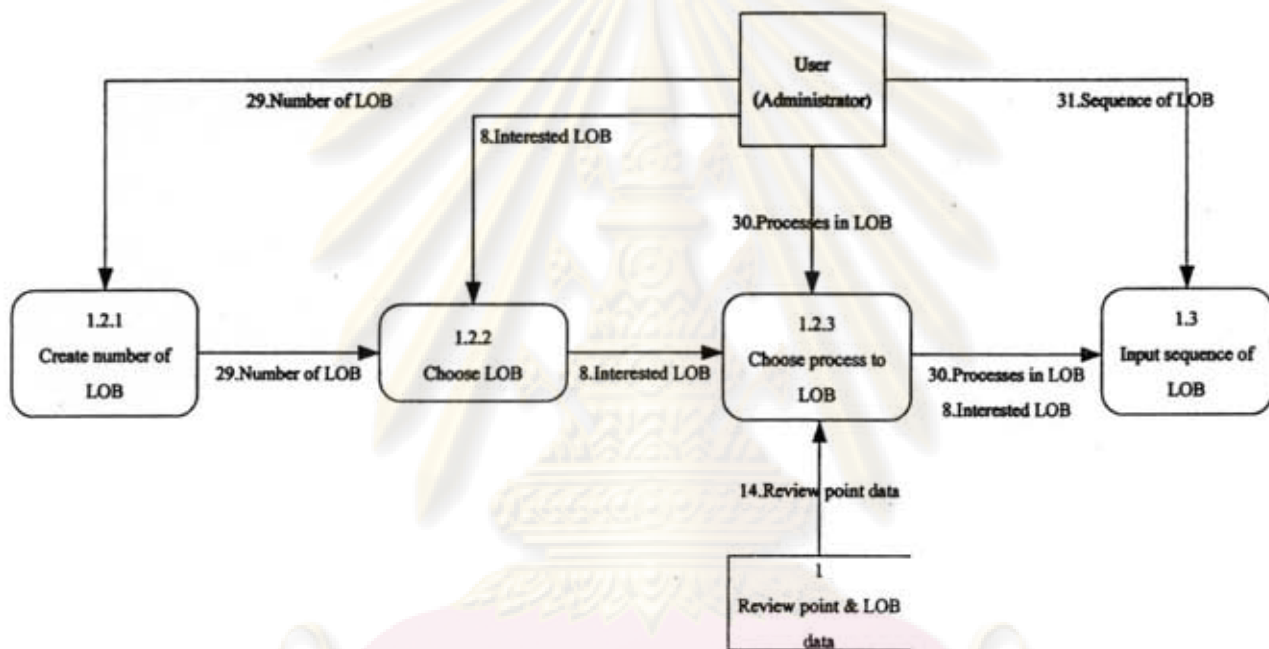
Level 2 of process 1.1



This is deeper DFD level of process 1.1 "create review point". To operate this step administrator user needs to choose P/O and team that wants to create review point. In this step system requires planning data from "Production Planning" to know teams that are used in each purchase order. Then, user can choose processes to set as review points. Processes that are showed on this step are operation processes flow in that order which brought from "Production Planning". And, information such as process name and process id are brought form "Process database".

After that, user also has to choose review frequency and percent acceptable variance. Then review point and its details that user set will be stored in "review point & LOB data" database.

Level 2 of process 1.2

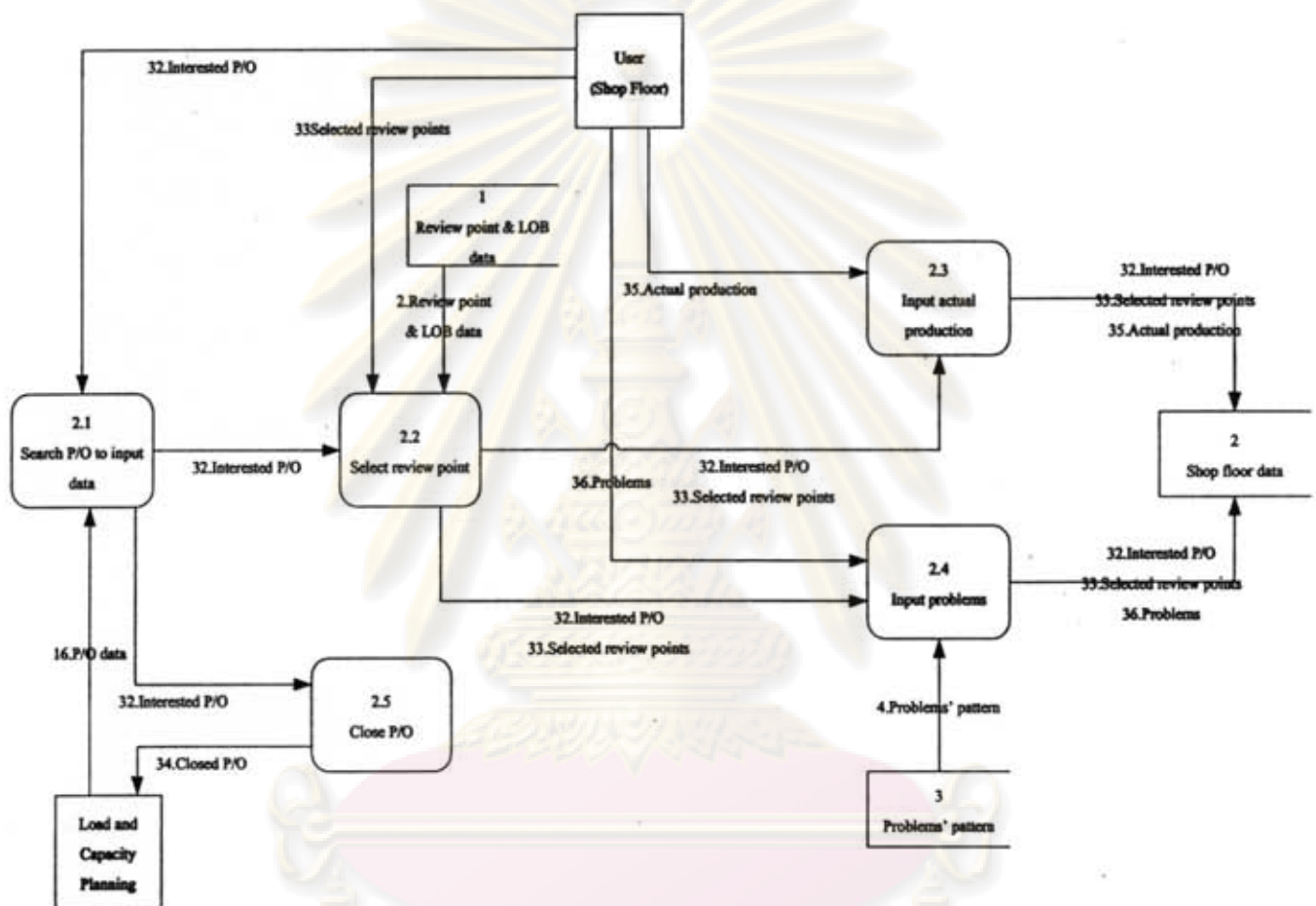


This is the deeper DFD level of process 1.2 "create LOB". Process starts at administrator user sets number of LOB and rename in process 1.2.1. After that user has to choose LOB that wants to setting at process 1.2.2 and choose process to locate in each LOB in process 1.2.3. In this step, system will bring the review points that were selected as review points from "Review point & LOB data" database to show on this process.

Furthermore, once user has selected all processes, user can also rearrange its sequence on LOB in process 1.3 in order to make it align with real operation process flow in shop floor.

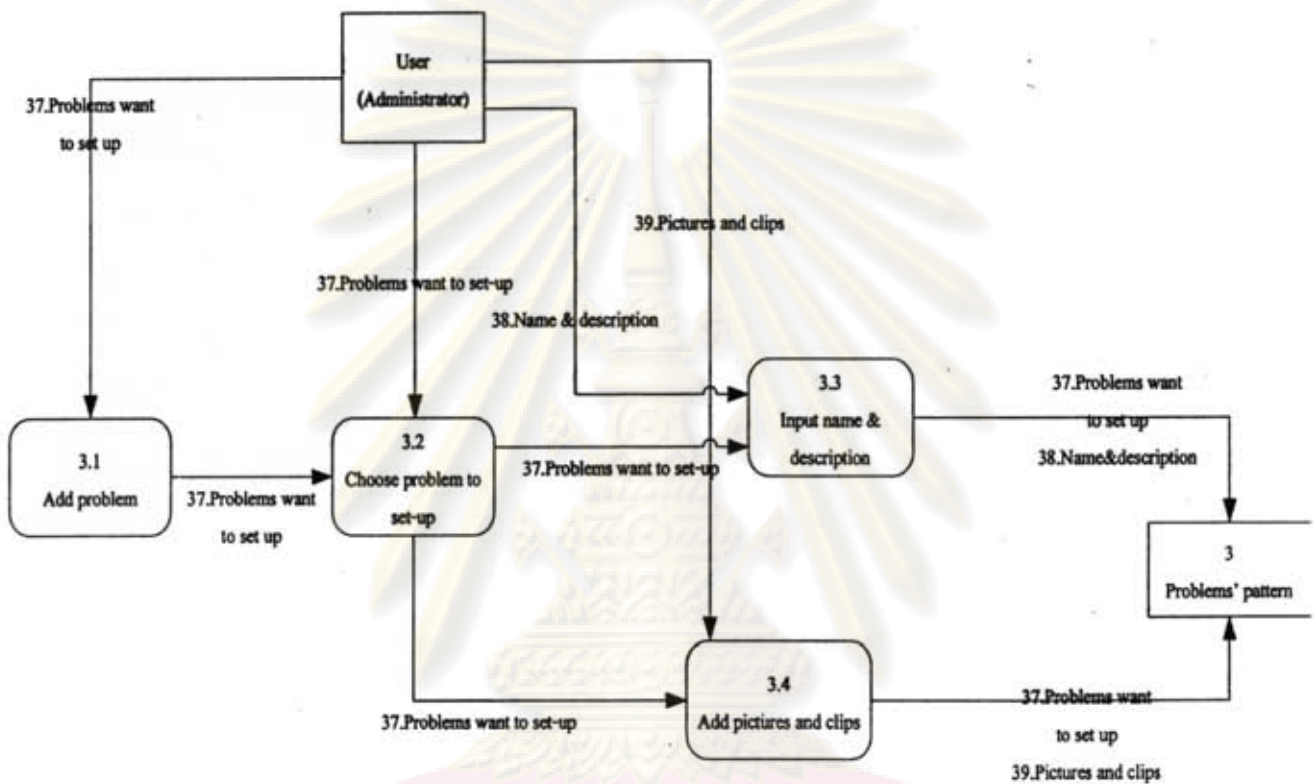
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Level 1 of process 2



This process concerns about how to input data in shop floor. The first procedure of this DFD is to search P/O to input data at process 2.1. At process 2.1 system will request for purchase order data from "Load and Capacity Planning" to show purchase order detail on the UI. Then user has to select review point which wants to input data at process 2.2. After user selected review point user can input data into system. The data that user can input including actual production and problem. The actual production is inputted in process 2.3, while problem is inputted in process 2.4. To input problem into system user can choose problems that have been set as pattern before which helps user to safe operating time. In the end, these two data including production and problem data will be stored in database 2. And in addition, when any purchase order is finished user can also confirms to close that order at process 2.5.

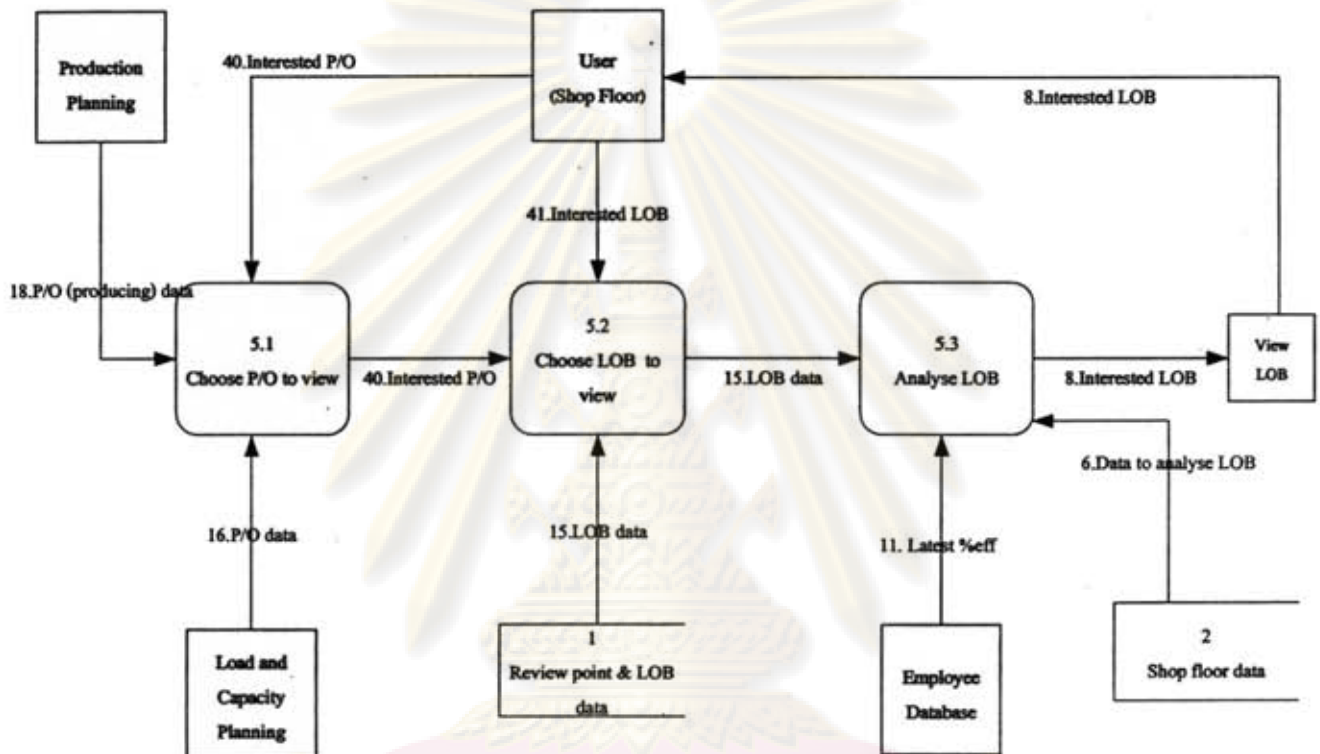
Level 1 of process 3



This process concerns about creating problems' pattern to use in shop floor. First step administrator user has to add new problem in the group at process 3.1. After that administrator user needs to choose the problem that wants to set-up at process 3.2. After selected problem user can input problem name and description at process 3.3 and adds multimedia file at process 3.4. And, finally all data will be stored in database 3 to use in shop floor in later step.

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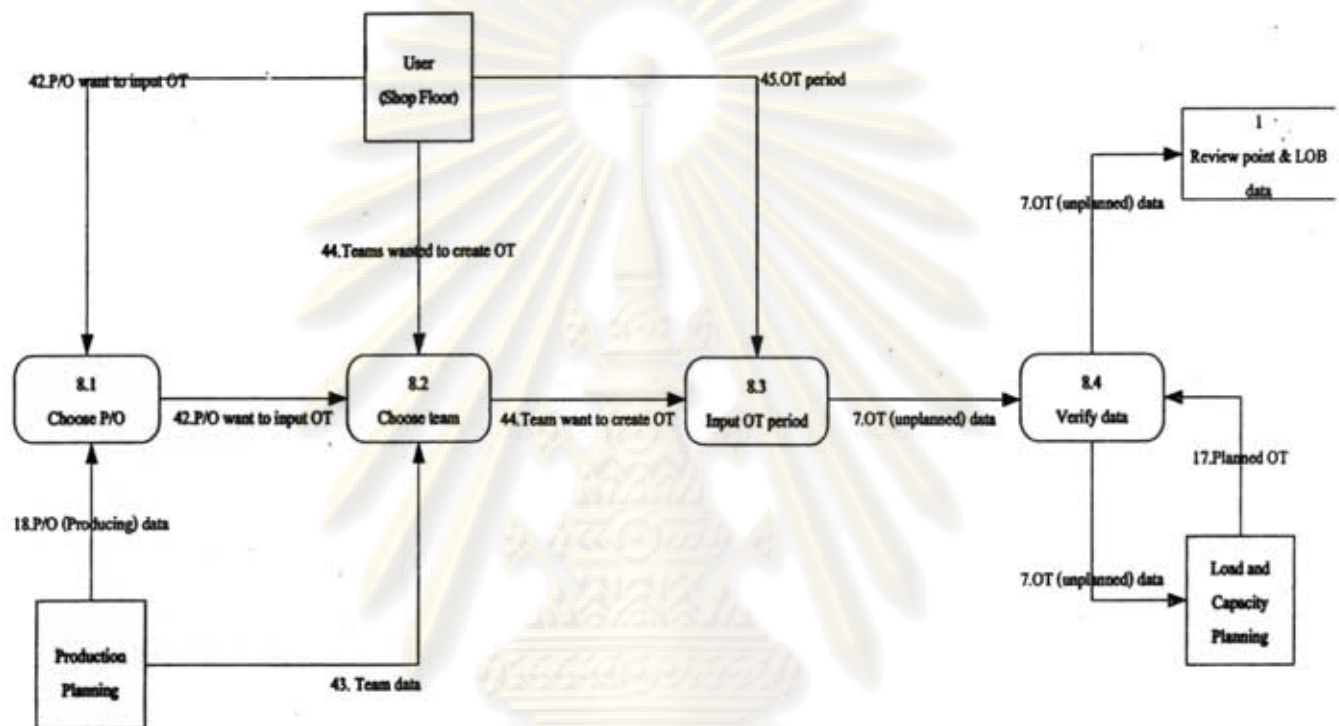
Level 1 of process 5



This process concerns about analysing and creating Line of Balance (LOB) that used to monitor progression in shop floor. First step starts when user chooses the purchase order wants to view LOB at process 5.1. One thing important in this step is purchase order that showed on this UI must be only the purchase order that is producing on shop floor which this information is brought from "Production Planning". Therefore, the order that has not started production yet or already closed order will not be showed on this UI.

After user has got the purchase order, user has to choose the LOB that wants system to analyse and draw which is process 5.2. Once user selects any LOB, the system will transfer that LOB data from database 1 and uses shop floor data from database 2 to analyse and draw LOB at process 5.3.

Level 1 process 8



This process concerns about in inputting unplanned overtime in shop floor. To operate this process first of all user has to choose the purchase order and team that wants to add overtime period at process 8.1 and 8.2, respectively. Again, in this step the purchase order that showed on this process must only be the purchase order that is producing in shop floor. The order that has not stated production yet or already closed order will not be showed on this UI.

After user has selected purchase order and team that wants to add overtime period, the following step is to input overtime duration at process 8.3. Once user inputs data into system in this step, the system will send the duration to verify with "Load and Capacity Planning" agent at process 8.4 in order to make sure that the duration of this unplanned overtime is not repetitive with planned overtime.



APPENDIX C
DATA DICTIONARY

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1. Planning data

No.	Data name	Description
1.	Planned purchase order	Purchase orders that have already planned the production plan will be sent to confirm the user. This data will help user able to know orders user can set the review point. Because user can set review point from the order that has already planned operation processes and allocated workers.
2.	Operation processes	All operation processes used in the purchase order.
3.	Team	Team that is allocated to responsible for the purchase order.
4.	Machine layout	The machine layout of each team in the purchase order.

2. Review point & LOB data

No.	Data name	Description
1.	Review point processes	The processes that user wants to set as review point.
2.	Line of Balance (LOB) data	Line of Balance (LOB) data includes number of LOB user wants to set, name of each LOB, the review points that user wants to locate on each LOB, and sequence of each review points on each LOB.

3.	% acceptable variance	Percent acceptable variance is used as the warning level. When actual production in shop can produce the output lower than the percent allowance that is set in this data, the system will warn user to know the situation quickly in order to response with it.
4.	Review frequency	The frequency that user wants to review the production in shop floor. This frequency is used to generate review time table that will be used to collect data in shop floor.

3. Status of P/O

No.	Data name	Description
1.	Status of purchase order	The status of purchase order includes non-selected, selected review point and selected LOB. This status helps user able to find the purchase order that wants to set quicker. For an example, if user wants to set review point in purchase order that has not set review point before, user can select "non-selected" status to reduce number of P/O will be showed on the screen in order to find P/O wanted to set quicker.

4. Review point data

No.	Data name	Description
1.	Review point processes	The processes that user has already set as review

		point.
2.	% acceptable variance	Percent acceptable variance is used as the warning level. When actual production in shop can produce the output lower than the percent allowance that is set in this data, the system will warn user to know the situation quickly in order to response with it.
3.	Review frequency	The frequency that user wants to review the production in shop floor. This frequency is used to generate review time table that will be used to collect data in shop floor.

5. Shop floor data

No.	Data name	Description
1.	Actual production	The actual output that shop floor can produce in each period of time.
2.	Problems	Problem that occurs in shop floor in each period of time.

6. Data to analyse LOB

No.	Data name	Description
1.	Actual production	The actual that shop floor can produce in each period.

7. OT (unplanned) data

No.	Data name	Description
1.	Unplanned OT purchase order	The purchase order that shop floor wants to increase unplanned overtime (OT).
2.	Unplanned OT team	The team that shop floor wants to increase unplanned overtime (OT).
3.	Unplanned OT period	The duration that shop floor wants to do unplanned overtime (OT).

8. Interested LOB

No.	Data name	Description
1.	Interested Line of Balance (LOB)	The Line of Balance (LOB) that user wants to view.

9. %Eff

No.	Data name	Description
1.	Worker efficiency	The percent efficiency of worker that responsible for each review point.

10. Employee data

No.	Data name	Description
1.	Employee data	The name of employee and information about their team, department, and section.

11. Latest % eff

No.	Data name	Description
1.	Latest worker efficiency	The latest skill efficiency of worker.

12. Processes data

No.	Data name	Description
1.	Processes data	The data about process includes process name and process id.
2.	Processes multimedia	The multimedia of process includes picture and clip file.

13. Warning

No.	Data name	Description
1.	Warning	Warning signal that is send to warn shop floor user when output of production gets lower than percent acceptable variation.

14. Review point data

No.	Data name	Description
1.	Review point processes	The processes that user has already set as review point.
2.	Review frequency	The frequency of time that user wants to review the production in shop floor. This frequency is used to generate review time table that will be used to collect data in shop floor.

15. LOB data

No.	Data name	Description
1.	Line of Balance (LOB) data	Line of Balance (LOB) data includes number of LOB user wants to set, name of each LOB, the review points that user wants to locate on each LOB, and sequence of each review point on each LOB.

16. P/O data

No.	Data name	Description
1.	Purchase order properties	Purchase order properties includes; <ul style="list-style-type: none"> • Purchase order id. • Job id. • Customer name

		<ul style="list-style-type: none"> • Product type • Product name • Style • Producing date • Finish date • Production quantity
--	--	---

17. Planned OT

No.	Data name	Description
1.	Planned OT purchase order	The purchase order that is "Load and Capacity Planning" section plans to add OT period.
2.	Planned OT team	The team that is "Load and Capacity Planning" section plans to add OT period.
3.	Planned OT period	The duration of time that is "Load and Capacity Planning" section plans to add OT period.

18. P/O (producing) data

No.	Data name	Description
1.	Producing purchase order	All purchase orders that are producing in the shop floor.

19. % Variance

No.	Data name	Description
1.	% acceptable variance	Percent acceptable variance is used as the warning level. When actual production in shop can produce the output lower than the percent allowance that is set in this data, the system will warn user to know the situation quickly in order to response with it.

20. P/O (producing) & team data

No.	Data name	Description
1.	Producing purchase order	All purchase orders that are producing in the shop floor.
2.	Team data	Teams that are allocated to work for each purchase order.

21. Review point pattern

No.	Data name	Description
1.	Pattern purchase order	The purchase order that is saved the review points as pattern.
2.	Review point processes	The processes that user has already set as review point.

3.	Review frequency	The frequency of time that user wants to review the production in shop floor. This frequency is used to generate review time table that will be used to collect data in shop floor.
----	------------------	---

22. Review point's status

No.	Data name	Description
1.	Status of purchase order	The status of purchase order includes non-selected, selected review point and selected LOB. This status helps user able to find the purchase order that wants to set quicker. For an example, if user wants to set review point in purchase order that has not set review point before, user can select "non-selected" status to reduce number of P/O will be showed on the screen in order to find P/O wanted to set quicker.

23. LOB's sequence

No.	Data name	Description
1.	LOB's sequence	Sequence of review points on each LOB.

24. Selected P/O

No.	Data name	Description
1.	Selected P/O	The P/O that user selects.

25. % Variance

No.	Data name	Description
1.	% acceptable variance	Percent acceptable variance is used as the warning level. When actual production in shop can produce the output lower than the percent allowance that is set in this data, the system will warn user to know the situation quickly in order to response with it.

26. Selected team

No.	Data name	Description
1.	Selected team	The team that user selects to create review point and Line of Balance (LOB).

27. Review frequency

No.	Data name	Description
1.	Review frequency	The frequency of time that user wants to review the production in shop floor. This frequency is used to generate review time table that will be used to collect data in shop floor.

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28. Selected processes

No.	Data name	Description
1.	Selected processes	Processes that user has selected to be review point that will be used to collect shop floor data in shop floor.

29. Number of LOB

No.	Data name	Description
1.	Number of LOB	The amount of Line of Balance (LOB) that user wants to create for that purchase order.

30. Processes in LOB

No.	Data name	Description
1.	Processes in LOB	The processes those are located on each Line of Balance (LOB).

31. Sequence of LOB

No.	Data name	Description
1.	Sequence of LOB	Sequence of review points on each LOB.

32. Interested P/O

No.	Data name	Description
1.	Interested P/O	The purchase order that user wants to input shop floor data.

33. Selected review points

No.	Data name	Description
1.	Selected review points	The review points that user wants to input shop floor data.

34. Closed P/O

No.	Data name	Description
1.	Closed P/O	The closed purchase order which is the purchase order that has already finished the production in sewing section.

35. Actual production

No.	Data name	Description
1.	Actual production	The actual output that shop floor can produce in each period of time.

36. Problems

No.	Data name	Description
1.	Problems	Problem that occurs in shop floor in each period of time.

37. Problems want to set up

No.	Data name	Description
1.	Problems want to set up	Problems that user wants to add in problem pattern.

38. Name & description

No.	Data name	Description
1.	Name	Name of Problem that user wants to add in problem pattern.
2.	Description	Description of Problem that user wants to add in problem pattern.

39. Pictures and clips

No.	Data name	Description
1.	Pictures and clips	The multimedia files of problem that user wants to add in problem pattern.

40. Interested P/O

No.	Data name	Description
1.	Interested P/O	The purchase order that user wants to view Line of Balance (LOB).

41. Interested LOB

No.	Data name	Description
1.	Interested LOB	The Line of Balance (LOB) that user wants to view.

42. P/O wanted to input OT

No.	Data name	Description
1.	P/O wanted to input OT	The purchase order that user wants to add overtime (OT) period.

43. Team data

No.	Data name	Description
1.	Team data	All teams that responsible to the purchase order user wants to add overtime (OT) period.

44. Teams wanted to create OT

No.	Data name	Description
1.	Teams wanted to create OT	Teams that user wants to add overtime (OT) period.

45. OT period

No.	Data name	Description
1.	OT period	The duration of time that user wants to add overtime (OT) period.

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APPENDIX D
REPORT

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Review Point (Note: Report of UI 1.1.1)**ABC 2007-1**

Customer: ABC Job: ABC 2007 Product Type: Shirt Product Name: Short sleeve shirt

Style: Slim fit Product Code: SM01 Producing Date: 13/11/07 Finish Date: 21/11/07

Due Date: 25/11/07 Shipment Date: 30/12/07 Quantity: 5,210 Producing Days: 5 days

% Acceptable Variance: 15%

Review Frequency: Every 1 hour

Summary Table of Review Point

No.	Process	Process ID.	Team	Worker Name

2007-1, collar Team 1

	1	2	3	4
1	SN1 Stitch the collar edge	SN2 Stitch the collar edge	OV1 Fuse and stitch the collar	IL3 Assembly
2				
3				
4				
5				

No.	Process	Process ID.	Team	Worker Name
1	Stitch the collar edge	7555	1	Mrs. Christina Lohanson
2	Stitch the collar edge	7555	1	Mr.Paul Smith
3	Fuse and stitch the collar	3000	1	Ms.Lolita Defry
4	Assembly	5700	1	Ms.Rose Riki

2007-1, Sleeve Team 2

	1	2	3	4
1	SN1 Stitch the sleeve edge	SN2 Stitch 2 sleeve parts together		
2				
3				
4				
5				

No.	Process	Process ID.	Team	Worker Name
1	Stitch the sleeve edge	1750	2	Mr.Nitipong Mekdhawatchai
2	Stitch 2 sleeve parts together	7555	2	Mr.Peerapat Niltuan

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Create Line of Balance (LOB) (Note: Report of UI 1.1.1.2 and 1.1.2.1)ABC 2007-1

Customer: ABC Job: ABC 2007 Product Type: Shirt Product Name: Short sleeve shirt

Style: Slim fit Product Code: SM01 Producing Date: 13/11/07 Finish Date: 21/11/07

Due Date: 25/11/07 Shipment Date: 30/12/07 Quantity: 5,210 Producing Days: 5 days

% Acceptable Variance : 15%

Review Frequency : Every 1 hour

LOB1

No.	Process	Process ID.	Team	Worker Name

LOB 2

No.	Process	Process ID.	Team	Worker Name

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Problem : Process

Child Lv 1	Child Lv 2	Child Lv 3

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Shop Floor Data (Report) (Note: Report of UI 1.3)

Producing Date 1/5

ABC 2007-1

Customer: ABC Job: ABC 2007 Product Type: Shirt Product Name: Short sleeve shirt Style: Slim fit Product Code: SM01
 Producing Date: 13/11/07 Finish Date: 21/11/07 Due Date: 25/11/07 Shipment Date: 30/12/07 Quantity: 5,210 Producing Days: 5 days

% Acceptable Variance: 15% Review Frequency: Every 1 hour

Review Point 1

Process : Short sleeve shirt

Line : Shirt Section : - Team : - Worker : -

Period	Time	Target	Produced	%Eff _{target}	%Variance	Meet target	Use to Update %Eff	Problem
1	8.00-9.00	50	50	100	0	✓	Use	-
2	9.00-10.00	50	30	60	40	✗	-	Sick
3	10.00-11.00	50	50	100	0	✓	Use	-
4	11.00-12.00	50	50	100	0	✓	Use	-
5	13.00-14.00	50	50	100	0	✓	Use	-
6	14.00-15.00	50	50	100	0	✓	Use	-
7	15.00-16.00	50	50	100	0	✓	Use	-
8	16.00-17.00	50	50	100	0	✓	Use	-
OT	2 Hours	100	100	100	0	✓	Use	-
All	-	500	470	94	6	✓	-	-

Line of Balance (LOB) (Note: Report of UI 1.4)

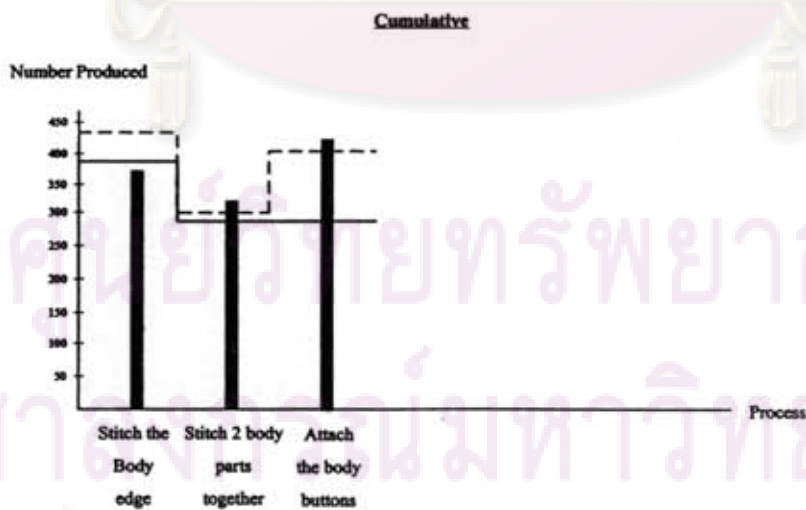
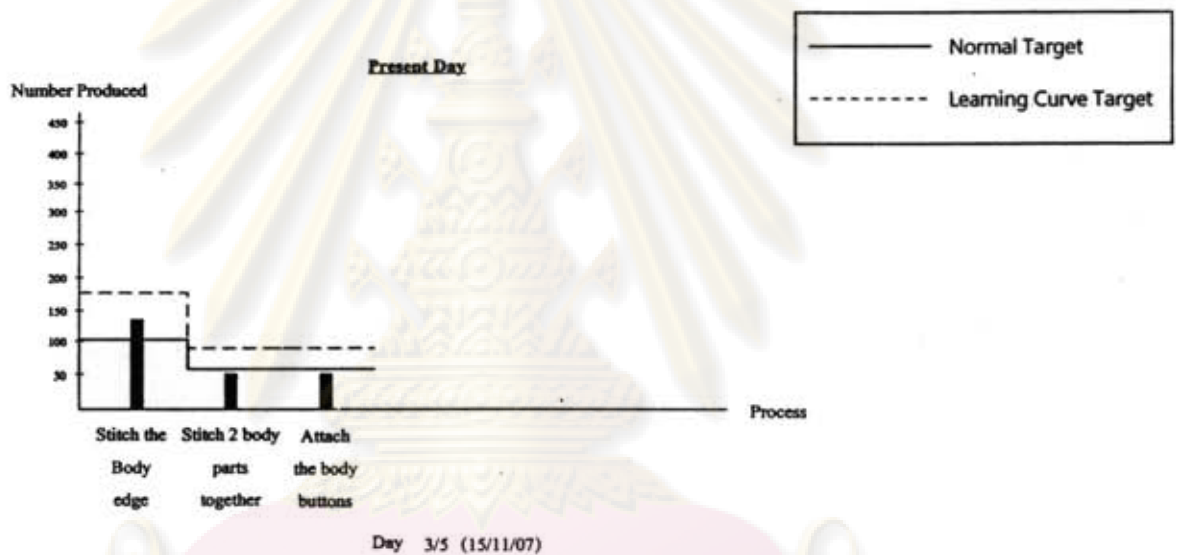
Producing Date 3/5

ABC 2007-1

Customer: ABC Job: ABC 2007 Product Type: Shirt Product Name: Short sleeve shirt
 Style: Slim fit Product Code: SM01 Producing Date: 13/11/07 Finish Date: 21/11/07
 Due Date: 25/11/07 Shipment Date: 30/12/07 Quantity: 5,210 Producing Days: 5 days

% Acceptable Variance: 15% Review Frequency: Every 1 hour

LOB 1



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Line of Balance (LOB) (Note: Report of UI 1.4)

Producing Date 3/5

ABC 2007-1

Customer: ABC Job: ABC 2007 Product Type: Shirt Product Name: Short sleeve shirt

Style: Slim fit Product Code: SM01 Producing Date: 13/11/07 Finish Date: 21/11/07

Due Date: 25/11/07 Shipment Date: 30/12/07 Quantity: 5,210 Producing Days: 5 days

% Acceptable Variance : 15%

Review Frequency : Every 1 hour

LOB 1 (Normal Target)**Present Day**

Sequence	Process	Target	Produced	%Variance	Meet Target
1	Stitch the body edge	100	140	0 %	✓
2	Stitch 2 body parts together	60	50	17 %	✗
3	Attach the body buttons	60	50	17 %	✗

Cumulative

Sequence	Process	Target	Produced	%Variance	Meet Target
1	Stitch the body edge	390	375	4 %	✓
2	Stitch 2 body parts together	290	320	0 %	✓
3	Attach the body buttons	290	430	0 %	✓

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Line of Balance (LOB) (Note: Report of UI 1.4)

Producing Date 3/5

ABC 2007-1

Customer: ABC Job: ABC 2007 Product Type: Shirt Product Name: Short sleeve shirt
 Style: Slim fit Product Code: SM01 Producing Date: 13/11/07 Finish Date: 21/11/07
 Due Date: 25/11/07 Shipment Date: 30/12/07 Quantity: 5,210 Producing Days: 5 days

% Acceptable Variance : 15% Review Frequency : Every 1 hour

LOB 1 (Learning Curve Target)**Present Day**

Sequence	Process	Target	Produced	%Variance	Meet Target
1	Stitch the body edge	180	140	22 %	×
2	Stitch 2 body parts together	90	50	44 %	×
3	Attach the body buttons	90	50	44 %	×

Cumulative

Sequence	Process	Target	Produced	%Variance	Meet Target
1	Stitch the body edge	440	375	15 %	√
2	Stitch 2 body parts together	310	320	0 %	√
3	Attach the body buttons	400	430	0 %	√

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OT (Unplanned) (Note: Report of UI 1.5)**ABC 2007-1**


Customer: ABC Job: ABC 2007 Product Type: Shirt Product Name: Short sleeve shirt

Style: Slim fit Product Code: SM01 Producing Date: 13/11/07 Finish Date: 21/11/07

Due Date: 25/11/07 Shipment Date: 30/12/07 Quantity: 5,210 Producing Days: 5 days

Team	Section	Line	OT
1	1	1	2 Hours
2	1	1	2 Hours

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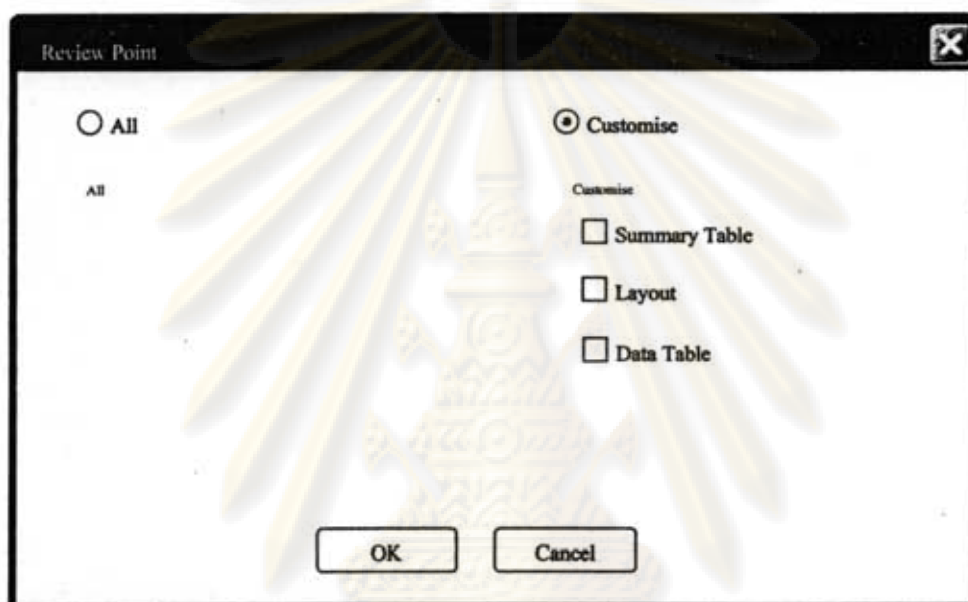


APPENDIX E
USER INTERFACE (UI) OF REPORT PRINT OPTION

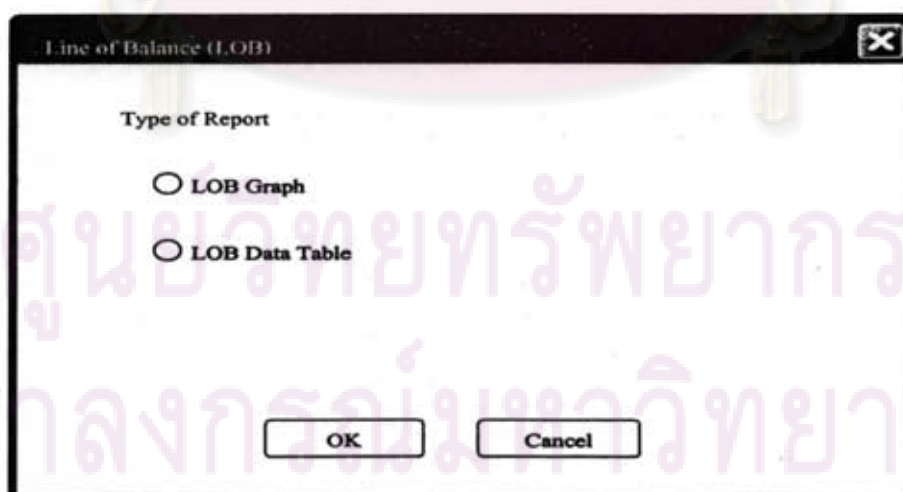
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As stated before in Chapter 5 many participants of report verification requires the system provides flexibility for user to choose the type of report and type of illustration instead of print all of it out. The major benefit of this flexibility is to help company to reduce printing cost and time. However, there are just some reports that need to have print option, and print option of those reports are showed as follow.

- Print option of UI 1.1.1 select review point



- Print option o UI 1.1.1.2 create Line of Balance (LOB) and UI 1.1.1.2.1 sequence Line of Balance (LOB)



- Print option of UI 1.2 set problems (Problem pattern)

Problem Pattern

All

All

Customise

Customise

Problem Tree Diagram

Problem Table

OK Cancel

- Print option of UI 1.2 set problems (Shop floor problem)

Shop Floor Problem

Interested time range

Please select time range

Timerange

3 months

6 months

9 months

1 year

1 1/2 year

2year

Interested Department

Please select department

All

Customise

Department

Department

Department

Department


Department

OK Cancel

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- Print option of UI 1.3 shop floor input





APPENDIX F
SYSTEM VERIFICATION QUESTIONNAIRE

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Questionnaire of User Interface (UI) Verification

Name: Position:

User Interface Name:

User Interface

1. Do you understand its objective from the-UI? Very Bad Bad Fair Good Very Good
 (Assumed that no explanation is conducted before)
 Comment:

.....

2. How long did you spend time to understand all functions in this UI (At first time)
 Time.....minutes Very Bad Bad Fair Good Very Good

3. Do you think this UI easily to use?
 Comment:

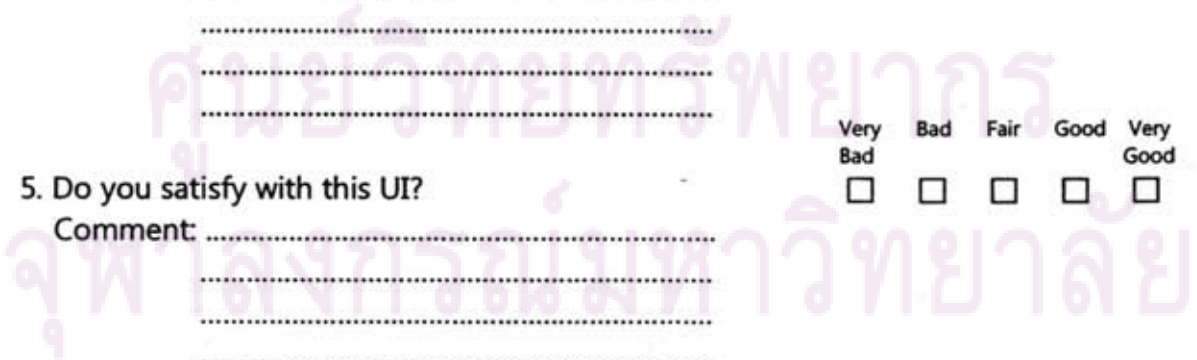
.....

4. Does this UI flexible enough to fulfill your requirements? Very Bad Bad Fair Good Very Good
 Comment:

.....

5. Do you satisfy with this UI? Very Bad Bad Fair Good Very Good
 Comment:

.....



Alignment with Actual Working Condition

1. Does information showed on this UI adequate to you?

Very Bad	Bad	Fair	Good	Very Good
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comment:

.....

.....

.....

.....

2. Do functions in this UI fulfill your expectation?

Very Bad	Bad	Fair	Good	Very Good
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comment:

.....

.....

.....

.....

3. Does this UI can apply to use in actual working condition?

Very Bad	Bad	Fair	Good	Very Good
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comment:

.....

.....

.....

.....

4. Does this UI can improve your shop floor monitoring performance?

Very Bad	Bad	Fair	Good	Very Good
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comment:

.....

.....

.....

.....

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Logic of Process

1. The employee efficiency in this UI is stored and updated by skill.

Correct

Wrong

Comment:

2. System will verify unplanned overtime (OT) period with planned over time (OT) from load and capacity planning to avoid repetition.

Correct

Wrong

Comment:

3. System will warn user when production is lower than % acceptable variation.

Correct

Wrong

Comment:

Note: Logic of process herein is just examples which in actual logic of process of each UI can be differently.

Questionnaire of Report Verification

Name: Position:

Report Name:

Report

1. Do you understand the objective of this report? Very Bad Bad Fair Good Very Good
 (Assumed that no explanation is conducted before)

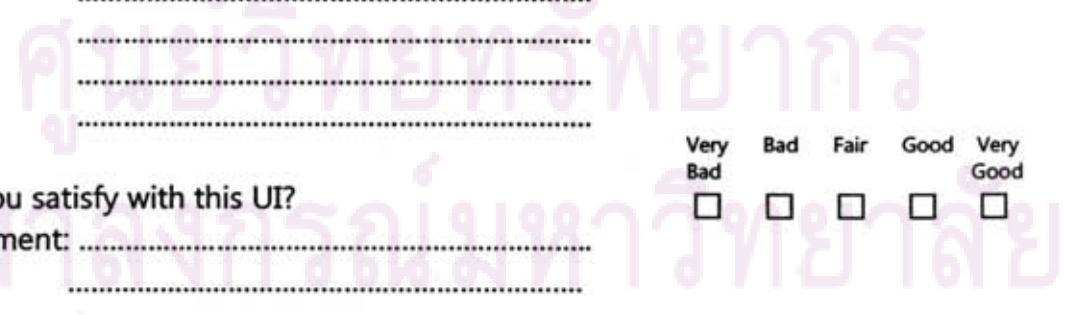
Comment:

2. How long did you spend time to understand all contents in this report (At first time)
 Time.....minutes Very Bad Bad Fair Good Very Good

3. How about legibility of this report?
 Comment:

4. Does print option in this report flexible adequate to support your requirements? Very Bad Bad Fair Good Very Good
 Comment:

5. Do you satisfy with this UI? Very Bad Bad Fair Good Very Good
 Comment:



Alignment with Actual Working Condition

1. Does information showed on this report adequate to you? Very Bad Bad Fair Good Very Good
 Comment:

.....

2. Does information in this report align with actual working condition? Very Bad Bad Fair Good Very Good
 Comment:

.....

3. Does this report can apply to use in actual working condition? Very Bad Bad Fair Good Very Good
 Comment:

.....

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Questionnaire of Overall of System Verification

Name: Position:

Reaction with Requirements and Concepts

1. Does this system can warn you to know shop floor problem quicker?

Very Bad Bad Fair Good Very Good

Comment:

2. Does this system can help manufacturer to better recognise progress in shop floor?

Very Bad Bad Fair Good Very Good

Comment:

3. Does Line of Balance (LOB) provided in this system can help user to clearly see progress and problem in shop-floor?

Very Bad Bad Fair Good Very Good

Comment:

4. Does worker efficiency provided in this system can help production planning able to plan target closer to actual output?

Very Bad Bad Fair Good Very Good

Comment:

5. Does shop floor information provided in this system adequate for production control to make corrective decision? Very Bad Bad Fair Good Very Good

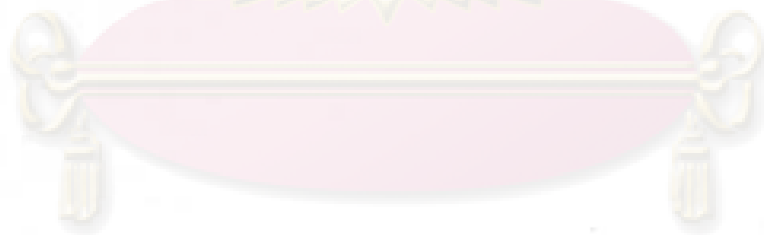
Comment:

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6. Does information of shop floor problem that collected and reported in this system useful for you to make productivity improvement? Very Bad Bad Fair Good Very Good

Comment:

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Conclusion

1. Does this system can implement to use in your company?

Very Bad	Bad	Fair	Good	Very Good
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comment:

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2. Does this system easily to use?

Very Bad	Bad	Fair	Good	Very Good
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comment:

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3. Does this system can fulfill your expectations and requirements?

Very Bad	Bad	Fair	Good	Very Good
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comment:

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4. Does this system can improve your production control and monitoring performance?

Very Bad	Bad	Fair	Good	Very Good
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comment:

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5. Do you satisfy with this system?

Very Bad	Bad	Fair	Good	Very Good
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comment:

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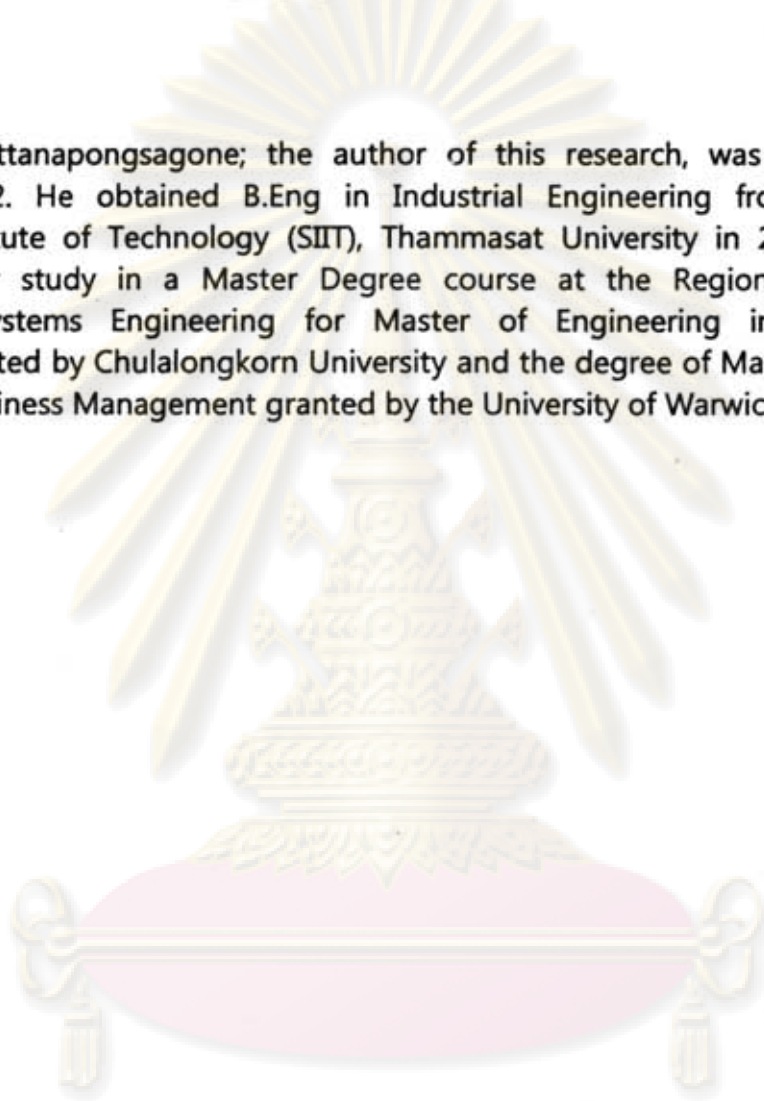
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BIOGRAPHY

Mr.Pheeraphol Pattanapongsagone; the author of this research, was born on the October 21, 1982. He obtained B.Eng in Industrial Engineering from Sirindhorn International Institute of Technology (SIIT), Thammasat University in 2000. He then pursues a further study in a Master Degree course at the Regional Centre for Manufacturing Systems Engineering for Master of Engineering in Engineering Management granted by Chulalongkorn University and the degree of Master of Science in Engineering Business Management granted by the University of Warwick.



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