Chapter 4
Process Analysis for Redesign

This issue will give information to understand traditional manufacturing environment and carefully identified hidden problems in some points, then analyze them before suggesting critical change areas and methods in terms of modern manufacturing system. All analysis results clarified below will effect the redesign determination, helping the conversion team to determine what process to convert and in which direction. It also provides a baseline against which to measure improvement.

1. Process Selection Criteria

There are three primary questions to determine on process selection:

- How much variety in products or services will the system need to handle?
- What degrees of equipment flexibility will we needed?
- What is the expect volume of output?

2. Understand Current Conditions

There are sustainable competitive positions in any industry. For example; cost leadership, differentiate leadership, or agility leader. It can be achieved by introducing new products or redesign whole new operation processes, but in the case study the scope of redesign is focused on manufacturing activities in the factory which included as process redesign.

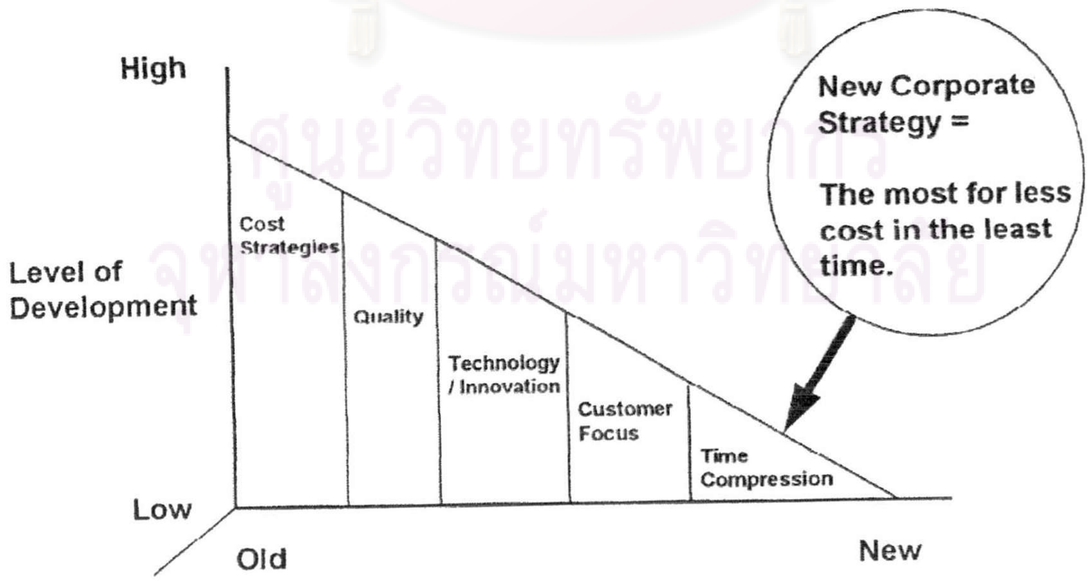

Figure 4-1; Trend of competitive strategies in manufacturing

The historical diagram represent that industrial competition trends today is interesting in time compression methods and flexibility more than other competitive factors. So the performance of S-Pak is likely to be poor and obsolete as it never clearly established modern basis for its competitive position and assign right methods and techniques into manufacturing activities.

Domestic companies in Thailand even S-Pak are still concern only on cost and quality aspects in providing effective manufacturing to satisfy customers without considering crucially in delivery time. So the main target for redesign will be aiming to achieved in better assembling lead-time by finding significant time compression methods to redesign traditional processes and environment.

2.1 Buying Characteristic – High Volume & Minor Parts Purchase

S-Pak realized that its essential manufacturer is the assembly plant, which converts all raw materials, in the form of subassemblies, moving along the assembly line until produce finished goods. According to the limit space, technology, and investment budgets so materials, components, spare parts, devices, some machine and services will be ordered or outsourced from outside providers which are available from vendors in Thailand.

That means S-Pak is using a multi-sourcing strategy to trade with more than one supplier on a single product or service. So the redesign plan should remain all materials and subassemblies to sustain outsourcing, therefore to concentrate resources on its core competency of improving agility from traditional system, because S-Pak plant is not a production (making) plant but it is an assembly plant so it should rather makes changes of the process's concept instead.

There are 20 major suppliers from total 53 suppliers providing items for split-type air conditioner factory. However, the company separates the relationship between the linkage of outsourcing decision into two levels; the first tier and second tier suppliers.

<u>1st group of suppliers</u>

This is a group of suppliers which the company do business transaction for a very long term. Some are here since the company has established, but for some reasons, do not merge but do transfer some equity, technology, people and information as well as goods and services. They also share operation leading to a reduction in costs and improve quality of sub-parts to sustain competitive advantage together. These alliances typically involve in part of company value chain especially manufacturing activities, response in supplying important parts to all branches of S-Pak factories.

S-Pak and these level suppliers are honest to each other. They are reliable and so on the suppliers provide credits offering. Usually, contacting frequencies are high and trade in quite a high volume. The suppliers reward S-Pak by offering a special promotion of discount if purchasing in high volume constantly and also offer great services. This causes large buying lot sizes and seems to distract the company from true internal manufacturing process difficulties. There are still more problem in delivering the products right on time, especially when ordering great lots.

Table 4-1; Lists of first tier of suppliers:

No.	Supplier Name	Product Supply
1	Fuji Consumer Product Co, Ltd. – OEM	Coil, compressor
2	Star (Thailand) Company Co, Ltd. – OEM	Coil
3	Sang Chai Equipment (1984) Ltd, Part.	Motor, fan, fan wheel, housing
4	Harn Engineering Co, Ltd.	Expansion valve, different valves
5	Sin Siam Inter-cooling Co, Ltd.	Solenoid valve, different valve
6	Refrigo Equipment Co, Ltd.	Spare part of air conditioner, refrigerator
7	Mechatric Co, Ltd.	Electronic and control device
8	J.T.S Machine Tools	Device, maintenance tool

In addition observation, current manufacturing purchases components of top beam set and fan coil control devices in minor parts and combine them in shop floor afterwards. New decisions come in mind that the factory could buy already-processed sets of these components provided by vendors where as:

- Grille, blead, rock blead, and plastic swing can be bought as one complete grille sets.
- Refrigeration control and terminal can be bought as remote control set.

<u>2nd group of suppliers</u>

This supplier group's relationship covers two regions; mostly medium or long-term trading commitment providing minor parts and equipments like casing, spare plastic and metal parts. The remaining is little of short-term trading commitment relationship service providers such as transporting provider. The overall relationship for this group is in good form. However, suppliers still rely much on each other with no seriously contracts that tie them together by law.

Contacting frequencies are not as high as the first group and they contribute special discount and commitment only when purchasing in large lot sizes beyond each delivery. S-Pak firstly made a decision whether to lift some contractors up to the first group by purchasing a lot more to improve better relationship but will generate the same problems as first tier suppliers.

Table 4-2; Lists of second tier of suppliers:

No.	Supplier Name	Product Supply
1	Engineering Equipment Enterprise Co, Ltd.	Spare parts
2	Kianguan Filter Co, Ltd.	Distributor unit
3	H.I.M. Engineering Co, Ltd.	Casing
4	Best Direction System Ltd.	Air condition spare part
5	U.N. Motor Work Co, Ltd.	Air condition spare part, electronic device
6	Advance Embedded Systems Co, Ltd.	Controller
7	Conic Engineering Co, Ltd.	Electronic device
8	M.P.V. Supply & Engineering Co, Ltd.	Spare part
9	Air Con. Component Industries Co, Ltd.	Different valves
10	Estel Company Limited	Transformer
11	Mahanakorn Trading Co, Ltd.	Piping materials
12	Kulthorn Co, Ltd.	Air condition spare part, electronic device

As we can see, both suppliers' groups have quite a significant effect on the purchasing quantity and lot size. Because it varies sensitively to traditional manufacturing environment by pushing pressure down to the factory to decide whether they will buy in high volume and receive a large volume discount and advantage by economic of scale or just loosing position of top priority customer. Eventually, traditional S-Pak chooses to sustain good relationships without investigating true cause and consequence of problems.

It is clarified and no questioning that a medium-size factory, along with limit space should carry on with buying decision rather than making all parts itself. Perhaps, the factory will admit that purchasing already-processed component sets are more advantage by reducing production lead-time and complicate tasks. They should maintain outsourcing strategy to reduce complexity in shop floor and improve method customizations to satisfy more customers, but study further for the small lot sizes issue.

However, this comes to the analysis for determining the new process redesign implementations in relate to lot sizes and production volumes simultaneously to consider how the factory manufacturing environment and the production amount should be. Do they need to change?

2.2 Production Decision – Large Lots Production

The current spilt-type manufacturing is emphasizing on mass production system. This creates association costs such as extended space, huge inventories, and all sort of following problems. Recognizing the real purpose, in the past companies produced in large lots because setting up for a different machine to produce variety of product ranges which have different design parts and processes. So much time from production was not economical unless the cost was spread over a large quantity to advantage by economic of scale.

But for air condition factory that does not have to set up any machine to assemble another product type and has processes similarities without varying to product models, what is the point in producing large-lot sizes?

2.3 Order Environment Decision – Unidentified

S-Pak does not identified itself whether the production (assembly) will be made to stock for an estimation of demand or make only to satisfy each customer order requirements. This concern in topics of order quantity, amount of inventories kept, and production capacity to decide.

2.3.1 Traditional Order Environment Information

Draft of factory layout in chapter 1 premised that certain areas of the factory are prepared for huge amount of inventories, which means the order environment seems to be making to stock, while the customer's order are bought in term of batches totally approximation of 20-50 units per day. For example, first customer order 3 units, second customer order 1 unit, third and forth customers order 10 and 15 units respectively, every requirement within a single day. In this case, the concerning assembling information refers that:

<u>Assembly Information</u>

- There are total 6 assembly lines – the final line can produce utmost 22 units per lot for fan coil unit and 15 units per lot for condensing unit in a production cycle (for single model).
    - 4 lines are for fan coil unit assembly
    - 2 lines are for condensing unit assembly

- The peak capacity of producing split-type AC is 88 fan coil units (22 x 4 cycles) and 75 condensing units (15 x 5 cycles) daily.
- The production schedule only shifts 3 times daily. That means no more than four models for each product were assembled per day, in morning period and afternoon period with large lot size.
- The summarization of raw material, WIP, and finished goods inventories consume about 1,800 square meters (almost 2/3 of overall working area).

<u>Ordering Information</u>

- Normally, customer's product requirement is less than 50 units per day.
- In summer (March – May), customers requirement usually raise over 50 unit per day.

The customers tend to wait utmost of 1-3 days of production including delivering time depend on requirement quantity, in which the production lead-time is lesser. The negotiation for receiving day can be discussed since requesting orders. So demand is unsteady and unpredictable. However there is enough record to estimate the upper and lower limit of sales and manufacturing capacity.

Table 4-3; Quantity and time customer can afford to wait

Order Quantity (unit)	Time that customers can accept (day)
1 – 10	1
11 – 30	1 – 2
31 – 50	2 – 3
> 50	≥ 3 days depending on the contract

2.3.1 Change of Order Environment – Make to Order

This is pretty obvious that the factory ordering characteristic is naturally making to order than making to stock. Inconsiderately, traditional system is performing contrary. Production department is aiming initially to achieve highest volume production. The assembling goal is set to drive workforce and resources to accomplish full assembling capacity daily (at least 50 units). This create huge amount of excess inventories but managers valued excess stocks as assets and risk prevention.

For make to order, inventories should seriously be reduced, especially finished goods inventory. The transportation to customer hand should be made directly from shop floor, in exact recipient right after packing stage is completed, no need to keep the products for many days.

The temperature of Thailand can even reach 35°C in middle of summer. It affected demand rate to rise tremendously. The daily sale might be as high as 60 – 100 units which sometimes exceed factory manufacturing capacity. So in that period the spaces should be adjusted to store higher stock level.

3. Problems and Area of Improvements

At this practical stage, S-Pak implemented team working approach. It assigned a team called 'conversion team' that combines the factory manager, production engineer, supervisor, and the researcher himself together to summarize useful ideas. Brain storming meeting of the redesign team are set up.

The study uses some tools and techniques to reveal the factors and problems involve in manufacturing department of the company. The objectives are to know where improvements direction should be heading and find effective solutions, which are final step of redesign implementations.

3.1 External Analysis – PEST

External factors might not obviously affect the manufacturing unit but it could be useful for the factory to search in new knowledge guidelines, especially new trends of technology and customer's behaviors in terms of macro demand. The team also entrust PEST analysis as one important decision tool. The study will apply this tool to realize how external factors really involve with redesign methods.

3.1.1 Politics

Politics is the heart of country development. Its impact can affect an economic as a whole especially on societal values, educational system, import and export, and etc. Although Thailand is said to have an unstable political situation, S-Pak is willing to obtain government support as they provide products for government agencies as one major customer. So the reputation of being government reliability products can guarantee that the manufacturing quality is already acceptable for domestic standard, and force the company to develop time aspect instead of price and quality, by endlessly redesign the processes for better efficiency for higher competing capability.

3.1.2 Economic

The current situation in financial and economic crisis that all countries in Southeast Asia are facing is the major caused of economic instability. Thailand is also suffered from the high rate of inflation as well as from the balance deficit. Overall, economic in Thailand is in a declining stage. The government has limited its credit which slows down the investment in real estate industry as a whole and in turn, affected to the sales of air condition industry as well. However, the household air conditioner, including split-type product already shows sign of recovery. One significant way to survive in this situation is to redesign the process in which other Thai air condition sellers look over.

3.1.3 Social

Nowadays, people are becoming more environmental and energy conscious as a result of government and many organizations effort in seriously promoting a lot of campaigns on these issues. As Thailand is in the transformation period toward an industrialized country, we consumed a lot of natural energy as well as produced many pollution including air, water, and noise pollution in both air condition itself (product) and large factory buildings (process). The growing trend toward the depletion of natural environments and energy has forced many organizations to conduct and enhance many promotional campaigns on reserving for the next generations.

This factor drives S-Pak factory to maintain its medium-size without expanding the factory area into crowd community. The redesign plan also avoids the usage of high capacity or multi-purpose machines and systems which are not environmental friendly. The factory should design to kept human force as the main mechanism to perform assembling activities by hand and equipments.

3.1.4 Technology

Technology also plays a major role in air condition industry. The trend toward intense competition in air condition industry as well as consumers' demand for non-CFC, air-purifying filter, anti-bacteria, and many other attributes have forced most producers to acquire new technology in order to innovate and improve their products.

For manufacturing aspect, the modern knowledge and concepts of management is emphasizing on focused factory, which is the small or medium size factory that have specialize manufacturing for specific products, in narrow range. Huge multi-purposes machine are in placed with numbers of small and cheap machines, but work effectively with new lean manufacturing concepts such as cellular manufacturing to design way of works instead of relying on advance technology which provide high cost and difficult to control the whole system.

3.2 Manufacturing Environment Selection – Cell

3.2.1 Product's Viewpoint

The team also applied more tools for the analysis. Product classification diagram is submitted. It helps us in identifying what design methods should be implemented by considering from the existing products viewpoint, for example; factory product range, product characteristic, customization level.
In this case, split-type air conditioner is justified as consumer durable goods but moving towards commodity goods because the manufacturing process is getting simpler. Figure 4-2a illustrates Split-type air conditioner position.

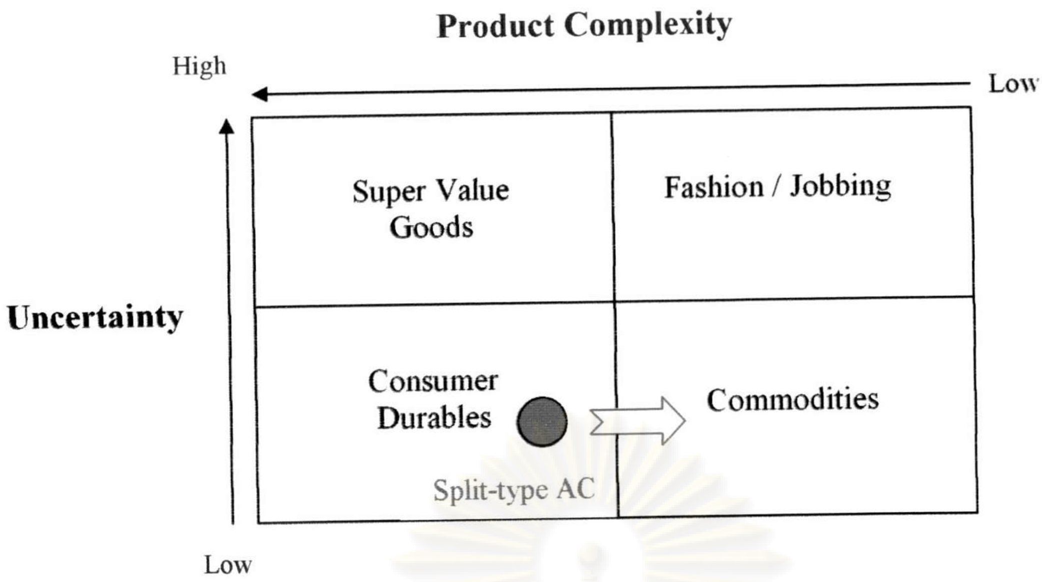

Figure 4-2a; Split-type AC position in product classification model

Another figure below expresses how split-type air conditioner matures along the curve of product cycle. It will follow that trend in the future waiting for another redesign method to perform cost reduction when it journey to that decline step, which is estimated in few years later. The factory has to recognize what is happening and change the design and manufacturing processes in order to accept that they need to compete in a different way throughout the life of air condition product, which therefore, has quite long life-cycle.

However, at the current stage it still located on the bottom-left quadrant which means the split-type is already a sophisticated product. The most suitable design referred in the model should be pursued on an objective of process-based redesign to improve in lead-time and flexibility.

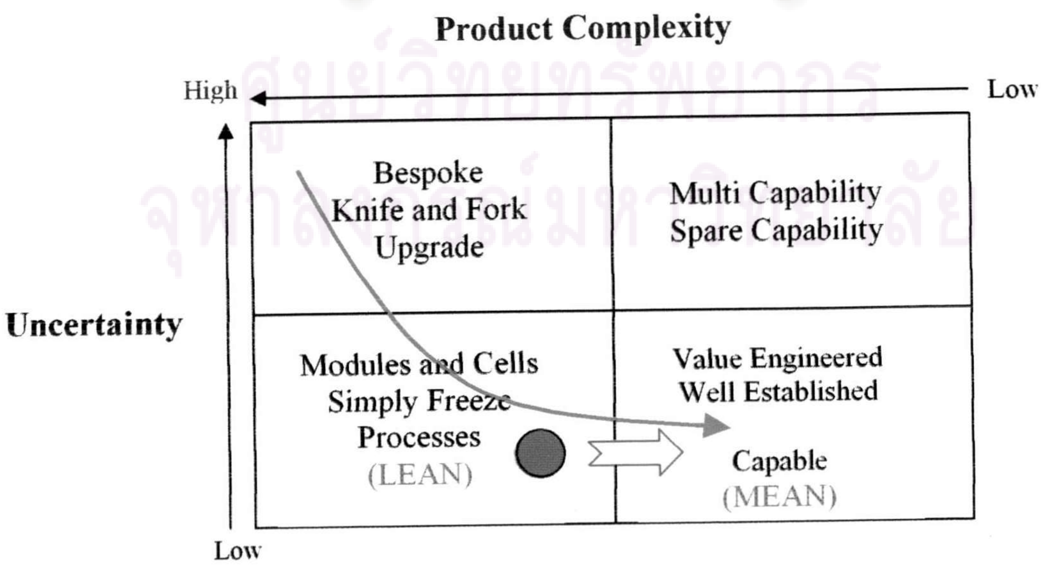

Figure 4-2b; Design manufacturing view for Split-type AC position

3.2.1 Process's Viewpoint

PQ analysis is another technique to define variety of production before using that result to select appropriate process. Figure 4-3 illustrates PQ analysis in term of types of product (X axis) and average production quantity (Y axis) for each product (fan coil model combine with condensing model). We obtain production quantity by calculating average selling units of the whole year.

Average sales for other seasons $= \frac{20 + 50}{2} =$ 35 units/day

Average sales for summer season $= \frac{60 + 100}{2} =$ 80 units/day

Average sales of an entire year $= \frac{(9 \times 35) + (3 \times 80)}{12} \approx$ 47 units/day

The quantity for each product is evaluated by historical purchasing data and then finds average quantity for per day.

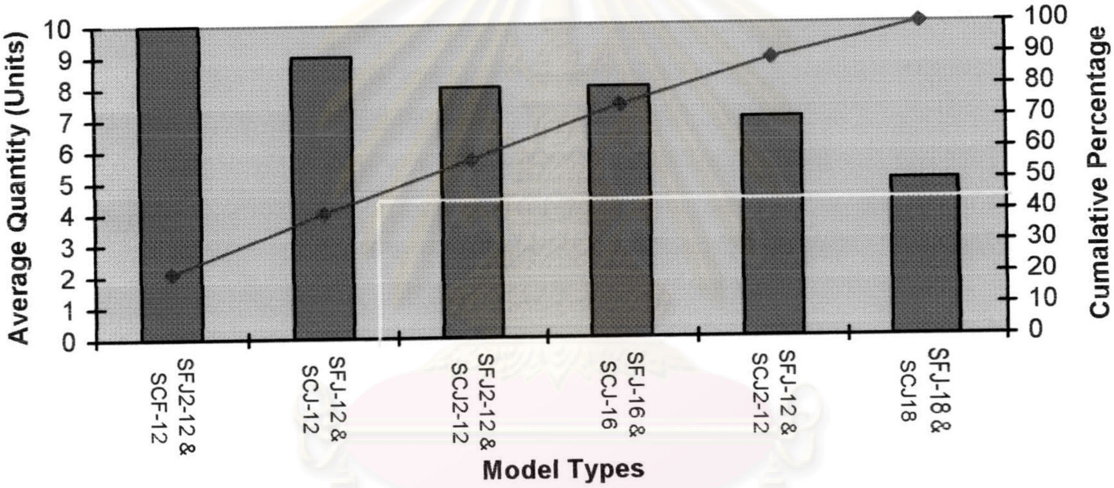

Figure 4-3; PQ analysis chart showing position at 40:60 ratios (medium variety)

The diagram justified that at 40% product types (X = 2.4) intercept Y axis for about 43% of total quantify (40:43 ratio) by numerical interpolation method. It means that the manufacturing characteristic for the factory is in 'medium customization level' because the cumulative percentage did not go beyond 60%.

To completion, following analysis diagram can be used to support the decision. Since the factory have never identified its manufacturing environment, process selection diagram in figure 4-4 helps us to clarify the most effective process choice by considering both production volume and product variety relationship.

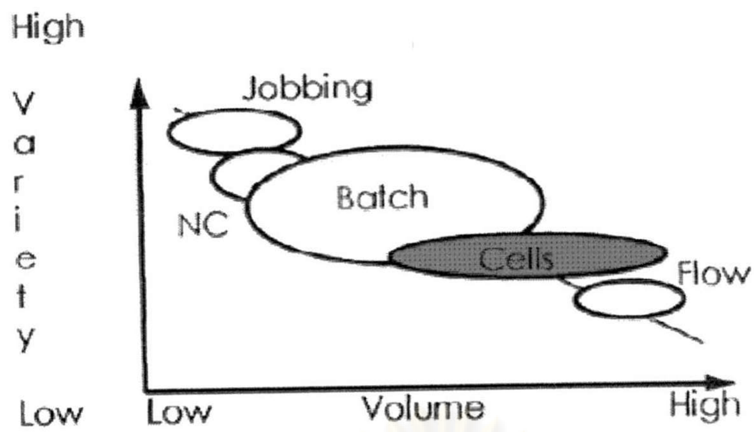

Figure 4-4; Effective process in volume and variety aspect

Logistics and Operations Management: University of Warwick, UK, 2003 (chap.1, p.6)

For the result, split-type air conditioner production (assembly) simply lies between batch and continuous flow environment according to its medium variety, moderate production volumes, and repetitive ordering of products. It obviously specified cells characteristics. Even there are four models of split-type air conditioner or more to come in the future update, but the differences still are only size, color, and specification of several parts or accessories, not the assembling procedures.

The assembling processes are still apparently similar in each model. Machines and equipments for combining sub-parts or spraying paint remain unchanged. There is no need to setup machines to produce other lots like batches or automatic control devices like operating a complete flow line. Number of product models has low effect on procedures. Most works are labor intensive which are usually repetitive, but not enough to justify full dedicated lines, but enough to setup groups of similar processes together in cells and depend on blue-collar skills for specific job such as operate powder coating machine, screwing, gluing, attaching sub-parts like body frame, panel, coil, valves, and compressor etc. So cell environment is the most appropriate and reasonable selection for factory redesign, which can be applied considerably to S-Pak assembling plant as well.

Cell assembling can involve all level of staffs and workers to share responsibility for output quality and making work decision without depending on engineers or supervisors of that station alone because S-Pak staffs are lacked of management knowledge and control. Cells provide higher decentralization in factory and expect opportunity for workers to become motivate and gain interest in their job.

Control in cells is usually based on pull type systems which reduce work in process inventories and bottle neck. Figure 4-5 shows an analysis diagram of choosing control methods influencing with volume and manufacturing complexities. The result of this analysis makes the redesign plan to implement Kanban system.

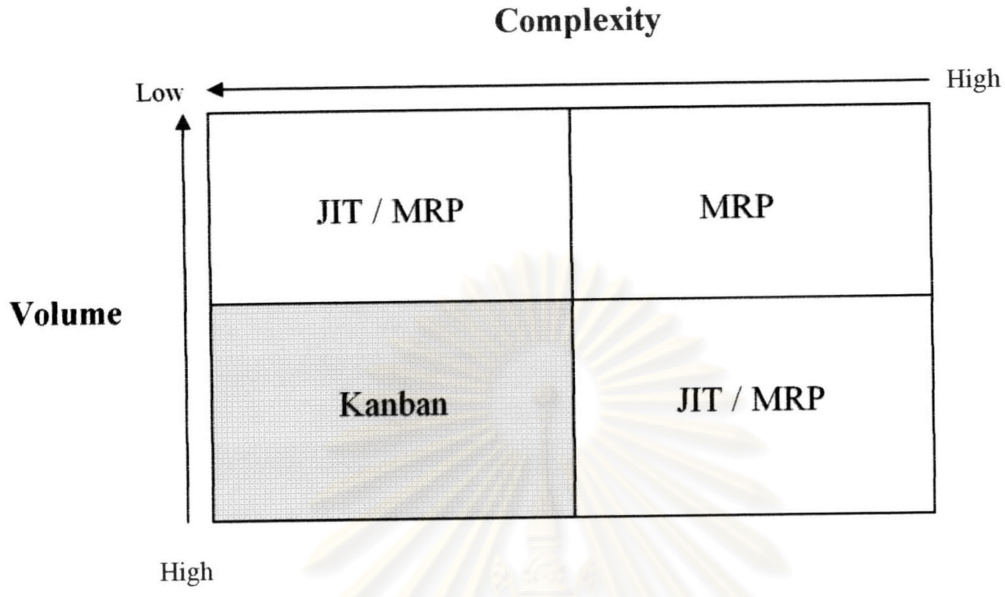

Figure 4-5; Analysis diagram for choosing control methods

3.3 Layout Analysis

Important information for redesigning implementation is to understand the macro view of the factory picture, observing in extent scope. This concern with couples of record surveys, interviewing employees in the management level, staffs level, and the workers performing on shop floor to ensure the actual situations or effectiveness of current manufacturing system correctly.

3.3.1 Comments on Current Layout

Study factory layout environment must identified categories of work stations, work flows, inventories positions, and where significant problems generated. Figure 4-6a to 4-6b will clarify major process sections and areas used for holding inventories. The first floor consists of condensing unit assembly and other processes stations such as painting station and cleaning station. Fan coil unit assembly will be performed on the second floor alone.

Figure 4-7a and 4-7b illustrated some processes flow and journey of work pieces transferring among each section since receiving raw material until distributing to customer's hand that involve with hidden problems.

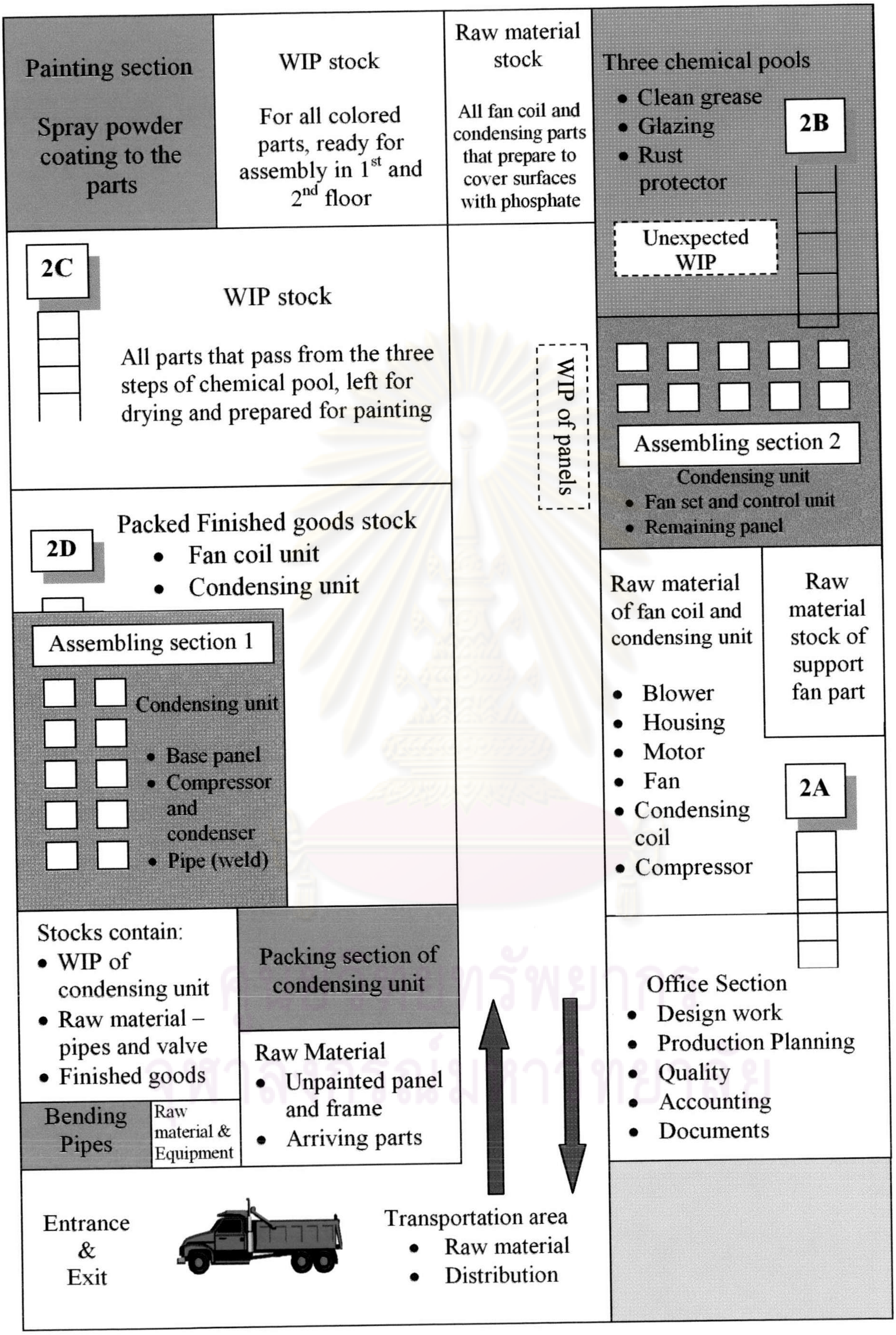

Figure 4-6a; Traditional layout of S-Pak factory – Floor 1

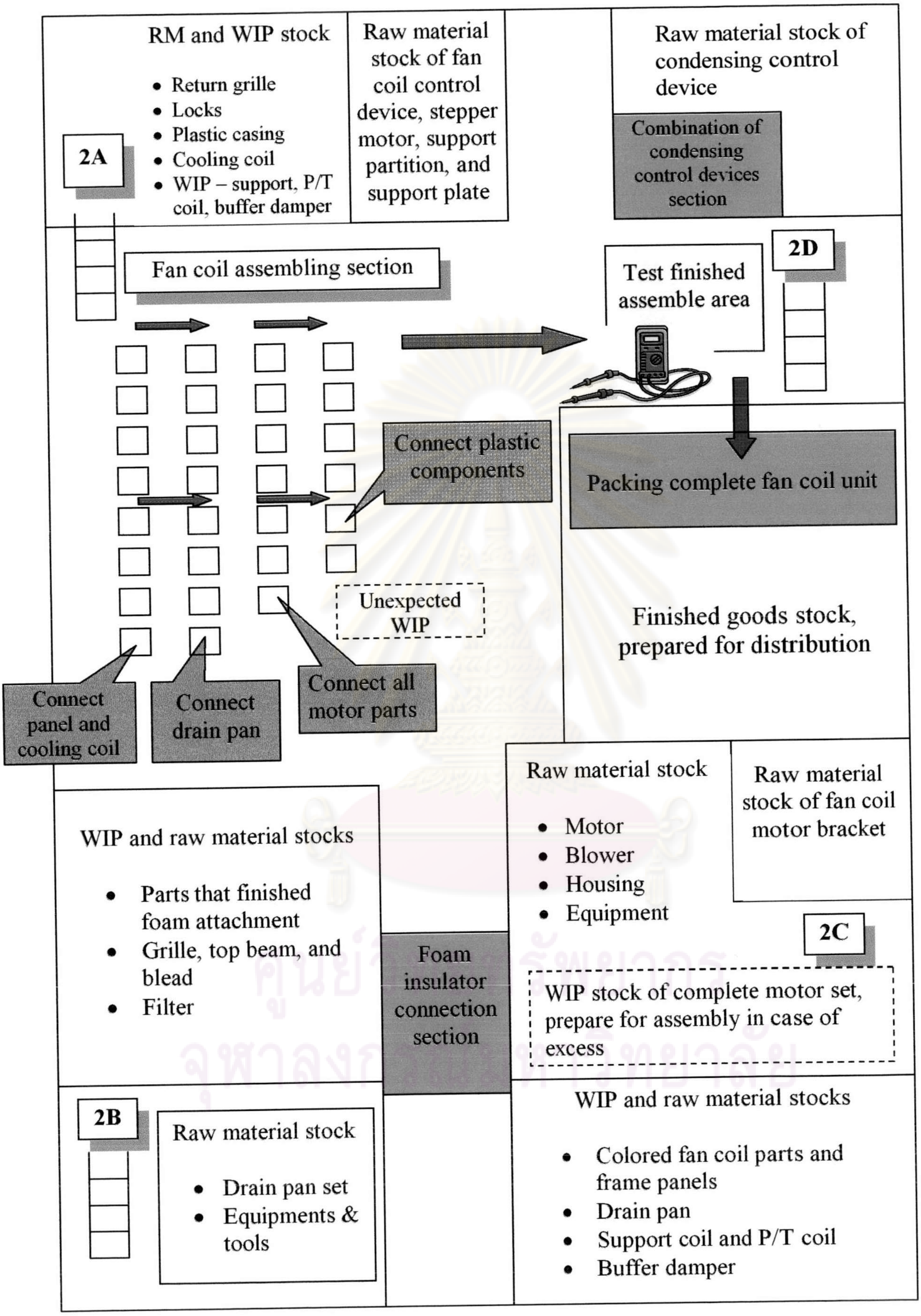

Figure 4-6b; Traditional layout of S-Pak factory – Floor 2

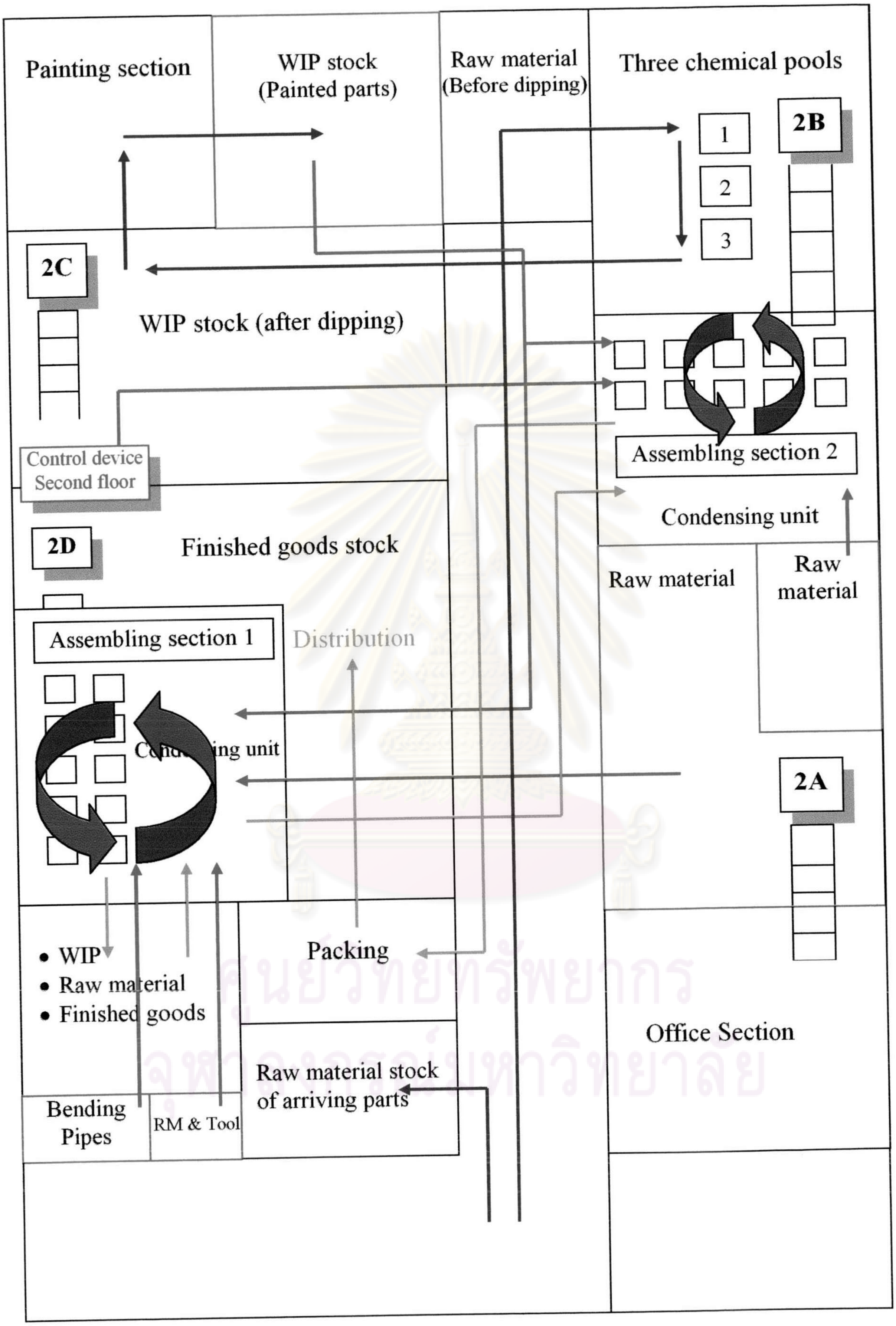

Figure 4-7a; Flow description define in the comment – Floor 1

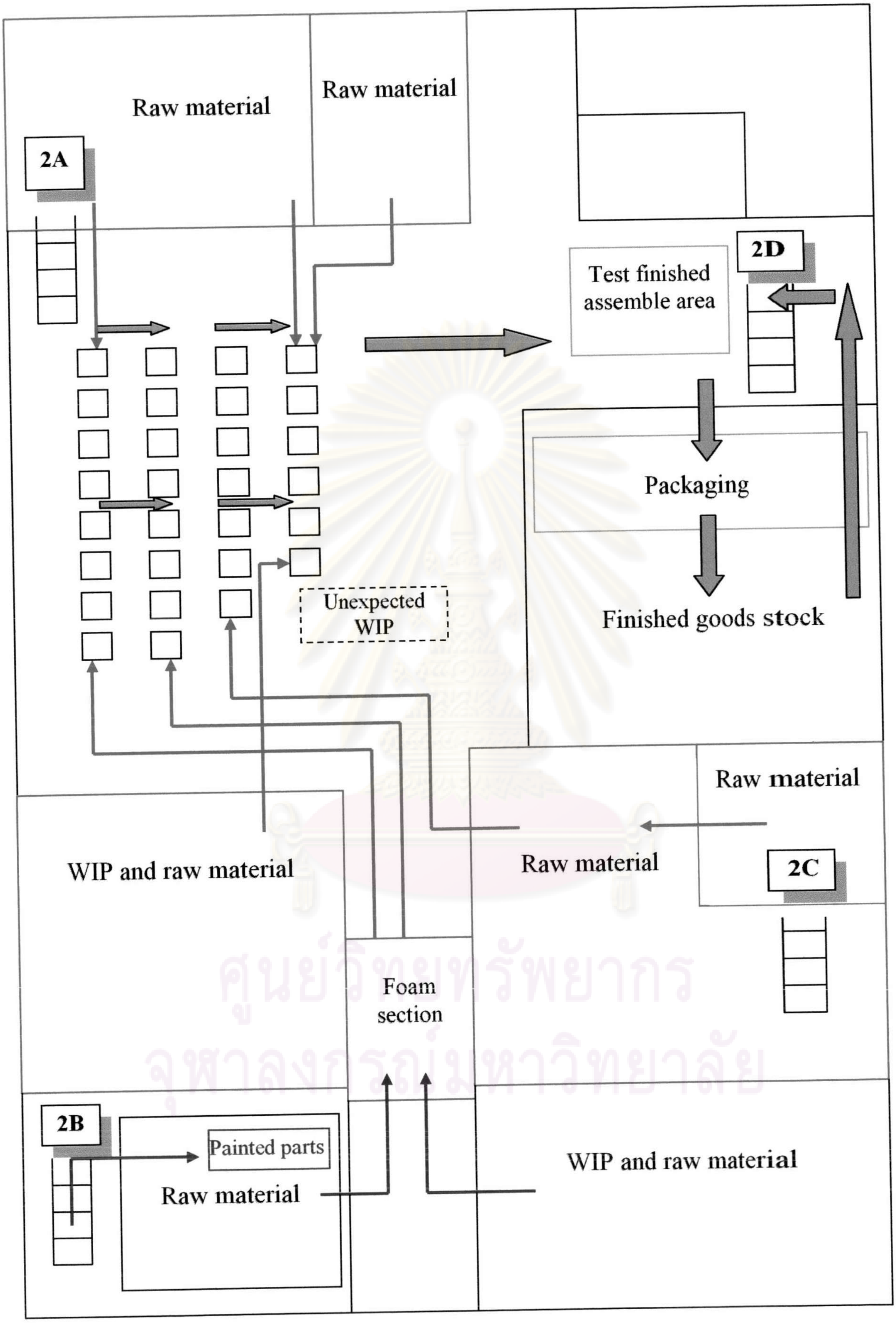

Figure 4-7b; Flow description define in the comment – Floor 2

The meanings of arrows in figure 4-7a to 4-7b:

- Blue arrows stand for parts flow of spraying and foaming processes.
- Red arrows stand for parts from all raw material and WIP stocks which supply sub-assemblies to the final assembly section.
- Green arrows stand for product paths after the final assembly process.

The conversion team started by considering carefully through the traditional layout and provided the following comments on some obvious issues for development:

One-way entrance and exit

According to the factory is located in the crowd area, not industrial estate. It is impossible to build another exit at the rear end of the factory while there is no road connected to those private properties. So the entrance in delivering raw materials or sub-parts is determined to use the same exit channel as distribution goods via one gate.

This creates internal traffics between contractors which dispatching items in high quantities with large trucks, vans, including staff's personal cars and customers at the front area of the factory almost every day. Furthermore, confusions pattern of stock in and out at the same path depicted by the arrows in figure 4-6a currently add more bottle neck.

Mixture of process between both floors

Because of poor and unplanned layout in the initial place, cause mixture of processes section between the two floors. Actually, the assembly activities should be separated distinctively for each item in each floor. In figure 4-6a and 4-6b, the first floor seems to focus on assemble condensing unit and the second floor focus on fan coil unit respectively. But things do not turn out as the factory manager planned.

There is a remaining of functional process activity and stock (concerning with controlling devices) of condensing unit mix with fan coil stocks on the second floor. This happens because of spaces limitation. The time waste on carrying sub-components up and down stairs cause non value-added activity, instead of arranging all activities in one ground.

Too far spraying station

Painting some metal parts like inside panel frames is done before final assembly. However, the powder coating station is located in deepest position of the factory. It is nonsense to build the first operation station in the deepest place. This increase the walking distance of workers to carry large scales of uncolored parts from the arriving part's stock to the spraying section instead of making it near and comfortable. The processes flow of spraying procedures is defined by the blue arrow in figure 4-7a.

Some metal parts are firstly kept at the arriving stock. The arriving stock is used as temporally storage in case the stock for uncolored parts (aside of spraying section) is full, or beginning to clutter. This usually occurs during high production rate months. The newly parts delivered by suppliers will be kept to handle that excessive quantity, queuing for painting process. Actually, arriving stock is unnecessary if the spraying section is arranged right at the raw material input spot, near the transportation area.

Confusion work flow

The team realized that traditional layout create confusion and disorder work flow in the system. Processed parts and product are moving circuitous depicts by all arrows in both floors.

As an example, workers push metal parts to the spraying section and then dipped them in the pool. Then they have to move the parts out of the WIP stock to prepare for assembly at another end of the factory (section 1) and then move backward to section 2, squeezing its way through piles of finished goods stock and return to packing stage and finally move to the finished goods stock again. Time is critically wasted during useless transportation procedures, moving here and there.

Too much work on assembly station

Figure 4-6a shown that there are only two assembling stations for condensing unit and each station contains various works performing on the work pieces. The assembling characteristic facilitates fixed-position work piece and move minor parts, components, and tools to assemble at the section defined by red arrows direction in figure 4-7a. This is not suitable for moderate volume production with medium-sized products. It collects all sorts of problems into one area and all responsibilities fall on blue-collar workers head in that section.

Recognizing condensing process charts in chapter 3, operation 1-8 are completely responsible in section 1 until finishing the pipes job. Then workers will transfer work piece by a hand lift trolley to next station which has the same characteristic defined by the green arrow which indicate the flow path between section 1 and 2.

One station is involved for almost half of assembling activities. So it consume high operation process time together, especially job concerning with pipes alignment and welding. It generates pressure, inflexible work flow, congestions, and bottle necks to both sections instead of sharing tasks to reduce intensive responsibility. Time is also wasted during transportation between raw material stocks to assembly workshop. If unknown errors occur, it directly affected the whole condensing line.

Team suggests that there should be higher distribution of work into work station cells to handle separate job which require grouping continuous process similarities. More stations must be separated apart such as motor cell, insulating cell, etc. and maintain only final assembly work on section 1. For example, the motor set can be combined at motor's cell (connect with the support fan), located near the motor stocks instead of carrying small components to consist at the assembly station.

Fan coil assembly section in second floor has only one assembling section but divided into 4 major lines; panel and cooling coil, drain pan, motor and controller, plastic parts assembly. However, the line is not properly planned in relative with stock distant and level of bottle necks control, excessive WIP, and inconvenient working environment. It could be designed with the same criteria of implementing cells design.

Unexpected WIP in final assembly

The traditional layout stimulates push system due to high stocks level every where on the factory ground. Each section just done on what they are told to do, producing full capacity, without caring how WIP might pile up in the next sequence and drives every sections rushing through works or not. Blue-collar workers think it is not their business.

The observation referred that there are unexpected WIP pile up most at the work area of chemical cleaning stage and in the plastic connection stage of fan coil final assembling unit because this process causes highest time than any other stages. Because the grille, blead, and control components are unexpectedly caused themselves an invisible sub-assembly stations aside the final assembly line. The workers unloaded parts from the stock and combined them right at the final assembly work place.

Since the fastest processes are panel and drain pan connection. So more WIP from previous stage (drain pan) are pushed to the plastic assembly line immediately and coincidently increase extra WIP, due to workers do not want supervisor to consider them as idle resources or not acting fully utilized, waiting for advance stage to finish first. Consequently, unexpected WIP turn to be a symbol of inefficient human resources measurement, not the methods or layout problems. Manager solved the problem by setting new production standard, allowing higher safety stocks and hire more workers to help the plastic parts assembly line.

<u>Uncomfortable movement of fan coil work pieces and finished goods</u>

The workers place fan coil work pieces on the floor and brought parts and equipments to the item and assemble them in steps, one after another in straight row. Once each step is completed on its process, the workers lift them by hand to the next line on the right hand position of the former line (defined by thick blue arrows in figure 4-6b), performing this pattern until the packing stage.

Transporting WIP along the assembly lines by hand is a very heavy task for workers and eventually creates high non value-added time. Furthermore, shifting packed finished fan coil down stairs to finished goods stock will require at least two workers to lift one unit at a time without the risk of accident and product damage. The team must find a way to reduce the problems.

3.3.2 Loads and Distances Analysis

The most common goals in designing layout are to minimize the transportation or travel distance of work flow following the rank of interdepartmental cooperation. For the case, it will be helpful to summarize necessary data like route's length and frequencies of interactions recorded among departments.

The analysis will determine the feasibility of the current layout whether is it properly designs in the initial place or not. Departments or stations which have frequent contact should located adjacent, or at least nearest to each other. Errors from that will only generate waste to longer production lead-time. The team must take time to measure distant between departments and direction (route) of workers journey within the factory. The path is normally counted from center of one department to another one.

Moreover, the team collected numbers of loads per day, which is done for 5 days and compute for average numerical. For example, the average work relationship for chemical pool and painting station in condensing unit production is 20 times per day. The assembly station 1 and assembly station 2 have 5 loads of interrelationship. Gathered information will be use to create an analysis table to compare with redesign layout in further chapter. It is a document that enables the team to modify more efficient layout although some work stations can not be changed.

The analysis is performing separately between fan coil and condensing unit. The final analysis output also put involvement of raw material goods flow from stock position to the workplace into an account with a different color symbol and lines.

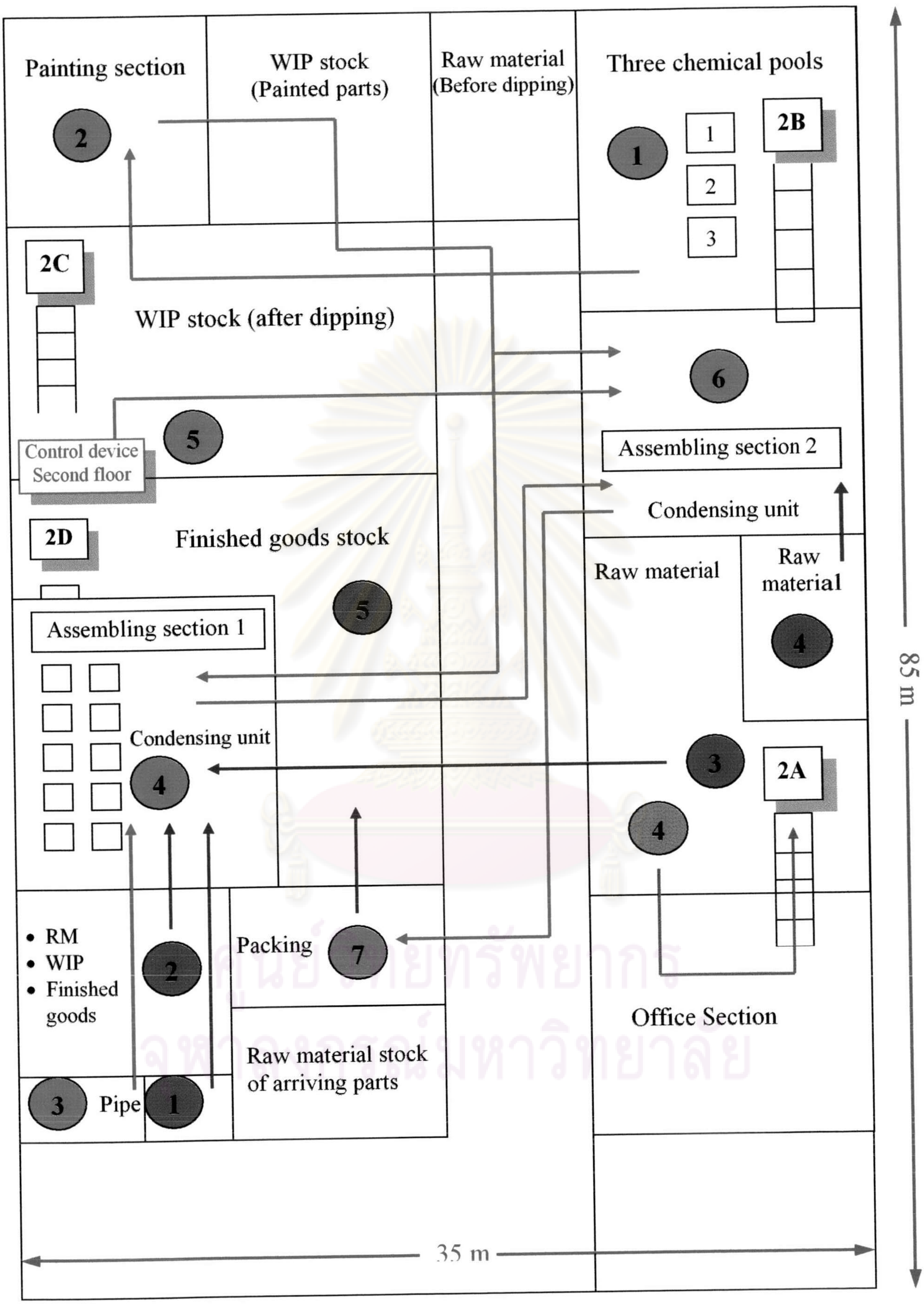

Figure 4-8a; Distant and loads among departments – Floor 1 (condensing)

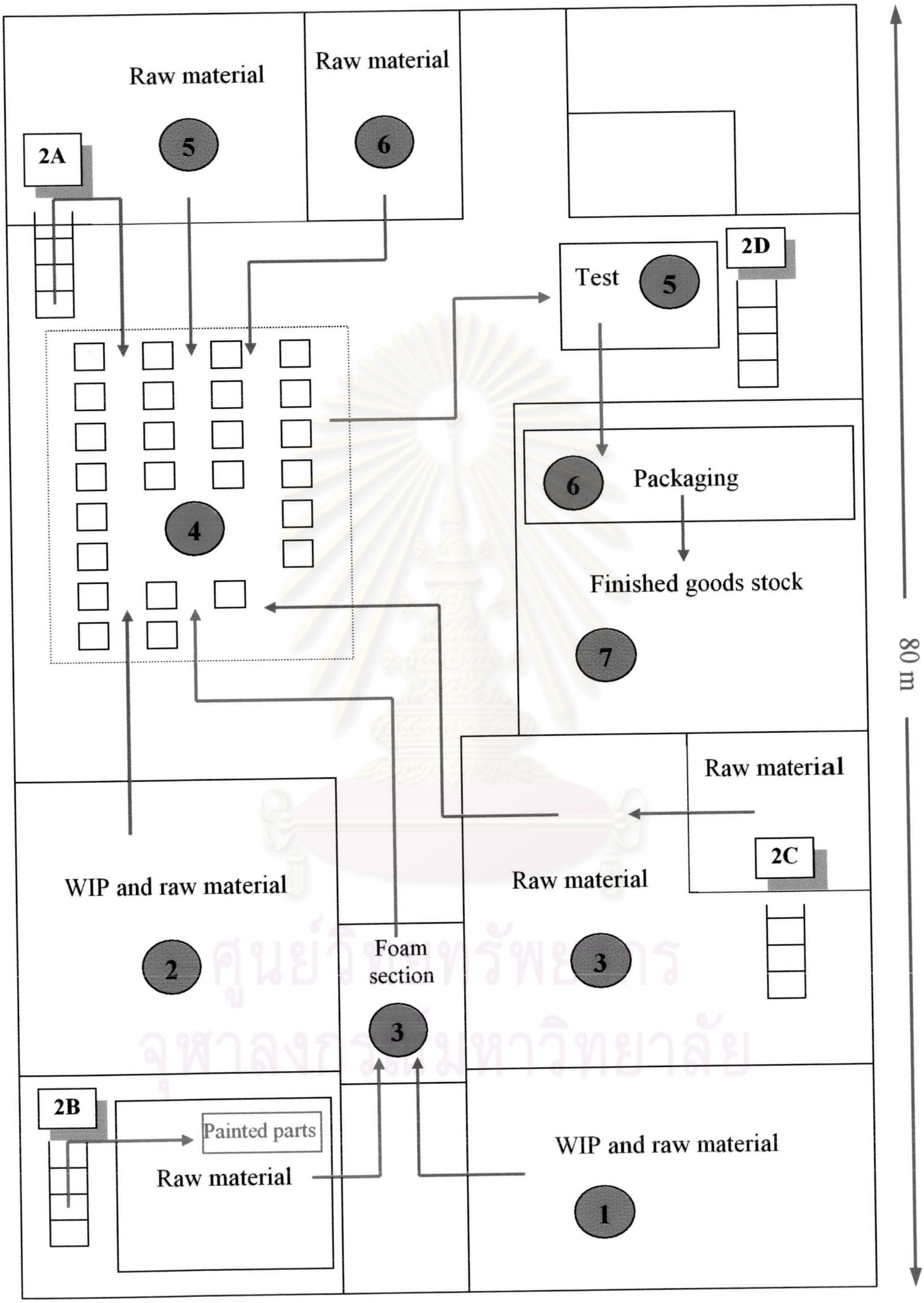

Figure 4-8b; Distant and loads among departments – Floor 2 (fan coil)

The meanings of arrows in figure 4-8a to 4-8b:

- Red arrows stand for interrelationship directions for each work station
- Blue arrows stand for directions of material path from the stock to the workplace of fan coil unit production
- Green arrows stand for directions of material path from the stock to the work place of condensing unit production

The summing of loads and distances value in the tradition factory layout can be describe by table 4-4. The first table represents a picture of work station interrelationship while the next table derives the output of stock location, or inventory layout feasibility. Both tables need to summarize to yield actual layout effectiveness. The paths which walk through the stair ways will slightly loss some energy. So the team assesses energy of walking upstairs into reasonable addition distances. For example, a distant between departments 5 – 6 on the ground floor is measured 40 meters, but noted as 45.

Table 4-4a; Output of loads and distances work station layout analysis

Condensing unit			
Department	Loads per day	Distance (m)	Loads x Distances
1 – 2	20	28	560
2 – 4	7	75	525
2 – 6	12	35	420
3 – 4	10	20	200
4 – 6	5	50	250
5 – 6	7	45 (stairs)	315
6 – 7	18	60	1,080
Total			**3,350**
Fan coil unit			
Department	Loads per day	Distances (m)	Loads x Distances
1 – 2	15	28	420
2 – 3	12	55 (stairs)	660
2 – 4	8	70	560
3 – 4	35	35	1,225
4 – 5	22	20	440
5 – 6	44	5	220
Total			**3,525**

Table 4-4b; Output of loads and distances stock layout analysis

Condensing unit (the *italic* number stands for stock department)			
Department	Loads per day	Distance (m)	Loads x Distances
1 – 4	7	15	105
2 – 4	14	8	112
3 – 4	40	25	1,000
4 – 6	20	4	80
7 – 5	15	8	120
Total			**1,417**
Fan coil unit (the *italic* number stands for stock department)			
Department	Loads per day	Distances (m)	Loads x Distances
1 – 3	20	8	160
2 – 4	10	20	200
3 – 4	8	20	160
4 – 4	10	20 (stairs)	200
5 – 4	20	10	200
6 – 4	15	12	180
6 – *7*	15	5	75
Total			**1,175**

The total value of condensing unit layout effectiveness is = 3,350 + 1,417
= 4,767

The total value of fan coil unit layout effectiveness is = 3,525 + 1,175
= 4,700

3.4 Current Time Observation

Before rearranging the workplaces and operator's performance in the new processes, the team must measure the current lead-time for one production cycle of the product flow. The team observes the time required for each action during several cycles then determines an average cycle time for the whole operation. The total processes divided into two issues; the value-adding and non value-adding operation time. The value-adding operation refers to stages of processing activities that transforms raw material into finished products. It adds higher value to the product after each operation. The non value-adding refers to stages of receiving, setting up, transporting, waiting, stocking, and packing.

Time is measured in both fan coil unit and condensing unit final assembly in terms of a single product flow (focus one piece of product) stated in table 4-4. The observer use stop-watch to evaluate every continuous operation then compare it with the non value-added time.

Table 4-5a; Time observation sheet for traditional fan coil unit production

Processes fan coil unit		**Numbers of observation / Observation time (seconds)**					
List	**Operations**	**1**	**2**	**3**	**4**	**5**	**Ave.**
Process and sub-assembly section							
1	Chemical cleaning (3 pools)	1,620	1,620	1,620	1,620	1,620	1,620
2	Drying	630	600	900	900	900	786
3	Painting (1 set)	430	442	440	435	438	437
4	Cut out foam insulator and inspect (1 set)	955	950	950	945	950	950
5	Stick foam to metal set (1 set)	310	315	308	315	311	312
	Total						**4,105**
Final assembly section							
1	Attach 4 plugs to the back panel	42	40	44	37	37	40
2	Connect service plate	22	20	22	23	20	21
3	Connect RH coil supporter to right panel	28	26	25	26	25	26
4	Connect right panel to back panel	28	32	30	28	32	30
5	Connect LH coil supporter to left panel	26	24	21	28	28	25
6	Connect left panel to back panel	33	31	28	29	33	31
7	Connect base panel	35	34	34	40	36	36
8	Strength and connection check	22	16	18	14	17	17

9	Attach buffer damper to coil	24	24	25	22	21	23
10	Attach RH-LH P/T coil	32	30	30	28	28	30
11	Connect cooling coil	43	37	44	45	48	43
12	Connect motor to bracket	30	34	36	37	34	34
13	Insert motor axle into the housing	18	22	20	17	23	20
14	Connect fan wheel with the motor axle	20	19	19	21	19	20
15	Connect housing with bracket	55	54	54	60	57	56
16	Strength and connection check	29	33	27	26	24	28
17	Connect motor set to RH-LH P/T coil	186	170	175	180	166	175
18	Connect drain pan to RH-LH P/T coil	133	127	118	122	130	126
19	Connect RH-LH louvers to top beam (air frame)	63	56	60	61	59	60
20	Connect top beam to left and right panel	45	46	40	48	40	44
21	Connect top panel	51	56	51	52	47	51
22	Attach support partition	37	42	44	38	40	40
23	Connect front panel	34	36	33	34	33	34
24	Connect grille with blead	23	20	24	25	20	22
25	Connect rock blead with grille	18	17	22	22	18	19
26	Connect grille with louvers	17	19	24	16	20	19
27	Connect support plate	15	14	14	15	15	15
28	Connect control devices	54	53	49	49	59	53
29	Make a return grille	40	41	37	44	48	42
30	Connect filter	19	14	14	12	14	15
31	Connect return grille to lock return	24	18	19	18	21	20
32	Connect lock return to base panel	34	35	28	26	28	30
33	Connect side plastic cases	35	31	29	31	34	32
34	Structure test	26	27	23	22	23	24
35	Insulator resistance test	61	51	75	62	65	63
36	Voltage test	70	55	57	58	55	59
37	Stick logo, nameplate, excise stickers	23	20	25	20	19	21
	Total						**1,444**

Transportation and waiting section (accumulation from overall production)		Note: not include reject and error situations					
1	Receiving (no QC inspection)	1,800	1,920	1,500	1,200	1,500	1,580
2	Waiting (in RW and WIP stocks and on shop floor)	28,800	32,400	43,200	43,200	35,000	36,520
3	Transporting or transmitting	2,600	2,800	3,000	3,200	3,000	2,920
4	Storing and unloading	1,500	1,800	1,800	1,620	1,500	1,644
5	Setting up	600	600	600	600	600	600
6	Packing	120	120	120	120	120	120
	Total						**43,384**

Table 4-5b; Time observation sheet for traditional condensing unit production

Processes condensing unit		**Numbers of observation / Observation time (seconds)**					
List	**Operations**	**1**	**2**	**3**	**4**	**5**	**Ave.**
Process and sub-assembly section							
1	Chemical cleaning (3 pools)	1,620	1,620	1,620	1,620	1,620	1,620
2	Drying	630	600	900	900	900	786
3	Painting (1 set)	770	766	780	785	778	776
4	Bending pipes (1 set)	125	119	121	118	127	122
	Total						**3,304**
Final assembly section							
1	Attach 2 wooden base supporters	24	28	27	24	22	25
2	Stick rubber supporter on base panel	25	22	18	20	22	21
3	Connect compressor	288	270	273	277	268	275
4	Connect condenser	188	175	174	180	183	180
5	Attach support service	18	18	20	17	23	19
6	Connect suction valve	24	20	21	20	21	21
7	Connect liquid valve	20	19	22	23	22	21
8	Weld to connect inlet and outlet compressor's pipes	167	177	165	182	175	173
9	Weld to connect liquid pipe	90	82	84	92	88	87
10	Coat suction pipe with insulator	22	16	16	18	20	18
11	Adjust motor to support fan	32	35	38	33	29	33

12	Connect fan to the motor	33	34	35	33	36	34
13	Connect fan set to bottom panel	35	33	36	38	36	36
14	Connect inner panel	28	32	30	37	30	31
15	Connect magnetic to support control plate	16	18	18	14	14	16
16	Connect compressor running capacity with support control	14	16	14	16	15	15
17	Connect motor running capacity with support control	16	17	16	18	14	16
18	Connect terminal box	24	27	22	21	22	23
19	Connect support control with inner panel	30	28	31	33	34	31
20	Connect wires to all components	49	35	42	40	55	44
21	Connect right side panels	30	28	30	32	32	30
22	Connect rear panel	38	32	33	32	32	33
23	Sticking foam with 2 panels	45	40	42	50	41	44
24	Connect ventury panel	36	32	31	34	31	33
25	Connect top panel	35	31	31	29	35	32
26	Checking strength and outlook	18	18	14	13	14	15
27	Insulator resistance test	62	58	70	60	56	61
28	Voltage test	64	78	62	61	64	66
29	Pressure test	72	65	64	70	62	67
30	Stick 2 stickers near the pipes	10	8	8	7	8	8
31	Stick logo, nameplate, excise stickers	21	22	24	24	25	23
	Total						**1,531**
Transportation and waiting section (accumulation from overall production)		Note: not include reject and error situations					
1	Receiving (no QC inspection)	1,800	1,920	1,500	1,200	1,500	1,584
2	Waiting (in RW and WIP stocks and on shop floor)	27,000	28,800	43,200	39,600	35,000	34,720
3	Transporting or transmitting	1,980	2,100	2,700	2,880	2,700	2,472
4	Storing and unloading	1,920	2,280	2,280	2,040	2,000	2,104
5	Setting up	600	600	600	600	600	600
6	Packing	120	120	120	120	120	120
	Total						**41,600**

The observation sheet clarifies that the final assembly time for one fan coil unit is approximately 23 minutes (1,399/60). The condensing unit requires more time in assembly of 25 minutes per unit (1,501/60).

The team also determines the value-added ratio from the given results of the observation sheet. The method is to compare value adding activities with non-value adding activities. The team discovered that current S-Pak manufacturing system surprisingly has low value-added ratios represent in figure 4-8. This does not include the waiting of goods in finished goods stock yet. There are significant opportunities in reducing production lead-time if the team can improve the manufacturing processes and cut off waste activities in waiting and transportation time for few hours. More techniques must have the ability to deeply reveal the core of manufacturing problems.

The percentage of fan coil value-adding time from total operation's time =
$$[(4,105 + 1,444) / (43,384 + 4,105 + 1,444)] \times 100 = 11.3\ \%$$

The percentage of condensing value-adding time from total operation's time =
$$[(3,304 + 1,531) / (41,600 + 3,304 + 1,531)] \times 100 = 10.4\ \%$$

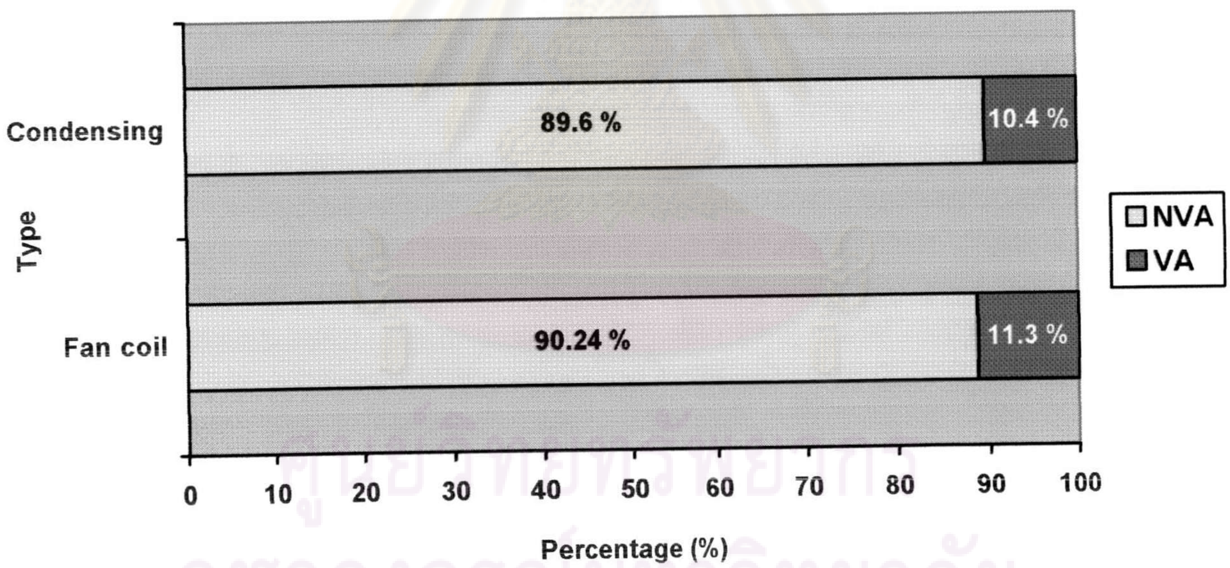

Figure 4-9; Value-added ratio of fan coil and condensing unit

3.5 Causes & Effects Analysis

Fish bone diagram is a tool to analyze the causes and effects within S-Pak factory. There is no better solution than investigate that true origin of problems and eliminating them in correct points. According to brain storming with the conversion team about the problem in current production process, there are three significant problem areas; personnel, environment, and method. Problems are either hidden or apparent.

3.5.1 Personnel

Problems from humans usually occur from low motivation or uncomfortable in work. Most workers are getting tired and stress due to pushing works through unbalanced station which creates bottle necks along the way. Apart from that, work for some functional processes and fan coil assembly unit on the second floor of the factory is repetitive and simple. So low-skill workers are enough to do the same things all day. For example, worker who is responsible for attaching drain pan will perform that job all day without changing and made him very boring.

Effect of fatigue from unhygienic working posture is significantly decrease work efficiency. In the final assembling unit where workers connect every parts and components into finished product, the work-piece is lying on the ground in one long straight row and workers have to bend down their back or sit on the heels to perform the job and every time he moves to the next piece of work. This create sickness such as back and neck ache, dizzy when looking down for long period and consequently causes bottle neck in the final stage of production from slow movement of work flow and people. Moving finished goods downstairs (from second 2nd Floor) repeatedly is also a tough job with non-value added action.

The conclusion of personnel problems are:

- Workers are tired with rush works
- Uncomfortable working posture
- Low motivation from bad working environment
- Boring from the same repetitive activity
- Low-skilled workers
- Can not exchange between stations when absent

3.5.2 Environment

The factory environment is considered bad because of space limitation. There are no preparation areas for workers or staffs themselves to rest. The first survey in 12.30 AM at lunch break realized that few workers were playing football in the transportation area right at an entrance. The place is beside finished good stocks and might crash into them. Even the working area has lots of congestion because of clutter excess WIP. Pile of equipments and work in process parts are untidy all over the place, blocking the walking path, easily to cause accidents and consume more spaces without notice.

Another significant problem due to limit space is that the factory is not possible to afford more internal spaces expansion to assemble alternative products in the future (it is unable to make outside expansion as well). S-Pak still has low market share in household small-medium size air conditioning system compare with York, Carrier, or Fujibishi, its main competitors.

Current specifications only support spilt-type air conditioner with low BTUs. The customers request for 21,000 BTUs or wall mounted type air condition model with new design to supply them otherwise will turn to other producers which provide various selections. New product introduction will require more raw material storages in containing more specific parts.

The conclusions of environment problems are:

- Congestion in working area
- No resting areas for relaxation, have lunch, or do some exercises for blue collar workers and staffs
- Accident often happens and there are risks of product damage
- Untidy and dirty working area
- No more space for future assembling expansion

3.5.3 Method

Although engineering teams are highly experienced in handling technical problems, but still lack of investigating the problem as a whole system. This happens due to traditional manufacturing operations is no more effective and efficient in current situation when market demand varies sensitively. To control the whole system, the factory must implemented modern concepts and management theories and practically put into actions.

<u>Ignore Importance of Quality</u>

The factory gives little concern with quality assurance in production. It leads to waste in time and resources. There is no material procurement check at the dispatching spot. In shop floor, only some checkpoints are established.

High WIP and Safety Inventories

Traditional production methods also stimulate mass production idea by producing as much as they could to stock. This creates high inventory storages all over the process since raw materials bought from suppliers to work in process (WIP) and finished goods, including safety stock. Inventories are buffers that tend to cover up recurring problems and will never resolve if the system carry on. Because the presence of inventory makes them seem less serious. For example, when next station ran out of sub-assembly parts in consequence of delay in previous station, there are sufficient WIP or safety stock left providing the next station without stopping the assembly line. In summer, the accumulative inventories back ups against peak demands.

However, sometimes the problems can be vital and causes people to be idle. The use of inventory as the solution can lead to increasing amounts of inventory if system halts (bottle necks) or absentees increase. It generates extra costs and spaces as well.

Many Bottle Necks along the Shop Floor

Bottle necks are also serious problem in increasing production lead-time and dissatisfied customers when delay in delivery occurs, even in high safety stocks. Most serious bottle neck is encountered in several processes like foam attachment, final assembly, and particularly the final stage testing, where finished goods are tested in all functions and standards.

Bottle necks and system halt make 22 units production per cycle becoming an ideal. Mostly in daily production, the factory fails to achieve the capacity due to many minor unexpected problems and obstacles during the processes. The events where they can assemble approximately 3 cycles from the expectation of 4 cycles often happen. But with the accumulation of stocks, the factory manages to survive critical situations when demand fluctuates. In summer, the factory solves the problems by hiring more workers in bottle neck stations and make over time (OT) to achieve at least 4 cycles per day.

Sometimes when serious problems happen in large quantities, it causes whole line to paralyze. The supervisor and quality control staffs must indicate where problems originated during manufacturing stages. It was possibly proven from two causes; people's error or defects from supplier. For real example, workers sometimes misunderstood the manual description and make assembling mistake for the whole lot, and there is no QC assigned in that work station to inspect each process stage.

Time will be waste to reject, disassembly, and search for source of problems. The team realized that because traditional system has little quality check after each process is completed, this needs to be resolved.

Many Non-Value Adding Activities

The time observation sheet already proven that manufacturing methods of S-Pak factory have so many non vale-adding activities occurred on shop floor. The stocking and transporting consume most time in all operations. Usually, the raw material components and WIP are hold in stocks for more than 5-6 hours before withdraws for assembly usage. When the stocks are overloaded and workers scatter parts cluttering over the workplaces, the items can be left idle for more than 8 hours. The unloading and storing items during operations can also create amount of time lifting heavy parts up and down from the shelves or transporting tools.

Manufacturing Inflexibility

S-Pak traditional manufacturing aims on what they proposed to the customers. But the basis of manufacturing environment could not satisfy what the customers really want. This is the reason why S-Pak also failed to compete with rivals who promote products alternative. Contrary, the factory only produce on fixed colored, models, fixed decoupling between fan coil and condensing unit, and fixed accessories of the product, reversing market niches.

The product range is also very narrow. The factory must change to meet two aspects; to support future growth of various air conditions such as wall-mounted type and 21,000 BTUs split-type and to increase flexibility to the current operation methods. So the redesign must enable flexibility within both processes and into the product itself.

The conclusion of method problems are:

- Ineffective management methods
- Inefficient working methods
- The methods of work currently cover the problems
- Outdate and unplanned manufacturing methods
- Bottle necks occurred during the process
- Non value-added activities and spaces
- High lead-time and delay between the assembling process until delivery to the customers
- Inflexible manufacturing processes and environment

After writing the fish bone diagram in figure 4-10, the team studied received information observed from shop floor to commit the final design solutions; what and how the core implementations will be? Eventually, fish bone has procured leading elements to constitute the 'manufacturing-type selection table' in the next topic which is the end title of redesign decision.

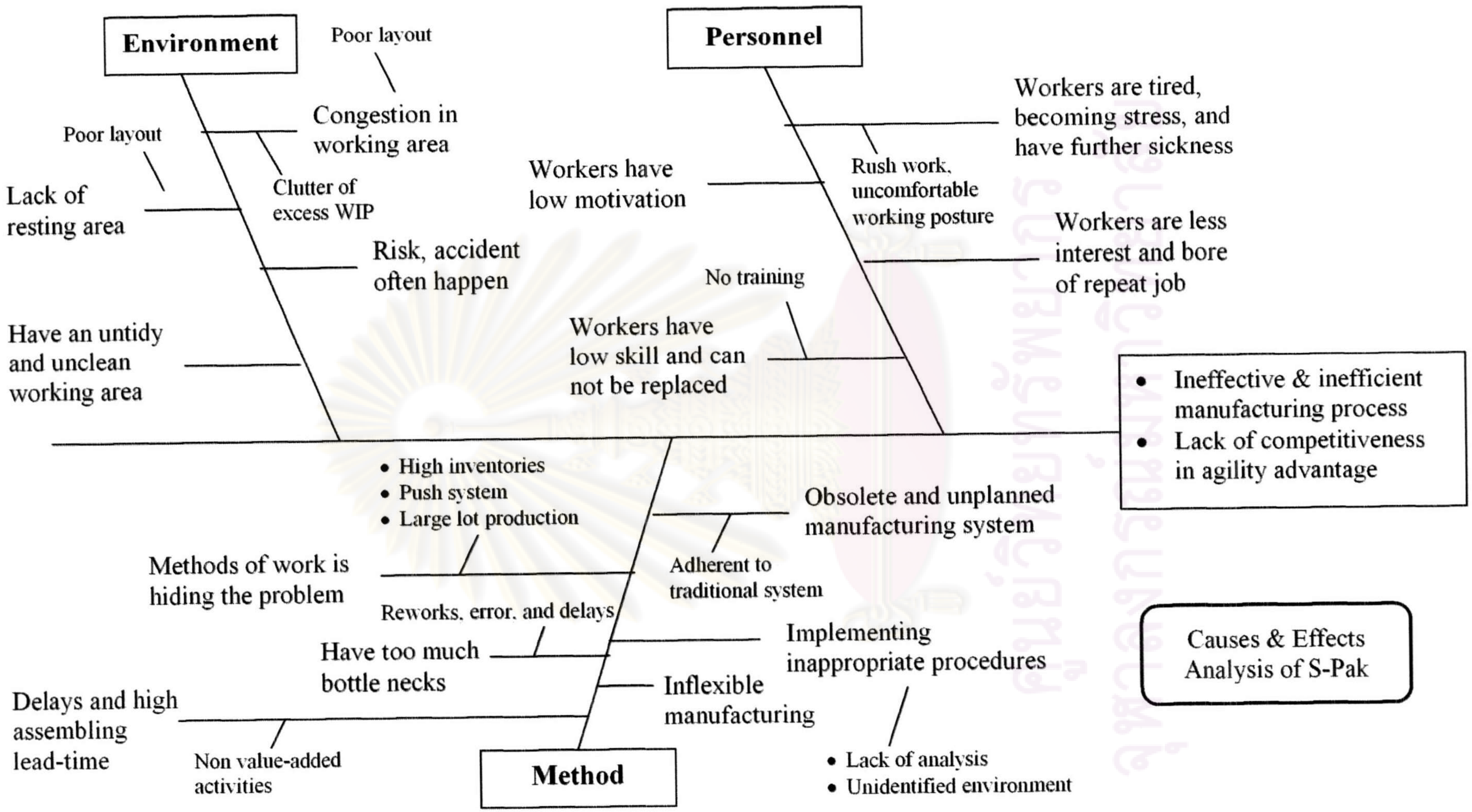

Figure 4-10; Fish bone diagram of Split-type assembling procedures

4. Final Decision

'Manufacturing-type selection table' is a comparison technique between existing problems against manufacturing types such as batches, flow, and cell whereas to see whether which types are most feasible to real redesign objectives. All problems will be weighted and computed for summarization. The type that obtains top marks is determined to be the core implementation.

Table 4-6; Manufacturing-type selection method for redesign S-Pak factory

Manufacturing Types / Targets to Current Problems	**Feasibility Rate of Improvement Selection**		
	Batch	**Cell**	**Flow**
Personnel			
Workers do not have to rush work	√	√	
Reduce boredom from the same repetitive activities	√	√√	
Have substitution when absentees occur	√	√	
Produce skillful or multiple skills workers	√	√√	
Environment			
Moderate production quantities / similar processes		√√	√
Use lowest working area	√	√	
Eliminating clutter inventories	√	√	
Prepare space for future expansion		√	
Method			
Changing from mass production (making to stock) to lean production	√	√√	
Plan for efficient working methods		√	√
Reduce production lead-time		√√	√
Apply pull system to reduce excessive inventories	√	√√	
Reduce bottle neck occurrences		√	√
Increase value-adding ratio		√√	
Increase production flexibility / require medium variety	√√	√	
Use small machines and tools / little set-up time requires	√	√√	
Total	**10**	**24**	**4**

- Symbol "√" stands for *fair compatibility level* of that manufacturing type to overcome the target of improvement – 1 mark
- Symbol "√√" stands for *high compatibility level* of that manufacturing type to overcome the target of improvement – 2 marks
- The "blank" (empty) box stands for a *non-affect, uncorrelated or low compatibility level* of that manufacturing type to overcome the target of improvement – 0 mark

As the results, batch, cell, and flow have the total scores of 10, 24, and 4 respectively. Batch manufacturing might be available for S-Pak environment but only in some aspects, when there is more production customization and machines require in the operations. Batches might be the good alternative but not the best way for current status. Conversely, flow manufacturing is too far to yield any substantial improvement from traditional stage. Referring to topic 5 in chapter 2, we will discover about the score of each target that:

<u>Workers do not have to rush work</u> – flow often make to stock to produce massive volume of goods so workers have to rush through work all the time without stopping. Conversely, batch and cell produce in rather lesser volumes and feasible for making products relying on daily customer's order.

<u>Reduce boredom from the same repetitive activities</u> – batch activities are intermittent while cell is in the middle between batch and flow. It stimulates workers to work in teams. Cell does not only provide variety of tasks to the worker but it stimulates team members to think by themselves and find the best way of working, which can increase job interest.

<u>Enable substitutions & Need high or multi-skill workers</u> – batch manufacturing requires high-skill workers. It is a good choice but cell might be a better alternative. Cell focuses more on the role of low-level workers with an idea of one-man per multiple machines or operations. It also enables personal incentives and job rotations.

<u>Moderate production quantities & Similar processes</u> – batch and cell are feasible of moderate production volumes and daily demand but still, batch production often use in factory that have machines setup for different product ranges such as sheet metal punching. In S-Pak, the job complexity is lower so cell manufacturing is more feasible.

<u>Use lowest working area</u> – flow is often applied for large factory but batch and cell will be more appropriate for medium or small scale factory like S-Pak. It is also more comfortable to do the layout analysis due to both types are counted as process layout (cellular), having intermittent workstations.

<u>Eliminating clutter inventories</u> – batch and cell support the concept of inventories reduction methods such as Kanban system and Just in Time.

Prepare space for future expansion – cell is the only manufacturing type in which clearly proposes an idea of continuous improvement and future awareness.

Changing from mass production to lean production – cell adopts the concept of lean production to change from traditional system. Lean production is the management of the present era.

Reduce lead-time & Increase value-added ratio – in responding to the lean production system, cell is the only manufacturing type that aims on improving lead-time, delivery time, and increasing the value-added ratio which are the core competence of S-Pak.

Plan for efficient working methods & Reduce bottle necks – in moderate to high production quantities with medium variety, the methods or motions study will be most comfortable of usage in planning for best performance by setting up standard working time. However, batch might be too complex to concern too much in motions. Cell and flow typically have the U-shape line to create better efficiency. They also have line balancing methods to reduce cycle time and relieve bottle necks more than batches.

Apply pull system to reduce excessive inventories – figure 4-4 and 4-5 represent that pull-system in controlling inventories such as Kanban has the highest compatibility with cell rather then other types.

Increase production flexibility for medium variety – batch production might enable highest flexibility, but in this case, medium flexibility level should be enough to handle customer customization demands. So cell takes the credit.

Use small machines and tools & little set-up time require – in factory with low machine usage, setup time is no longer a problem in causing lead-time. This is why cell manufacturing got the best compatibility level.

Cellular manufacturing has the most rational solution, defines by it top score. The conversion team agrees that. It calibrates in achieving on any expecting targets, while others can not. The concepts unite strong points of batches and flow and lay in the middle.

Cell fully emphasizes on team-working, producing moderate volume and variety, aims on reducing in-process inventories, production lead-time and non value-adding activities, and apply more compatibility with pull system. The most important factor is that it is most feasible for medium scale factory (and focus factory), which base on focus products (Split-type air condition). The team concludes that the processes in critical areas need to be redesign systematically by using lean manufacturing together with cellular layout.