CHAPTER IV

DATA COLLECTION AND ANALYSIS

4.1 Chapter Overview

According to the research procedure in section 1.9, this research can be divided into 3 main section; ground works, solution creation and solution evaluation. In this chapter, the first of three parts in the research procedure 'ground works' shall be carried out. Given below is the ground works section extracted from the research procedure.

Ground Works

1. Update Layout
2. Collects relevant manufacturing data
3. Analyse the production flow and material movement
4. Establish product families according to the manufacturing processes requirements
5. Use the information acquired to determine overall performance of the company and to identify key issues with the current manufacturing system i.e. bottleneck, machine utilisation rates

The first and most important step is to update the layout. It is critical that the most updated version of the factory layout is acquired in order to provide a valid base to develop from. It is futile to study an obsolete version of the layout as it is no longer relevant. After the most updated version of the layout is acquired, the manufacturing data must be collected to prepare for the current situation analysis. Manufacturing data such as machining time, transfer distances, manufacturing sequences etc. will be collected to be used with various tools and techniques that have been mentioned in section 2.1. These analyses will reveal the problems and characteristic of the current layout.

4.2 Data Collection and Analysis

In this section 4.2, the data collection and analysis will cover the five items given in the ground work section of the research procedure as shown earlier in the beginning of this chapter.

4.2.1 Current Layout Information

The engineering department is responsible for updating the plant layout and for keeping the record as up to date as practically possible. However, with the high workload and back logs, this duty has somewhat been neglected and the floor plan is very much out of date. Therefore, the first task of this project is to update the plant layout. The key factory area data that are needed to update the layout are the positions of the machines and supporting fittings. Objects like drawing tables, water coolers and tools cabinet are not presented on the factory schematics. If they are not identified early on, they can be potentially problematic down the track. These details need to be included on the schematic to ensure that the product flow paths are not obstructed. Figure 4.2 on the next page shows the layout that has been updated in December 2006. Figure 4.1 below shows the keys to the layout. The current layout is of a functional layout type. The blue lettering in figure 4.1 shows the rough separations of the different functional departments. The areas that are used for the manufacturing of the orthopaedic products are in the enclosed blue area. The red dimension showing that the distance between the columns is 5meters is given as a reference dimension since the layout has been scaled to fit the report's printing margin.

KEY	Symbol	Machine type	KEY	Symbol	Machine type
L		Lathe machine	**H**		Hydraulic press
S		Slotting machine	**X**		saw/sand paper grinder
M		Milling machine	**SH**		Sharpener
G		Grinding machine	**W**		Welding machine
D		Drilling machine	**A**		Air pump
MC		CNC milling machine	**EP**		Polishing machine
LC		CNC lathe	**CH**		Electric hoist

Figure 4.1 – Layout keys

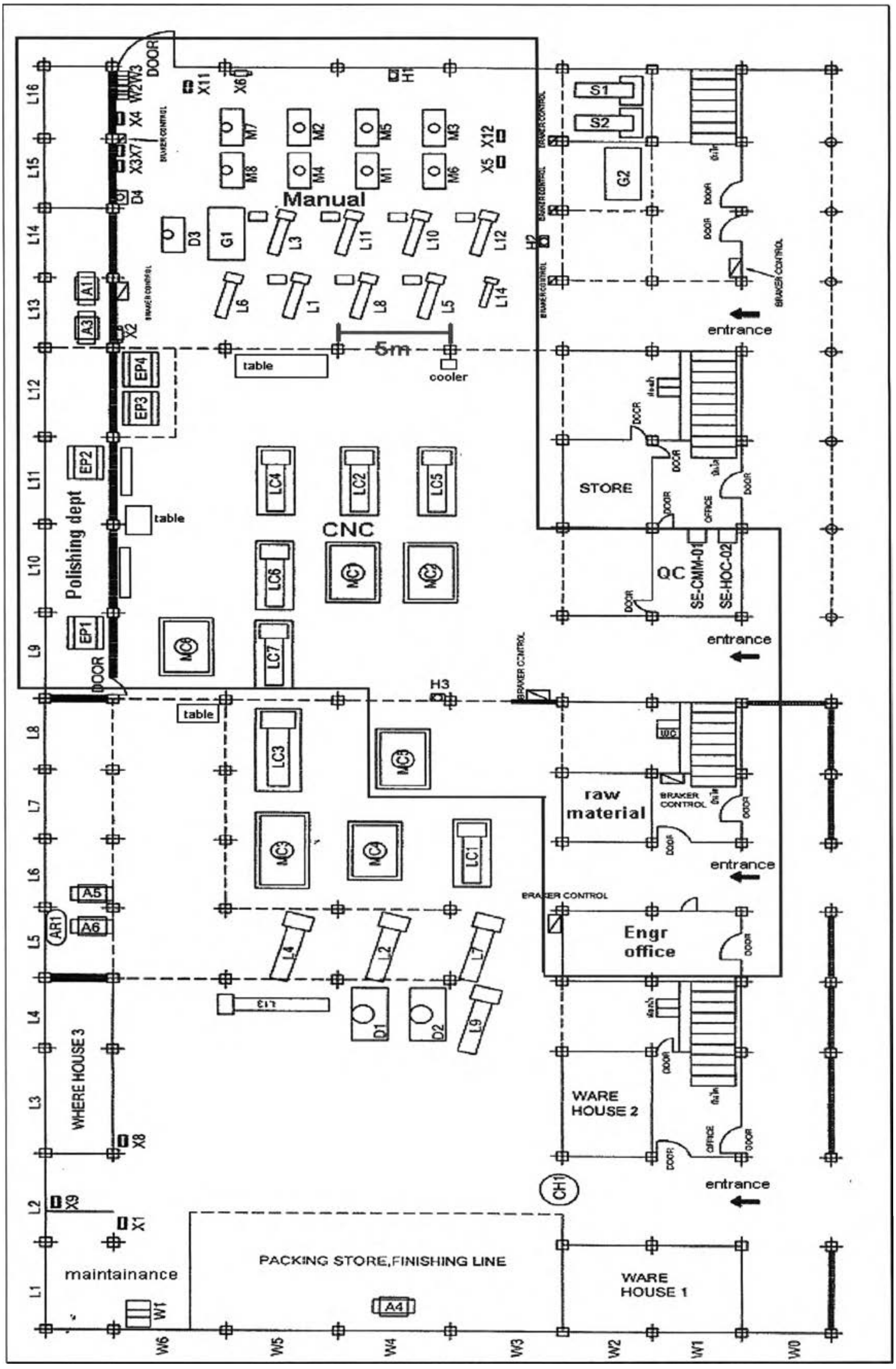

Figure 4.2 – Layout of the factory showing the functional layout. Current as at December 2006

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4.2.2 Manufacturing Data Collection

4.2.2.1 Which Products are we going to collect the Data From?

The first question that arises when trying to collect the manufacturing data is "which products shall we collect the manufacturing data from?". The company produces many types of screws, bone plates and instruments. However, after careful analysis of the product range, it has revealed that the large product range is only caused by the different in sizes of the product. For example, there are more than ten cortical screw products, but the only differences are the length and the diameter of the screws. These features do no affect the manufacturing sequence, the longer screws will only take a couple of minutes longer to produce but still follow the same manufacturing sequence as the shorter ones. Therefore, the product that will be selected will be the ones that have unique manufacturing sequence. Overall there are four different types of screws, two types of bone plate and three types of instruments. The details of these products are given in table 4.1 on the next page. These selections give a good representation of the different manufacturing sequences that are present in the product range.

Table 4.1 – Reasons of why these products were selected

Product	Reason that it was chosen
Cortical screw Pedicle screw Cortical screw Poly screw	The company produces a total of four different types of screws. Each with its own unique design and manufacturing sequences. Therefore, four types of screws were chosen.
Bone plate 8H Y plate	The bone plate's product can be separated into two main types; flat bone plates and bended bone plates. Bone plates 8H represent the straight ones while the Y plates represent the bended ones.
Compression pliers Inner hexagon holder Spine cage	Most of the instruments are manufacture solely within the manual machines department. There are more than 20 different instruments that the company produces. However, theses instruments can be categorized into three distinct group; pliers type, screw driver shaped type and small unique parts. Although the manufacturing sequences of the different instruments are not exactly similar to each other like the screws or bone plate family, the main differences are in the frequency that it travels between the lathe and the milling machine (some product are more complex than others) but it still remains in the manual department. Hence, these three products have been chosen according to their overall shape that gives a good representation for the rest of the instruments.

4.2.2.2 Data collection

After the product selection has been completed, it is time to collect the actual manufacturing data. There are two main types of data that are required to carry out the current layout analysis; time of each activity and distances. The process flowchart will be used as the form to record the data (time, distance and process sequence). Another type of data is also important for the design process; the products volume data. The product volume will be used to prepare the travelling chart which will be use to determine the machine placement priority in the design process. The details of the collecting method shall be explained below.

Time of Activities

The time of each activity shall be collected by studying and recording the processes and interviewing the operators. The author will physically observe the processes and records the time taken for each activity on to the process flowchart. The operators will also be interviewed to confirm that the observed results are in the norms. A stopwatch will be used to measure the activity that can be completed in the matter of minutes. For activities that take more than one hour to complete, a time note will be taken to record the start and the finishing time of the process and the time taken can be determine by figuring out the time differences.

Distances Data

The distances will be measured using a scaled factory schematic. However, because the schematics was developed in an A3 paper size but the author is working with an A4 size paper due to printing limitations, the scale on the A4 schematic must be recalibrated in order to get a valid result. This was achieved by using a measuring tape to actually measure the key distances in the factory, namely the distances between columns (as shown as the red dimension in figure 4.2), and to compare it with the measured value from the schematic. With this scale established, the schematic can be used to provide the transfer distances of the product. To obtain accurate product transfer distances, a string will be used to replicate the flow path of the product since human do not strictly walk in a straight line and corners at 90degress. The string will provide a more natural and realistic product flow path.

Products Volume Data

The product volume data is readily available. The engineering department already has manufacturing records in the Microsoft Excel format. Only minor rearrangements are required to convert the data into useful information. Table 4.2 below shows the summarised 2006 production volume data which will be used as the proposed volume for the design.

Table 4.2 – The proposed volume that will be used in the cell formation process will be based on the 2006 production volume

	2006 production volume
Screws	
Poly	9820
Pedicle	7875
Compression	18997
Cortical	22135
Set screw	23087
Plates	
Curved	8279
Flat	7620
Instruments	
Pliers	414
Small parts	821
Screw drivers	1789

4.2.3 Analysis of the Collected Data

With the layout updated and the manufacturing data collected, the next step is to analyse the information. Three tools will be used in this stage; process flowchart, string diagram and travelling chart.

4.2.3.1 Process Flowchart Analysis

The process flowchart technique will be used to shows all the activities involved in the manufacturing process of the products. The process flowchart will reveals the sequence of the activities, time of each activity and the transfer distances. The analysis will clearly separate the activities that are value added activities from the non-value-added activities. This will help when designing the new layout as the non-value-added activities can be easily identified and improved on or eliminated. Non-value-added activities are things like machine setup and product transfer. If these activities can be improved or eliminated, then the overall manufacturing process will be more effective. Table 4.3, 4.4 and 4.5 shows the process flowchart for the compression screw, y plate and compression pliers respectively. These three process flowcharts are only an example of the nine products chosen. One item from each product group has been selected to provide a brief example of what manufacturing data was collected and what manufacturing activities are required in the making of these different products. The complete range of process flowcharts can be found in appendix A. It should be noted that the total calculated process time on the process flowchart does not included the two activities (where applicable); wait for outbound transport and wait for outside process activities (i.e. laser, hardening, wire cutting). This is due to the fact that the waiting time for the parts to be picked up by the suppliers and the outside process cannot be controlled by the company and the redesigning of the layout will not affect these activities. The design of the new layout will only concentrates on the internal processes that can be directly controlled by the company. The values in the process flowchart are per batch of production. On average, the screws, the plates and the instrument are made in batches of 100, 65 and 10 respectively. The machines that are assigned to the product are the machine that the product is most likely to be using when forming the cell.

Table 4.3 – Process flowchart for compression screw – batch of 100

Step		Description	Time [min]	Distance [m]
1	○ ➡ □ D ▽	Move from stock to lathe, LC4	0.57	33
2	○ ⇨ □ ◗ ▽	Machine setup (once only)	70.00	
3	● ⇨ □ D ▽	Lathe work	1050.00	
4	○ ⇨ ■ D ▽	Inspect (done during machining)	75.00	
5	○ ➡ □ D ▽	Move to hydraulic pump H2	0.42	24
6	● ⇨ □ D ▽	Pump - hexagon pattern	225.00	
7	○ ➡ □ D ▽	Move to polishing dept	0.67	39
8	● ⇨ □ D ▽	Polish/clean	18.00	
9	○ ➡ □ D ▽	Move to QC	0.45	26
10	○ ⇨ ■ D ▽	QC	600.00	
11	○ ➡ □ D ▽	Move to outbound storage	0.42	24
12	○ ⇨ □ D ▼	wait for transport	2days	
13	○ ⇨ □ ◗ ▽	Send to laser and wait	2.5days	
14	○ ➡ □ D ▽	move from office to polishing dept	0.78	45
15	● ⇨ □ D ▽	Boil	3.00	
16	○ ➡ □ D ▽	Move to storage	0.98	57
		Total	2035.28	248

Table 4.4 – Process flowchart for Y plates - batch of 65

Step		Description	Time [min]	Distance [m]
1	○ ➡ □ D ▽	Move from stock to bender, hydraulic pump H3	0.28	16
2	● ⇨ □ D ▽	Bend	195.00	
3	○ ➡ □ D ▽	Move to milling centre, MC5	0.13	7
4	○ ⇨ □ ◗ ▽	Machine setup (once per batch)	70.00	
5	● ⇨ □ D ▽	Milling work	1105.00	
6	○ ⇨ ■ D ▽	Pre check	3.00	
7	○ ➡ □ D ▽	Move to polishing dept	0.35	20
8	● ⇨ □ D ▽	Polish	15.00	
9	○ ➡ □ D ▽	Move to QC	0.45	26
10	○ ⇨ ■ D ▽	QC	325.00	
11	○ ➡ □ D ▽	Move to outbound storage	0.42	24
12	○ ⇨ □ D ▼	Wait for transport	2days	
13	○ ⇨ □ ◗ ▽	Send to Laser and wait	2.5days	
14	○ ➡ □ D ▽	move from office to polishing dept	0.78	45
15	● ⇨ □ D ▽	Boil	3.00	
16	○ ➡ □ D ▽	Move to storage	0.98	57
		Total	1709.400	195

Table 4.5 – Process flowchart for compression pliers – batch of 10

Step		Description	Time [min]	Distance [m]
1	○ ➡ □ D ▽	move casting from office to manual lathe	1.03	60
2	○ ⇨ □ ◗ ▽	Lathe setup (once only)	90.00	
3	● ⇨ □ D ▽	Find pliers centre	35.00	
4	○ ➡ □ D ▽	Move to manual milling centre	0.13	8
5	○ ⇨ □ ◗ ▽	Machine setup (once only)	30.00	
6	● ⇨ □ D ▽	Mill pliers body	4500.00	
7	● ⇨ □ D ▽	Mill pliers base	1800.00	
8	○ ➡ □ D ▽	Move to manual lathe	0.13	8
9	● ⇨ □ D ▽	Lathe work	300.00	
10	○ ➡ □ D ▽	Move to assembly	0.27	15
11	● ⇨ □ D ▽	Assemble	550.00	
12	○ ⇨ ■ D ▽	testing	450.00	
13	○ ➡ □ D ▽	Move to polishing dept	0.47	27
14	● ⇨ □ D ▽	Polishing	300.00	
15	○ ➡ □ D ▽	Move to QC	0.45	26
16	○ ⇨ ■ D ▽	QC	50.00	
17	○ ➡ □ D ▽	Move to storage	0.98	57
		Total	8108.47	201

4.2.3.2 String Diagram Analysis

The process flowcharts have provided the manufacturing information in an organised and useful format. Although it revealed the manufacturing sequences, it did not show the actual movement of the product. The string diagram technique will be used to shows the actual product movement on the shop floor. This will reveal whether the machines are in the suitable position or not and will help with the new layout designing process. Like the process flowcharts section, only 3 string diagrams will be shown to give the reader an idea of the situation in the factory. A complete set of string diagrams can be found in Appendix A. Figure 4.3 to 4.5 shows the string diagrams for the three selected products.

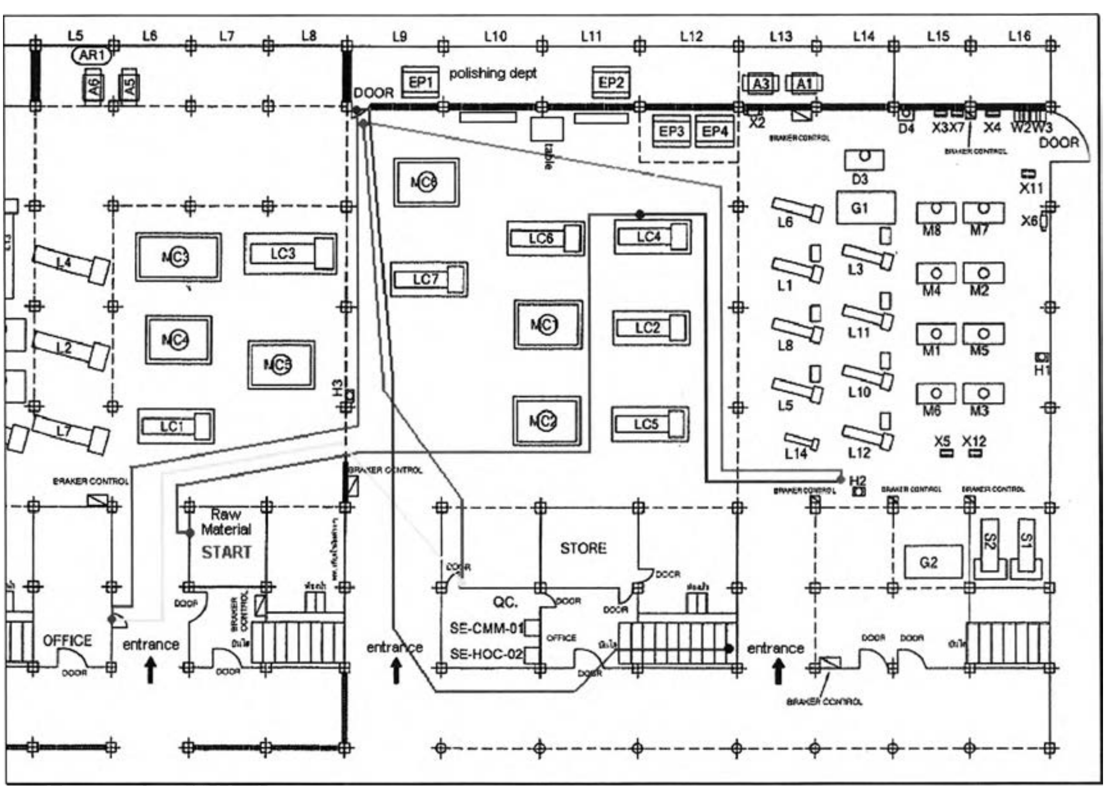

Figure 4.3 – String diagram for compression screw showing the unnecessary product movement across the shop floor

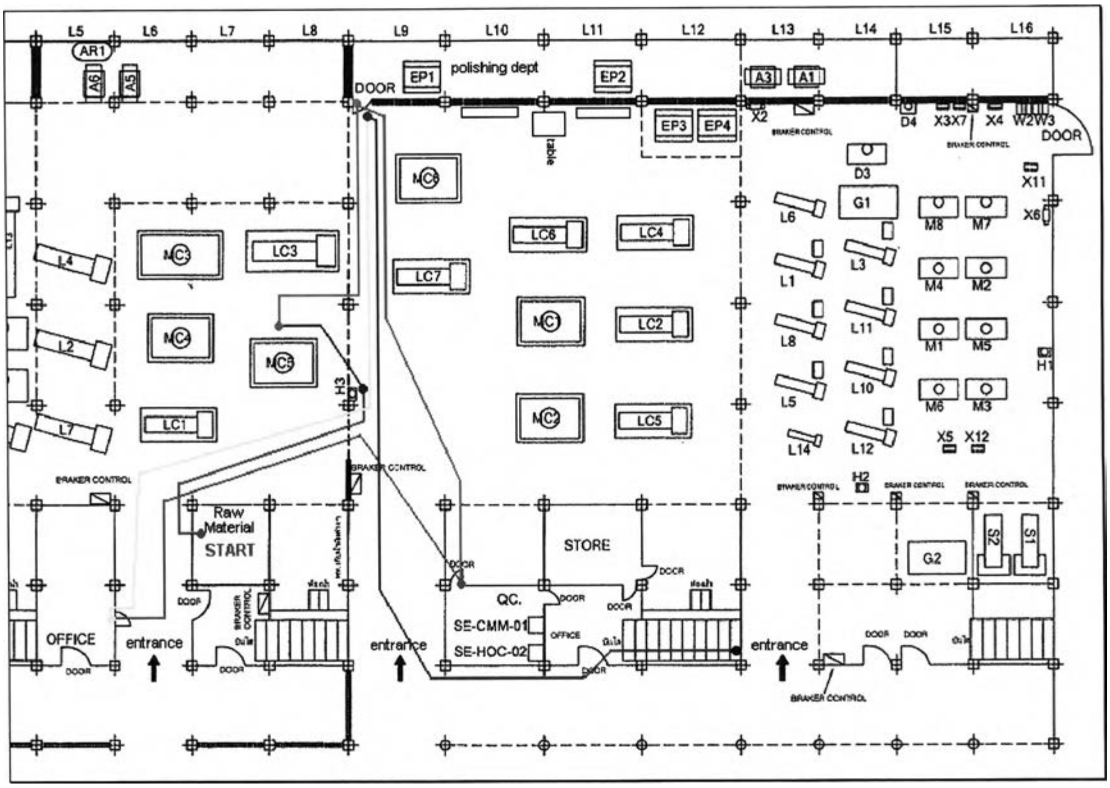

Figure 4.4 – String diagram for Y plates showing the product movement

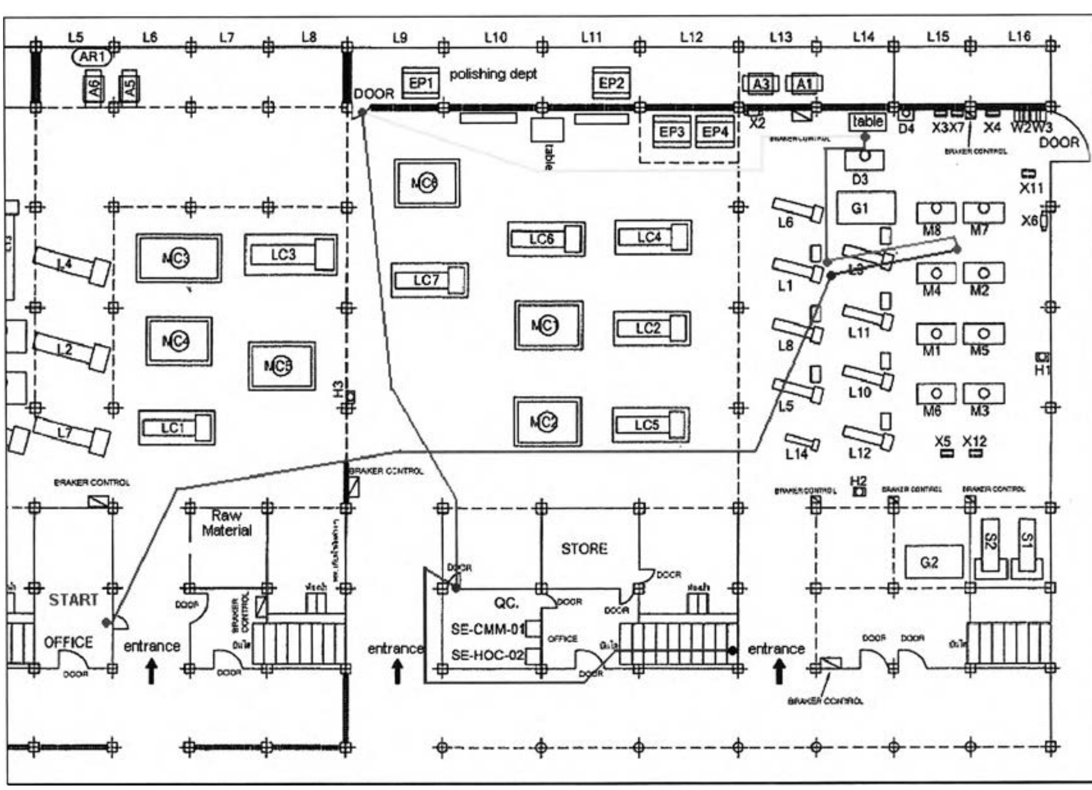

Figure 4.5 – String diagram for compression pliers showing the unnecessary product movement across the shop floor

As shown earlier in figure 4.2 that the orthopaedic products are only manufactured in the blue area of the factory, the string diagram will only shows the relevant part of the shop floor and not the whole factory in order to gives a better resolution picture in this limited space.

It should be noted that the actual flow-paths of the parts are smoother than those depicted in the diagrams. Straight lines are used because the curvatures are difficult to reproduce in the drawings. Nevertheless, these diagrams give a very good representation of the real situation. Each coloured lines on the string diagrams represents the movements while the coloured dots represent the activities. As the string diagrams have shown, the manufacturing flow path are scattered everywhere throughout the factory. Further analysis of the current situation will be carried out in section 4.2.5.

4.2.4 Cells Formation

With the data collected through the process flowchart and the manufacturing flow path illustrated by the string diagrams, the next step is to decide which machine is to be used for which product and systemically group the products into family. The product will be grouped according to its machining process requirements so that cells can be formed for the new layout.

4.2.4.1 Product Grouping Using PFA

The production flow analysis (PFA) will be used to group product with similar manufacturing requirements together. Table 4.6 below shows the raw data table for the machine selection matrix. As mentioned in section 4.2.2, the machines were selected base on the product technical needs. The amount of machine required per product is based on the 2006 production volume analysis (see appendix B for details).

Table 4.6 – Raw data table for the machine selection matrix

	bone plate	compression pliers	compression screw	cortical screw	inner hexagon holder	pedicle screw	spine cage Ti	poly screw	y plate	set screw
MC1	×									
MC5									×	
MC6						×		×		
LC2				×						
LC4			×							
LC5						×		×		
LC6										×
LC7								×		
Manual Lathe		×			×		×			
Manual Milling		×			×	×	×	×		
H1								×		
H2			×	×				×		×
H3									×	

With the machine selection information entered in the process flow analysis matrix, the next step is to group the products with similar machining process together to form manufacturing cells. Table 4.7 below shows the rearranged process flow analysis table.

Table 4.7 – Rearranged process flow analysis table to form manufacturing cells.

	Screws					Plates		Instruments		
	poly screw	pedicle screw	compression screw	cortical screw	set screw	Curved plates	Flat plates	Pliers type	Small type	Screw driver type
MC1							×			
MC5						×				
H3						×				
H2	×		×	×	×					
LC2				×						
LC4			×							
LC6					×					
MC6	×	×								
LC5	×	×								
LC7	×									
H1	×									
Manual Milling	×	×						×	×	×
Manual Lathe								×	×	×

The coloured box in table 4.7 above shows the potential manufacturing cells to be used in the new layout design. These three cells are: Screw cell, bone plate cell and instruments cell. There is also a possibility of creating a sub-cell within the screw cell as shown by the dotted box. It should be noted that the polishing process cannot be grouped into any particular cell because it is a process that is required by all of the products. Further more, the ventilation requirement of the process requires that the polishing and cleaning machines must be placed outside in an open-air area. As the result, the polishing department will be excluded from the design scope. Table 4.7 also showed that there is overlapping process requirements for the manual milling process. Fortunately, there are many manual milling machines available in the factory and one or two machines can be taken for the screw cell.

4.2.4.2 Available Machine Time

With the machine selection and cell formation process completed, the next step is to determine the actual amount of machine time availability and how much of each machine time is wasted with the setup activities. The aim of cell manufacturing is to reduce the non-value-added setup time and regain the time to use it for actual production.

Total Available Machine Hours

Currently, the normal operating hour is 8am to 5:30pm with a one-hour lunch break (9.5 hours per day). The factory operates 6 days per week and 50 weeks per year (2weeks national holidays); giving a total of 300 operational days. Therefore, each CNC has 2550 available hours per year (171000 minutes). When needed, the CNC machines are also able to operate with overtime and night shift. The overtime shift runs from 6pm to 8:30pm and the night shift runs from 8:30pm to 8am.

Actual Available Machine Hours

In a normal working day, the machine will not be able to operate 100% of the total time available. The machine will have downtime for activities like lunch break, machine setup, tool changes and shift transfer. Table 4.8 below shows the actual machines time available.

Table 4.8 – Table showing total and actual available machine time

	Yearly available minutes	Setup [min]	Tool change [min]	Break [min]	Actual time available	
					[min]	[%]
CNC						
MC1	171000	7620	762	18000	144618	84.57%
MC5	171000	4938	459	18000	147604	86.32%
MC6	171000	12387	1770	18000	138844	81.20%
LC2	171000	15495	3099	18000	134407	78.60%
LC4	171000	13298	2660	18000	137043	80.14%
LC5	171000	12387	2477	18000	138136	80.78%
LC6	171000	12698	3232	18000	137070	80.16%
LC7	171000	6874	1375	18000	144751	84.65%
Manual						
H1	171000	negligible	negligible	18000	153000	89.47%
H2	171000	negligible	negligible	18000	153000	89.47%
H3	171000	negligible	negligible	18000	153000	89.47%
Manual Milling (6)	1026000	18722	negligible	108000	899279	87.65%
Manual Lathe (4)	684000	17481	negligible	72000	594520	86.92%

The setup and tool change time were calculated based on the 2006 production volume. The individual setup time differences of each machine are based on the different amount of setup required by the product that the machine is associated with. The machines are needed to be setup for every batch of production. The average batch size for the screw, plate and instrument products are 100, 65 and 10 respectively. Therefore, the setup frequency can be calculated by dividing the production volume by its respective batch size. It is also known that when a new order arrives at the machine, it will take approximately 1 hour to setup and calibrate the machine; hence the total time spent on machine setup can be calculated by multiplying the setup frequency by the setup time (see appendix B for details of calculation). The same concept is used for calculating the tool change time. On average, the tool pieces wears down and are changed every 50 parts for the lathe and every 100 parts for the milling station. Tool change time is around 7minutes for lathe and 10 minutes for milling station, only minor calibration is required after the tool change. Apply the same calculation method as above and the tool change time can be calculated.

With the cell manufacturing concept, the setup downtime can be significantly reduced. With the machine being dedicated to specific products, unlike the original functional layout where machines are used for multiple products, the machines will not needed to be setup as often as before. It should be noted that there are also other downtimes such as machine break down, raw material outage, and insufficient demand. However, these downtimes will not be considered in this research because the cell manufacturing theory will not effect or improve these activities.

4.2.4.3 Capacity Check

With the actual time available of each machine known and the cell formed, the next step is to check if the cell will have enough capacity or not. Table 4.9 below shows the load percent of each machine. The values were calculated by dividing the machine time requirement of each product (see appendix B) by the actual time available (table 4.8 earlier). All of the values are below 100% except for machine LC5, which has a total of 130%. This machine will be required to operate with some night shift to cover the extra load.

Table 4.9 – All machine have enough capacity to cover the production volume except LC5 that will need night shift.

	Screws					Plates		Instruments		
	poly screw	pedicle screw	compression screw	cortical screw	set screw	Curved plates	Flat plates	Pliers type	Small type	Screw driver type
MC1							47.42%			
MC5						96.25%				
H3						16.23%				
MC6	58.76%	42.84%								
LC2				74.03%						
LC4			73.05%							
LC5	37.53%	94.60%								
LC6					76.08%					
LC7	67.84%									
H1	32.09%									
H2	6.42%		18.62%	21.70%	15.09%					
Manual Milling	19.59%	13.09%						43.57%	24.00%	11.66%
Manual Lathe								2.33%	1.10%	13.09%

4.2.4.4 Transfer Frequency Analysis

With the string diagrams completed and the production volume known, a travelling chart will be prepared to shows the frequency that the products travel between the different machines. This information is needed to establish a machine placement priority guideline. The machine-couple with the most transfer frequency shall be placed as close to each other as possible to maximise the design's effectiveness. Table 4.10 below shows the travelling chart for all the parts. The transfer frequencies between the machines are also based on the 2006 production volume.

Table 4.10 – Travelling chart showing the transfer frequency between the machines couples

	MC1	MC5	H3	MC6	LC2	LC4	LC5	LC6	LC7	H1	H2	Manual Milling	Manual Lathe	polishing	Raw material	Office	QC
MC1														9525	9525		
MC5			5731											5731			
H3		5731													5731		
MC6							22119					9844x		12275			
LC2											35544				35544		
LC4											23656				23656		
LC5				22119											22119		
LC6											21319				21319		
LC7											12275				12275		
H1														24550		12275	
H2					35544	23656		21319	12275			12275x		80519			
Manual Milling				9844x							12275x		4298	3262		4472	
Manual Lathe												4298		518	5498	2754	
polishing	9525	5731		12275						24550	80519	3262	518			86536	131713
Raw material	9525		5731		35544	23656	22119	21319	12275				5498				
Office										24550		4472	2754	86536			108850
QC														131713		108850	

4.2.5 Summary of Problems with the Current Layout

From the primary analysis carried out using the process flowchart, string diagrams and process flow analysis; two of the most concerning problems is the large amount of time used for machine setup and poor material flow path on the shop floor. In 2006, a lot of time was used to setup the machines. The machine setup, which is a non-value-added activity, is keeping the parts outside the machine. The factory should have been able to produce more. The parts spent too much time waiting and travelling from one machine to another while it should have in the machine receiving value-added operations. The setup time and travelling distance must be reduced to improve the situation.

4.2.5.1 High Machine Setup Time

One of the major problems that the shop floor is facing is the large amount of time taken to setup the machine. The machines need to be setup and calibrated every time the machine has a new order. On average, the machine setup and calibration takes approximately 1 hour to complete. If the setup frequency can be reduces, then the factory can improve the machine utilisation. Table 4.11 below shows the total time used in 2006 for setup. This must be reduced to improve machine utilisation.

Table 4.11 – Table summarising the setup time of each machine and product during 2006. [min]

	Screws					Plates		Instruments		
	poly screw	pedicle screw	compression screw	cortical screw	set screw	Curved plates	Flat plates	Pliers type	Small type	Screw driver type
MC1							7620			
MC5						8916				
H3										
MC6	6874	5513								
LC2				15495						
LC4			13298							
LC5	6874	5513								
LC6					12698					
LC7	6874									
H1										
H2										
Manual Milling	2946	2363						1242	1437	10734
Manual Lathe								3726	1232	12523

4.2.5.2 Raw Material Storage Position is not Effective

Generally, the product will start its manufacturing process as bar stocks from the raw material storage. This is one of the most frequent transfer points. The raw material storage is located adjacent to the orthopaedic equipment manufacturing area which is farther than necessary. Once again, this is a result of unplanned expansion. During the expansion, the storage area was placed where ever there was room available, it was not planned to effectively integrate into the manufacturing process.

4.2.5.3 Office Position is Not Effective

The production office is located next to the raw material storage area, which is even farther. The production office also doubles as inbound and outbound storage. Parts that required outsourced process such as laser, wire cutting, anodising, hardening and casting, will be dropped off in the office and wait for expediting. Generally, parts will arrive at the office via the QC department and parts that have returned from the outsourced process will be transferred to either the polishing department for cleaning or the hydraulic pump for assembly. Therefore, the office should be located near, or have a direct path to these departments. These movements are one of the most frequent transfers. Unfortunately the office cannot be moved very easily. Most of the shop floor area is not suitable for office work, they are mainly open space. Walls, windows and air-conditioning system must be relocated, which can be very costly. However, some machines such as the assembly hydraulic pump may be moved closer to the office to reduce the transfer distance. Further consideration is required when designing the new layout to achieve a balanced office location. One possible new location for the office is the store room. The store room is used for storing valuable tools such as special drill pieces, expensive machine inserts, and precision measuring instruments. The store room is only used when new machine insert or special tools are required and are accessed rarely during the day. The store room and the office can be switched if needed. Additionally, the store room is already air-conditioned, the office and store room can simply be switched without too much hassle.

4.2.5.4 Functional Layout is Causing the Product to Travel All the Way Across the Shop Floor

The layout of this factory can be classified as a functional layout type. There is a rough separation between the different machines, mainly the manual and the CNC machines as figure 4.2 have shown early on. Although the functional layout is easy to setup and is very flexible, it does not provide the most effective method of manufacturing. Parts that required multiple processes from multiple departments are required to travel between the departments. Travelling is a non-value-added activity. If it can be reduced or eliminated, then the efficiency of the manufacturing process can be improved. For example, figure 4.5 earlier shows the flow path of the compression pliers. It has to move from the stock area across to the CNC lathe, then move back to the CNC milling, then travel across the factory to the manual lathe and so on. These machines must be aligned to provide the shortest and straightest flow path so that non-value-added activities are minimised. The problem arises when trying to arrange the machines so that all parts will benefit equally. The key is to provide the parts that have the most volume and transfer frequency with the most benefits, as identified in the travelling chart (table 4.10).

4.2.5.5 Current Travelling Distance of the Original Design

Table 4.12 below summarised the travelling distance and time of each part for the original design (to complete the production cycle). This information was gathered from the process flowcharts in section 4.2.3.1 and appendix A. These values will be used as a baseline values for comparison with the two new designs.

Table 4.12 –Current travelling distance and time of each part to complete all the process; baseline values.

	Travelling distance [meters]	Travelling time [second]
Screw		
Poly -body	328	338
- head	182	187
Pedicle	272	280
Compression	248	255
Cortical	239	246
Set screw	154	159
Plates		
Curved	195	201
Flat	198	204
Instruments		
Comp pliers	201	207
Spine cage	160	165
Inner hex holder		
-shaft	378	389
- handle	182	187