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Plant Layout Analysis and Redesign

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By

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Plant Layout Analysis and Redesign

Honors Capstone Project

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Conducted at SPX Fluid Power Inc.
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Project Abstract

SPX is hydraulic company located in Rockford, Illinois that manufactures high-pressure hydraulic components. They make a variety of products that include hand-pumps, hydraulic pumps to be used in heavy machinery, hydraulic rams and pistons for leveling structures, railroad equipment, cable tools and much more. Our focus for this project is to produce a plan for redesigning the current production floor layout for SPX. To do this we obtained all of the current data for the facility including high-volume part numbers and their routings. After we gained this information we conducted a CORELAP algorithm analysis to determine placement of the departments in the layout. These results were then used to find the optimal layout for the facility and then reanalyze the material flow. Upon comparing the original and revised flow, it was shown that if out improvements were implemented, SPX would save about 15% on material handling costs each year which translates into about $500,000 a year. We recommend implementation of the revised layout due to the fact that the return on investment will only take about a year and overall profits will be significantly higher for SPX in the future.

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Introduction and Background

SPX Fluid Power is a hydraulics company headquartered in Rockford, Illinois that manufactures a variety of high-pressure hydraulic components. Their facility has been in its current location for over 30 years; however, it has undergone quite a few changes. Originally Fenner Fluid Power, the company was bought out by SPX Corporation of Minnesota and then merged with another hydraulics company from England. The building was rearranged and expanded to handle this new capacity; however, the overall layout still remains segregated and disjointed. SPX makes a variety of products that include hand-pumps, hydraulic pumps to be used in heavy machinery, hydraulic rams and pistons for leveling structures, gear pullers, lifting jacks, cable-working tools and also portable high-pressure pumps. These portable hydraulic pumps and rams are used all over the world for a variety of applications where high-pressure hydraulic power is required. Some of the most common applications of the pumps are bridge leveling, building relocation, lift-vehicles, powering rescue tools such as the "jaws of life", and pulling gears and bearings from large machinery. SPX manufactures a diversified line of products that have been specifically designed for numerous applications and specifications.

Problem Description

Due to the fact that the SPX production facility is a conglomerate of several companies, the layout is disjointed and not well laid-out. Many of the production lines remain from the original Fenner design, however there are other instances where lines have been combined in an effort to integrate the companies. Other areas were settled by simply placing machines or assembly lines wherever they would fit – oftentimes not in a desirable location. For instance, machine centers are currently running production in a corner of the building hidden behind the receiving department. Other lines sit idle between the storeroom and tool room due to low demand – the lines' products are necessary to produce so the lines cannot be removed but they may only run a few days out of the month. The layout is so flawed that the warehouse is located all the way across the facility from shipping and receiving. SPX is in dire need of a plant redesign to streamline flow and raise efficiency.

Our project team has taken on the challenge of redesigning the plant layout in an effort to alleviate some of these problems. The design of a facility is a crucial aspect of the company's overall success because it is underlying in most operations. A good layout will facilitate the flow of materials throughout the building without creating bottlenecks or traffic jams while at the same time, moving material as efficiently and cost effectively as possible. A layout may not be as easy to come about as it seems – there are many constraints and variables that have to be taken into account. Structural monuments or items that cannot be moved are present throughout the facility and have to be worked around. These structures include bathrooms as well as huge assembly lines that, if moved, would cost the company large sums of money – upwards of $6,000 for the twin Makino milling lines. However, if our new layout proves to be substantially beneficial, it might be a good idea to move these monuments because in a couple of years, SPX could make up for the cost of moving them through implementation of our new design. What we are planning on doing is to place the departments, including the monuments, where we feel they would yield an optimal flow. Later we will see if leaving those monuments where they were would make a big difference in the total saving cost. Also, the problem of adjacency comes into play in situations where the optimal design can simply not be followed, for instance the paint booth cannot be located next to a welding station due to fire and explosion hazards. Our new layout design will have to accommodate to these conditions and be in compliance to safety ordinances.

Objectives

Companies thrive by making money so it comes as no surprise that the end objective of this project is to save money. There are many different ways that a company can go about saving money, and SPX is currently engaged in a few such ventures. This particular project, however, is aiming to save the company money by making the flow of materials through the facility more efficient. This gained efficiency will monetarily help the company in a variety of ways. A more efficient conveyance of materials will most obviously save transportation costs but also helps in other instances. More efficient operations will mean that SPX can produce products at a faster rate and thus expect more revenue through sales. Also, better flow will result in reductions in inventory that is held to fill orders because not as much safety stock will be required as a cushion between departmental operations.

Within the project itself, we have established, with SPX engineering management, a set of goals and objectives to be accomplished by this project. First, we want to create an accurate from/to chart that contains all of the information about which materials are going where and how. This chart will allow us to create a visual representation of material flow which will partially reveal where the layout needs to go. Our next goal is to use the data collected to create a new layout for the facility. It is this end-goal that will ultimately lead to the monetary savings that are expected. Our group will not address the moving of equipment and workstations, but will instead simply supply an optimal picture of what the facility should look like. Our final goal will be to present this picture to the management along with an idea of how much money could be saved if implemented. Once completed, we hope that this project can greatly aid SPX both financially and also in daily operations.

Methodology Overview

Completion of this project will require a system of data collection and analysis stretched out over a four-month semester. Most of this work will be completed at SPX, however, some will also be completed off-site. A large portion of this project consists of data collection which has accounted for the entire beginning phase. Once all of the necessary data has been collected, it will be analyzed, processed and sorted into useful information. Finally, this information will be displayed in a visual manor so the benefits can be fully appreciated and quantified.

Overall, our methodology is not extremely complicated, but does require quite a bit of work and knowledge. We will be relying very little on help from current employees of SPX which means that our knowledge gained through education at NIU will be the most important tool available. Our project team has little experience in the real world of industry, so we will have to fall back on the information obtained in such classes as Facilities Planning, and Production Planning and Control. Theory will be applied to a real life problem for the first time in our young careers and should prove to be successful and beneficial to both ourselves and to the company.

Data Collection

Data collection is a large part of most projects and also one of the most important because the outcome of a project is only as good as the information that it is based upon. To be able to map the flow of materials through the SPX facility, we had to first find out where materials are used. To do this, the project team obtained a list of all of the workstations in the facility which totals about 90 when including recently added lines and excluding lines that have become obsolete. Workstations include any station where material is processed in a value-added manner. This includes machining centers, assembly benches, paint booths, and welding centers. Using the Syteline system, SPX's data base and information processing system, our team explored each work center using the 'Work Center Where Used Report' as seen in Figure 1. The information that we were able to obtain from this particular screen was the end-product part number for whatever units were run across each line. For our purposes, we selected the top three to five items for each station according to last years sales by volume and recorded the item numbers in a spreadsheet as seen in Figure 2.

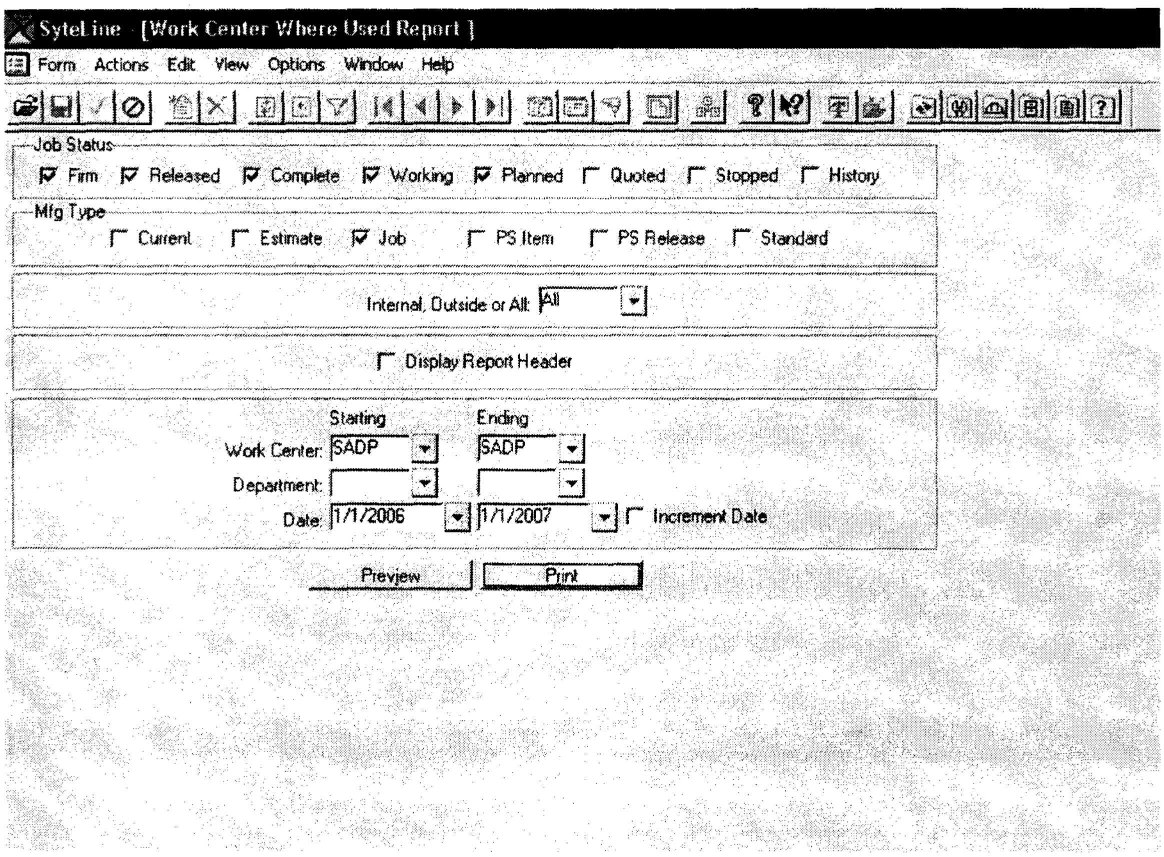
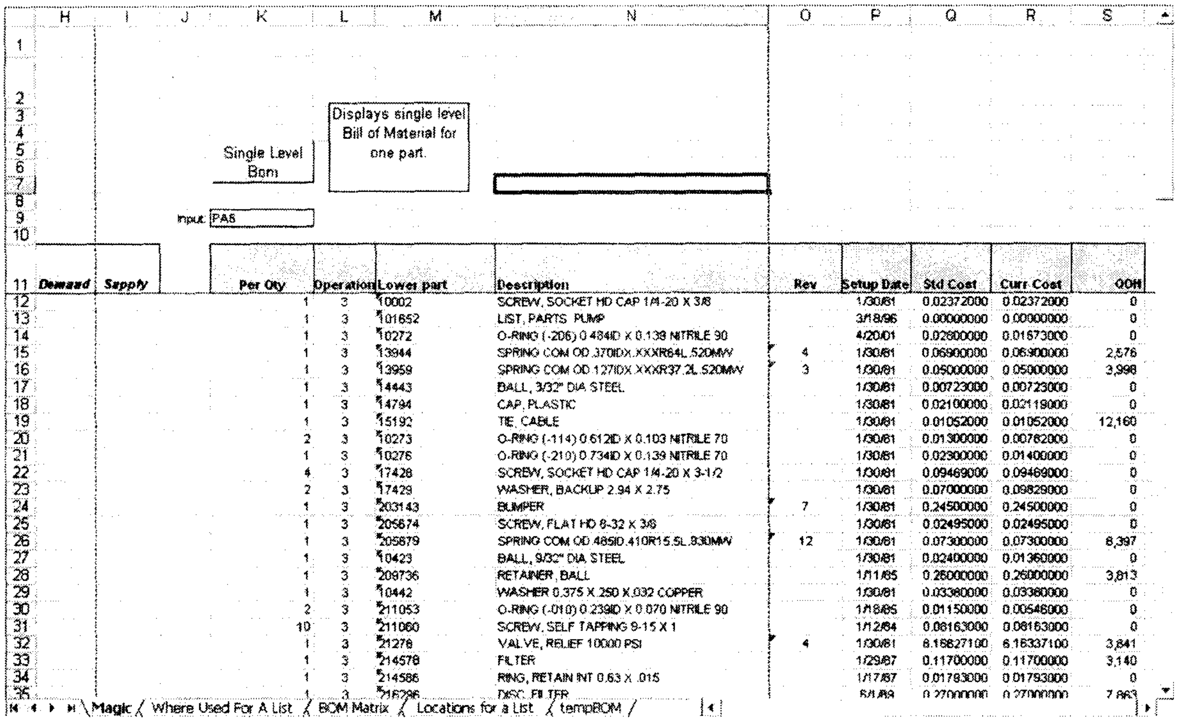


Figure 1: Syteline Work Center Where Used Screen

	A	B	C	D	E	F	G	H
1	WC: Work Ctr	WC: Name	WC/DEPT: Department	DEPT: Description	Last Year 1st Highest Usage	Last Year 2nd Highest Usage	Last Year 3rd Highest Usage	Last Year Other Highest Usage
2	246	MURATA MW200G	501	ENDHEAD DEPARTMENT	N1-9000-05AL	n/a	n/a	
3	272	MORI SEIKI SH-50	501	ENDHEAD DEPARTMENT	N1-0004-97AL	N1-0027-32AL	n/a	
4	AB01	MISC. GEN HYD	536Y	RAM ASSY & TEST FF1	208380	TWH50	TWH20	
5	AB04	SWING CLAMP ASSEM.	536Y	RAM ASSY & TEST FF1	100915	351013	100223	110071
6	AB05	SWING CLAMP ASSEM	536Y	RAM ASSY & TEST FF1	351752	351063	100895	
7	AB06	WORK SUPPORTS	536Y	RAM ASSY & TEST FF1	100172	100917	204666	9675
8	AB09	PA9 ASSEMBLY	536Y	RAM ASSY & TEST FF1	WHEE-61428	PA9-GRC	63-0005	
9	AB13	MISC. GEN ASSEMBLY	536Y	RAM ASSY & TEST FF1	9692	0500	202817	
10	AB50	TIRE TOOLS	536Y	RAM ASSY & TEST FF1	28705FA	IMT210	HS2000	
11	AB80	RAM ASSY TEST	536Y	RAM ASSY & TEST FF1	58497	n/a	n/a	
12	AB81	RAM ASSY TEST	536Y	RAM ASSY & TEST FF1	311922	52144	J15A-SL	
13	AB83	RAM ASSY TEST	536Y	RAM ASSY & TEST FF1	RSS202	52624	RSS502	
14	AB85	ASSY CYLINDER	536Y	RAM ASSY & TEST FF1	C1010C	C254C	C106C	
15	AB86	RAM ASSY & TEST	536Y	RAM ASSY & TEST FF1	34149	RH202-VIC	RA554-Q4893	RH302
16	AB89	RAM ASSY TEST	536Y	RAM ASSY & TEST FF1	9798	9796	9795	
17	AC01	HAND PMP PACK	536Y	RAM ASSY & TEST FF1	P159	P19	P55	P59
18	AC07	CARTON & LABEL	536Y	RAM ASSY & TEST FF1	63-0004	C104C-VIC	RSS302	
19	AC55	PREPARE FOR SHIPMEN	536Y	RAM ASSY & TEST FF1	46206	52626	35897	RSS502
20	AM01	PA6 AIR PUMP ASSY	536Y	RAM ASSY & TEST FF1	IMT200	4020	PA6	
21	AM02	P55/P59/P157 PUMP A	536Y	RAM ASSY & TEST FF1	P55	P59	P159	2000401
22	AM02L	P19L/P59L ASSEMBLY	536Y	RAM ASSY & TEST FF1	66639	2000402	P19L	
23	AM05	PE4000 PWR PMP	536Y	RAM ASSY & TEST FF1	60557	PE4004S	66225	
24	AM06	PQ PWR PMP ASY	536Y	RAM ASSY & TEST FF1	3000265	306957	PQ1204S	
25	AM15	P460/TESTER PUMP AS	536Y	RAM ASSY & TEST FF1	40559	HOO6391	3-3554	
26	AM21	PE21 PWR PUMP	536Y	RAM ASSY & TEST FF1	100186	PE213	PE214	
27	AM34	BUILDING BLOCK ASSY	536Y	RAM ASSY & TEST FF1	251506	3000105	PG182HP-R	
28	AM51	MANIFOLD ASSEMBLY	536Y	RAM ASSY & TEST FF1	66626	65234	n/a	
29	AT04	TEST STAND	536Y	RAM ASSY & TEST FF1	PA6M-1ESCO	200383	PA4-WHEE	
30	AT05	S&S AirPump Assembly	536Y	RAM ASSY & TEST FF1	58477	52390-11	n/a	
31	AT94	FLOW TESTERS	536Y	RAM ASSY & TEST FF1	9754	305993	9764	
32	255	HAHN & KOLB GRINDER	502B	Gardner/Toyoda/Hahn Cell	1002-BC	n/a	n/a	

Figure 2: Spreadsheet with highest-used end-products

With the top 300 or so end-products identified, our next task was to break down these items into their components so a true flow could be established. Using the program 'BOM Magic', (Figure 3), which is a Syteline program adapted into an excel spreadsheet, we were able to extract a list of about 1,000 high-moving components in the factory. The next step in our methodology required that the routing of each one of these components be identified – one of the most important steps in the project because it is what the entire outcome is based upon. The Syteline system is not set up very well for data mining of this type so we had to be especially careful in this instance of the project. The 'Item Current Routing' screen yields routings that only include workstations throughout the building. Our study could not be completed with this information alone because it negates the effect of shipping, warehouses, and store rooms, all of which are vital to the flow of materials. To combat this issue, we used the 'Stock Loc' tab from the 'Items' screen (Figure 4) in Syteline to reveal where items are stored throughout the facility.



Row	Demand	Supply	Per Qty	Operation	Lower part	Description	Rev	Setup Date	Std Cost	Curr Cost	QOH
12			1	3	10002	SCREW, SOCKET HD CAP 1/4-20 X 3/8		1/30/81	0.02372000	0.02372000	0
13			1	3	101652	LIST, PARTS PUMP		3/18/96	0.00000000	0.00000000	0
14			1	3	10272	O-RING (-206) 0.484ID X 0.139 NITRILE 90		4/20/01	0.02800000	0.01673000	0
15			1	3	13944	SPRING COM OD .370IDX.XXXR64L.520MW	4	1/30/81	0.06900000	0.06900000	2,576
16			1	3	13959	SPRING COM OD .127IDX.XXXR37.2L.520MW	3	1/30/81	0.05000000	0.05000000	3,998
17			1	3	14443	BALL, 3/32" DIA STEEL		1/30/81	0.00723000	0.00723000	0
18			1	3	14794	CAP, PLASTIC		1/30/81	0.02100000	0.02119000	0
19			1	3	15192	TIE, CABLE		1/30/81	0.01052000	0.01052000	12,160
20			2	3	10273	O-RING (-114) 0.612ID X 0.103 NITRILE 70		1/30/81	0.01300000	0.00762000	0
21			1	3	10276	O-RING (-210) 0.734ID X 0.139 NITRILE 70		1/30/81	0.02300000	0.01400000	0
22			4	3	17428	SCREW, SOCKET HD CAP 1/4-20 X 3-1/2		1/30/81	0.09469000	0.09469000	0
23			2	3	17429	WASHER, BACKUP 2.94 X 2.75		1/30/81	0.07000000	0.09829000	0
24			1	3	203143	BUMPER	7	1/30/81	0.24500000	0.24500000	0
25			1	3	205674	SCREW, FLAT HD 8-32 X 3/8		1/30/81	0.02495000	0.02495000	0
26			1	3	205879	SPRING COM OD .485ID.410R15.5L.930MW	12	1/30/81	0.07300000	0.07300000	8,397
27			1	3	10423	BALL, 9/32" DIA STEEL		1/30/81	0.02400000	0.01360000	0
28			1	3	209736	RETAINER, BALL		1/11/85	0.26000000	0.26000000	3,813
29			1	3	10442	WASHER 0.375 X.250 X.032 COPPER		1/30/81	0.03380000	0.03380000	0
30			2	3	211053	O-RING (-010) 0.239ID X 0.070 NITRILE 90		1/18/85	0.01150000	0.00546000	0
31			10	3	211060	SCREW, SELF TAPPING 9-15 X 1		1/12/84	0.08163000	0.08163000	0
32			1	3	21278	VALVE, RELIEF 10000 PSI	4	1/30/81	6.16827100	6.16337100	3,841
33			1	3	214578	FILTER		1/29/87	0.11700000	0.11700000	3,140
34			1	3	214586	RING, RETAIN INT 0.63 X .015		1/17/87	0.01793000	0.01793000	0
35			1	3	216296	DISC, FILTER		6/1/89	0.27000000	0.27000000	7,863

Figure 3: BOM Magic Screen.

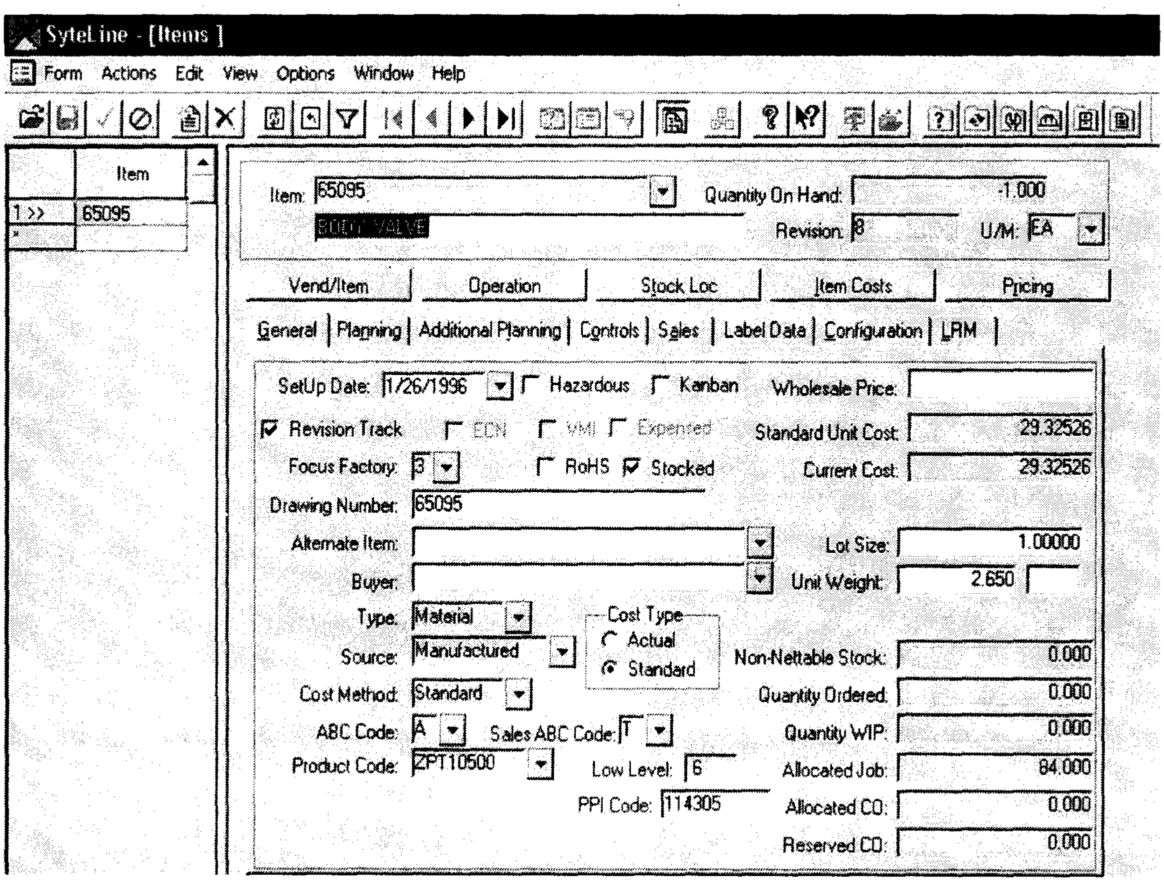


Figure 4: Syteline Items Screen

Analysis

With all of this information collected, the next step is to begin building the relationship chart which shows how each workstation, storage location, and shipping location interacts with each other. The purpose of the chart will be to quantitatively measure flow amongst departments. The chart used most often is the from/to chart (Tompkins, White, Bozer, Tanchoco, pgs. 103-104). This from/to chart will basically be a large spreadsheet that has all of the vital stations listed on both axis' and will then be filled in according to how materials are moving between each entity. This is another area that requires special attention, because all parts are not created equal. Depending on the size and weight of items, they will be moved in different fashions and in different quantities or unit loads across the facility. Our success in this project is dependent upon mapping flow accurately which can only be done by differentiating between the properties of parts – for instance two parts may have the same flow in terms of quantity, but one part may be the size of a golf ball and another could weigh over 100 pounds. We have decided to address this problem by implementing a classification system which will give a rough idea of the mass of items and how they are transported. Unit loads can be a tricky thing to work with because the size of them is always changing due to differing order sizes. It is for this reason that it has been decided that an exacting unit load system is not required and would be wasted effort – an approximation will serve our purposes justly. This classification will be applied by using a multiplier – the higher the multiplier, the bigger the part which implies higher flow. Once all of the 1,000 or so parts have had their flow tabulated between each station, then the next phase of the project can begin.

Mapping

Facilities layout design has been a longstanding problem in industry due to the difficulties in defining relationships amongst departments and complexity of measuring the effectiveness of implemented layouts. However, through the years important factors involved in layout design have been identified, presumably found by an on-going process of trial and error. Some of these factors are as follows: ability to adapt and expand in the future, flow of materials and products, use of floor space, and safety. A layout's ability to adapt to a changing product mix and new technologies is very important due to the ever changing nature of business. The flow of materials and products through the designed layout is very important as long travel times can cause vast increases in material handling costs. Placement of paths between workstations is also very important in keeping travel times short. This is accomplished by minimizing the total amount of distance between workstations while at the same time streamlining routes as much as possible. The layout's use of the existing floor space is very important because the company will require a new layout design when they out-grow their current facility. By minimizing wasted space, the company will not outgrow their facility as quickly and therefore not need to relocate – a cost savings in the long run. Finally safety is an important factor in a facility's layout for obvious reasons but it is of particular importance when designing the layouts of facilities that contain volatile materials (Hillstrom). Luckily SPX's facility does not house a large quantity of hazardous materials, however, safety will still be a primary concern.

SPX has been looking into revising their layout for quite some time, and in fact are making changes and moving workstations as this project is progressing. This fact makes our job slightly more difficult in some ways, but also helps us out in others. We are assuming that the layout is staying the same as what it was when we started our study, so if our design is implemented, some stations will have to move twice. On the upside though, because SPX is already working on their layout issues, our project team has been supplied with a very accurate and detailed blueprint of the entire production section of the facility. This blueprint not only helps us locate each station in the layout, but also reveals a relative size that we have to work with when redesigning the arrangement of departments. A problem with this layout was that not every station in the facility was identified, which would make it very difficult to map when trying to create our algorithm. To get a better idea of where everything was located, we talked to the manufacturing engineering manager and he was able to clear up some of the discrepancies. In doing this we were able to accurately label all of the departments, which will make it possible to do an accurate analysis. Also, as mentioned above, locations in the facility are constantly moving so the blueprint that we have doesn't completely match the current layout of the floor. What we decided to do was use the current layout that is found on the blueprint since all of the departments listed on the blueprint are still in use. This made it possible for us to define a starting point even though locations continue to change around us. We will be utilizing the CORELAP algorithm as much as possible to effectively and strategically place the departments according to adjacency data that we obtain from our analysis.

The CORELAP algorithm is an acronym for "computer relationship layout planning." While CORELAP is traditionally a process carried out by a computer, we will apply its methods manually. CORELAP utilizes closeness relationships amongst departments, or workstations in our case, to produce a layout. These closeness relationships are designated by the letters (A, E, I, O, U, X), each representing the degree of relationship between workstations. Each of these letters has a numerical value assigned to it from which a total closeness rating (TCR) for each department will be calculated. This calculation is done by taking the sum of those closeness relationships for each department. The department with the highest TCR will enter the plan first and the departments with the highest closeness to that first department will enter next. The TCR will also act as a tie-breaker between potential entering departments. This will continue until all departments have been placed in the layout (Tompkins, White, Bozer, Tanchoco, pgs. 376-377).

Our team will utilize this blueprint in both solving the layout problem, and also in displaying the final result and gains from our work. There will be one map, or spaghetti diagram, created using the current layout that shows the material flow as it presently exists. The flow will be represented as lines connecting each point that a given item moves from or to. We will not only use this blueprint to rearrange the departments, but also implement it as a tool of comparison once we have redesigned the layout. When we have reached the point in which we are confident that we have constructed the best layout, the lines representing material moving through the facility will once again be placed onto the new layout blueprint which will reveal the gains of our effort. The lines will be shorter and more organized which will visually demonstrate the benefits obtained through our rearrangement.

Improvement Metrics

One of the final objectives that we will address is quantifying the cost savings. This will be a part of the project that is somewhat gray because it is near impossible to predict exactly how much money will be saved due to the number and complexity of contributing factors. We will, however, attempt to measure the overall distance traveled by the materials handling vehicles in the facility which can be presented as a percentage of travel distance saved or combined with cost estimates per unit distance to produce a monetary value. We will also have to try to estimate the amount of inventory reduction due to smoother operations. This can also be estimated by using the percentage of distance traveled between the old layout and new layout as a type of efficiency rating. By applying this rating to the total value of inventory held, we should be able to get a rough estimate of how much money could be saved once the redesigned layout is implemented and inventories whittled down. Finally, we would expect the production output to increase with increased efficiency, so we can again apply our efficiency rating to the quantity of goods produced, to give an idea of how much more product is being shipped out the door, thus creating more revenue.

Results

Routings

Each of the individual parts that we were able to extract from the bills of material has an associated routing through the facility. This routing information is a step by step representation of the parts movement. This includes stations at which the part is machined and prepared to be used in a finished good, as well as holding locations before the part is finally used in the completion of a product at another workstation(s).

It was important for us to extract this routing information from Syteline in order to accurately track the flow of these parts that are used in the high volume finished units that our study included. We were able to extract these routings on a part by part basis for all of the 600 plus parts we obtained. These routings were recorded into an excel sheet, and the workstations where the part was used were also recorded in this sheet. We then went through these routings, one by one, adding the class that is associated with each part in the appropriate square in our relationship chart. This time consuming process was the only way that we could build the relationship chart that we needed in order to quantify workstation relationships.

540	VALVE, SOLENOID 4 WAY 115V	AM72	PP1	PPVR4B				AM46			
541	BODY, CYLINDER	OPFH02	AS04	R702F				AB86			
542	ASSEMBLY PUMP BODY P618	DC607B	PP1					AM18			
543	BODY, MANIFOLD	MH95	OPFE01	9000 PP5B01				AM51			
544	3/16X20G-.035X8.60/8.64 SAE J525/524TUBE	PP6B02	PPKB03					AM71			
545	1 1/4 RND x 48" (S4MAX 1144 CF 125K MY F	BLMR12G						FV42	266		
546	9/16 RND 4140/4142 CF ANN	BLMR11C						LB23	GL68		
547	1-5/8 RND x 4.840/4.900 4140/4142 CF ANN	RMM	L402E					LC51	LU83		
548	3 IN RND x 48 IN 4140/4142 CF ANN	M114A						LM31			
549	1-3/4 SQ x 0.370/0.430 ALUMINUM 2024-T35	OPCA01	PPMCAB2	R303D				MH82			
550	3 IN RND x4.84/4.88 1144 CF 100,000 MY	OPSAW	RMM	L102E				LC51	LU94		
551	3-1/2 RND x 1.360/1.410 4140/4142 CF AN	RMM	L404D					LU83			
552	1X.780 x 28.813/28.187 ID A-512 MDSR	OPSAW	RMM	M104A				WF15			
553	5 RND x 2.340/2.400 4140/4142 HR ANN	OPSAW	RMM	M115A	L104D			AB83			
554	4-1/4 RND x 1.480/1.510 1144 CF 100,000	OPSAW	RMM	L204C				AC55	LU94		
555	2-7/8X2.375 ID x 2.385/2.445 A-513 TP5	OPSAW	RMM	M103C	M102G	M106C		LU94			
556	1-1/4 RD x 48" (S4 MAX) ALUM 2011-T3	BLMR12G						266			
557	3-5/8X2-1/2 x 0.880/0.940 A-513 TP5 TUBI	OPSAW	RMM	M103B	M106F			LU83	MV92		
558	6X .875W x1.13/1.18 A-519 CF	OPSAW	RMM	L203C	L301D			LU83			
559	4-1/4X.688W x1.58/1.62 A-519 CF SMLS	OPSAW	RMM	L401G				WL16	LC51	LU94	
560	1-1/8X2 x 3.845/3.905 ALUMINUM 6061-T651	OPSAW	PPMR1A					MH87			
561	8 IN RD x 2.640/2.700 4140 HR ANN	OPSAW	RMM	L101D	L401F			AC55			
562	9-1/4 RND x .660/.710 ALUM 7075-T651	OPCA01	AMMR03	INSP/100				MH81			
563	1-1/2X2-1/2 x 3.830/3.880 ALUM 6061-T651	OPCA01	AMMR08					MH82			
564	1-1/2 RND x 48 (S4 MAX) ALUM 2024T351	BLMR12A						266			
565	4 X .109W x 21.740/21.800 A513 TP1 HR PS	OPSAW	RMM					LU58			
566	4 X .109W x 17.485/17.515 A513 TP1 HR PS	OPSAW	L304E	L303E	L202E			FV42	WL16	LU68	
567	3 1/2 RND x4.574/4.594 1144 CF 125,000 MY	OPSAW	RMM	M114A				AB05			
568	5-1/4 RND x 6.94/7.00 DE SPEC 880	OPSAW	RMM	M115A	L303B	L301D	L103B	PC95	PC06		
569	5-1/4 RND x 11.19/11.23 DE SPEC 880	OPSAW	RMM	M115A	L103F	L303E		LU58	PC95	PC06	
570	5-1/4 RND x 16.20/16.24 DE SPEC 880	OPSAW	RMM	INSP/100	L403G	L304C	L402G	PC06			
571	6-1/2 RND x 7.20/7.24 DE SPEC 880	OPSAW	RMM	L302C	L202D	L401A	L303B	PC95			
572	7-1/4 RND x 9 4/9.5 DE SPEC 880	OPSAW	RMM	M115A				FG61			
573	7-3/4 RND x 3.20/3.26 DE SPEC 880	OPSAW	RMM	L203C	L402D			FG61			
574	5/16 RND D2 TOOL STEEL	BLMR11C						LB23	GL68		
575	2-1/4RND X 48" 1144 CF 125K MY	M114A						LM31			
576	2-3/8X48" RND 1144 CF 125K MY	RMM	M114A					AB05			
577	2.375 RND x 48" MAX 2024-T351 ALUM	RMM	M114A					LM31			
578	AL BRZ WIRE .045	WAV	M108C					FG61	WL16	LC51	LU94
579	GAUGE,2.5"UNIVERSAL,FILLED, 2500/500 PSI	R504B	PP7R3D	PRAR02D	PP9B14	WARR		AM34			
580	GAUGE, 4", UNIVRSL, FILLED, 1000/200 PSI	R303B	PP7R4C	WARR				AM55			
581	HYD OIL, 1 GALLON	DC106A	PP1R07B	HP2R1C	DCWALL			AM06	AM21	AM34	AM17
582	HYD OIL 2 1/2 GALLON CONT	PP1	DC104A					AM05			
583	TEE ADPT, 1/4" 3/8" NPTF F, 3/8" NPTF M	PP6R10C	APPR03C	PRAB01	PP9B14	WARR		AM34			
584	CONNECTOR, 1/4" NPTF M, 3/8" NPTF F	PP6R3B	PRAR01E	WARR	DC200FLOOR			AM46			
585	MOTOR, ELEC 24VDC UL REVERSIBLE	R110E						PLA			
586	ADJUSTING SCREW	PLA						PLA			
587	MOTOR, ELEC 24VDC 800W 60MM (REV)	PLA	SMKR22					PLA			
588	GEAR PUMP F80	R201C						PLA			
589	TANK 0.7- SQF - HOLE (FFRN	755	R302A					PLA			

Figure 5: Sample Routing Sheet

Monuments

Certain components of the facility layout were determined to be monuments by SPX. These monuments included bathrooms, training rooms, locker rooms, and a few large production lines. These monuments had to be worked around due to the fact that they could not be altered in anyway. This decision was made by SPX management; therefore any change that we would have liked to make to these monuments would have been outside the scope of our project.

Relationship Carts

The required relationship charts that we created to analyze the material flow of SPX took up a large portion of the time allotted for the project. These charts were made to analyze the flow between workstations, point of use locations, and departments. Determining a good way to represent material flow through the facility was the first challenge that we faced. We had to devise a way to take dimensional and mass difference into account without having to study each part individually. It was decided that assigning classes to each part would represent the mass of the part, how hard this part was to move, whether a forklift was used to move it or if it was transported on a hand cart by one of the material handlers. The classification system that we decided on consists of values ranging from one to four; one being small, easily movable items, and four being heavy, bulky, or difficult to move parts.

From/To Chart

A from/to chart was also developed to quantify the relationships between the workstations, point of use locations, and departments. Each of the entities were placed on the X and Y axis with the X axis representing 'From' and the Y representing 'To" Ultimately, this chart allowed us to locate the areas with the highest flow and ensured that the distances between those workstations were minimized. The chart was filled in by utilizing the part routings obtained from Syteline and recording the part class in the square corresponding to the entities described in each routing. This entailed a large amount of data collection as well as a lengthy manual mapping process. A small sample of these routing can be seen in figure 5.

Two-Way Flow Chart

Upon completion of the from/to chart, we translated the entire spreadsheet into a chart representing two-way flow in which all entries were summed below the diagonal line. This was done partially due to the face that the direction of the flow really doesn't have any bearing on our results; secondly, having all of the numbers summed in one location allowed us to accurately gauge the flow to each one. For instance, a part moving from PP6 to PTST will travel the exact same path as if it were traveling from PTST to PP6. This translated chart made it possible to identify relationships amongst entities and aided in the formation of station groupings while simultaneously supplying information to be visually mapped in the spaghetti charts.

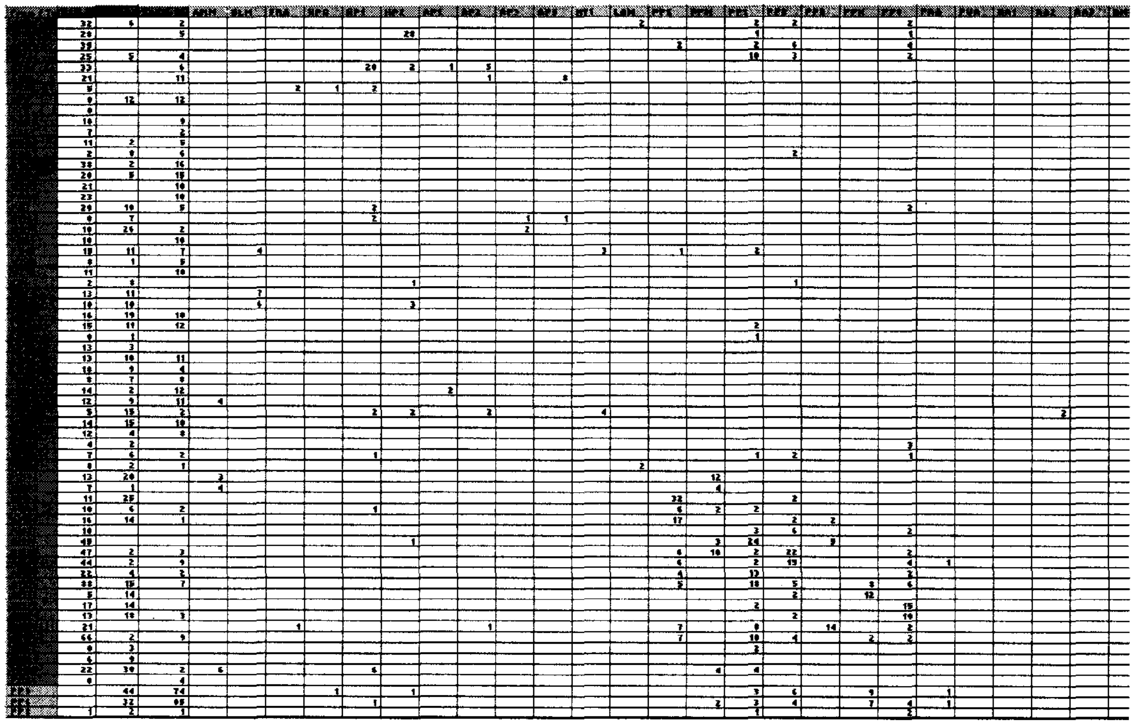


Figure 6: Flow Chart

Distance Matrix

To determine the distances used in our distance matrix, we relied on a pre-existing CAD layout of the facility provided to us by SPX engineers. This layout was as updated and true to the existing layout as possible; however some differences were unavoidable due to the fact that subtle changes are made to the floor layout everyday. To remedy this issue, we took the original printout on day one of the project and essentially froze it in time so we would have a consistent base to work off of. On this layout, we marked each workstation, POU, and department with a colored dot (red for departments, green for workstations, and orange for POU's). This marking system aided us in performing operations with the layout such as measurement and routing analysis while also denoting entity type and marking the original printout as the baseline for comparison. In the long run, changes made to the layout during our project will not have any consequences upon implementation of the move – we simply needed a set starting point. In a worst case scenario, some of the workstations would simply be moving from different locations than specified in our original printout; however the end arrangement will be as specified in our revised print.

The next step was to measure the distances between workstations that had material flow between them. Straight line distances were chosen as opposed to rectilinear, due to the fact that the aisles in the new layout were going to be reconfigured and these changes would lead to discrepancies. The straight distances were the best choice given our unique problem. A standard tape measure was used to measure these distances on the layout, from one workstation center to the other. We then multiplied by a scaling factor to yield the actual distances that would be represented in the facility. This information was then entered into an Excel worksheet for use in future calculations.

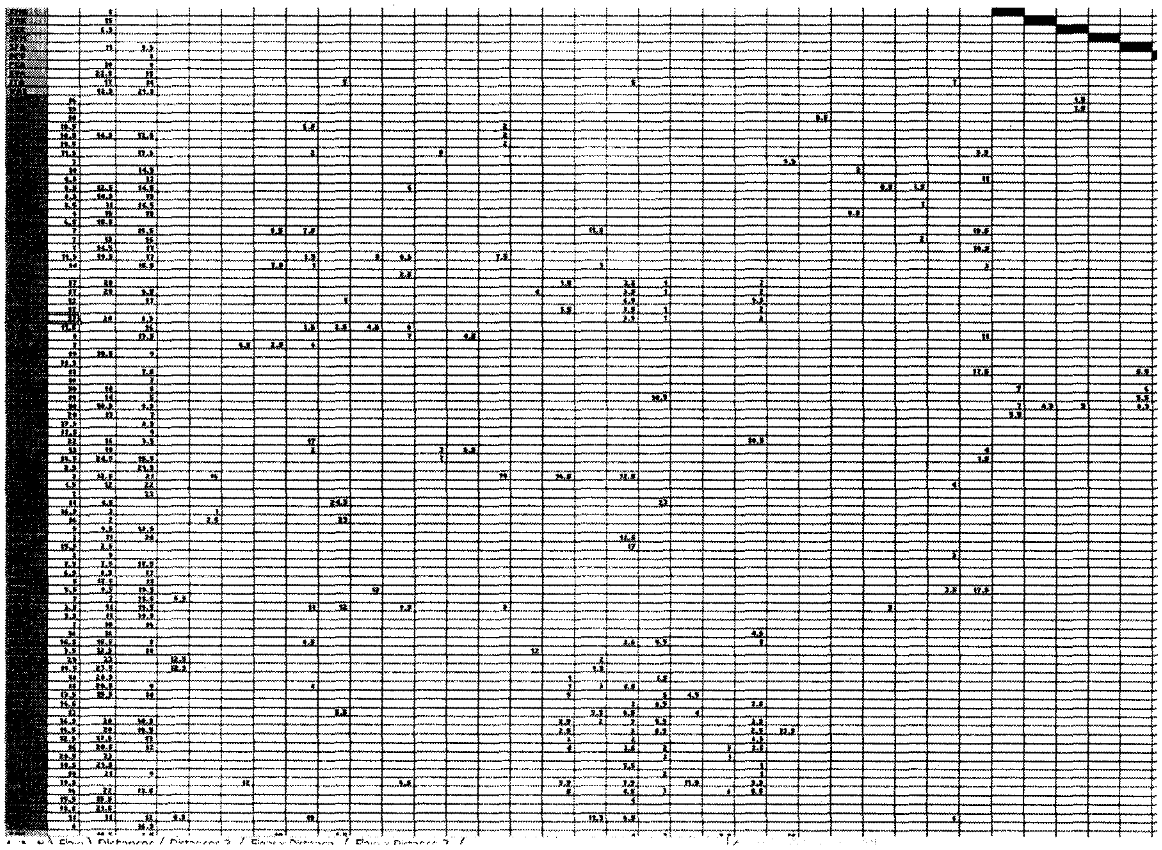


Figure 7: Distance Matrix

Flow x Distance

The final step to obtaining the total material flow was to combine the previous two tables. To get our final flow data, a worksheet was created that multiplied the flow sheet by the distance sheet; this produced results for any relation that contained any flow whatsoever, however it was particularly helpful in identifying areas of the layout to focus on – those that had unusually high numbers compared to the others. This worksheet was summed for each workstation, point of use location, and department to find the total travel associated with each. These were then sorted and put in descending order for placement purposes. Finally, the entire worksheet was summed to give the total material flow through the facility using that particular layout. This number, related to cost gives the total transportation expenditure to move materials through the SPX production area.

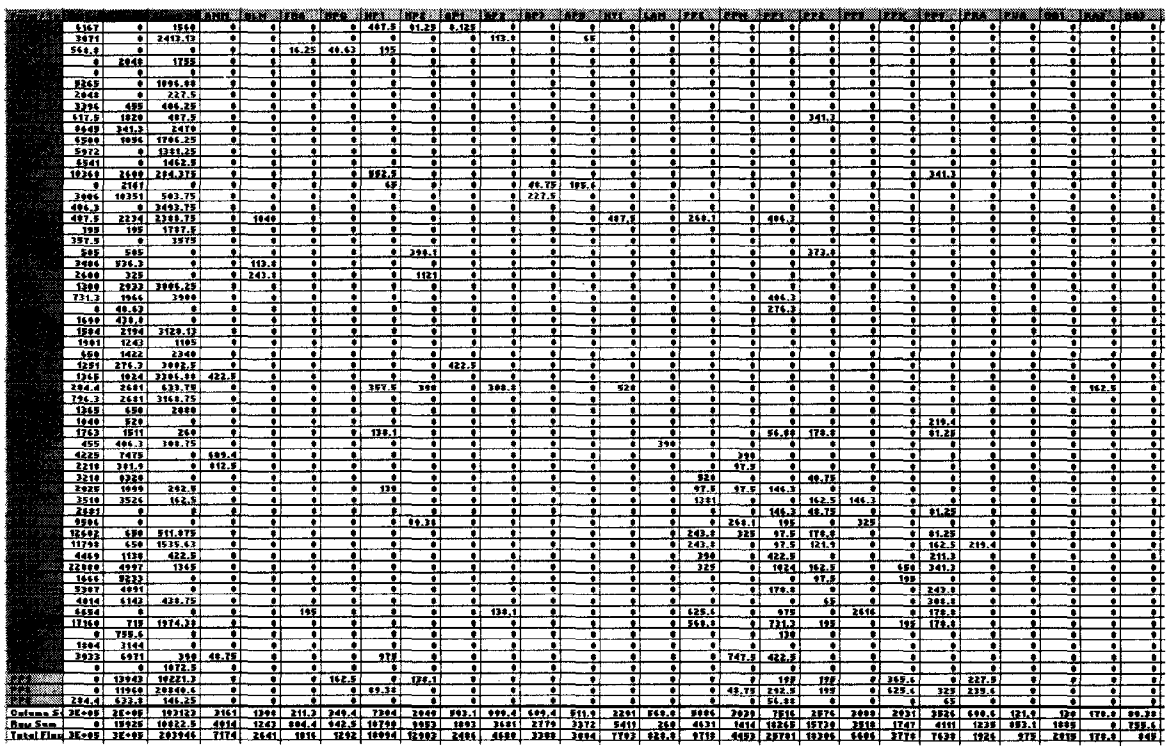


Figure 8: Total Material Flow

Once all of the departments, POU's and workstations were placed in the revised layout, the above process involving all three excel sheets was repeated to produce the total flow of our improved layout. The comparison will be discussed in detail later in the report.

Placement

Placement of the workstations, departments, and point of use locations was accomplished by analyzing the relationship chart. The flow x distance chart was extremely useful in identifying the largest problem areas in the existing layout. A high number in this chart meant that the two associated workstations had a large amount of flow between them and also a long distance to travel. By searching for these large numbers in the flow x distance chart, some part groupings were formed in order to cut down on the distances amongst the related workstations.

The workstations were then placed in the layout according to their relationships with entities that were already in the layout. The total flow x distance for each workstation was also totaled in the excel worksheet so the most important workstations were identified. The workstations with the highest total flow x distance were examined first and placed in the layout according to their relationships with the workstations already placed.

The shipping and receiving departments were left in their existing location, so no major structural changes would have to be made. Also through our relationship charts we were able to determine that the stockroom, which is currently in a far corner of the facility, should be in a centralized location. This determination was made by identifying that the stockroom had a large amount of flow with nearly every workstation, department, and point of use location in the facility. Therefore the stockroom was moved to a centralized location in the layout, and all other non-monuments were removed from the layout. The workstations were then placed in the layout, either one by one or by the groupings that were formed earlier. This process was repeated until all of the workstations were placed in the layout.

These placements were made directly using AUTOCAD software. A layout of the facility was obtained previously and the workstations were plucked from that layout and placed in our new revised layout. The composition of these workstations was not changed even if it would have been beneficial because that was outside of our scope. A change in workstation composition may have been the movement of a bench or shelf. These small changes could have made the workstation into a more manageable size/shape so as to fit in the layout better. These changes, however helpful, would have been too presumptuous on our part, as the workstation layout was set that way for a reason and without knowledge of the workstation's process, these changes could have been detrimental the workstation's function.

Placement started primarily around the shipping and stockroom. The upper right of the layout filled in rather quickly with workstations that had high correlation with shipping. Also workstations that had a high relationship with the stockroom were placed as near as possible to it. That caused the middle of the layout to fill in very quickly as well. A few of the workstations that we studied had very little flow with anything and therefore those were placed in the far corners of the layout, so as to save the valuable space near the stockroom for the more highly correlated workstations. These placements were sometimes difficult as the workstations had odd shapes and sizes. Also the groupings that were formed earlier had to be placed together simultaneously; therefore a lot of rearranging and shifting to fit had to take place concurrently. The pre-existing layout monuments also posed a challenge as they had to be worked around and they also took up space that could have been better utilized by other workstations. Ultimately the revised layout was completed and new aisles had to be formed. These aisles were formed by compacting groups of workstations. These shifts created paths for workers, forklifts, and anything else that would have to travel through the facility.

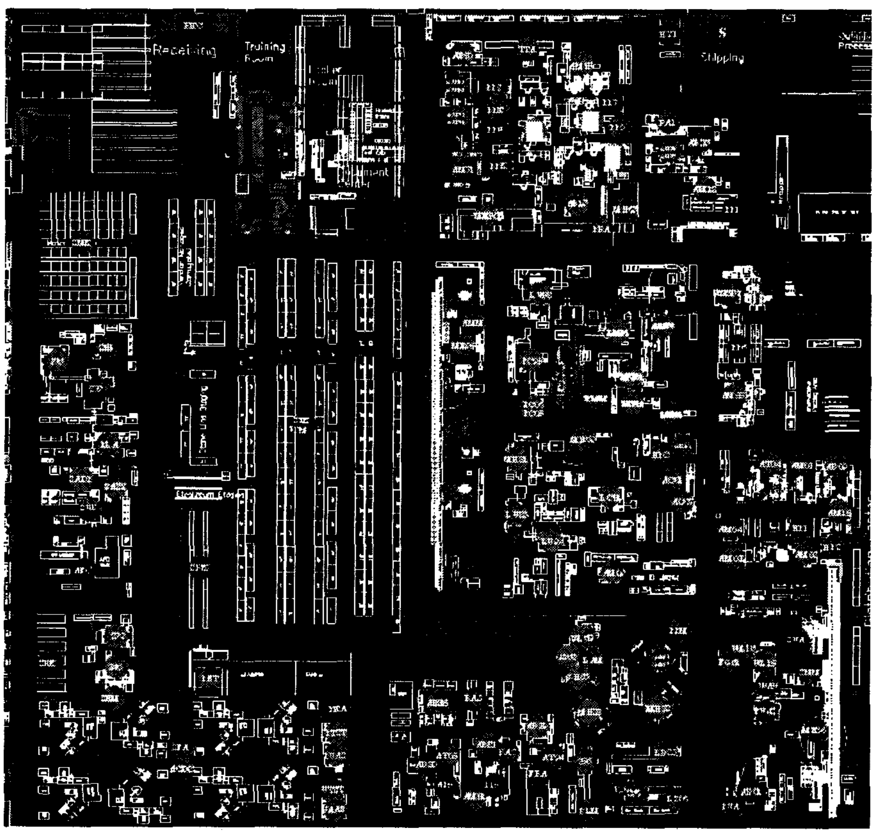


Figure 9: Revised Layout Overview

Figure 10: Revised Layout Shipping Detail

Figure 11: Revised Layout Lower Right Detail

Flow Analysis

The distances of the revised layout were found using the same method as we obtained the distances of the current layout. These new distances were then entered into the excel workbook containing the flow information. A new worksheet was created that multiplied the flow by the new distances. A total of all the entries in this worksheet was made and compared to the total of all the entries in the original distances x flow worksheet. It was found trough this comparison that 15% of travel was eliminated. This is a significant amount which will have a substantial impact on the SPX's bottom line.

Flow Map

In order to visually represent the flow savings of our revised layout, flow maps of the old and new layouts were made. These flow maps were made by printing out the large CAD drawings of the layouts and then mapping the flow directly on the paper using a standard highlighting marker. This method was chosen due to its simplicity and ease. The highlighting marker created a transparent line which made the improvements easier to see.

These flow maps confirmed our findings of 15% travel savings. The lines were considerably shorter on the revised layout's flow map than they were on the old layout. This is mostly due to the centralization of the stockroom, as well as the placement of workstations around the shipping department. A smoother flow is also apparent on the revised layout as the groupings create for simpler and shorter travels for parts.

Cost Analysis

Determining the amount of money that SPX spends yearly on transportation costs was a very difficult task that required us to make many assumptions. First we took the figures given to us by the company as though they were completely accurate. We had to simply accept these values as we did not have time to conduct our own study. SPX uses 14 forklifts with operators each day. We were given the cost for operating forklifts at $40 per hour. An additional 4 material handlers are used at a rate of $25 per hour. These figures along with the 307 operating days, working 13 1/3 hours per day were multiplied together in order to determine the transportation cost as follows:

Forklifts		Material Handlers		Operating Hours		Working Days
((17 x $40)	+	(4 x $25))	x	(13.33hr/day)	x	(307day)

This formula derives a total yearly transportation cost of $3,192,720. The 15% savings which we determined would be just under $500,000 per year ($478,908). The estimated cost to make the layout changes provided to us by the company was also a very rough estimate. A cost of $1,500 per machine moved in terms of rigging costs coupled with lost production revenue and other miscellaneous expenses yielded a total cost of around $500,000. Therefore the initial investment in the move would be returned in about a year through the reduced transportation costs alone.

<u>Impacts</u>

As with any project, the SPX redesign will have associated impacts in the social, environmental, and ethical areas. Social impacts will come as the result of the machine centers and work stations being relocated. The disassembly and transportation process will require that segments of the production floor will be unable to work for extended periods of time meaning that temporary unemployment will ensue. Also, once the move has been completed, most workers in the facility will have to form new employee relationships as they will not be in the same locations of the facility and will be surrounded by a largely different workforce. Overall, a new work dynamic will be created that everyone will have to get used to and this could prove to be troublesome for certain employees. Also, a varying amount of stress will be placed on the SPX workforce by the new design of the workstations. Some workers have been working in their current position for over 10 years and have no doubt grown accustomed to their surroundings. They come to work and do the same thing every day always knowing where everything is that they need to complete their job. Changing this could prove to be a stressful and frightening occasion and will have to be dealt with by the management.

The environment is always a big concern in today's day and age. It is very important to analyze every step of a project to make sure that it is environmentally friendly both in implementation, and once the projects outcome is fully functional. Our facility redesign will not have a huge environmental impact; however it will have a few. Due to the fact that we have reduced fuel consumption by 15 percent, we will theoretically use about 15 percent less energy for transportation each year. This means that electricity and propane will be conserved, thus reducing pollution. On the other hand, however, we will be consuming a fairly large amount of resources in the reconstruction process itself. Rigging services will be utilized to move the work centers and this process will consume fuel. Also, during reconstruction, a variety of building materials will be used including wood, steel, and plastic among others. This use of new material will mean that the old material will have to be discarded. Luckily, SPX has a very strong recycling program so there will be little waste. Production processes will not be changed in the implementation of our project; the machines and work stations will merely be moved, and so environmental factors will remain constant in this regard. Overall, this project will not adversely affect the environment, and in the long run, will actually benefit it.

The SPX redesign will come with a few ethical concerns as well. As mentioned in the social impacts segment, employee relations will be changed. Floor integrity may weaken a small amount as a result of everyone being moved around. It could be difficult for some to make new friends and form bonds with fellow workers. This factor could result in an overall lower worker moral. Also, with less flow of materials, it is possible that fewer material handlers will be needed in the facility. Ethically, layoffs are a hard subject to deal with – they are hard on the individual who was terminated, and also on that person's family. Financially, layoffs can be devastating and are most likely our largest ethical concern. On the flip side of this, workers in the facility would most likely see bigger Christmas bonuses as a result of total profits being higher. Monetarily, the redesign is bitter sweet as some workers will earn more money and others will possibly lose their jobs. Safety is a huge focus of industry today and at SPX, safety levels will change as the facility layout changes. With less transportation of materials through the factory, there will be a lower chance of a forklift accident or collision with a worker. Also, less material handling will mean that lifting injuries will be less likely.

Project Limitations

To fully explore any project or experiment, different angles and approaches must be taken. Even when completely thorough, every project team will encounter a host of project limitations. In the SPX floor layout, the most notable limitations that we noticed were with respect to monuments, workstation layout, and time.

Monuments were a tricky part of the project to have to deal with because they could have been handled in different ways; each method producing very different outcomes. Due to the fact that we decided to leave monuments in their current locations including the bathrooms, document center, and both makino lines, our reorganization options were limited. These monuments are all fairly large so they had great impact on the optimization of revising the layout. For instance, centralizing the stockroom was a large goal of ours because it sees so much material flow; however, the aluminum makino is in the direct center of the facility and kept us from doing this. It was decided by the management that the expense of moving these monuments would not be worth the gains in the long run; however, we think that it would be financially beneficial and would return the investment in a short amount of time.

We also experienced a large amount of problems implementing the use of the CORELAP algorithm for placing multiple departments in a layout. CORELAP works by placing departments with the highest flow first, and then each department after that based on strength of relationships. In implementing this technique in the past, we have dealt with theoretical square departments of uniform shape and size, but this project proved to be completely different. First we encountered the problem that not all of the departments could be moved independently because they were designed specifically to be associated and serve each other as are most of the POU's. Next, when moving the work centers or groups of work centers, we were forced to orient them into the layout based on their shapes and sizes. These factors mean that efficient and accurate placement is near impossible using the standard CORELAP procedure – large gaps are produced all over the layout and aisles are not kept intact for material movement. With these factors combined, we were forced to use a variation of the standard algorithm that involved placement based on size and shape constraints couple with flow relation. This means simply that we could not fully optimize flow but did the best that we could based on available space. If we were able to run CORELAP in the computer instead of manually, or if we could assume a uniform workstation size and shape, then the results produced would yield savings of even higher than 15%.

The SPX layout project had a scope that we could not work outside of because of time and resource constraints. An example of this scope limitation is illustrated by the workstation layout situation – it vastly limited the variations that could be produced in the redesign. As mentioned before, the workstations were difficult to piece together because of size and shape irregularities. The only way to remedy this would be to have the ability to alter the design of the workstations in order to fit in available space. True optimization of the layout would require us to have this alteration ability and is one of our largest limitations in this project.

The final limitation that we encountered is a real problem in most real-life projects – time. The largest, most time-consuming part of this project was the data collection portion. When implementing Pareto analysis, usually 20% of parts are analyzed which represent 80% of the total material flow (class A parts). Because SPX has over 10,000 SKU's, achieving our goal of 20% would have taken a much longer time, especially because the Syteline system is so user-unfriendly when it comes to data mining. Had we been able to analyze the usage and routings of this larger sample, our results may have been slightly different but were unable to due to time limitations. We also could have explored some other variations of mapping as outlined above had we been allotted more time.

Future Considerations/Recommendations

Based on the project limitations listed above, there are a fair number of future considerations that we or others at SPX should look into. First and foremost, it would be beneficial to conduct a more in-depth data mine to give a more solid information base to the project. We would like to capture at least 20% of the total number of SKU's to feel totally confident that an accurate representation of flow has been established. This task would take a fair amount of extra time; however, the new information should be able to be incorporated into existing data which would prevent the need to totally re-conduct the entire project.

Secondly, we feel that it would be beneficial to run the CORELAP calculations again without any monuments to work around. Ideally, it would be best to start with an empty box and see what layout that pure flow would dictate. This would be the only way to obtain a truly optimal layout and would also be a great comparison tool to see if moving the monuments would indeed warrant spending so much extra money on rigging.

Another future project could be to place the departments into the layout with the ability to change their sizes and shapes. This could be done by either disregarding dimensions and running conventional CORELAP or by working each department into the floor plan one at a time and resizing or reshaping them during placement. Changing the structure of individual workstations would be a large task and would make the redesign even more complicated, however, it could be done in a minimalist fashion so that design changes would be fairly simple to implement.

A final aspect of this project to reconsider in the future would be to reanalyze the costs of moving materials through the facility and also the cost of implementing a new layout. Overall, most of the cost analysis that we were able to conduct was fairly generalized and estimated. Our SPX contact gave us estimated operation costs for material handling that took into account rental fees, fixed costs, overhead, and maintenance costs, among others therefore we feel that the calculated transportation costs that we came up with are mostly accurate. However, to be able to evaluate the projects return on investment, we really need more accurate data concerning the rigging and moving costs to relocate machines and departments. Arriving at these figures precisely would be fairly difficult due to unforeseen expenses; however, it would be beneficial to know how long it would take to pay the project off. In the long run, this data could also be used to compare to the estimated returns on investment of the alternate project possibilities discussed above.

Conclusions:

This type of project is always interesting to conduct because it can produce such a variety of outcomes. It was unclear through the first 95% of the work, whether or not it would pay off in the long run – the work was monotonous and did no hint at the benefits as we worked. In the end, however, a savings of 15% annually seems to be worth the work. Granted, the analysis and diagnosis of the problem are just the tip of the iceberg when looking at the logistics of moving all of the machinery and workstations of SPX, but the important thing to note is that the groundwork has been laid, the first step taken. Overall, the cost analysis does not pinpoint the exact amount of time that will be required to regain the expenditures needed to complete this venture: however in the long run, this data does not have to be exact. The bottom line is that we will save the company about a half million dollars a year – a large enough figure to raise some eyebrows. Whether it takes a year or a year and a half to pay for itself, the company will be experiencing much higher profits in a relatively short amount of time.

We are glad that we were able to make this kind of an impact at SPX. A project of this magnitude seems daunting – and it is true, there is a large amount of work required, but it is something that had to be done. With the current engineering staff employed at SPX, this project would never have been initiated due to short staffing. The daily life of the engineers is far too full to tackle this kind of project so the task fell to either our project team or a more expensive consulting firm. We feel that we have given SPX our highest quality work that rivals what any other team could have done with the allotted resources. All in all, this project was a great learning experience for our project team and a very profitable experience for the SPX Fluid Power Corporation.

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