

Techniques for the Evaluation, Reduction, and Elimination of Excess Material Flow within Industrial Facilities

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Introduction

The flow of material represents 2, and practically even 3, of the 7 wastes as defined by LEAN practitioners. As such, the methods for evaluating, reducing, and eliminating excess material handling are fundamental to any LEAN improvement initiative.

The 7 wastes defined by LEAN practitioners include the following:

1. Overproduction
2. Waiting (**reduced by eliminating storage locations**)
3. **Transportation handling more than once**
4. Inventory
5. **Motion**
6. Over-processing
7. Defective production

Material handling involves the Movement (relocation) of Materials (container, parts, tooling, kanban triggers) using Methods (fork trucks, people, carts). The focus of any improvement study is aimed largely at improving, or eliminating the Movement because the Materials and Methods themselves may neither be conducive to change nor offer significant benefits for cost and time savings.

The Movement of material involves 3 basic activities

1. Pickup
2. Transport
3. Set-down

Of these, Pickup and Set-down are often a surprisingly large component of the overall transport time (ranging from 25% to 75%), and thus may represent the greatest opportunity for improvement. Obviously, eliminating the movement entirely will bring about the greatest potential improvement, however eliminating the pickup and setdown activities of a trip by combining two travel distances and eliminating the intermediate storage, or process will often bring similar results. Eventually, reducing travel distances will deliver additional benefits, but should be considered only after all opportunities for eliminating the movement have been exhausted.

Finally, it may be possible to alter the method for delivery in order to achieve additional reductions. Some common method changes which have proven to deliver significant results involve the following.

1. Convert from unit-load deliveries (fork trucks delivering specific loads from, and to, specific locations) to Tugger delivery routes (fixed routes operating at fixed intervals involving tow trains of containers where multiple materials are delivered, or picked up, at once).
2. Use of conveyors or flow-thru racks, where materials are placed upon receipt to the factory, and then delivered to the point of use (and or stored intermediately), when required. Study your pickup and setdown procedures to seek method improvements.

Systematic Design Approach

With the fundamental objective defined as the elimination, or reduction of material movement, the challenge now shifts to the identification of the material handling activities to be eliminated or reduced.

At a high level, the process for improvement will involve the following.

1. Collect whatever data is currently available in an electronic format regarding the flow of materials
2. Define a plan to collect remaining information required to perform selected analyses
3. Generate the initial Current State Analysis
4. Develop a series of alternatives (future state proposals) and evaluate each
5. Select one or two future state proposals and identify their prospective savings
6. Detail out one of those plans for specific savings and implementation.
7. Prepare and present final report to management

The Current State and Future State material handling studies will often involve the collection, diagramming and reporting of all, or at least a substantial amount, of the flow of materials in the facility. Application software, such as the Flow Planner from Proplanner (hereafter referred to as the FP application), or similar applications, can make this process quick and accurate, and provide a solid basis for the subsequent evaluation of the Current State analysis necessary to construct the many proposed Future State alternatives.

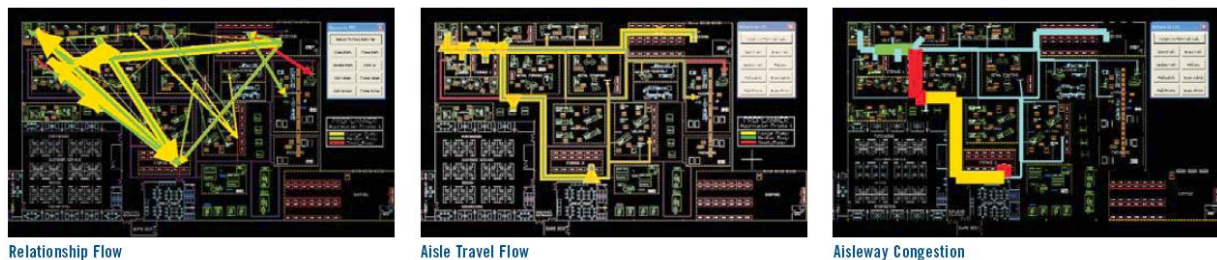


Figure 1. Three common types of flow diagrams (For detailed examples see Appendix)

The FPC application will create the following.

Material flow diagrams, also called Spaghetti Diagrams (shown in figure 1)

- Relationship Flow Diagrams may be color coded by Product type, Part type, Method type, Container Type or Trip Frequency. This diagram shows the quantity and type of flow between locations in the facility and is used to quickly identify specific delivery routes and/or locations for reduction or elimination.
- Aisle Flow Diagrams which show the actual (shortest) path of material delivery for each method through the plant. These diagrams are mostly used to evaluate obstructions to flow (turns, intersections, aisle widths) and actual travel distances for use in determining the standard time for operator deliveries.
- The Congestion Flow Diagram which shows the combined frequency of flow for material handling methods down every segment of the facility's aisle network.

FPC Simple Report - Microsoft Internet Explorer

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Go Links

SIMPLE AGGREGATE SUMMARY											
AGGREGATE	FROM	TO	FREQUENCY	TOTAL DISTANCE FEET	TRIP DISTANCE FEET	EFF. TRIP DISTANCE FEET	TRAVEL TIME SECONDS	L/U/L TIME SECONDS	TOTAL TIME SECONDS	TRIP TRAVEL TIME SECONDS	COST \$
Large_Pump	RECEIVING	STORAGE1	2,700.00	569,484.00	210.96	210.92	37,972.47	81,000.00	118,972.47	14.06	660.96
	STORAGE1	BORE	2,700.00	132,759.00	49.16	49.17	8,848.05	81,000.00	89,848.05	3.28	499.16
	HAND-FINISHING	STORAGE2	2,454.54	372,672.81	151.85	151.83	24,847.40	73,636.36	98,483.76	10.12	547.13
	STORAGE2	DE-BURING	2,454.54	411,552.72	167.70	167.67	27,442.35	73,636.36	101,078.71	11.18	561.55
	RECEIVING	RECEIVING-STORAGE	818.18	29,110.84	35.61	35.58	1,942.49	24,545.45	26,487.95	2.37	147.16
	RECEIVING-STORAGE	ASSEMBLY	818.18	61,633.00	75.35	75.33	4,109.78	24,545.45	28,655.24	5.02	159.20
	RECEIVING	STORAGE2	932.14	149,841.51	160.79	160.75	9,991.80	27,964.29	37,956.09	10.72	210.87
	STORAGE2	ASSEMBLY1	135.00	17,505.45	129.68	129.67	1,167.13	4,050.00	5,217.13	8.65	28.98
	STORAGE2	HOLEPUNCH	257.14	43,734.37	170.08	170.08	2,915.64	7,714.29	10,629.93	11.34	59.06
	HOLEPUNCH	METALCUTTING	514.29	34,755.72	67.54	67.58	2,315.75	15,428.57	17,744.32	4.50	98.58
	BORE	STORAGE2	2,454.54	485,802.56	197.88	197.92	32,381.15	73,636.36	106,017.51	13.19	588.99
	STORAGE2	HAND-FINISHING	2,454.54	372,672.81	151.85	151.83	24,847.40	73,636.36	98,483.76	10.12	547.13
	STORAGE2	METAL-STAMPING	480.00	41,558.40	86.57	86.58	2,770.39	14,400.00	17,170.39	5.77	95.39
	METAL-STAMPING	WELDING	480.00	34,521.60	71.89	71.92	2,300.37	14,400.00	16,700.37	4.79	92.78
	METALCUTTING	WELDING	720.00	105,962.40	147.20	147.17	7,065.51	21,600.00	28,665.51	9.81	159.25
	WELDING	SUB-ASSEMBLY	360.00	22,921.20	63.64	63.67	1,527.37	10,800.00	12,327.37	4.24	68.49
	RECEIVING	MILLING	102.86	10,414.58	101.26	101.25	694.36	3,085.71	3,780.07	6.75	21.00
	DE-BURING	DE-GREASING	2,262.86	165,188.78	73.04	73.00	11,018.54	67,885.71	78,904.25	4.87	438.36
	MILLING	METAL-FORMING	102.86	8,590.58	83.45	83.42	572.23	3,085.71	3,657.94	5.56	20.32
	METAL-FORMING	DE-BURING	102.86	7,697.01	74.82	74.83	513.05	3,085.71	3,598.76	4.99	19.99
	STORAGE2	MOLDING	60.00	3,745.20	62.39	62.42	249.56	1,800.00	2,049.56	4.16	11.39
SUB TOTAL			23,364.53	3,082,115.03			205,492.79	700,936.35	906,429.14		5,035.74
Medium_Pump	RECEIVING	STORAGE1	750.00	158,190.00	210.96	210.92	10,547.91	22,500.00	33,047.91	14.06	183.60
	STORAGE1	BORE3	750.00	41,250.00	65.01	65.00	2,750.32	22,500.00	25,250.32	3.67	140.28
	HAND-FINISHING	STORAGE2	681.82	103,520.73	151.85	151.83	6,902.06	20,454.54	27,356.60	10.12	151.98

Done My Computer

Figure 2. The FPC reports include all output calculated from deliveries plotted on the drawing

Reports (shown in figure 2)

- Travel Distances, Time and Cost of each material flow path and aggregate distances, times, and costs of selected groups of handling paths.
- Itemized lists of pickup and setdown times by part, location, method and container.
- Volumes of material delivered, along with average lot sizes of parts moved per delivery.

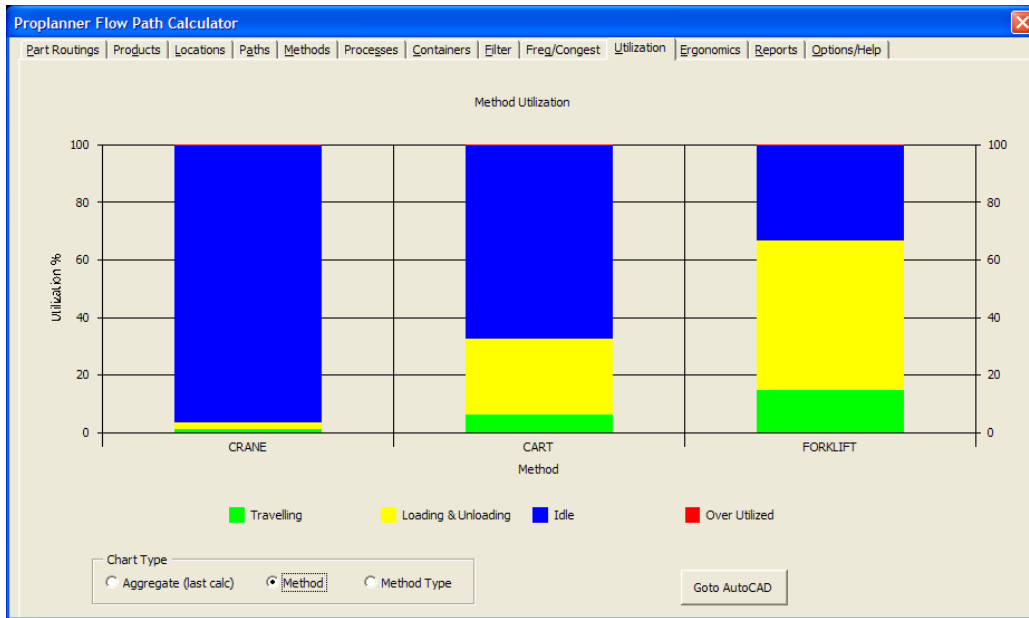


Figure 3. The FPC charts show Utilization percentages

Charts (shown in figure 3)

- Utilizations of material handling devices, device groups, or device classes
- The percent of time spent on pickup/setdown versus traveling.

Techniques for Reducing and Eliminating Flow

As mentioned previously, the primary objective of any Material Flow Improvement study is to first attempt to eliminate the material handling task entirely, or at least the pickup and setdown activity. Subsequently, reductions in material flow and handling can be accomplished by reducing the pickup and setdown times, reducing the travel distances and finally by reducing obstructions to smooth and efficient flow (i.e. turns, intersections, congested aisles, etc.)

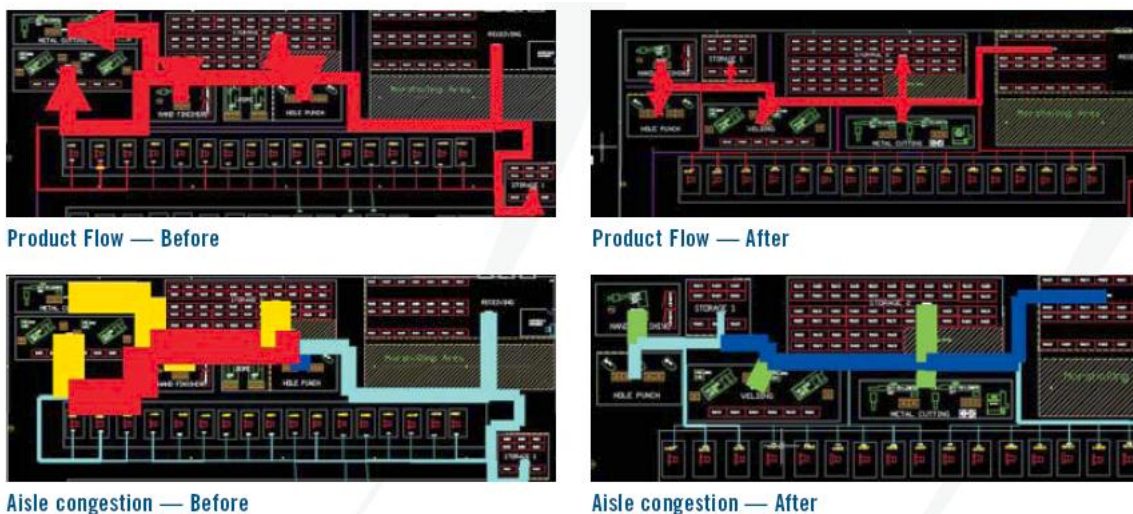


Figure 4. Typical Flow Study Diagrams – Both Current and Future State

Eliminating material handling deliveries

The complete elimination of a material handling activity is the most coveted and yet most elusive objective of any material handling study. Clearly the most obvious and beneficial solution involves the co-location and synchronization of sequential processes. For example, moving two machines together and dedicating them to a common process family.

These opportunities can best be seen by color coding the material flows according to common process family and then evaluating those locations where the material for a process family visits, and where this flow is either exclusively, or dominantly, belonging to that process family. Co-locating the equipment at these locations would be an easy to identify (albeit possibly expensive to perform) material handling elimination.

Other techniques for the elimination of material handling activities involve the following.

- Eliminating off-line storage locations and thus delivering the material from the dock directly to the point of use (POU), or pulling material directly from the trailer at the dock as needed.
- Outsourcing the handling task to a supplier (i.e. Fasteners delivered to the usage location by a supplier, instead of being delivered to a receiving dock and then moved to the location separately).
- Automating the handling activity via conveyors, AGV's, etc.
- Eliminating the process or combining it with another process (i.e. move the part from paint to shipping via a conveyor running through a furnace that dries the paint).

The best way to evaluate the benefits afforded by the elimination of material handling is to compute the cost of the intermediate location in terms of the following.

- Inventory wait time (average dollars of inventory times the annual inventory holding cost percentage – usually 15%-25% of the cost of the materials)
- Pickup and Setdown time
- Additional delivery distance as a result of needing to visit the intermediate storage location, versus bypassing this location by transporting directly from the FROM to the TO location.

In the FP application, the ability to skip intermediate storage locations is simply performed by turning off deliveries to intermediate storage locations and then comparing the results from that obtained when these storage locations were included. When using this feature, it is important to identify deliveries to intermediate storage locations separately from that of the delivery's origin and destination locations when creating the routings data file.

While more difficult to analyze, but just as important to evaluate, is the opportunity for the co-location of concurrent processes. Essentially this involves attempting to create Focused Factories, Group Technology Cells, or even Mixed Model Assembly Lines by combining equipment into a workplace. Performing such an analysis in the FPC involves modifying the original routing file and AutoCAD drawing, into a new routing file and AutoCAD drawing which describes the new material flows.

Visualizing the opportunity for process combinations can be accomplished by color coding the flow diagram according to common process families (i.e. Product families). The locations can then be moved around in the drawing in order to streamline each process family individually, and then segregate the flows between these process families. Often, this procedure may involve adding equipment or processing capabilities unique to each family in order to optimize the

arrangement of the processes (locations) in each family, such that material handling between sequential processes can be eliminated.

Reducing Material Handling Pickup and Setdown Time

If the delivery cannot be eliminated, then the next evaluation should focus on the reduction of the container pickup and setdown times. This is especially true if the pickup and setdown time percentage of the total time approaches, or exceeds, 50 percent (which is common).

Obviously, any analysis of pickup/setdown time reduction should first occur on those pickup and setdown times which are the longest, and also which occur the most frequently. Since the FP application can dynamically determine the pickup and setdown times for specific deliveries according to the container type, container quantity, method and location, it may be necessary to perform a Pareto analysis on those derived times by copying and pasting the material handling report into MS Excel and sorting the pickup/setdown times according to those which are highest and those with the greatest frequency.

It is important to prioritize pickup and setdown times by individually looking at the processing time and the frequency at which this time occurs in order to better understand the manner in which the improvement can likely be achieved (i.e. a reduction in time for a long-time-low-frequency task, or the reduction in time for a short-time-high-frequency task will involve a different design approach).

Reducing Travel Distances

The primary objective in reducing travel distances is to focus on those distances (process flows) which have the highest frequencies of travel. These distances are easy to determine by simply looking at the material flow diagrams and identifying those lines which are thickest. In addition, it is recommended to copy and paste the material handling distance and frequency report (or input CSV file) to MS Excel and then sort the frequencies from high to low to create a Pareto Analysis which will quickly identify those material handling activities which will benefit the most from a travel distance reduction.

The FP application includes a capability to color code the material flow lines according to their frequency of travel. This can be accomplished by color coding percentage ranges of flow frequency, or by setting specific frequency quantity ranges as having specific colors.

Additionally, it is recommended to perform a location group analysis (essentially a cluster flow analysis) which involves the diagramming and reporting of material flow between departments, or groups of locations, as opposed to evaluating the flow between each location in those groups. With these cluster (group) diagrams, it will be easy to see the aggregated effect of material flow frequency between groups of locations, and identify opportunities for significant flow distance reduction. Often substantial benefits can be achieved as a result of reducing the distance between entire groups of locations (i.e. departments, workcenters, assembly lines, storage areas and docks) versus that of individual locations.

In addition to the obvious approach of reducing the travel distances between sequential processes, there exist several other analysis techniques and operating philosophies which can result in substantial reductions in material flow.

- Utilization of Route-based delivery methods, such as tuggers
- Installation of Point Of Use (POU) docks
- Geographically zoning material handling operators and equipment
- Relocating and/or breaking up storage locations

Utilization of Route-based delivery methods

Route-based delivery methods, such as tuggers, offer substantial opportunities for the reduction of travel distances while moving the same quantity of material during the same time interval. These distance reductions are the result of shared travel (i.e. multiple parts move on the same path at the same time) and reduced deadheading (i.e. traveling empty from a delivery location to the next pickup location). Additionally, route-based delivery methods are often much easier to manage and control and thus do not suffer from the problems of ineffective utilization and scheduling that are a common source of inefficient unit load (Fork Truck based) material handling systems. It is important to note that being ineffective involves performing work (i.e. travelling) but not advancing the work (i.e. moving material), whereas being inefficient involves not having the work to do when the resources are available to do it.

Installation of Point of Use docks

Other opportunities for travel distance reduction include the installation of additional docks (i.e. POU Point Of Use docks) whereby material distances can be greatly reduced. In addition, if material is stored in the trailers then it is likely that at least one material handling activity can be entirely eliminated by using the POU docks. Bulky materials with high frequencies are often the most optimal candidates for POU dock justification.

Geographically zoning material handling operators

Zoning material handling operators and equipment is another prospective improvement opportunity. Significant reductions in average material flow distance can be achieved in plants where the policy is to allow any material handling operator to move material from and to every area in the plant. By focusing material handling operators within distinct zones of the facility the average "per-trip" travel distances of those operators will be reduced, dead-head time and distances will be reduced and the material handling activities will be easier to manage.

Relocating and/or breaking up storage locations

Since storage areas are often the lowest cost places to relocate, it is recommended that the relocation of each storage area in the facility be evaluated. The FP application's Flow Path Filtering capability is recommended when determining where these locations should be moved to. It is also recommended that centralized storage areas be broken up into smaller storage areas if there exist significant flows to and from these areas, such that 2 areas would offer significant flow distance reductions versus one central storage area.

Reducing Travel Obstructions

Additional reductions in material handling cost and time can be achieved by reducing obstructions to flow along aisles with significant material handling frequencies. Consequently reducing these obstructions will often result in significant relative reductions in safety hazards and damaged materials thus providing additional economic justifications for the improvement.

The FP application includes the ability to force devices to stop at intersections and turns, which will result in an increase in the total travel time for devices. In these situations, travel times for paths of equal distance, but unequal complexity (i.e. turns and intersections), can be expected to be different from one another.

Common obstructions to flow include the following.

- Narrow Aisles with high frequencies of travel, or in which wide loads are delivered (relative to the width of the aisle).
- Aisles with significant handling activities, and/or operators walking, which create the need for handling equipment to slow down or stop intermittently.
Turns and Intersections which require equipment to slow down and/or stop

Locating Electronic Material Handling Data

The first step in any computerized analysis task is to look around the organization for any electronic data that exists which relates to the scope and domain of the study which you are about to perform. Some might initially write off the fact that no information exists in the current facility which could be of any use to your study due to the estimated inaccuracy and incompleteness of this information. This may be true, however it is likely that the process of evaluating this electronic information could be helpful in the following ways.

- Validating the extent to which this data is, or is not, complete may be helpful to other members of the organization who may be using this data for other planning and pay purposes.
- Your use, and subsequent cleanup and validation of this data could benefit others in your organization which would provide additional downstream benefits, and justification for your project.
- If computerized systems exist in your organization which can warehouse and maintain information that is required for material handling analysis, then it is in the best interests of the organization to utilize those systems for the warehousing of the information that you will be collecting for your project. This will provide for a much easier evaluation next time. If those systems do not exist, then the company should evaluate the purchase, or development of a PFEP (Plan For Every Part) database, such as the one offered by Proplanner.

Trans Date	Update time	Item number	Item description	Location In Warehouse	New location	Trans qty	Workstaion ID
1/30/2006	3:36:54	5631866	MNT-CRADLE,LOWER	BB063	BB042	23	MABYERS
1/30/2006	3:51:35	5433154	GUARD-PROP SHAFT,FRONT	AA232	AA201	75	MABYERS
1/30/2006	6:05:14	5910052	STAND-SIDE C	BB032	D803	25	DMGODFR
1/30/2006	6:06:15	7051011	VALVE-CHECK, VENT	CC122	D802	200	KJOATMA
1/30/2006	6:07:16	5432598	BUSHING-STABILIZER LINK	BB051	D804	200	DMGODFR
1/30/2006	6:08:16	2410627	ASM-TAILLIGHT,LED	AA071	D802	60	KJOATMA

Figure 5. Export of electronic move tickets from MAPICS.
MAPICS is an MRP/ERP system sold by INFOR

Often the company will have a manufacturing IT person or department who can be the best source for identifying the location, completeness, and accuracy of information that can be beneficial to a material handling analysis. The list below identifies common sources of this electronic information.

- Electronic Move Tickets are used at many companies and are an excellent source of complete and accurate material handling delivery information. Essentially these tickets record "What" material was picked up by "Which" method (driver) "When" and subsequently transported "From" which location "To" which location. This information can be very easily imported into the FP application and these actual deliveries can be effortlessly diagrammed, aggregated and reported. An example of a MAPICS (a common MRP/ERP system) output of this dispatching data is show in figure 5.
- Inventory Dispatching Orders or Electronic Kanban Triggers identify that material is needed in a particular location at a particular time. While they often don't identify where the material was previously located, or which driver delivered it, they can be easily combined with a material storage location and operator zone file in order to create a quick and accurate input routing file.

- Inventory Requirements from MRP and ERP systems are essentially files of part quantity requirements information during particular time periods. These files state “What” materials (parts) are consumed at “Which” locations during “When”. In addition, these systems often know the estimated delivery quantity (i.e. standard pack) from which the material delivery frequency information can be computed. It is possible to automatically create the routing information by combining this information with a spreadsheet that identifies where each part is received, stored and consumed.
- Finally, in the unlikely event that the firm does not have a Move Ticket system, Inventory Dispatching system, Kanban Triggering System, MRP parts ordering system, or Electronic Dock parts receipt system, it will be necessary to define a set of common process families and essentially walk the parts through the facility in order to document these material routings. It will likely be recommended that this be done for a few sample parts even if the company estimates that they have an accurate set of input process data, as it is possible that data could have become corrupted in the import process and finding this out at the beginning of the analysis will save a great deal of potentially wasted analysis time later in the study when this problem would likely be discovered.

Collecting Material Handling Data

Material routings and a layout drawing are the two fundamental pieces of information required in any material handling analysis study. It is very likely that the plant has an electronic drawing of the facility (often in AutoCAD), however it is just as likely that this drawing is not up to date or is of insufficient detail. As such, it will often be necessary to validate that the drawing intended for use, be accurate in detail (and dimension) with regards to elements such as aisles, docks, storage areas and machines. Once this information has been validated, it will then be necessary to position the location names and aisle centers in the AutoCAD drawing, using Text Labels and Lines respectively, on predefined layers of the drawing. Name the locations by their functionality or activity group and not columns within the plants as this may change.

While part routing information can often be found in an electronic format (at least in part), it is likely that information regarding part containerization, pickup times, setdown times, transportation methods, delivery quantities and sometimes even storage locations is not electronically available. As such, the majority of the manual data collection activity will involve the collection of this missing information.

Process Routing Data Requirements

Process Routings comprise the foundation of any material handling analysis. A routing consists of the Movement of a Material using a given Method. These routings are defined according to a common process family (called Products in the FP application).

Figure 5 shows the routings defined for the tutorial included with the FP application. The field in the top left corner of this form shows that the displayed routings belong to the process family (i.e. Product) Small Pump. The first process routing is for the part “Housing”, in which 100% of these housings move from the Receiving location to the Bore location via an intermediate storage location called Storage1. These housings move from Receiving to the Storage1 location using a method called Crane that moves 1 Tub of 20 housings. From Storage 1, the housings are moved to the Bore location via a Cart method. Another file, called the Parts and Products file, specifies the production volume of Small Pumps during the analysis period (typically 1 week, 1 month or 1 year), as well as the number of housings required per Small Pump. Since the routing line indicates the number of pumps moved per trip, the FPC application is able to determine the Frequency of flow between the Receiving, Storage1 and Bore locations as attributed to the Housings.

Delivery Quantities

There are several other ways in which data can be formatted for the FP application to determine Frequency of flow between locations. The previous example demonstrated the most robust option, and would be appropriate for studies whereby the frequency of trips needs to be derived from the part requirements (i.e. MRP/ERP) data when no actual electronic data regarding material deliveries is available. In these situations, it will be necessary to determine the typical quantity of parts moved by a method at a particular time. This quantity is often referred to as the "Standard Pack" and is often not available (or not accurate) within the MRP system. As such, it will typically be necessary to manually collect these delivery quantities by walking the shop floor and observing the typical move quantities for each part.

Methods assigned to routes

The method used to move material is also not commonly available within an electronic format. As defined below, move methods represent the people, equipment, or group of people and equipment used to move the material. In very small facilities, or in plants with electronic move tickets, it will be practical and beneficial to associate a move with the individual who performed it. In larger organizations it will likely be more appropriate to define groups of material handling staff (organized by geographical operating area, by equipment type, or by job type (i.e. direct/indirect)), and then assign a specific group as a method used on a route. While these methods will need to be defined by the analyst, it is common that rules can be observed that would allow the analyst to assign large groups of routings to specific methods within a spreadsheet very quickly.

As a special note, it will be very important to ensure that material moves by direct labor personnel (equipment operators and assemblers) are uniquely identified with different methods than those of dedicated material handling operators, referred to as indirect labor. Often, these areas of responsibility will be fundamental in determining accurate material handling labor requirements and task assignments.

The file shown in this example is a simple Comma Separated Values format (CSV) used with MS Excel. As such, most of the data entry can be done in MS Excel and then imported into the FPC application.

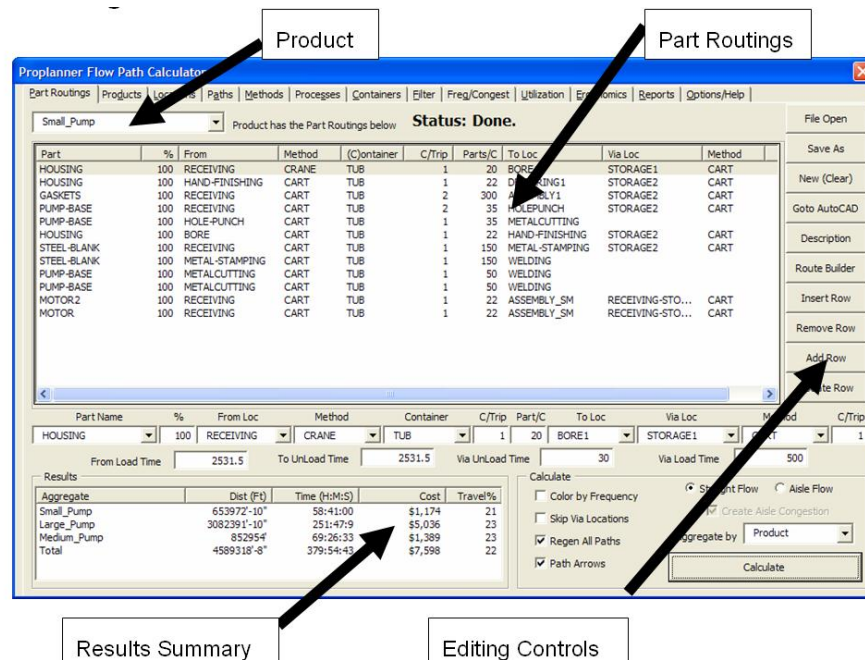


Figure 6. Main Routing Screen for the FPC application

Material Handling Method Data Requirements

Methods, as previously discussed, define the operator(s) and equipment responsible for the transport of a material (i.e. a part) from a specific location to another specific location. Often, Methods represent common groups of people and equipment that operate in defined geographical regions of the plant, or who move defined types of material, as defined by their equipment capability or skill. Material pickup and setdown times are assigned to methods as are method types, which define the performance and cost attributes for a particular method.

Method data is easy to define and often never exists in an electronic, or even written, format prior to the material handling study. While it is quick and easy to define methods and method type attributes, it is the pickup and setdown time information that will often take a substantial effort to collect. Unfortunately since a substantial amount of the material move time consists of pickup and setdown time, it is very important for the analyst to be very accurate and complete in their collection of this piece of information

The screenshot displays the 'Proplanner Flow Path Calculator' window. It features a menu bar at the top with options: Part Routings, Products, Locations, Paths, Methods, Processes, Containers, Filter, Freq/Congest, Utilization, Ergonomics, Reports, and Options/Help. Below the menu bar is a table with columns: Method, Calc, Qty, Type, Load, Unload, Start Loc, and Color. The table contains two rows: 'CART' (Yes, 1, HAND, 5, 5, RECEIVING, 1) and 'FORKLIFT' (Yes, 1, FORK, LOAD, UNLOAD, RECEIVING, 2). Below this table is a form for defining a new method, with fields for Method Name, Calc, Qty, Method Type, Load Process, UnLoad Process, Start Loc, and Color, along with Update, Add, and Remove buttons. At the bottom, there is another table with columns: Type, Qty, Eff. %, Max Mins., Fixed \$, Variable \$, Straight S..., Accel/Decel, Turn Angle, Aisle Path Layer, and Color. This table lists 'HAND' and 'FORK' methods with their respective attributes. Below this table is a form for defining a new method type, with fields for Method Type Name, Qty, Eff. %, Max Mins., Fixed \$, \$/Hour, Speed, Accel/Decel, Turn Ang, Aisle Path Layer, and Color, along with Update, Add, and Remove buttons. At the very bottom, there are buttons for 'Goto AutoCAD', 'Import Methods', and 'Save Methods'.

Method	Calc	Qty	Type	Load	Unload	Start Loc	Color
CART	Yes	1	HAND	5	5	RECEIVING	1
FORKLIFT	Yes	1	FORK	LOAD	UNLOAD	RECEIVING	2

Type	Qty	Eff. %	Max Mins.	Fixed \$	Variable \$	Straight S...	Accel/Decel	Turn Angle	Aisle Path Layer	Color
HAND	1	80	115200	0	20	15	5	100	PF_AISLEPATH	1
FORK	1	50	115200	3000	40	15	5	100	PF_AISLEPATH	2

Figure 7. Methods Data Requirements

Pickup and Setdown times

By default, Methods in the FP application have a fixed pickup and setdown time, however in real life, the time to pickup and setdown a container of material will vary according to the following.

- Container type
- Container quantity
- Container status (full or empty)
- Location (congested, easy to maneuver, etc.)
- Method type (fork truck, tugger, etc)

It is common to see analysts attempt to collect observed time data (stopwatch time) for every delivery route. While sometimes required with specific, very unique delivery situations, this practice is highly discouraged, due to the fact that it is a very expensive technique that often results in questionable accuracy, consistency and data reusability. The FP application does support the specification of pickup and setdown times with any routing in order to support instances in which this technique is required. In these situations, those route-based pickup and setdown times will override the time determined by the methods used by that route.

Alternatively, the FP application supports the definition of pickup and setdown processes, which provide a means for specifying components of the pickup and setdown task as associated to attributes of that task (i.e. Location, Method, Container Type, Container Quantity and Container Status). With these processes, the analyst need only identify the component times of the pickup and setdown activities (i.e. time per container type, container status, location accessibility and move method). With these component times, and a properly constructed process description, pickup and setdown times can be quickly, accurately and consistently determined, by the FPC application, for practically all material handling tasks within the facility. Moreover, by using component derived times, it is much easier and more accurate to evaluate and compare recommended process improvements prior to actually performing them.

Component times can be defined using either observed time (stopwatch) standards and/or predetermined time standards such as MTM or MODAPTS. Clearly, predetermined times are preferred over that of observed times due to their superior consistency and self-documenting abilities. As such, the FP application supports the definition of processes using MTM, MODAPTS and other commercial and private predetermined systems.

Finally, if observed time systems are used, it will be necessary to determine the appropriate worker allowances (i.e. personal, fatigue, etc.) in order to ensure that the standards are fair. Also, it will be necessary to determine if these allowances apply to the manual pickup and setdown tasks or if they also apply to the automated delivery of materials.

Defining the Scope of a Material Handling Study

It is often difficult to constrain the scope of a material handling study to a particular area in the facility, as it is likely that facility-based changes may be required in an effort to support the benefits in any particular area without potentially pushing the material handling costs to another area in the plant. The following list identifies common topics for discussion and determination in defining the scope for any particular study.

1. **Time period of analysis (shift, day, week, month, year).** Often a year is used in many studies because it best represents the time frame over which the layout and material handling policies are likely to remain in place. In addition, this time frame makes it easy to associate the financial savings reported in the FP application to the annual savings.
2. **Number of delivery/pickup locations in study.** When defining handling locations in the plant, it will be important to have a consistently defined naming convention in order to reduce confusion.
3. **Number of parts/containers/routings in study.** Typically, studies involving thousands of routing lines in the CSV file are not a problem for the FP application or the complexity of the study. Routings exceeding 10,000 will likely require evaluation in phases, due to the difficulty in editing, filtering and visualizing that many flow lines within the AutoCAD application. Flow Planner can handle an unlimited number of routing lines, but the Excel file limit of 64,000 is a practical upper bound. Studies involving this many flow lines could take several hours to a few days to calculate. For more information on Calculation Performance, please refer to that chapter later in this document.
4. **Unit load study and/or Tugger study.** Are the trips for delivery represented by individual fork moves or train-load of carts moving from location to location throughout the plant. Evaluating both unit-load and tugger delivery methods, wherein tugger delivery routes must be defined, can take more time and complexity to

perform.

5. Does the study include stockroom tasks or just in-plant deliveries?
6. Does the study include Kanban card pickups or just material delivery?
7. Does the study include the handling of dunnage and empty returnable containers?
8. Does the study include supplier deliveries and the determination of appropriate docks for delivery.
9. Does the study include the evaluation of existing historic deliveries (like those collected from a dispatching software application) and/or does it include the evaluation of probable future delivery requirements.
10. Does the analysis team consist of engineering and shop floor members of the plant, or is it entirely composed of external consultants. In other words, is the analysis team expected to determine the new alternatives and come up with a final design, or are they working as a member of the in-plant team and thus primarily supporting that team with visual and quantitative feedback regarding alternatives.

Calculation Performance

Flow Planner works within the AutoCAD application, and the calculation speed for an analysis can vary according to several different factors which are categorized according to Routing Data and Layout Data.

Routing Data

- The length of the routing file used for the study will greatly impact the performance of the calculation. Each routing line is calculated independently, and then aggregated into a memory resident results table according to the aggregation method selected by the user when the calculation was run. Aggregations by Method Type or Group will generate the smallest tables, where aggregations by Product+Part will generate the largest tables. Larger tables take more memory and will slow the calculations.
- Routing files that contain references to many unique locations will create additional flow lines, location labels and aisle intersection nodes. Together, the impacts of increasing the calculation times of additional locations can be significant for large studies. As such, if there are locations very close to one another, the analyst should consider combining them.

Layout Data

- The single greatest performance issue is the size of the AutoCAD drawing in terms of the number of objects. The Flow Planner application needs to search the AutoCAD drawing for text labels, flow paths, and aisle intersections, and these queries can take a long time for a large drawing. A quick way to resolve this issue, is to select your location labels and draw your aisles with all of the objects in the drawing. Then you can WBLOCK out the aisles and locations layers into their own AutoCAD drawing. Loading only this drawing back into AutoCAD will allow the flow diagrams to be calculated very quickly. Finally, you can XREFERENCE your layout drawing back into your Flow study to show the two together.
- AutoCAD is very sensitive to processor performance, and internal RAM memory. In addition, a 64bit computer/OS will make a significant improvement. Optimizing your AutoCAD computing environment will greatly speed up the performance of the Flow Planner Calculations.

Discrete Event Simulation and Flow Analysis

There is often a lot of confusion on when, and how, to utilize Discrete Event Simulation software and techniques on a Layout study involving Material Flow Analysis.

The objective of Simulation software is to evaluate the timing impacts of dependent events on inventory levels and throughput times. This is accomplished by evaluating increments of time (seconds or minutes) and observing system performance over a period of minutes and hours. Simulation software requires detailed information about processing times, routing logic, and subsequent variability on how these times and routes are likely to change. Simulation studies then employ experimentation; whereby the engineer tries different schedules and lot sizes and evaluates the subsequent impact on system performance. The result of a simulation study is the best selection of scheduling logic, inventory buffer sizes and order lot quantities.

The objective of Flow Analysis is to visualize and quantify the movement of material in a facility with respect to aisles, docks and equipment over the course of days, and months, or most commonly a full year. Longer time periods are required for Flow studies because the Flow of materials is directly dependent upon the location of equipment which will remain static for one to multiple years. Flow analysis software requires plant-wide material routing information (where the parts go, not when or why), and the containerization (parts/container) and frequency of these movements within a dimensionally accurate drawing of the facility. Flow studies create diagrams that are used by teams of people to visualize location/based and travel/based information over these aggregated long time periods. The result of a Flow study is the visualization and quantification of material flow such that a team of people can quickly come to a consensus on how to co-locate processes into focused factories, or modify the layout to allow for the reduction of lot sizes within sequential steps of the process routing.

Eventually, selected areas (departments, cells, products, processes, etc.) for a layout alternative derived from a Flow Analysis may be evaluated using simulation software to arrive at a desired production scheduling rule, and to quantify the anticipated inventory level and throughput time reductions possible by such a layout change.

Conclusion

A Systematic Material Handling and Flow Analysis evaluation of any industrial facility is likely to uncover substantial opportunities for improvement that can be expected to greatly exceed the cost, and time allocated to this evaluation. It is perhaps a mixed blessing that there are so many different ways to evaluate, eliminate and improve material handling within a common industrial facility. As such, it is highly recommended that material flow diagramming and analysis applications be utilized such that organizations can quickly and accurately visualize, quantify and evaluate the many different alternative designs derived from a comprehensive and accurate data set, constructed from actual material handling delivery requirements within the organization.

Finally, it is necessary for any material handling analyst to approach this problem in a structured and systematic manner in order to ensure that those opportunities which could generate the most significant improvements are discovered, presented and justified, such that they are eventually implemented and their benefits recognized.

About the Author

Dr. David Sly is a globally recognized expert in the evaluation and design of Manufacturing Process and Plant engineering systems. He received his BS, MS and PhD degrees in Industrial Engineering and an MBA from Iowa State University. David is an adjunct faculty member in both the College of Engineering and College of Business at ISU. He is a registered Professional

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Engineer in the State of Iowa and a Senior member in the Society of Manufacturing Engineers and the Society of Industrial Engineers as well as the Modapts and MTM work measurement organizations. David is the author of the FactoryCAD and FactoryFLOW applications now owned by Siemens PLM solutions. He is also the designer of the Proplanner Process Engineering application, and associated Workplace Planner and Flow Planner applications. David's applications are in use at over 800 companies including Ford, GM, Chrysler, Deere, Case, Caterpillar, Intel, National Semiconductor, Maytag, Whirlpool, Paccar, and Mack/Volvo, in over 36 different countries.

Appendix A Checklist for Data Collection

Routing Information (see Appendix C for example)

1. Try to locate electronic information regarding parts. This is the most critical first step. Each plant will have some electronic information about the parts delivered to, or consumed at, the plant. The electronic information that can be found, will form the framework of the manual data collection study (with regards to detail, naming conventions, accuracy, effort, etc). This electronic information will be used to create the initial Data collection spreadsheets which are then used by the field analysts to collect and validate the material handling information in the field.

Some sources include:

- a. Parts received at docks
 - b. Parts consume at locations
 - c. Parts delivered by drivers
2. Determine the location naming conventions
 - a. This should be a plant standard and thus will be used within any of the electronic data that is received from the plant
 - b. These should be fairly specific (i.e. within a few feet of accuracy).
 - c. Some locations may be only a center point in a fairly large workstation or machine. If parts go in one end and come out the other, and if these distances are more than 2 or 3 feet, then it will be necessary to split the location into 2 locations (i.e. MachineA_In, MachineA_Out).
3. Identify common Process (i.e. Products) families.
 - a. These would be products, assemblies or processes which share a great deal of commonality and around which you intend to focus the material flow. Often these are specific product families with common manufacturing processes, locations and equipment.
 - b. These common process families will be coded as Product families within the FPC application and will represent the default data grouping (aggregation) of the flow results (i.e. color coding of the flow paths, computation of flow frequency between locations, subtotals of distance, cost and time)
4. Create a spreadsheet of part routing information (see example below).
 - a. What part (name and description)
 - b. % of Flow (amount of the total quantity of parts consumed in the product (i.e. process family from part 2 above) takes this particular route.
 - c. From location – Origination of that part number in the plant (might be multiple)
 - d. To location – Final destination of that part number
 - e. Via Location – is one or more intermediate storage locations between From and To locations.
 - f. Method (listed below) this is the device/operator used for the movement activity.
 - g. Container name – container name that the parts are transported in (i.e. pallet, tub, etc.)
 - h. Parts per container (also called standard pack) – how many parts fit in a standard container
 - i. Containers per trip of the method – how many containers of the part are moved by the specified method at one time (on average).

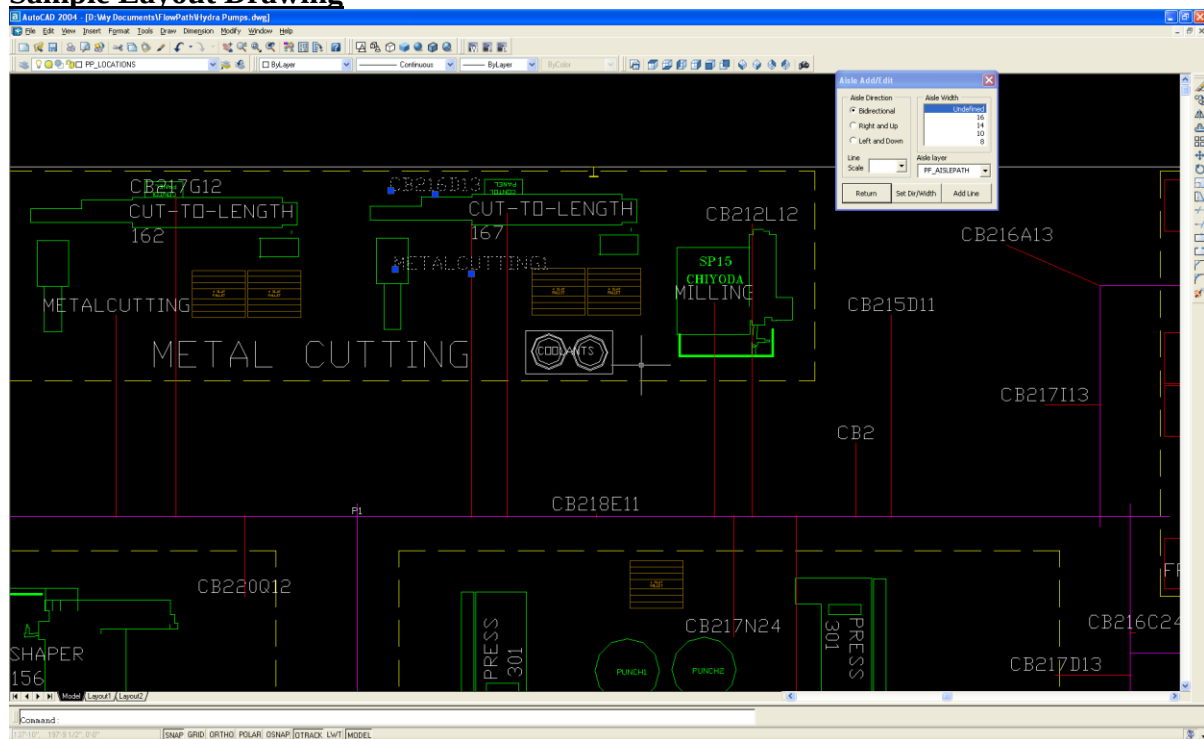
Methods Information (see Appendix C for example)

1. Try to locate electronic information regarding movement methods (most often you will not be able to find any)
2. Document the types and quantities of material handling equipment and when and where they work
 - a. Certain shifts
 - b. Certain parts or containers
 - c. Speed of device
 - d. Hourly operating cost (not including operator) (i.e. fuel, power, maint)
3. Document types and quantities of material handling people, and when and where they work
 - a. Direct labor (shifts, locations) – only if they do material handling tasks
 - b. Indirect labor (material handler shifts, locations)
 - c. Dedicated to piece of equipment or floating (if so what equip do they use)
 - d. Labor rate (fully burdened)
4. Document Load (pickup) and unload (setdown) times for each type of equipment.
 - a. Identify the task elements of the pickup and setdown activity. Often these element times will vary according to type of material handing device, type of container, or congestion of the location. In other words, document common load/unload scenarios or processes.
 - i. Get off truck
 - ii. Move container
 - iii. Unband/band package
 - iv. Place on shelf
 - v. Etc.
 - b. Classify each task element of a move. These will be the elements from the Load/unload process or scenario described above.
 - i. Classes of containers (i.e. bins, totes, boxes, pallets) and subclassify according to relevant size groups (small, med, large)
 - ii. Classes of locations (i.e. difficult to move around in, easy to move around in).
 - iii. Classes of equipment (i.e. different times for different types of equipment operating on the same container in a similar location)
 - iv. Classes of tasks (i.e. unbanding, placing parts in a different container, placing parts on a shelf, rotating inventory). Sometimes it is easiest to classify tasks by locations and thus their time is added to any container or method that visits that location.

Layout Information

1. Try to locate an existing AutoCAD drawing
2. Check that the aisle locations and widths are drawn and are accurate.
 - You can draw lines down the center of the aisles where material handling equipment can operate. This can be done by marker on a layout drawing, or in the AutoCAD program on a layer that you choose.
3. Locate every receiving, storage and delivery location in the drawing, as per the naming convention used in the input routing data (listed above)
 - You can write these locations in on a print-out of a drawing, or you can use the AutoCAD text command (centered text option) and add these text labels to the drawing on any layer that you choose.

Sample Layout Drawing



Appendix B Checklist for Input Data Forecast

Entity	Available (Y/N)	Time to gather data
Drawing (All files must be .dwg)		
• Dock Information		
• Intermediate storage information		
○ Rack information		
○ Part location information		
• Supermarket information		
○ Rack information		
○ Part location information		
• Aisle information		
○ Direction of the aisle		
○ Width of the aisle		
○ Fixed routes/pass through points		
• Line side location information		
Part Information		
• Part data from		
○ Electronic Move Tickets		
○ Inventory Dispatching Orders or Electronic Kanban Triggers		
○ Inventory Requirements from MRP and ERP		
• Parts that are moved in Bulk (Forklifts, Hi-Lo's etc.)		
• Parts that are moved on Tuggers		
• Container information for each part		
• STANDARD PACK DATA – Average quantity moved at a time		
Method Information		
• Types of devices available		
○ Forklifts		
○ Tuggers		
○ Hand Carts		
○ Others		
• Load unload time for each device		
• Speed, acceleration of each device		
Container Information		
• Types of containers		
• Size of containers (L x B x H)		
• Number of containers that can be carried/stacked at a time		
○ Full		
○ Empty		
Load/Unload time for each container		

Appendix C Sample Input Routing File

Microsoft Excel - Hydra Pumps.csv														
File Edit View Insert Format Tools Data Window Help Adobe PDF														
Type a question for help														
100%														
Reply with Changes... End Review...														
Arial 10 B I U														
*ROUTINGS (Product														
A1	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	*ROUTINGS (	Us	Part	Flow%	From	Method	Container	Containers/Trip	Parts/Container	To	Via Loc	Via Method	Via Containers/Trip	
2	Small_Pump	2	HOUSING	100	RECEIVING	CRANE	TUB	1	20	BORE1	STORAGE1	CART	1	
3	Small_Pump	1	HOUSING	100	HAND-FINISH	CART	TUB	1	22	DE-BURING1	STORAGE2	CART	1	
4	Small_Pump	1	GASKETS	100	RECEIVING	CART	TUB	2	300	ASSEMBLY1	STORAGE2	CART	2	
5	Small_Pump	1	PUMP-BASE	100	RECEIVING	CART	TUB	2	35	HOLEPUNCH	STORAGE2	CART	2	
6	Small_Pump	1	PUMP-BASE	100	HOLE-PUNCH	CART	TUB	1	35	METALCUTTING				
7	Small_Pump	1	HOUSING	100	BORE	CART	TUB	1	22	HAND-FINISH	STORAGE2	CART	1	
8	Small_Pump	0	STEEL-BLANK	100	RECEIVING	CART	TUB	1	150	METAL-STAM	STORAGE2	CART	1	
9	Small_Pump	1	STEEL-BLANK	100	METAL-STAM	CART	TUB	1	150	WELDING				
10	Small_Pump	1	PUMP-BASE	100	METALCUTTING	CART	TUB	1	50	WELDING				
11	Small_Pump	1	PUMP-BASE	100	METALCUTTING	CART	TUB	1	50	WELDING				
12	Small_Pump	0	MOTOR2	100	RECEIVING	CART	TUB	1	22	ASSEMBLY	RECEIVING-S	CART	1	
13	Small_Pump	1	MOTOR	100	RECEIVING	CART	TUB	1	22	ASSEMBLY	RECEIVING-S	CART	1	
14	Large_Pump	0	HOUSING	100	RECEIVING	FORKLIFT	PALLET	1	20	BORE	STORAGE1	FORKLIFT	1	
15	Large_Pump	1	HOUSING	100	HAND-FINISH	FORKLIFT	PALLET	1	22	DE-BURING	STORAGE2	FORKLIFT	1	
16	Large_Pump	1	MOTOR	100	RECEIVING	FORKLIFT	PALLET	1	22	ASSEMBLY	RECEIVING-S	FORKLIFT	1	
17	Large_Pump	1	GASKETS	100	RECEIVING	FORKLIFT	TUB	2	300	ASSEMBLY1	STORAGE2	FORKLIFT	2	
18	Large_Pump	1	PUMP-BASE	100	RECEIVING	FORKLIFT	PALLET	2	35	HOLEPUNCH	STORAGE2	FORKLIFT	2	
19	Large_Pump	1	PUMP-BASE	100	HOLEPUNCH	FORKLIFT	PALLET	1	35	METALCUTTING				
20	Large_Pump	1	HOUSING	100	BORE	FORKLIFT	PALLET	1	22	HAND-FINISH	STORAGE2	FORKLIFT	1	
21	Large_Pump	0	STEEL-BLANK	100	RECEIVING	FORKLIFT	PALLET	1	150	METAL-STAM	STORAGE2	FORKLIFT	1	
22	Large_Pump	1	STEEL-BLANK	100	METAL-STAM	FORKLIFT	PALLET	1	150	WELDING				
23	Large_Pump	1	PUMP-BASE	100	METALCUTTING	FORKLIFT	PALLET	1	50	WELDING				
24	Large_Pump	1	PUMP-BASE	100	METALCUTTING	FORKLIFT	PALLET	1	50	WELDING				
25	Large_Pump	1	PUMP-BASE	100	WELDING	FORKLIFT	PALLET	1	50	SUB-ASSEMBLY				
26	Large_Pump	1	VALVE	100	RECEIVING	FORKLIFT	PALLET	1	175	MILLING				
27	Large_Pump	1	HOUSING	100	DE-BURING	FORKLIFT	PALLET	1	25	DE-GREASING				
28	Large_Pump	1	VALVE	100	MILLING	FORKLIFT	PALLET	1	175	METAL-FORMING				
29	Large_Pump	1	VALVE	100	METAL-FORM	FORKLIFT	PALLET	1	175	DE-GREASING	DE-BURING	FORKLIFT	1	
30	Large_Pump	0	PLASTIC-RAV	100	RECEIVING	FORKLIFT	PALLET	1	300	MOLDING	STORAGE2	FORKLIFT	1	
31	Medium_Pump	0	HOUSING	100	RECEIVING	FORKLIFT	PALLET	1	20	BORE3	STORAGE1	FORKLIFT	1	
32	Medium_Pump	1	HOUSING	100	HAND-FINISH	FORKLIFT	PALLET	1	22	DE-BURING2	STORAGE2	FORKLIFT	1	
33	Medium_Pump	1	MOTOR	100	RECEIVING	FORKLIFT	PALLET	1	22	ASSEMBLY	RECEIVING-S	FORKLIFT	1	
34	Medium_Pump	1	GASKETS	100	RECEIVING	FORKLIFT	TUB	2	300	ASSEMBLY1	STORAGE2	FORKLIFT	2	
35	Medium_Pump	1	PUMP-BASE	100	RECEIVING	FORKLIFT	PALLET	2	35	HOLEPUNCH	STORAGE2	FORKLIFT	2	
36	Medium_Pump	1	PUMP-BASE	100	HOLE-PUNCH	FORKLIFT	PALLET	1	35	METALCUTTING				
37	Medium_Pump	1	HOUSING	100	BORE	FORKLIFT	PALLET	1	22	HAND-FINISH	STORAGE2	FORKLIFT	1	
38	Medium_Pump	0	STEEL-BLANK	100	RECEIVING	FORKLIFT	PALLET	1	150	METAL-STAM	STORAGE2	FORKLIFT	1	
39	Medium_Pump	1	STEEL-BLANK	100	METAL-STAM	FORKLIFT	PALLET	1	150	WELDING2				
40	Medium_Pump	1	PUMP-BASE	100	METALCUTTING	FORKLIFT	PALLET	1	50	WELDING3				
41	Medium_Pump	1	PUMP-BASE	100	METALCUTTING	FORKLIFT	PALLET	1	50	WELDING4				
42	Medium_Pump	1	STEEL-BLANK	100	METAL-STAM	FORKLIFT	PALLET	1	150	WELDING5				
43	Medium_Pump	1	PUMP-BASE	100	METALCUTTING	FORKLIFT	PALLET	1	50	WELDING3				
44	Medium_Pump	1	PUMP-BASE	100	METALCUTTING	FORKLIFT	PALLET	1	50	WELDING4				
45														
46	*PRODUCTS (	Qu	Color	Calc)										
47	Small_Pump	##		1 Yes										
Hydra Pumps														
Ready NUM														

Hydra Pumps

Ready

NUM

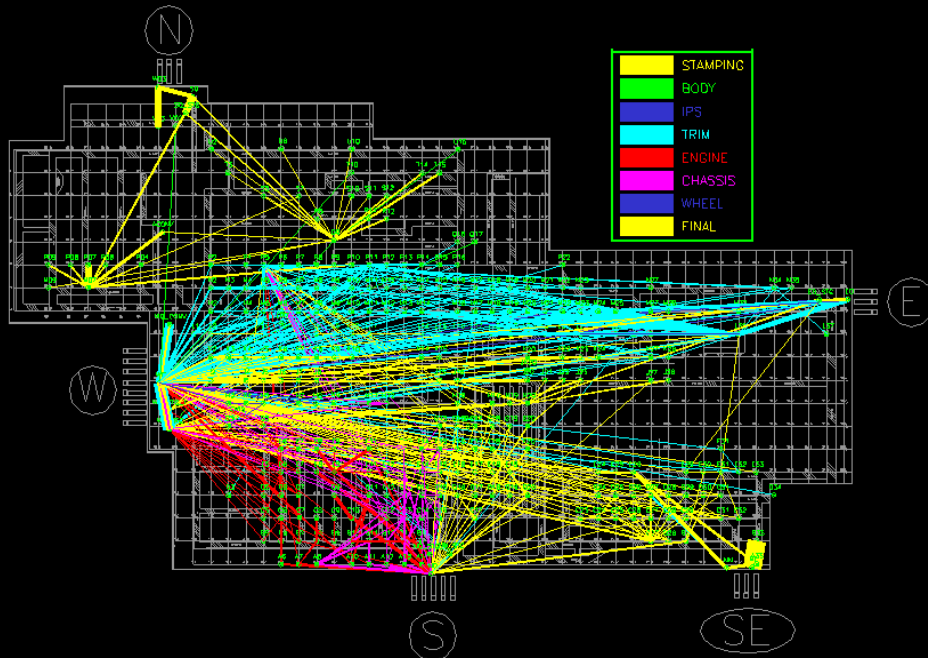
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The screenshot displays the Microsoft Excel application window titled "Microsoft Excel - Hydra Pumps.mhe". The interface includes the standard menu bar (File, Edit, View, Insert, Format, Tools, Data, Window, Help, Adobe PDF) and a toolbar with various icons for file operations and formatting. The spreadsheet itself is organized into columns labeled A through L. The data is structured into several sections, including a table for equipment types (CRANE, CART, FORKLIFT) with associated quantities and costs, and a section for containers (TUB, PALLET) with dimensions and weights. The spreadsheet also contains various formulas and calculations, such as =1000 and =15000, and a section for processes (PROCESSSES) with time and activity codes. The status bar at the bottom indicates the file name "Hydra Pumps" and the current cell address "A1".

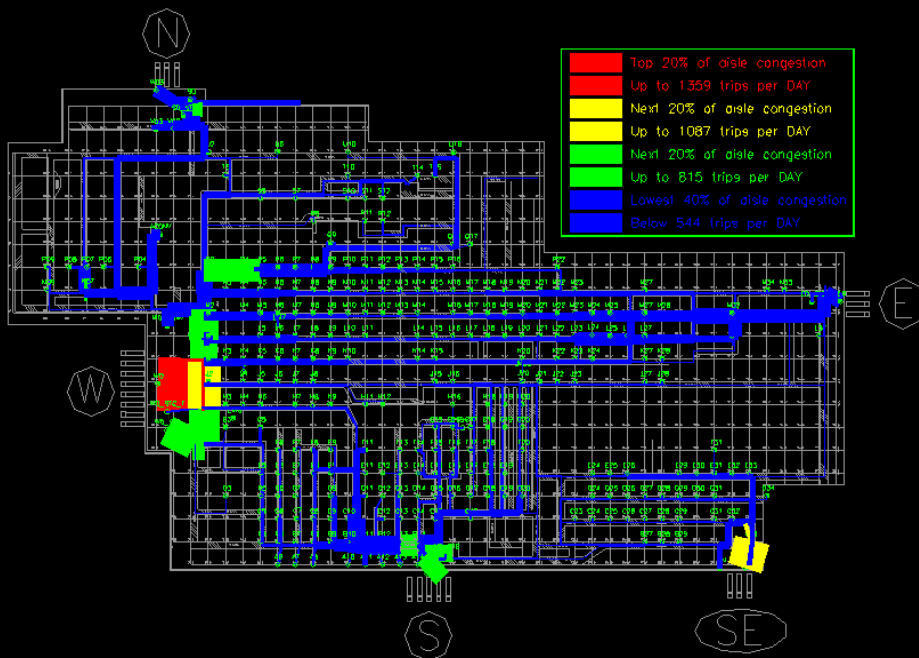
A	B	C	D	E	F	G	H	I	J	K	L
*METHODS (Name)	Quantity	Type	Load Process/Time	Unload Process/Time	Total Travel Se	Start Loc	Color	Calc	Total Load+Unload Secs)		
CRANE	1	FORKLIFT	15	15	7031.93807601	START	1	Yes	15000		
CART	1	CART	15	15	36571.5959714	START	1	Yes	152662.322387697		
FORKLIFT	3	FORKLIFT	15	15	262505.108237	START	1	Yes	894066.16973877		
*METHODTYPES	Eff%	Fixed\$	Var\$	Straight Speed	Accel/Decel	TurnAngle	Aisle Layer	Layer	Max	Min	Qty
CART	100	0	20	15	5	5	PF_AISLEPATH	1	9600		1
FORKLIFT	100	0	20	15	5	5	PF_AISLEPATH	1	9600		3
*CONTAINERS (Name)	Length	Width	Height	Full Qty	Empty Qty	Color)					
TUB	1	1	1	1	1	1					
PALLET	1	1	1	1	1	1					
*PROCESSSES (Name)	Time in sec	Time in MOD/MU	Activity Code	Special Code	Weight Code)						

Appendix D Sample Output

Flow of all parts - Color coded by department of use



Flow of all parts - Aisle congestion diagram



Utilization Reports



Summary Reports

FPC Simple Report - Microsoft Internet Explorer

Address: C:\Documents and Settings\Adam.PROPLANNER\Local Settings\Temp\FPCReport.XML

SIMPLE AGGREGATE SUMMARY											
AGGREGATE	FROM	TO	FREQUENCY	TOTAL DISTANCE FEET	TRIP DISTANCE FEET	EFF. TRIP DISTANCE FEET	TRAVEL TIME SECONDS	L/U/L TIME SECONDS	TOTAL TIME SECONDS	TRIP TRAVEL TIME SECONDS	COST \$
Large_Pump	RECEIVING	STORAGE1	2,700.00	569,484.00	210.96	210.92	37,972.47	81,000.00	118,972.47	14.06	660.96
	STORAGE1	BORE	2,700.00	132,759.00	49.16	49.17	8,848.05	81,000.00	89,848.05	3.28	499.16
	HAND-FINISHING	STORAGE2	2,454.54	372,672.81	151.85	151.83	24,847.40	73,636.36	98,483.76	10.12	547.13
	STORAGE2	DE-BURING	2,454.54	411,552.72	167.70	167.67	27,442.35	73,636.36	101,078.71	11.18	561.55
	RECEIVING	RECEIVING-STORAGE	818.18	29,110.84	35.61	35.58	1,942.49	24,545.45	26,487.95	2.37	147.16
	RECEIVING-STORAGE	ASSEMBLY	818.18	61,633.50	75.35	75.33	4,109.78	24,545.45	28,655.24	5.02	159.20
	RECEIVING	STORAGE2	932.14	149,841.51	160.79	160.75	9,991.80	27,964.29	37,956.09	10.72	210.87
	STORAGE2	ASSEMBLY1	135.00	17,505.45	129.68	129.67	1,167.13	4,050.00	5,217.13	8.65	28.98
	STORAGE2	HOLEPUNCH	257.14	43,734.37	170.08	170.08	2,915.64	7,714.29	10,629.93	11.34	59.06
	HOLEPUNCH	METALCUTTING	514.29	34,755.72	67.54	67.58	2,315.75	15,428.57	17,744.32	4.50	98.58
	BORE	STORAGE2	2,454.54	485,802.56	197.88	197.92	32,381.15	73,636.36	106,017.51	13.19	588.99
	STORAGE2	HAND-FINISHING	2,454.54	372,672.81	151.85	151.83	24,847.40	73,636.36	98,483.76	10.12	547.13
	STORAGE2	METAL-STAMPING	480.00	41,558.40	86.57	86.58	2,770.39	14,400.00	17,170.39	5.77	95.39
	METAL-STAMPING	WELDING	480.00	34,521.00	71.89	71.92	2,300.37	14,400.00	16,700.37	4.79	92.78
	METALCUTTING	WELDING	720.00	105,962.40	147.20	147.17	7,065.51	21,600.00	28,665.51	9.81	159.25
	WELDING	SUB-ASSEMBLY	360.00	22,921.20	63.64	63.67	1,527.37	10,800.00	12,327.37	4.24	68.49
	RECEIVING	MILLING	102.86	10,414.58	101.26	101.25	694.36	3,085.71	3,780.07	6.75	21.00
	DE-BURING	DE-GREASING	2,262.86	165,188.78	73.04	73.00	11,018.54	67,885.71	78,904.25	4.87	438.36
	MILLING	METAL-FORMING	102.86	8,590.58	83.45	83.42	572.23	3,085.71	3,657.94	5.56	20.32
	METAL-FORMING	DE-BURING	102.86	7,697.01	74.82	74.83	513.05	3,085.71	3,598.76	4.99	19.99
	STORAGE2	MOLDING	60.00	3,745.20	62.39	62.42	249.56	1,800.00	2,049.56	4.16	11.39
SUB TOTAL			23,364.53	3,082,115.03			205,492.79	700,936.35	906,429.14		5,035.74
Medium_Pump	RECEIVING	STORAGE1	750.00	158,190.00	210.96	210.92	10,547.91	22,500.00	33,047.91	14.06	183.60
	STORAGE1	BORE3	750.00	41,250.00	55.01	55.00	2,750.32	22,500.00	25,250.32	3.67	140.28
	HAND-FINISHING	STORAGE2	681.82	103,520.73	151.85	151.83	6,902.05	20,454.54	27,356.60	10.12	151.98

Done My Computer