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MATERIAL FLOW ANALYSIS OF AUTOMOTIVE ASSEMBLY PLANTS USING FACTORYFLOW

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ABSTRACT

When designing a new assembly plant or retrofitting an existing plant, it is critical to determine where *all* the materials will be received, stored and used. Variable width and color material flow diagrams created by FactoryFLOW are especially useful for presenting this information. FactoryFLOW automatically finds the shortest route from origin to destination along an aisle network for all materials/parts involved. Once routes are determined, FactoryFLOW draws the routes, outputs travel distances, times, and costs to report files and scales the thickness of flow lines according to the flow intensity of each part.

The input data required by FactoryFLOW is the kind of basic from-to information typically already available in a database or spreadsheet. Among other output reports, FactoryFLOW generates detailed reports on manpower requirements by equipment type. FactoryFLOW's from-to chart shows the flow intensities and distances between all from-to locations analyzed. The distance intensity chart plots each part's move intensity against its travel distance on an X-Y graph.

With the help of powerful personal computer systems and user friendly graphical environments, material flow studies of over 10,000 parts within facilities of over 5 million square feet can be accomplished by a novice user in under an hour.

1 THE TOOLS IN BRIEF

FactoryFLOW is a detailed material flow analysis tool that works inside of AutoCAD® on a PC or SUN workstation to analyze, diagram, and report material flow within factory layouts. FactoryFLOW takes the assembly plant layout drawn or imported into AutoCAD and combines part/product routings from spreadsheets, material handling databases, or MRP systems. FactoryFLOW then automatically generates intelligent detailed material flow diagrams on flow-group named layers inside of the AutoCAD system, with variable width and color flow lines illustrating flow intensity or cost. Once the diagrams have been generated, FactoryFLOW creates detailed reports on material flow cost, distance, frequency, time and space requirements at different locations inside the plant. One key benefit of the FactoryFLOW system is that it can analyze up to 80,000 routes or nearly 30,000 different part numbers simultaneously, with most analyses taking less than 1 hour to compute on a pentium PC.

While AutoCAD is used as a robust and cost-effective graphics engine for the graphical components of the analysis, AutoCAD need not be used as the CAD system for the facility. AutoCAD's excellent DXF and IGES interfaces make importing and exporting the CAD graphics from CAD systems such as Intergraph, Prime, Catia and Cadam relatively simple. Since FactoryFLOW only requires locations of columns, machines, storage areas, aisles, and docks, the graphics conversion problems associated with text, dimensions, linetypes, layers and colors do not pose a problem.

2 MATERIAL FLOW DIAGRAMS FOR ASSEMBLY PLANTS

When designing a new assembly plant or retrofitting an existing one for a new model or entirely new vehicle, it is critical to determine where *all* the materials will be received, stored and used. With the typical vehicle containing over 3000 different parts and as many as 10,000 different part numbers, it is nearly impossible to evaluate the impact of the assembly plant's material flows as a whole without a tool specifically designed for the task. Until FactoryFLOW, no tools were available that could effectively combine the graphic and textual elements of the material flow analysis problem within the constraints of the large data sets required to aid in dock assignment, aisle sizing, and congestion elimination. FactoryFLOW was designed to evaluate the flows of all materials for an entire assembly plant based on existing MRP and CAD data.

2.1 Dock assignments and storage locations—Euclidian paths

In the initial stages of layout design, assembly plant designers need to know what materials are received at which docks, where these materials are stored, and where they are used. Variable width and color material flow diagrams created by FactoryFLOW are especially useful for presenting this information. These diagrams are critical tools in the evaluation of all material flow issues in that they separate fact from assumption and allow the design team members to focus their attention on the solution of real problems with everyone using the same data to evaluate probable and workable solutions.

Meetings without accurate and effective flow diagrams often revolve around localized issues on the minds of those in attendance, resulting in the team constantly jumping from one problem to another; without the common global perspective flow diagrams can promote, the team often winds up back where it started weeks later with even less time and increased pressure for real results. Even worse, without reliable analyses to justify space requirements, designers almost always allow too little storage space, resulting in long travel paths to remote corners of the plant where parts have been jammed in to any available spot.

With material flow diagrams generated in a Euclidian fashion (straight line from origin to destination) as in Figure 1, designers can easily visualize the origin and destination of materials, using the color of the lines to identify part groupings and the thickness of the lines to gauge relative cost or intensity of flow. Designers can query an individual line to identify exactly what part number, routing, and material handling method it represents.

With flow lines color coded according to the received location/dock, the Euclidian diagrams are excellent for evaluating where materials received at one location end up. A good dock assignment will result in clusters of color in a fanned fashion around the docks of the plant.

FactoryFLOW's Euclidian material flow diagrams are very useful for the evaluation of dock assignment problems and storage location changes. Once material flow problems have been graphically identified, designers can easily move the material origin and/or

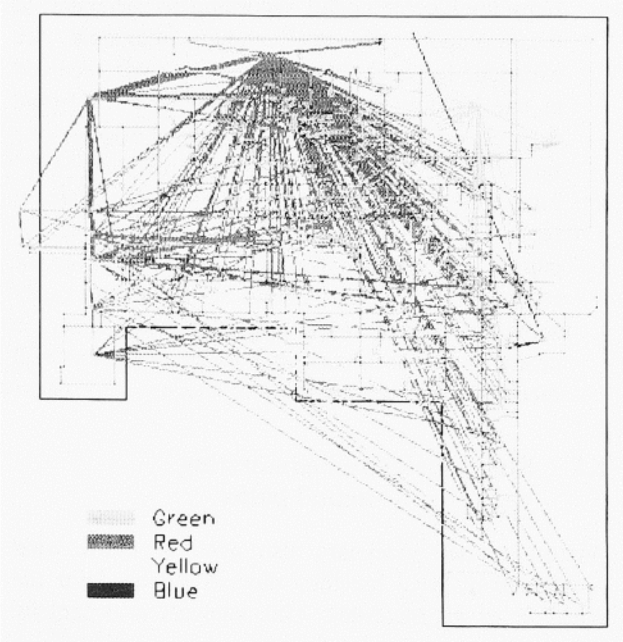

Figure 1: Euclidian Flow Diagram

destination points to other locations in the facility and receive instant graphical feedback on the factorywide effects of those changes.

Once material flow has been determined, space analyses should be performed to determine space requirements at each location (see the related article "Space Planning and Inventory Analysis of Automotive Assembly Plants"). Often there is not enough space available at the desired storage locations and alternates need to be selected, which may in turn result in a further shuffling of low intensity materials to more appropriate areas of the facility. FactoryFLOW coupled with a systematic design approach makes this process relatively straightforward and painless. And unlike dynamic analyses, Material Flow diagrams can be plotted out in color and evaluated in a conference room team environment.

2.2 Color coding

In Figure 1, flow line colors identified material origin. FactoryFLOW allows the designer to color-code the material flows in any manner desired. Designers may assign colors to define materials, products or even material handling systems. Up to 256 colors may be selected and used to identify different material flow patterns or trends. Through the use of color, the designer can quickly identify how well materials and flows are clustered and/or concentrated within the facility. Here are brief descriptions of two common color coding schemes for automotive assembly plants:

- Flow lines color coded according to the received location/dock. These Euclidian diagrams are excellent for evaluating where materials received at one location end up (as in Figure 1). A good dock assignment will result in clusters of color in a fanned fashion around the docks of the plant.
- Flow lines color coded according to the material type (body components, chassis components, engine components, trim components and interior components). These Euclidian diagrams easily show how well each type of component is clustered within the facility with regard to material receiving, storage, and point of use.

2.3 Sizing aisles and eliminating congestion—actual paths

Assembly plant designers also need to know what routes and material handling devices are used for the transport of all materials. This analysis is especially important in the process of sizing aisles and eliminating congestion. Often safety and product damage problems can be traced to an aisle or corner that is simply too small for the volume of traffic it is required to handle.

FactoryFLOW's actual path material flow diagrams (Figure 2) are invaluable to the automotive assembly plant designer. By simply drawing a line down the center of each aisle and connecting the lines to workcenter locations, the designer enables FactoryFLOW to automatically find the shortest route from origin to destination for all 3000 parts of a typical vehicle. Once routes are determined, FactoryFLOW outputs travel distances, times, and costs to report files (discussed later) and scales the thickness of flow lines according to the flow intensity of each part to create an actual path material flow diagram. Intensity is defined as the number of trips required to move parts.

Once a material flow analysis through the aisle network is computed, designers can use FactoryFLOW to quickly determine the necessary manpower and equipment requirements to move all materials through the plant at varying levels of production. Since the material handling device speed and load/unload times are used, as well as actual travel distances through a dimensionally correct CAD-based aisle network, results are virtually indisputable. Further enhancements currently under development even include such details as acceleration, deceleration, corners, long and short sections of travel, one-way aisles and increased load/unload times based on material type.

With flow lines generated, FactoryFLOW's congestion analysis module can sum the total flow of materials down each segment of the aisle network and

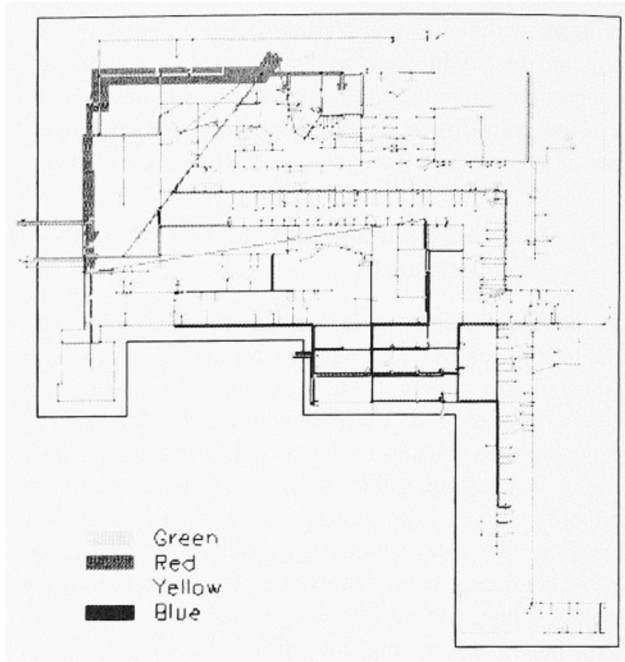

Figure 2: Automatic Actual Path Flow Diagram

generate a composite flow diagram of the aisle system (Figure 3). In this diagram, the top 10% of flows are the thickest and are color coded red, the next 20% are a bit thinner and colored yellow, the next 20% green, and the last 50% are shown in a thin blue line. The percentage break points can be varied. As in FactoryFLOW's other material flow diagrams, flow lines in the congestion diagrams can be queried to list the total volume of traffic along the aisle segment.

Designers can now quickly evaluate which aisles have the heaviest traffic along them by focusing on the red and yellow congestion lines, and can change material receipt and storage locations or aisle sizes as appropriate.

2.4 Additional Diagrams—From-To Charts and Distance Intensity Chart

From-to charts and distance intensity charts are other diagramming aids that are particularly useful for the design of automotive assembly plants.

With the from-to chart (Figures 4 and 5), the designer can quickly evaluate the flow intensities and distances between all from-to locations in the facility. In addition, designers can determine the total volume of flow or intensity of flow out of and into each location based on all parts in the plant. Like the flow diagrams, the from-to charts can be plotted out in color on a large sheet of paper for team involvement and interaction. The color coding is similar to the

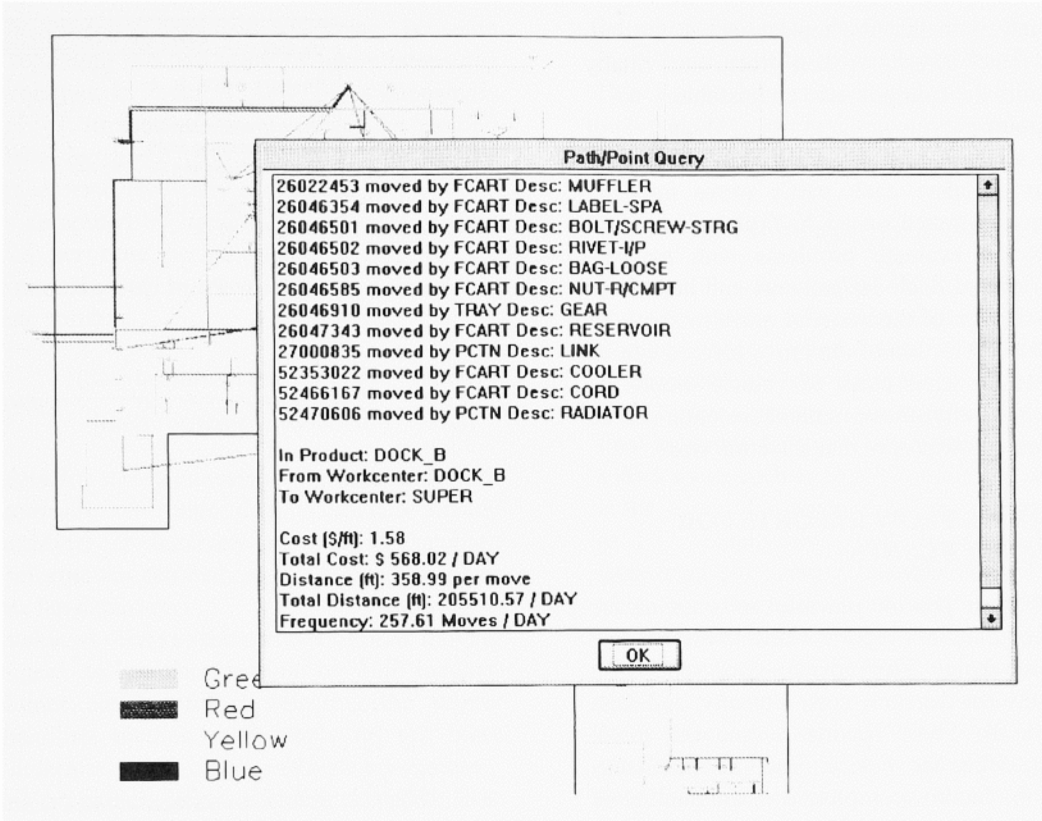

Figure 3: Congestion Flow Diagram With Path Query Report

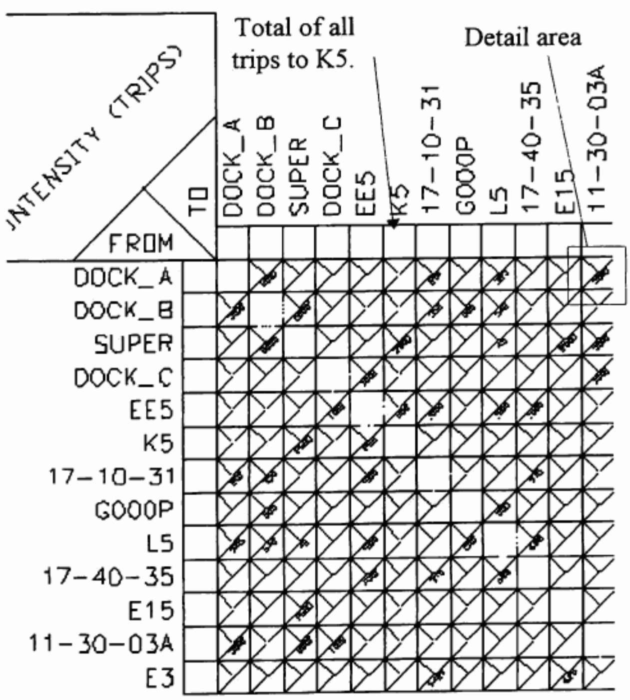

Figure 4: From-To Chart

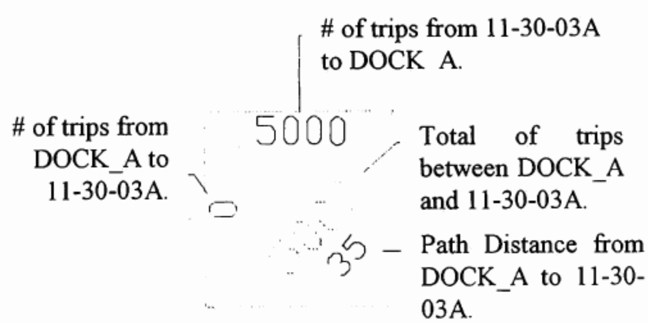

Figure 5: From-To Chart Detail

congestion analysis in that the top intensities are red, then the next level is yellow, then green, and finally blue. Once again, the split points are adjustable.

With the point query command report (Figure 6) of points on the distance intensity (DI) chart (Figure 7), designers can visualize each part's move intensity against its travel distance on an X-Y plot. This chart makes it easy to evaluate problems with material storage locations and dock assignments and how these relate to the selection of the material move method. DI charts prior to the selection of the move method can be used to determine what class of vehicle would be required. DI charts after move method selection can be used to determine how proper that selection was.

3 MATERIAL FLOW REPORTS FOR ASSEMBLY PLANTS

Diagrams and charts provide powerful information for designers. Of course, text reports likewise have a role to play in layout design. The most common reports on material flow are the distance, cost, intensity, and time reports (Figure 8). These reports outline the travel distance (using either the aisle or Euclidian methods) for all parts in the facility, complete with the number of moves required per day, the cost per move, and the number of manpower and equipment minutes required to make those moves.

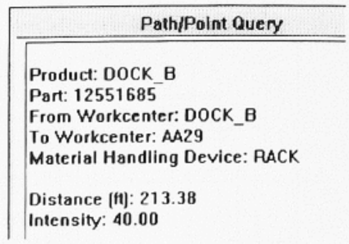

Figure 6: Point Query Report

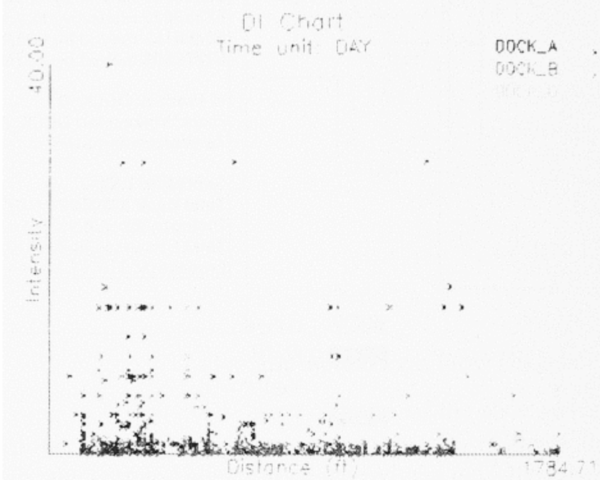

Figure 7: Distance Intensity Chart

MATERIAL HANDLING REPORT
By Products

Product name: DOCK_A	Production volume:	120 / DAY	
	Distance	Cost	Intensity
Between CHEM and 17-10-04	119.41 Ft.	SK 48.36	0.41 Moves
Between DOCK_A and CHEM	3,258.68 Ft.	SK 1,006.06	6.73 Moves
⋮			
Between J3 and 17-30-82SL	8,275.81 Ft.	SK 40.66	8.00 Moves
Between E3 and 11-30-03A	2,296.37 Ft.	SK 106.14	8.00 Moves
Total	395,571.90 Ft.	SK 9,842.26	722.44 Moves
Product name: DOCK_B	Production volume:	120 / YEAR	
	Distance	Cost	Intensity
Between DOCK_B and SUPER	99,056.46 Ft.	SK 10,511.58	257.61 Moves
Between SUPER and 25-10-01	194.58 Ft.	SK 11.22	0.29 Moves
⋮			
Between DD13 and 17-10-31	1,648.13 Ft.	SK 29.74	1.00 Moves
Total	35,353.88 Ft.	SK 1,252.23	57.09 Moves
Grand Total	1,549,859.51 Ft.	SK 43,330.21	2,317.79 Moves

Figure 8: Simple Material Handling Report, Organized By Product Name

Often in material flow reports there is some confusion regarding the definition of move intensities and move volumes. In FactoryFLOW, move intensity is the number of trips required to move the needed materials from location 'A' to location 'B' within the analysis time period (typically a day or a year). Move intensity is computed by determining how many parts are required per time period, then dividing by the number of parts that can be moved per trip, as shown in the following formula.

$$\text{Move intensity} = \frac{\text{(Daily build quantities) * (Parts per vehicle)}}{\text{(Units / container) / (Containers / move)}}$$

Input data for move intensity information, as with most of FactoryFLOW's input data, is typically already in a spreadsheet or database of material handling container information somewhere in the assembly plant or corporate headquarters.

Move volumes relate to the number of parts moving without regard to containerization or unit loading. Move volumes are helpful in selecting the proper material handling method, and intensities are more helpful in determining the layout and aisle congestion.

One major benefit of performing material flow studies on this information is that mistakes (especially big ones) become readily apparent when diagrammed. Typical mistakes include, but are not limited to, the following list:

1) Improper pieces per container or containers per move
2) Improper dock location for receipt
3) Improper storage location
4) Not enough space at storage location
5) Wrong material handling device
6) Improper destination
7) Part no longer used
8) Major part is missing
9) Improper parts per car

Mistakes that are not caught prior to the product launch are often very embarrassing and costly to correct out in the field. Accurate and validated information is critical to modern manufacturing operating strategies as defined in ISO 9000 and other quality assurance standards.

With accurate output reports on travel distances, costs and times, designers can be very effective in computing manpower requirements. FactoryFLOW generates detailed reports on manpower requirements by equipment type so that changes in the layout, daily build quantity and part list can be quickly and easily evaluated. Often designers write this data to a comma-delimited file using FactoryFLOW, then import it to Excel® or Lotus® spreadsheets for further analysis. This is one key reason why all of FactoryFLOW's output reports can be saved in either space or comma delimited ASCII files.

3.1 Input Data and the Analysis Process

The input data required by FactoryFLOW is the kind of basic From-To information already available in a database or spreadsheet somewhere in the organization. In an assembly plant, parts are typically routed from a dock to some intermediate storage area, then on to the final assembly location. Often the receiving location is a dock name such as DOCK_A and the storage location is the name of a supermarket or column location such as F17. Finally the point-of-use location is an IE (industrial engineering) number like 12-15-62. In this case, each number is a further refinement of the assembly line position and its assembly responsibilities.

Cimtechnologies Corporation has written several translators to quickly and effortlessly bring flow data from other systems into FactoryFLOW. Often the translators are nothing more than programs that move data from one column to another and supply default values for missing information. Similar functions can also be performed in spreadsheets with a little more effort and user aptitude.

Once the routing data is loaded into FactoryFLOW and the designer has loaded a layout in AutoCAD, FactoryFLOW will read all of the unique material routing location names and look in the drawing for location tags. The first time FactoryFLOW is run, no tags will exist, so the designer will be prompted for the position of each unique location. Once the designer places a tag at all named locations in the drawing, FactoryFLOW will perform the analysis (either Euclidian or Aisle Network) and generate the corresponding diagrams and reports.

At this point, FactoryFLOW is like a big graphical spreadsheet for material flow. Designers can simply move location tags around with their mouse and recalculate the results. Learning FactoryFLOW is easy for the computer literate assembly plant designer as the program utilizes a full dialog box interface with on-line help and pull down menus. In addition, the 260+ page manual with step-by-step tutorial is straight forward and written for the beginning user with no knowledge of the material flow analysis process or AutoCAD.

4 CONCLUSION

Before FactoryFLOW was available, performing a detailed material flow analysis of Automotive Assembly plants was rarely done, and often was not entirely cost-effective and helpful. With the help of more powerful computer systems and more user friendly graphical environments such as AutoCAD, material flow studies of over 10,000 parts within facilities of over 5 million square feet can be accomplished by a novice user in under an hour. FactoryFLOW was developed over the past eight years in conjunction with material handling engineers at Deere and Company, The Ford Motor Company, General Motors, and other manufacturers as well as many dedicated professors and engineering consulting firms. FactoryFLOW is now achieving worldwide acceptance at over 800 different firms in over 30 countries, and is installed within plants of or being evaluated by nearly every automotive manufacturer in the world.

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