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AUTOCAD BASED INDUSTRIAL LAYOUT PLANNING AND MATERIAL FLOW ANALYSIS IN FACTORYFLOW AND PLAN

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ABSTRACT

You cannot adopt JIT, FOCUSED FACTORIES, MANUFACTURING CELLS or even GROUP TECHNOLOGY without first modifying the factory floor layout. These new technologies are founded on the common theme of CONTINUOUS FLOW MANUFACTURING whereby your materials and WIP travel from process to process in the most direct manner possible. It is the reduced lot sizes and increased interprocess communication that give you the increased quality and reduced throughput times that truly effect the bottom line. The techniques described in this paper outline the most effective and efficient means for accomplishing the goal of the "World Class Layout".

1 MATERIAL FLOW ANALYSIS TECHNIQUES IN AUTOCAD WITH FACTORYFLOW

FactoryFLOW is an AutoLISP and C based program written inside of the AutoCAD CAD package. This program greatly simplifies the creation of material flow diagrams and significantly enhances the benefits received from them. The following section describes how these diagrams are created, and what they can be used for. (Muther, Haganas 1987).

1.1 Overview of Objectives in Analyzing Material Flows

The key objectives in analyzing material flows are:

a) Graphical and quantitative evaluations of alternative layouts.

b) Focused Factory and Manufacturing Cell development via color coded material classes.

c) Presentation of material flows to management and shop personnel for quicker project acceptance.

d) Documentation of material flows for project implementation and new personnel education

e) Satisfaction of government vendor requirements.

1.2 Computing Material Flow Costs and Distances

As with any quantitative analysis we need numbers to benchmark progress. The most applicable numbers to use in a flow oriented layout are material travel distances and costs.

Travel distance is measured on a per-trip basis and then multiplied by the intensity of the flow (number of trips) to create the total travel distance, often referred to as "transport work". In addition, an effectiveness factor is often applied which takes into account the amount of unproductive distance that must be traveled for every foot/meter of productive distance traveled.

Travel cost is measured by first computing the time to move the total travel distance, including pick up and set down time, and then factoring this time against the variable costs for the selected material handling method. In addition, the fixed costs for the material handling method are then apportioned to the flow paths which used the device based on the amount of that device's total use along that specific route.

Iteratively computing costs and distances in AutoCAD is key to making the whole process practical. FactoryFLOW contains the cost and distance algorithms which extract the current activity area positions and distances of flow. From this information, FactoryFLOW can create detailed reports on travel costs, distances and intensities in as much detail as is required by the study.(Sly, Labban, Tamashunas 1990)

	Distance	Cost
Between RECEIVING and ASSEMBLY	1,012,000 Ft.	$ 3,960
Between RECEIVING and EXTRUDE	590,469 Ft.	$ 881
Between EXTRUDE and HEAT	0 Ft.	$ 2,920
Between HEAT and RAILS	509,821 Ft.	$ 4,420
Between RAILS and ASSEMBLY	1,483,929 Ft.	$ 4,630
Between HEAT and STEPS	622,940 Ft.	$ 5,107
Between STEPS and ASSEMBLY	3,178,571 Ft.	$ 5,658
Between ASSEMBLY and PACKING	0 Ft.	$ 3,420
Between PACKING and SHIPPING	1,904,464 Ft.	$ 4,720
Between RECEIVING and PACKING	688,000 Ft.	$ 1,791
Grand Total	9,990,194 Ft.	$ 37,508

Figure 1: Sample Detailed Material Handling Report

1.3 Developing Material Flow Diagrams and Distance Intensity Charts

Product flow diagrams show the actual flows of material through the facility. Often these flows are grouped according to the types of material, parts, or products being transported. These flows are then categorized by CAD layer and color. The flow diagrams can be drawn through the factory aisles (Actual Path), directly between activities (Euclidean Path), or at only horizontal and vertical directions (Rectilinear Path).

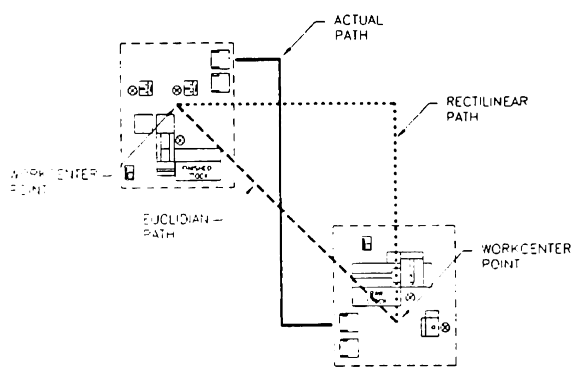

Figure 2: Diagram of Different Path Methods

The thickness of these lines show the intensity or cost of flow for that product along that route. An arrowhead is also added to each of the flow lines in order to show the direction of the particular flow. Finally, each flow line is "intelligent", in that the user can query the flow line to determine what is flowing across it at what handling costs and intensities with which material handling methods. The key benefits of these diagrams are for documentation, presentation purposes and the ability to use color for developing focused factories and manufacturing cell layouts.

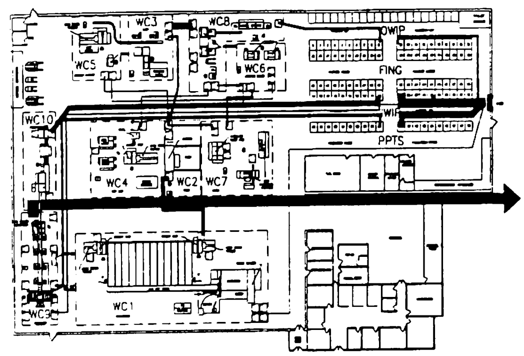

Figure 3: Sample Material Flow Diagram (Actual Path)

Composite flow diagrams show the total intensity or cost of flow along a specific route. All flows for all products between two areas are added together and represented by one line whose thickness represents the composite intensity or cost. Composite flow lines are always shown in the Euclidean fashion since one line represents the flows of many products which may take different routes to and from the activities. Like the product flow lines, composite flow lines are also intelligent allowing the user to query them for information on composite flow distances and costs. The key benefits of composite flow diagrams is that they show the total volume of flow between activities and can thus be used for overall layout planning.

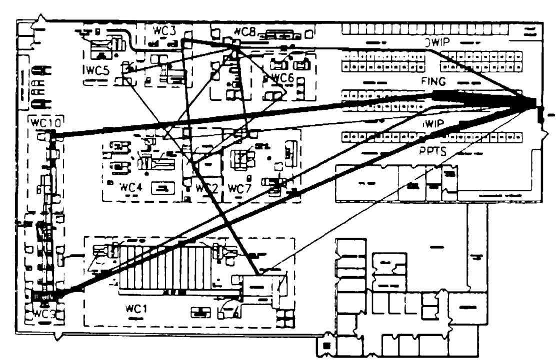

Figure 4: Sample Composite Flow Diagram

Distance Intensity Charts are XY plots of flows with the X-axis representing single trip travel distances of routes and the Y-axis representing the amount of trips made along those routes, or the amount of material (measured in a common load unit) transported along those routes. Distance intensity charts are beneficial for evaluating classes of material handling equipment that should be used along certain routes and in quickly identifying inefficient moves as a result of travel intensity or distance.

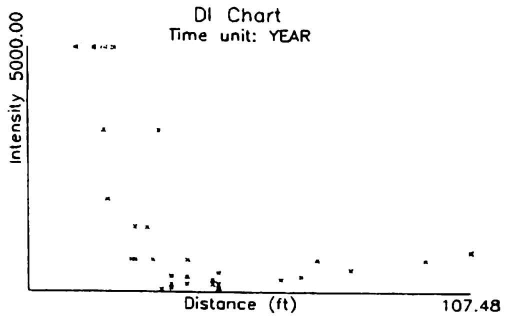

Figure 5: Sample Distance Intensity Chart

1.4 Using Material Flow Analysis Techniques as a Predecessor to Dynamic Simulation

In most industrial facilities the layout is relatively static, thus the layout must be designed to be optimal throughout the rapidly changing production schedules and product varieties that are expected to occur over its life. Because of this, the layout should be designed with input data containing the expected quantities of routings that would occur during its life without regard to when they happened.

This analysis should also be done in a dimensionally correct graphics environment capable of handling large amounts of graphical information efficiently. Because of this, a static analysis of material flows in AutoCAD becomes the best way to start a production system study.

Since the dynamic aspects of production schedules, wip, and the material handling system responsiveness are all dynamic criteria which feed off of the static layout, it is critical that in order to achieve the best designs in the shortest possible time, designers must first fix the layout with static analyses before undertaking studies from a dynamic perspective.

2 SYSTEMATIC LAYOUT PLANNING WITH FACTORYPLAN

FactoryPLAN is an AutoLISP and C based program written inside of the AutoCAD CAD package. This program greatly simplifies the creation of relationship diagrams and charts and significantly enhances the benefits received from them. The following section describes how these diagrams and charts are created, and what they are used for.

2.1 Overview of Systematic Layout Planning

Systematic Layout Planning (SLP) developed by Richard Muther in the 60's (Muther 1973)(Muther, Wheeler 1988) is a method of developing layouts from bi-directional relationships established between activity areas. This method allows for the combination of both qualitative and quantitative criteria into a systematic approach that a team of people can effectively use in establishing and justifying industrial and office layouts. By bringing a systematic and scientific approach that extensively uses descriptive graphics to solve the layout problem, significant improvements can be made to the process of generating high quality layouts in record time.

2.2 Developing Spaces and Relationships

To begin a relationship analysis the user must first determine which activity areas are to be studied. An activity area can be a machine, a department, a storage area, a dock, or even doors, windows and stairs. Once these areas have been identified, the user then must determine the space requirements of each, as well as, the bi-directional relationships that they have to one another. These bi-directional relationships are typically specified using a vowel scale of 'A, E I O U and X', whereby an 'A' relationship is one that must Absolutely be close for the layout to be accepted and an 'X' is one that must not be close for the layout to be accepted. These relationships are determined according to material flow, noise, cleanliness, supervision, shared utilities or many other factors.

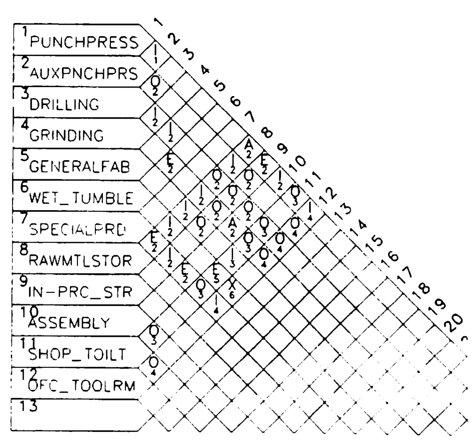

Figure 6: Sample Relationship Chart

2.3 Creating Space/Relationship Diagrams

Once the activities and their relationships have been determined, the user undergoes a systematic process of generating the best layouts possible for final project presentation and acceptance. Like with the development of the relationships, layout generation is typically done in a group with one member manipulating the spaces in the FactoryPLAN program on top of AutoCAD. This "interactive group" method of layout generation has proven very beneficial in generating excellent layouts in the shortest possible times with the greatest probabilities of acceptance (Sly, Polashek 1993).

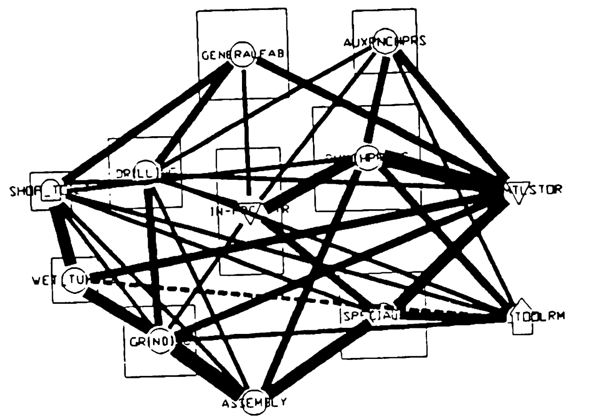

Figure 7: Sample Space-Relationship Diagram

2.4 Scoring Mechanisms in Relationship Analyses

FactoryPLAN computes a layout score by first adding up the distances of all of the 'A' relationships in the layout and multiplying this composite distance by the user specified 'A-relationship score factor'. The program then repeats this process for the 'E, I, O and X' relationships, and then adds the totals of all of these relationship scores to get an overall layout score. Since in 'A' relationships, workcenters are supposed to be very close together and in 'X' relationships far apart, and since the 'A' score is always positive and the 'X' score always negative, the lowest overall layout score is the best. Therefore, comparing alternative layouts is a simple matter of comparing their layout scores to determine how much each alternative is better or worse than another. This score is simply a benchmark, however, and may not actually reflect the best overall layout for reasons to difficult to mention in this overview.

Many papers have been written on optimization techniques to the relationship layout problem. Unfortunately, none have been able to develop an optimization routine that takes into account variable space sizes and shapes as well as varying evaluations of closeness satisfaction. Therefore, a software package that uses standard deterministic algorithms to develop a complete layout is not an effective layout optimization tool. The only method that would enable the computer to be effective would be an AI (Artificial Intelligence) based software program that could analyze the system using the many rules and methods that the operator would.

3 SUMMARY

The development of industrial facility layouts that support the desired manufacturing philosophy are key to the success of that philosophy. This paper has outlined practical, efficient and effective methods to develop industrial layouts using CAD graphics based static analysis techniques. It has been proven that using these methods with a team involvement by management, engineering and shop floor personnel can, and do, generate the best possible layouts in the shortest possible time. In addition, it has been shown how this static analysis can significantly help reduce the time and effort to model production schedules, WIP inventories, and throughput times using dynamic simulation methods.

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