BEFORE DYNAMIC SIMULATION: SYSTEMATIC LAYOUT DESIGN FROM SCRATCH

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ABSTRACT

Excellent production design and planning depends on accurate simulation of a high quality layout. A good layout project will always begin with an analysis of the production volumes of the products with common process sequences and tool requirements in order to create manufacturing families. For each of these families you can select the "best manufacturing practices" that need to be used and re-engineer the processes and tooling to fit the desired throughput and inventory requirements. Once you know the manufacturing practices to be used for each family, you can begin developing layouts through a systematic flow and non-flow evaluation process. Static flow and relationship analysis software tools Factory-FLOW and FactoryPLAN/OPT lend themselves to a systematic process leading to effective layout design in record time.

1 PRODUCT ANALYSIS

A good layout project begins by evaluating the major product family divisions and determining the appropriate levels of detail for classification. For example, a garden equipment manufacturer may select major component subassemblies used in multiple final product lines for classification, instead of the actual product lines themselves. You will then create a pareto chart similar to that shown in Figure 1 with products listed in decreasing order from left to right according to production volume. You will next want to reclassify some of your products into families that have very similar process routings and update the pareto chart. Strive for a pareto chart in which 80% of your products make up less than 20% of your production volume. If this ratio is not possible, you may choose to create multiple pareto charts based on highly different product types and manufacturing processes. Part quantity reduction is often another benefit of this type of analysis. Obviously the fewer unique products you make, the less your manufacturing complexity.

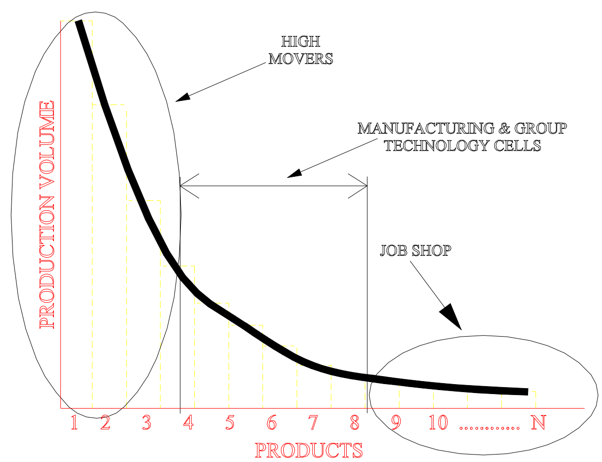

Figure 1: Products/Volume Pareto Chart

2 MANUFACTURING PRACTICES SELECTION

The next stage of your analysis will involve the selection of the appropriate manufacturing practices for groups of your product families. For example, your high volume products with very common processes will be good candidates for product focused manufacturing systems. Product focused systems include assembly and machining lines in which all of the necessary equipment is located in the same sequence as the manufacturing process and is often dedicated and balanced to the pace of the line.

Your very low volume products will be easy to identify and will be candidates for “Job-shop” facility arrangements in which equipment is often located according to shared tooling or operator needs. These low volume products are likely candidates for outsourcing, and therefore you should reevaluate their manufacturing profitability before proceeding with the layout project.

Finally, your "in-between" volume products will be likely candidates for manufacturing cells, group technology cells, and focused factories. These products often share some of their manufacturing processes with other products and thus will need to be reclassified accordingly. This "in-between" group of products will always be the most difficult to design manufacturing practices and layouts for; however, they also often represent the greatest opportunity for reductions in cost, throughput time and inventory. FactoryFLOW was designed to aid in this layout-oriented classification process by allowing you to color code common process flows with the desired equipment used in order to systematically create manufacturing cells from lists of products and tools.

Once you have properly classified your product families into desired manufacturing practices, you should undergo a thorough review of the manufacturing processes in each family. A layout is totally dependent on process sequences and equipment availability. Now is the time to create an efficient process that can translate into a productive layout. Skipping this opportunity will often result in layouts that fail to reduce throughput times and inventory, since you are doing little more than rearranging the furniture within the plant. While you cannot receive the benefits from JIT, focused factories or manufacturing cells without creating a layout that supports these manufacturing practices, you likewise cannot benefit from cellular and focused layouts operating with traditional manufacturing practices.

3 EQUIPMENT SELECTION

Proper equipment selection is just as critical as proper manufacturing process design, and is often the step most ignored by layout planners. Sharing tooling among dissimilar product families and processes will result in significant penalties to efficient layouts, throughput times, and inventory. Eliminating shared tooling is therefore the most important goal in equipment selection. Too often inefficient layouts are created to provide flows from many different product areas in the plant to low cost equipment. If this equipment were duplicated and placed within different zones, the resulting inventory and throughput savings would likely far exceed the cost of the additional equipment.

Another important tool selection decision involves the use of expensive flexible equipment or inexpensive dedicated equipment. Expensive flexible equipment should only be used in cells with a high degree of process variability, and not used to join dissimilar cells. Therefore, the primary goal in tool selection is once again to isolate the processes and tooling in the cells from one another via dedicated low tech tooling whenever possible. Inventory and throughput times are reduced more by product-oriented manufacturing cells than from process-oriented Group Technology cells.

4 MATERIAL FLOW ANALYSIS

Material Flow is the primary activity that drives a factory layout. Good layouts have smooth and short flows with a minimum of backtracking and crossover. There are several different types of layout configurations available, and a typical factory will consist of several layout types among the different product families. Figure 2 illustrates common linear, S, U and L configurations often used in Product flow and cellular applications.

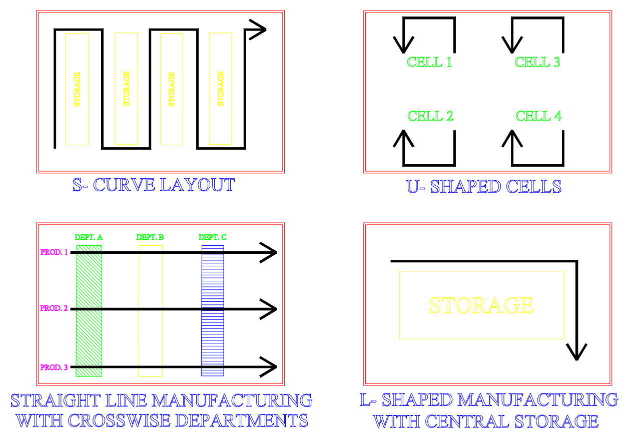

Figure 2: Layout Configurations

Material flow diagrams illustrate material moves. FactoryFLOW can generate a variety of diagrams from the same set of product data, allowing the user to focus on different aspects of flow. The key diagram from which all others are computed is the product flow diagram (Figure 3). This diagram shows different products/subassemblies/materials/processes in different colors and with line thickness according to either number of trips or cost. This diagram can be presented with actual paths for better numerical evaluation and aisle congestion analysis, or Euclidean paths for better visual evaluation of workcenter interrelationships. One key of the product flow diagram is that it is intelligent: a user can click on a line to find out what it represents. In addition, if users rearrange the equipment in the AutoCAD drawing, they need only select CALC again and FactoryFLOW can find all of the new locations, regenerate the flow diagram, and recompute the costs, distances, intensities, and time. It is this iterative approach with instant graphical and quantitative feedback that makes quantitative layout evaluation feasible.

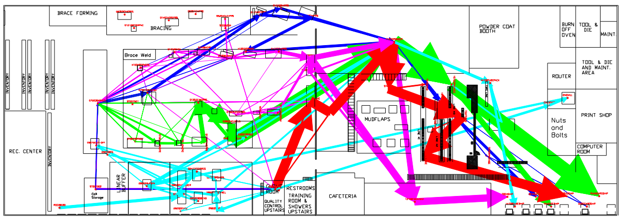

Figure 3: Product Flow Diagram

5 RELATIONSHIP ANALYSIS

Another important consideration in any layout analysis are the non-flow factors such as noise, dirt, contamination, supervision, safety, shared tooling, and so on. These activity relationships are best defined by listing all of the unique activities in a relationship chart (Figure 4) and categorizing the closeness affinity for each activity pair in a team meeting. You can enter these relationships into a spreadsheet or directly into FactoryPLAN's relationship editor in order to quickly get high quality relationship charts and diagrams complete with layout scores of your facility. It is important to evaluate the qualitative non-flow factors independent of the flow factors, even if it is desired to perform a relationship analysis that involves both flow and non-flow constraints.

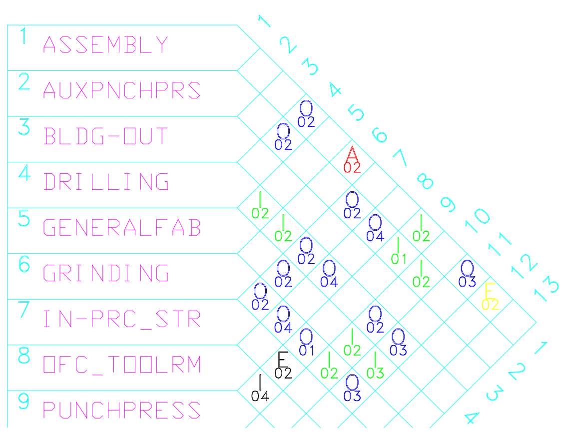

Figure 4: Activity Relationship Chart

FactoryPLAN also allows users to evaluate the layouts according to material flow intensities between activities. These flow intensities can come from FactoryFLOW studies, production analysis spreadsheets, or even be entered directly into FactoryPLAN via the supplied editor. Entering the flows directly is often the quickest and easiest for small facilities of less than 250k square feet, or manufacturing facilities with few dominant material flows, where using tools like FactoryFLOW may be overkill. FactoryPLAN can diagram non-flow relationships or flow-oriented relationships independently, or FactoryPLAN can aggregate these two kinds of relationships together using user-supplied weighting factors in order to generate layout diagrams and scores that best represent all relevant equipment and department adjacencies. Figure 5 shows an example of a relationship diagram.

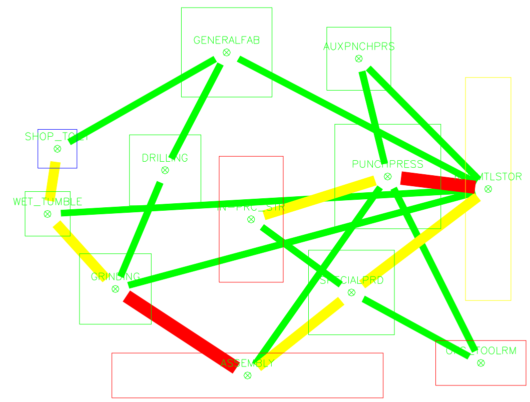

Figure 5: Activity Relationship Diagram

6 LAYOUT OPTIMIZATION

Once all of the processes and tooling requirements have been determined, and the flow and non-flow relations between them identified, optimization tools like FactoryOPT can be employed. FactoryOPT uses a spanning tree algorithm to generate a near-optimal arrangement of activities in a block layout based on flow and non-flow relationship data. You can interact with this arrangement at the spanning tree node diagram level or after FactoryOPT generates a block layout in AutoCAD. Once a good arrangement has been generated, FactoryPLAN and optionally FactoryFLOW can be used to diagram and score additional layout alternatives.

FactoryOPT can generate layouts with up to 256 unique activities using up to 128 different algorithm combinations. FactoryOPT can receive flow, non-flow, or aggregated flow/non-flow relationships as input. FactoryOPT works entirely inside AutoCAD along with FactoryPLAN. FactoryOPT is based on the spanning tree algorithm developed for SPIRAL by Marc Goetschalckx from Georgia Tech. Figure 6 shows an AutoCAD-based spanning tree diagram created by FactoryOPT.

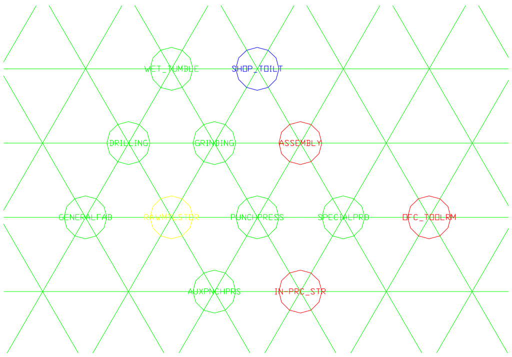

Figure 6: Spanning Tree Diagram

7 CONCLUSION

Successful layout projects are based on solid process and equipment definitions combined with a systematic flow and non-flow diagramming, evaluation, and benchmarking process. Layout projects that do not begin with thorough product, process and equipment evaluations or do not contain detailed relationship and material flow studies often result in design teams constantly bouncing from issue to issue with no end in sight. Software tools like FactoryFLOW, FactoryPLAN, and FactoryOPT can make short work of diagramming, scoring, and presenting layout alternatives within a systematic design framework. Such tools are becoming as necessary to factory layout designers as word processors are to typists.

ACKNOWLEDGMENTS

FactoryCAD, FactoryPLAN and FactoryFLOW are registered trademarks of Cimtechnologies Corporation. AutoCAD is a registered trademark of Autodesk, Inc.

AUTHOR BIOGRAPHY

DAVID P. SLY is President and Founder of Cimtechnologies Corporation and original author of the FactoryCAD, FactoryPLAN, and FactoryFLOW products. Mr. Sly has been involved with industrial facilities layout and design for over a decade, performing consulting and development projects for John Deere, Ford, GM, SEMATECH, AT&T, and many other fortune 100 manufacturers worldwide. Dave received his bachelors and masters degrees in Industrial Engineering as well as his MBA from Iowa State University. He is a registered professional engineer in the state of Iowa, and is a member of the Society of Manufacturing Engineers, Institute of Industrial Engineers, and the Society for Computer Simulation.