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AN APPROACH AND INTERFACE FOR BUILDING GENERIC MANUFACTURING KANBAN-SYSTEMS MODELS

Edward J. Williams
Onur M. Ülgen

Engineering Complex, IMSE
4901 Evergreen Road
University of Michigan - Dearborn
Dearborn, MI 48128 U.S.A.

Chris DeWitt

Suite 1006 West
Three Parklane Boulevard
Production Modeling Corporation
Dearborn, MI 48126 U.S.A.

ABSTRACT

Simulation of manufacturing systems, historically the first major application area of discrete-event process simulation, is becoming a steadily more proactive and important strategy for achieving manufacturing efficiency. Concurrently, lean manufacturing has become a nearly essential corporate strategy to compete successfully in an increasingly austere and global business environment. Furthermore, industrial engineers responsible for supporting successfully competitive manufacturing operations have less and less time available for manipulating details deep within a simulation model in order to evaluate numerous complex alternatives. Convergence among these trends motivated the development of a generic manufacturing kanban-systems simulator that has Kanban inventory optimization capability, and an accompanying interface, described in this paper.

1 BACKGROUND AND MOTIVATION

Improvement of manufacturing systems was one of the earliest significant applications of discrete-event process simulation analysis, and has consistently been one of the largest (Law and McComas 1999). Recently, improvements to manufacturing systems have stressed the importance of achieving lean production (Duggan 1998); manufacturing systems contributing to lean production reduce inventory via just-in-time techniques, reduce space requirements by shortening distances parts must travel, and reduce costs by elimination of non-value-added activities associated with inventory and material-handling (Heizer and Render 2001). Indeed, three of the eleven essential steps to eliminate waste, identified by (Cary 2002), are inventory reduction, motion reduction, and transportation reduction. Hence, there arises an "almost instantaneous demand to see its [simulation's] benefits extended as far and as quickly as possible." (Hartwig 2001). Selecting the kanban container size and the number of kanbans for each part type in a kanban system has been investigated in the past under deterministic and stochastic conditions (Monden and Aigbedo 2001; Askin and Goldberg 2002). Simulation is an effective tool in finding the proper values of these parameters in a stochastic environment.

Timely and effective introduction of technology, such as process simulation, into a manufacturing organization, is one necessary step to achieving high competitive ability (Banerjee 2000). Increasing the efficiency and ease of use of input and output interfaces to simulation models, thereby saving time and reducing error risk on behalf of industrial and process engineers, contributes greatly to the successful integration of process simulation into ongoing process improvement (Krug 2001). An extensive survey of simulation usage versus non-usage in German industry identified complexity and difficulty of use as a significant barrier to the application of simulation technology (Hirschberg and Heitmann 1997).

In this paper, we first describe the modeling context motivating the development of a generic kanban-system model and its data-input interface. We next describe the interface, the model, its built-in kanban optimization algorithm, typical user execution of the model, and representative model outputs. Last, we discuss plans for enhancement of the model and its outputs, and summarize the current status of this work.

2 OVERVIEW OF THE MODELING CONTEXT

The generic model and its interface apply to a manufacturing or assembly system whose workstations are supplied by joint implementation of "Call" ("Electronic Kanban") and "Card" ("Card Kanban") systems. The Call system is conceptually responsible for sending signals (presumably electronic) to a warehouse or marketplace which supplies the manufacturing or assembly system. The Call system is responsible for sending these signals when inventory levels along the manufacturing or assembly line fall to a defined "trigger reorder" point ("Signal Kanban"). The Card system is responsible for the generation of kanban cards and the conceptual transformation of these cards into material delivery to line workstations from the warehouse or marketplace, in keeping with the usual definition of kanban cards as representing authorization to begin work (Hopp and Spearman 2001). The user of the model, typically an industrial, production, or process engineer, is presumably concerned with averting line stock-outs, reducing inventory levels within the constraint of averting line stock-outs, and avoiding congestion among the transport devices (e.g., tug trains) supplying the line via defined itineraries. The user will concurrently wish to lower the number of transport trains, relative to both the Call and Card systems, consistent with these objectives, due to both the capital costs and the operational costs of such material-handling equipment.

3 STRUCTURE OF THE MODEL INPUT INTERFACE

The model input interface is an Excel© workbook containing seven worksheets. Within all worksheets, the user arranges information concerning one entity within rows, and hence places information of the same type within columns. The following list provides a summary of the seven worksheets and the purpose of each:

1. StationInfo, using four columns, specifies relationships between raw material usage points and raw material delivery locations.
2. StopInfo, using three columns, specifies aisle segments and relationships between those segments and origins of material.
3. KBInfo, using nine columns, specifies usage points, usage rates, packaging information, and delivery routes for raw material.
4. RouteDesc, using five columns, defines routes used by the delivery trains.
5. TrainSched, using five columns, specifies number, lengths, and schedules of delivery trains.
6. Misc, using fourteen columns, specifies miscellaneous logic flags and delay times (such as loading and unloading delays).
7. TransferInfo, using one column, specifies a list of aisle segments blocked to trains while skillets are transferred between assembly lines.

Additionally, the workbook contains macros which check the input data for errors or internal inconsistencies and alert the user to any problems. For example, if the user inadvertently defines a raw material usage point but this usage point appears on no routes, the user will be warned of this discrepancy. Color coding, shading, and embedded comments within the worksheets increase the ease and reliability of their use.

4 STRUCTURE OF THE SIMULATION MODEL

The simulation model is built in WITNESS™ (Thompson 1996), and thus supports run-time animation as well as simulation. The model contains two large arrays of WITNESS™ "elements." The elements in one array are WITNESS™ "buffers" representing workstations which consume parts as raw material. The WITNESS™ "machines" in the other array represent stop-points along delivery routes where trains pick up kanban cards and/or deliver needed parts upon demand. Relative to the model, the inputs within the Excel© workbook sheets specify interrelationships (e.g., which stop-points supply which workstations) by using the indices of the two part arrays. This model, significantly, uses neither WITNESS™ "tracks" nor WITNESS™ "vehicles." The secondary advantage of this abstinence is greater model execution efficiency. This efficiency supports correct model usage, inasmuch as engineers are not tempted to run too few or too short replications (in the statistical sense) to shorten model execution time. More significant still is the ability afforded the user to modify the routes (either which workstations are supplied on which routes *or* which stop-points are on which routes) within the Excel© workbook, with no need to revise the WITNESS™ model.

5 BUILT-IN KANBAN OPTIMIZATION ALGORITHMS

This simulation model has an additional feature that creates kanbans (kanban cards and containers) whenever a station starves for a part type. The option for automatic generation of kanbans is triggered in the simulation based on user input at the beginning of a run. If the model is run under kanban-generation mode, the user, by starting with a low number of kanbans for each part type, can actually optimize the number of kanbans in the system. Since the kanbans are generated whenever needed, the lowest amount of kanban inventory will be achieved and thus identified by running the simulation in this mode.

6 USER EXECUTION OF THE MODEL

After creating and checking the workbook described in Section 3, the engineer opens the WITNESS™ model, as described in Section 4. The user then assigns a warm-up period and a run length, and also chooses whether to run the model in "Advance" mode (animation provided) or "Batch" mode (faster execution without animation). During a run with animation, workstations (i.e., raw material usage points) appear as solid squares and stop points (i.e., raw material delivery points) appear as hollow squares. In

"Advance" mode, typical animation niceties (such as identification of machine status by color and updating of variables in simulated time) are also provided.

7 MODEL OUTPUTS

Typically, the most significant performance metric of the system being analyzed is the number of stock-outs. Model output includes the mean number of stock-outs per shift, mean stock-out minutes per shift, and mean length of stock-outs.

Detailed output on supply trains is also provided; this output comprises, for example, aggregated percentage of time a train is loading (or unloading) its cargo and hitching (or unhitching) trailers, percentage of time a train is moving, percentage of time a train is blocked due to intra-aisle congestion, statistics on containers loaded (handled) per trip, and train trip times.

A list of aisle segments sorted by volume of traffic is also output.

Additionally, detailed statistics pertinent to inventory levels include hourly recordings for each part at the production line, in units of hours. Low levels suggest increasing the starting inventory; high levels suggest either decreasing the starting inventory, decreasing the container pick quantity, or decreasing the container quantity and/or volume. This portion of the output also specifies the remaining inventory at a workstation (again, in units of hours that would have been required to exhaust that material) at the times when new material arrives – that is, how narrowly was a stock-out averted? This information helps the engineer choose an appropriate "trigger" (reorder) point for raw materials, a vital consideration in supply-chain management (von Uthmann 2001).

8 ENHANCEMENT PLANS

This model and its interface have been verified, validated, and successfully applied in two applications, both within the automotive industry. One application was within a trim-&-final assembly shop; the other, within a body shop. In both cases, the model users successfully evaluated dynamic material flow within each plant and determined the correct quantity of trains to deploy in each plant relative to specific input conditions.

As is consistent with the original purpose of conducting analyses to avoid stock-outs, the current model includes neither workstation downtime nor transport equipment downtime. Certainly, a production engineer does not plan stock-out avoidance on the basis of "the machine will be down enough time that it won't run out of raw material to process." Similarly, preliminary assessments of ability to supply a line may assume no downtime among transport equipment. However, the engineer must then assess the robustness of the supply system to transport-equipment failures. Currently, engineers using this model can add downtime within the WITNESS™ model. A planned enhancement is the ability to specify downtime frequencies and durations within the Excel© workbook.

Another enhancement under consideration is examination of the WITNESS™ output reports for adherence to constraints not directly related to the simulation logic; the most important of these constraints are ergonomic lifting restrictions for drivers. These constraints could then be modified by the engineer relative to weight and bulk of various parts supplied to the manufacturing line, thereby ensuring compliance with increasingly common and significant restrictions upon, for example, maximum weight or volume handled at one time, or cumulative weight lifted by an operator per shift (Konz and Johnson 2000).

Engineers using this model have become increasingly concerned with the implications of high vehicle congestion within aisles for pedestrian safety. Indeed, pedestrian-vehicle collisions, which almost invariably result in severe injury, or even death, to the pedestrian, have become a significant concern within the ergonomics and planning of material supply systems (Feare 2000). Therefore, additional enhancements are planned to the reporting of frequency and severity of traffic congestion, such as allowing the user to specify pedestrian crosswalks for which detailed reports of vehicle traffic intensity in both directions will be provided. Such reports would include not only "number of vehicle passages per unit of time" but also "frequency of time gaps of specified length between successive vehicle passages."

9 SUMMARY AND CONCLUSIONS

We have provided a general modeling and interface technique for simulation analysis of manufacturing or assembly systems using "Call" and "Card" systems to achieve lean manufacturing. There remain significant opportunities for enhancement of both the analyses included within this technique and the data and information whose input and output can be conveniently automated on behalf of the client engineer.

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AUTHOR BIOGRAPHIES

EDWARD J. WILLIAMS holds bachelor's and master's degrees in mathematics (Michigan State University, 1967; University of Wisconsin, 1968). From 1969 to 1971, he did statistical programming and analysis of biomedical data at Walter Reed Army Hospital, Washington, D.C. He joined Ford Motor Company in 1972, where he worked until retirement in 2001 as a computer software analyst supporting statistical and simulation software. After retirement from Ford, he joined Production Modeling Corporation, Dearborn, Michigan, as a senior simulation analyst. Also, since 1980, he has taught evening classes at the University of Michigan, including both undergraduate and graduate simulation classes using GPSS/H™, SLAM II™, SIMAN™, ProModel®, or SIMUL8®. He is a member of the Institute of Industrial Engineers [IIE], the Society for Computer Simulation International [SCS], and the Michigan Simulation Users' Group [MSUG]. He serves on the editorial board of the *International Journal of Industrial Engineering – Applications and Practice*. During the last several years, he has given invited plenary addresses on simulation and statistics at conferences in Monterrey, México; İstanbul, Turkey; Genova, Italy; and Rīga, Latvia. His email and web addresses are <`williame@umdsun2.umd.umich.edu`> and <`www.personal.umd.umich.edu/~williame`>.

ONUR M. ÜLGEN is the President and founder of Production Modeling Corporation (PMC), a Dearborn, Michigan, -based productivity improvement services company as well as a Professor of Industrial and Manufacturing Systems Engineering at the University of Michigan-Dearborn. He received his Ph.D. degree in Industrial Engineering from Texas Tech University in 1979. His present consulting and research interests include simulation and scheduling applications, lean manufacturing, and ERP systems.

Under his leadership PMC has grown to be the largest independent productivity company in North America in the use of simulation, scheduling and other software tools in an integrated fashion. PMC has successfully completed more than 3000 productivity projects for different size companies. PMC clients include General Motors, Ford, DaimlerChrysler, McDonnell Douglas, Johnson Controls, Aeroquip, Samsung, Whirlpool, General Electric, Sony, and Corning. He is a member of the Institute of Industrial Engineers and American Production & Inventory Control Society. His email address is <`ulgen@umich.edu`>.

CHRIS DEWITT is an applications engineer at Production Modeling Corporation. He has worked extensively in discrete-event simulation modeling, especially in the areas of manufacturing and product development. He has also worked as a software implementation consultant for Enterprise Resource Planning and finite-capacity scheduling systems. Mr. DeWitt received a B.S. degree in Industrial and Manufacturing Systems Engineering at Ohio University in 1998. He is a member of Tau Beta Pi and Alpha Pi Mu. His email address is <`chris@pmcorp.com`>.