Proceedings of the 1989 Winter Simulation Conference
E.A. MacNair, K.J. Musselman, P. Heidelberger (eds.)

A VISUAL SIMULATION MODEL OF A WORKSTATION IN A ROLLING MILL FACILITY

Pierre Lefrançois
Marie-Hélène Jobin
Marie-Claude Roy
Groupe de Recherche en Gestion Logistique
Faculté des sciences de l'administration
Université Laval, Cité universitaire
STE-FOY, (QUÉBEC) G1K 7P4

Gérald Gamache
Head, Industrial Engineering Department
Société d'aluminium Reynolds du Canada
CAP-DE-LA-MADELEINE, (QUÉBEC) G8T 7W9

ABSTRACT

The objective of this research is to develop a visual simulation model to evaluate the performance of a workstation in a rolling mill facility by analyzing the interactions between the jobs to be processed and the scheduling rules used. The model has been developped using the CINEMA software and executes on a IBM PC/AT microcomputer. The simulation model is currently used to design job scheduling rules and compare their performance in reducing setups, work-in-process inventories and flow time.

1. INTRODUCTION

The Société d'Aluminium REYNOLDS du Canada operates aluminum smelters and a rolling mill facility in the Province of Québec, Canada. The last stage of the transformation process at the smelting facilities implies the casting of aluminum ingots which may then be used in the rolling mill facility to manufacture aluminum coil sheets: building material products, fin stock, cable stock... and aluminum foil: domestic and converted foil (e.g. pie plates). The rolling mill facility is a network of workstations where the processing of a customer order may imply numerous passes through several machine centers in as many production areas: rolling mills, annealing furnaces, slitters. The routing for a given job may necessitate visits to half a dozen or more workstations and a job may visit a workstation more than once; the processing time for a given job arriving at a machine center however is not exactly known as it depends on the number of pounds of aluminum to be processed, the processing to be done (annealing, rolling, slitting...) and on the specific metallurgic characteristics of the in-process and finished aluminum alloy used. Planned and unplanned shutdowns are likely to occur, as are down periods to allow for setup operations.

To illustrate the complexity of the transformation process, Table 1 presents the routing sequence for a sample of jobs typically processed at the facility.

The rolling mill facility may be characterized as an open dynamic job shop, a production system which has been the concern of a wide body of research. So far, numerous research works have consisted of comparing scheduling rules on a set of performance criteria such as mean lateness, work-in-process inventories or the usage rate of machines. Graves (1981), Panwalker and Iskander (1977) and Baker (1976) offer nice reviews of the models and methodologies of scheduling.

The specific scheduling problem which motivated this work however is not easily solved by existing scheduling optimization schemes. In particular, most of them if not all do not integrate unviolable constraints such as scheduling the jobs so that the widths of the aluminum sheet coils to be processed are in a decreasing order. This justified among other reasons to design or adapt scheduling rules and setup policies specific to the production system considered.

Of the two approaches considered, a mathematical programming (MP) model and a visual simulation (VS) model, the second was chosen for the following reasons.

2. OBJECTIVES AND ADVANTAGES OF THE VISUAL SIMULATION MODEL

Both simulation and mathematical or algorithmic models play an important role in the practice of O.R..

Used as an artificial representation of the full-scale system modeled, MP models suppose that an objective function, decision variables and constraints are identified. MP models however prove to be difficult to apply for optimizing scheduling rules in a complex production environment (Graves 1981); the specific case we consider is one such complex environment. Stochastic or non-linear constraints, a multiobjective non-linear function and the enormous dimension of the MP problem are necessary to make its representation consistent and to maintain the logic of the system modeled. This played a large role in the selection of a simulation and particularly of a visual simulation model as a modeling tool. The advantage resulting from the ability of this modeling tool to directly connect the behaviour of the model and the behaviour of the production system was further enhanced by the fact that use of visual modelling allows the VS model to speak the same language as the user (Rahn 1986).

Product	Job* Size	Number of Operations	Routing Sequence**
85	44 000	5	C-300, 875, 862, 875, 893
77	10 605	7	628, C-300, 719, 875, 862, 875, 893
76	10 984	5	C-300, 875, 862, 875, 893
66	17 320	7	628, C-300, 875, 862, 875, 890, 695
807	7 283	8	628, 629, 890, 345, 714, 760, 770, 879
36	190 850	10	628, C-300, 719, 875, 862, 875, 629, 714, 948, 712
808	79 782	10	628, 629, 719, 875, 862, 875, 629, 345, 714, 712
810	19 231	8	628, 629, 890, 345, 714, 760, 770, 659
879	24 109	7	628, 629, 890, 345, 347, 348, 910
84	27 780	7	628, C-300, 719, 875, 862, 875, 893
99	20 150	5	628, 629, 719, 875, 890
2	15 760	6	628, 629, 719, 875, 345, 948
73	52 525	7	628, C-300, 719, 875, 862, 875, 893
6	16 348	11	628, C-300, 719, 875, 862, 875, 890, 345, 948, 669, 948
67	29 580	7	628, C-300, 719, 875, 862, 875, 893
59	80 640	6	628, C-300, 719, 875, 875, 893

* Job size in pounds at first station visited.

** The routing sequence specifies the stations visited in order.

Table 1: Product Routing Characteristics

Simulation using computer-based models began in the 1950s. Animation to portray a running simulation has also existed for many years, Amiry (1965) for example uses a VS model to represent a steelmaking plant. Use of animation is rapidly increasing and nearly all new simulation languages now have this capability, showing value of using graphics and icones to display data to the user. CINEMA (Pegden 1985) is one such VS software which offers the ability to use animation in presenting simulation experiments. Other widely used softwares with more or less capabilities are XCELL (Conway et al. 1985), MODELMASTER (General Electric 1986), TESS (Musselman 1986), SEE-WHY (Fiddy 1981) and SIMFACTORY (CACI 1987).

VS models offer a great advantage when modeling complex production systems. A number of performance criteria can effectively be studied and visually portrayed to the user; criteria such as the work-in-process inventories, the mean flow time, the mean lateness or the occurence of downtimes can easily be examined. Product entry schemes, work-orders, processing times and interruption schemes may also be visualized to show interactions between these variables and the performance criteria. A number of operating parameters can finally be included within the model to more exactly represent the constraints faced by both schedulers and shop-floor operators.

The principal objective of the VS models we developed is to obtain detailed information concerning an individual workstation. The VS model is developed as part of a research program for the CEFRIO (Centre Francophone de Recherche en Informatisation des Organisations) jointly with the Société d'Aluminium REYNOLDS du Canada. The model runs on an IBM PC/AT microcomputer and it has been designed to be easily adaptable to other operating parameters.

3. MODELING APPROACH

The first step to develop the CINEMA simulation model has been to configure the workstation considered, in our case rolling mill C-300. The characteristics of the workstation were specified using data gathered from historical records and interviews with industrial engineers and schedulers. A scheduling protocole identifying the logical reasoning behind the actual scheduling of jobs was of great help at this stage of the research; the protocole developed by the industrial engineering group at REYNOLDS offered a comprehensive description of the scheduling activities. A first VS model of the facility developed using SIMFACTORY was also used to help understand the overall operating characteristics of the rolling mill.

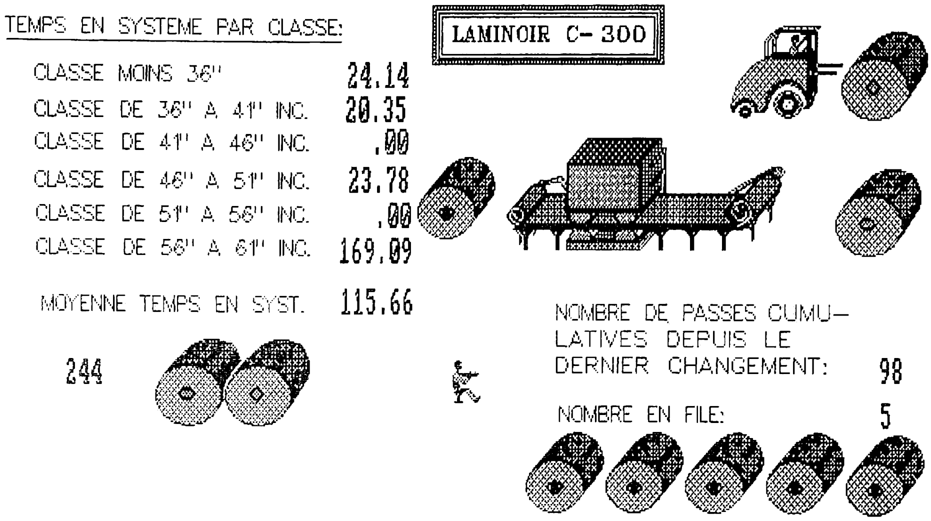
In the CINEMA model the following characteristics were considered:

1. The job's arrival pattern which was expressed by means of a statistical distribution.

2. The weight of the aluminum to be processed in a job. When it arrives at workstation, a job consists of a given weight of aluminum which was anticipated and expressed by a statistical distribution. A job consists of a given number of aluminum sheet coils and all coils in a job share the same characteristics of alloy, thickness, width and routing sequence.

3. The number of passes in a given job. When a job arrives at workstation, it may necessitate up to three passes. The first two passes are generally consecutive whereas an at least twelve hours lag is inserted between passes two and three. The statistical distribution of the number of passes in a job was thus another input to the model.

4. The width of the aluminum sheet coil to be processed is also an important factor to be considered. An unviolable constraint relates to scheduling jobs such that the width of the sheets are in a decreasing order; the edges of a sheet of aluminum make scratches on the rolls used to reduce thickness. This prevents subsequent processing of wider sheets without regrinding rolls (which is considered as a



```
TEMPS EN SYSTEME PAR CLASSE:                LAMINOIR C- 300

  CLASSE MOINS 36"                 24.14
  CLASSE DE 36" A 41" INC.         20.35
  CLASSE DE 41" A 46" INC.           .00
  CLASSE DE 46" A 51" INC.         23.78
  CLASSE DE 51" A 56" INC.           .00
  CLASSE DE 56" A 61" INC.        169.09

  MOYENNE TEMPS EN SYST.          115.66
                                              NOMBRE DE PASSES CUMU-
                                              LATIVES DEPUIS LE
    244                                       DERNIER CHANGEMENT:     98

                                              NOMBRE EN FILE:         5
```

Figure 1: Screen display for the C-300 visual simulation model

setup). The width of the aluminum sheet coils is also expressed by the means of a statistical distribution.

5. The statistical distributions of the processing and setup times.

6. The job scheduling rules.

The second step has been to define the proposed outputs of the model among which are:

1. The animated portray of the rolling mill, the work-in-process inventories, the loading and unloading activities, the setups and downtimes.

2. Real-time statistics on the work-in-process inventories.

3. Mean flow-time of jobs at workstation.

4. Real-time statistics on the number of jobs processed between setups.

Comparison between these output statistics and those gathered from historical records helped validate the VS model.

4. USE OF THE VS MODEL

Figure 1 presents the animated portray while figure 2 depicts the process sequence of the simulation model.

The model is currently used to identify and compare numerous scheduling rules at workstation C-300. Among the rules tested, a first group places emphasis on reducing the mean lateness whereas the second aims to reduce the number of setups. In the first case, the approach proposed is to schedule the jobs to be processed according to due-dates (similar to the SLACK/OPN rule). A setup occurs whenever the width of the aluminum sheet coils of the next job to be processed is larger than the previous one. In the second case, the approach proposed places emphasis on a sorting of the jobs according to the width of the aluminum sheet coils (decreasing order) so as to minimize the number of setups.

To simulate the operations occurring at workstation C-300, the program first generates job arrivals; the jobs generated correspond to the product schemes observed from historical data. The INITIATE SET-UP event is initiated whenever the conditions dictated by the scheduling rule used are met. The SORT JOBS procedure is then executed so as to sort the jobs in queue according to the scheduling criteria used. The PROCESS JOBS is then executed and a new setup is initiated whenever the widths of the aluminum sheet coils are no longer decreasing. The COMPUTE STATISTICS procedure summarizes and displays the statistics on the WIP inventories, the mean flow-time etc...

The VS model proves to be particularly useful in comparing the scheduling rules and, moreover, is of great help in identifying how to adapt rules to improve the performance of the workstation. The picture is easy to understand and people familiar with the rolling mill could question the aptness of a given scheduling rule to reduce WIP inventories, mean flow time or set-up occurences. Another advantage of the VS model proves to be the ability for the user to watch the simulation run, not only collect summary data at the end. This is of great help in identifying temporary periods where a scheduling rule may be of poor value while its performance may show to be quite valuable over the complete simulation run.

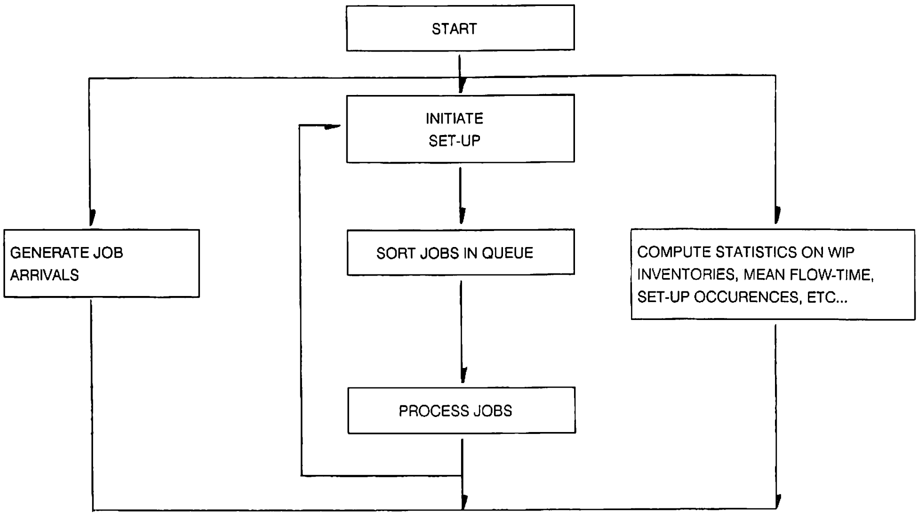


Figure 2: The simulation process sequence in the VS model

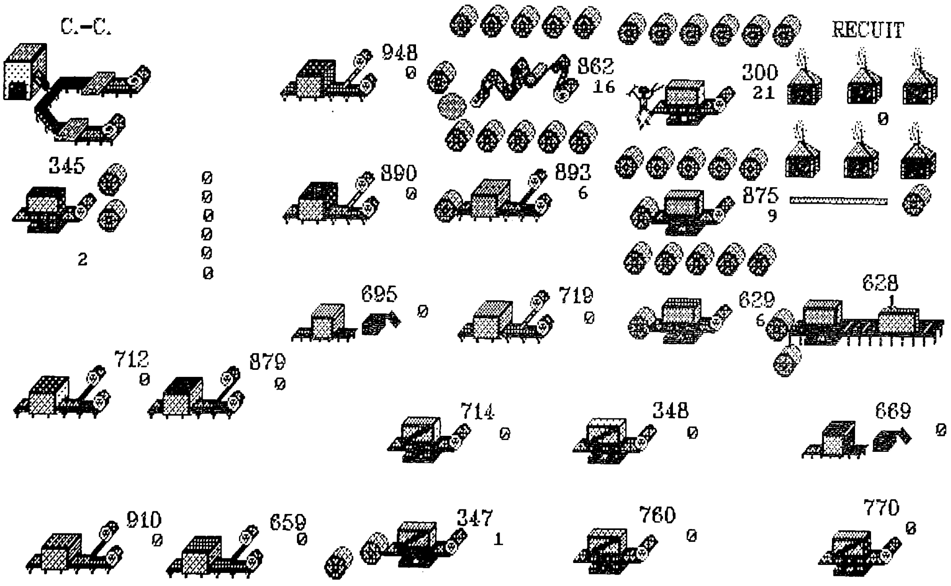


Figure 3: Screen display for the facility simulation model

5. CONCLUDING REMARKS

This paper has looked to a visual simulation model of a rolling mill workstation. The model was developed to analyze the interactions between the jobs to be processed and the scheduling rules used. The VS model was particularly helpful in providing a visual environment for displaying the production system elements and their changes in state over time.

Part of a research program whose purpose is to design and compare scheduling and production planning tools in a rolling mill facility, this work is a first step toward the development of a visual interactive simulation (VIS) model of the facility. Figure 3 presents a preliminary screen display for the later model. The VIS model should allow the production planners and schedulers to modify some of the decision rules and structures of the model while the simulation runs. The VIS model will thus more exactly capture the behaviour of the production system as decision-makers react and adjust their decisions over time according to the state of the variables they consider important. Further papers from the authors will report on these developments.

ACKNOWLEDGEMENTS

This research was supported by the Canada NSERC (grant A-6837), Le Fonds FCAR de la Province de Québec (grant 87-EQ-3505) and CEFRIO (Centre Francophone de Recherche en Informatisation des Organisations).

REFERENCES

AMIRY, A.P., 1965, **The Simulation of Information Flow in a Steelmaking Plant**, Digital Simulation in Operational Research, Hollingdale ed., English University Press, London, England.

BAKER, K.R., 1976, Introduction to Sequencing and Scheduling, Wiley.

CACI, 1987, SIMFACTORY with Animation, 12011 San Vincente Boulevard, Los Angeles, CA 90049.

CONWAY, R., W.L. MAXWELL and S.L. WORONA, 1985, User's Guide to XCELL Factory Modeling System, Scientific Press, Palo Alto, CA.

FIDDY, E., J.G. BRIGHT and R.D. HURRION, 1981, **SEE-WHY: Interactive Simulation on the Screen**, Proceedings of the Institute of Mechanical Engineers C293/81, pp. 167-172.

GENERAL ELECTRIC, 1986, MODELMASTER Software Description, P.O. Box 8106, Charlottesville, VA.

GRAVES, S.C., 1981, **A Review of Production Scheduling**, Operations Research, v29, pp. 646-675.

MUSSELMAN, K.J., 1986, **TESS as a Catalyst for Change**, Paper presented at the TIMS/ORSA Joint National Conference, Los Angeles, CA.

PANWALKER, S.S. and W. ISKANDER, 1977, **A Review of Scheduling Rules**, Operations Research, v25, pp. 45-61.

PEGDEN, L.A., T.I. MILES and G.A. DIAZ, 1985, **Graphical Interpretation of Output Illustrated by a SIMAN Manufacturing Simulation Model**, in Proceedings of the 1985 Winter Simulation Conference, The Society for Computer Simulation, San Diego, CA., pp. 244-251.

RAHN, R.J., 1986, **Approaches to Simulation**, Paper presented at the 1986 CORS Conference, Toronto, June 1986.

AUTHOR'S BIOGRAPHIES

PIERRE LEFRANCOIS is associate professor of quantitative methods and operations management in Département Opérations et systèmes de décision of Université Laval. He received a M.Sc. in computer sciences and operations research from Université de Montréal and a Ph.D. in management science from Université Laval. His research interests are in production planning and forecasting and inventory control systems. He is the author of articles in International Journal of Forecasting, International Journal of Production Research, The Journal of the Administrative Science Association of Canada and other journals. He is a member of IIF, TIMS, ORSA, APICS and ASAC.

Pierre Lefrançois
Département Opérations et systèmes de décision
Université Laval
Ste-foy, Québec, G1K 7P4
(418) 656-3010
Bitnet: LEFRANCP@LAVALVM2

MARIE-HÉLÈNE JOBIN is a Ph.D. student in the Département Opérations et systèmes de décision of Université Laval. She holds a B.A.A. in administrative sciences and a MBA with specialization in operations management from Faculté des sciences de l'administration at Université Laval. Her current research interests are in simulation modeling of production systems and in scheduling.

Marie-Hélène Jobin
Département Opérations et systèmes de décision
Université Laval
Ste-foy, Québec, G1K 7P4
(418) 656-2098

MARIE-CLAUDE ROY holds a B.A.A. in administrative sciences from Faculté des sciences de l'administration at Université Laval. She is currently research assistant for the Groupe de Recherche en Gestion Logistique at Université Laval. Her current interests are in production-operations management and computer sciences. She is a member of APICS.

Marie-Claude Roy
Département Opérations et systèmes de décision
Université Laval
Ste-foy, Québec, G1K 7P4
(418) 656-2098

GÉRALD GAMACHE is head of the industrial engineering department for the Cap-de-la-Madeleine plant of the Société d'Aluminium Reynolds du Canada. He holds a bachelor of applied science degree in industrial engineering from École Polytechnique de Montréal. His industrial experience includes industrial engineering work for Québec Cartier Mining, Westinghouse, Cegelec and Hewitt Equipment; he also acted as a private consultant. He is a member of Ordre des Ingénieurs du Québec, IIE and APICS.

Gérald Gamache
Société d'Aluminium Reynolds du Canada
290 Saint-Laurent
Cap-de-la-Madeleine, Québec, G8T 7W9
(819) 373-6370