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SIMULATION STUDIES IN A HOT MILL FACILITY

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ABSTRACT

This paper illustrates several phases of a simulation study done in a hot mill facility for a prominent U.S. steel producer. The first phase of the study focuses on operational and material handling issues for the Hot Mill Banding, Weighing and Marking stations. The next phase provides additional support for the objectives of the first phase, along with technology transfer and training to support practical operations at the client's site. The final phase addresses strategic issues at downstream operations from the Hot Mill Banding, Weighing and Marking line and the impact of any operational strategy on the whole system. The models for this project have been developed using the AUTOMOD II simulation software and were executed on an IRIS - Silicon Graphics Workstation.

The focus of this paper is to interpret the results obtained in the first completed phase and to share the experience of the whole project in terms of lessons learned. Likewise, the paper points out the extensibility and the synergistic advantages that can be obtained by focusing at an early stage on the customer's short and long term goals and objectives.

1 INTRODUCTION AND BACKGROUND

Daxus Corporation is a Pittsburgh-based systems integration company which realizes and promotes the benefits that a decision-support tool such as simulation can offer. The capability to obtain insight and comprehension concerning a system's performance, along with the ability to act based on this data and to measure the results of these actions, is priceless to companies planning for major innovations or investments. Starting with a small scale effort, Daxus' simulation group has drawn from the "openness" (in the sense that simulation products can be utilized by people other than programming experts) of the new simulation products and our vast experience in the steel industry to provide sound and long-term support to our customers.

During the 1990s, the U.S. steel industry faces increasing competition from products such as plastics, aluminum, and composites. Several classic strongholds of the steel industry, such as the automotive and the food can industry, are already under direct attack by these competitive products. Similarly, tough competition will continue from international companies. In addition to the already positioned countries like Japan and Korea, new players will enter the arena. Thailand and Taiwan, among others, are countries who will be joining the Pacific Rim steelmaking capabilities. Additional competition could come from Eastern Block countries. With the political changes of the last two years, Eastern Block nations will potentially attract large amounts of capital from international firms enticed by the financial advantages and with goals of installing new technology.

Increasing competition, along with events such as the clean air legislation, are forcing the U.S. steel industry to make continuous improvement part of their strategy for the coming decade. A key element of this strategy is continuous capital investment to address issues of modernization, scale reduction, automation, etc. Equally important is the technological development and, as the final part of the formula, worker training. This last element is closely tied to the technological development since the increased use of sophisticated equipment has, in turn, resulted in the need for a more educated, flexible, and participatory workforce.

In this spirit, a $35 million renovation was planned for a mid-western production facility of a major U.S. steel producer. The project focused on the hot mill facility, specifically involving a material handling system that processes incoming coils and delivers them to an intermediate storage location.

The simulation project undertaken by Daxus was divided into three phases:

Phase 1: Analysis of the Hot Mill Banding, Weighing and Marking Material Handling System, completed in 1990.
Phase 2: Additional experiments and training on the Hot

Mill Banding, Weighing and Marking Material Handling System.

Phase 3: Coil Transfer Vehicle (CTV) Simulation Study being considered by the customer.

2 PHASE 1: ANALYSIS OF THE HOT MILL BANDING, WEIGHING, AND MARKING MATERIAL HANDLING SYSTEM

2.1 Description

The customer needed to assess the capability of the Hot Mill Banding, Weighing and Marking Material Handling System to handle changes in future expanded operations. In this system, coils coming from the hot mill are banded, pressed, weighed, and marked with pertinent data before being sent to an intermediate storage location. The changes incorporated new machinery into the existing system, as well as an increase in production. The company also required the development of a blueprint for the process control logic of the conveyors and routing of the coils. Following is a description of the system to accompany Figure 1.

The focus of this simulation study starts at the discharge point for coils from the hot strip mill. The incoming coils are either single, double, or triple-banded depending on their size, weight, subsequent use and destination. At the end of the hot strip mill, the coils are placed on a first transfer car and transported to the intermediate saddle set down point located by the banders. Currently there are three banders which perform operations. Banders 1 and 3 are primary, while bander 2 is used as a secondary. The following list represents the original sequencing on the banders for the coils as they enter the banding area and is used for back-up testing purposes:

Coils 1 - 20 on banders 1 and 3
Coils 21 - 30 on banders 2 and 3
Coils 31 - 50 on banders 1 and 3
Coils 51 - 60 on banders 1 and 2

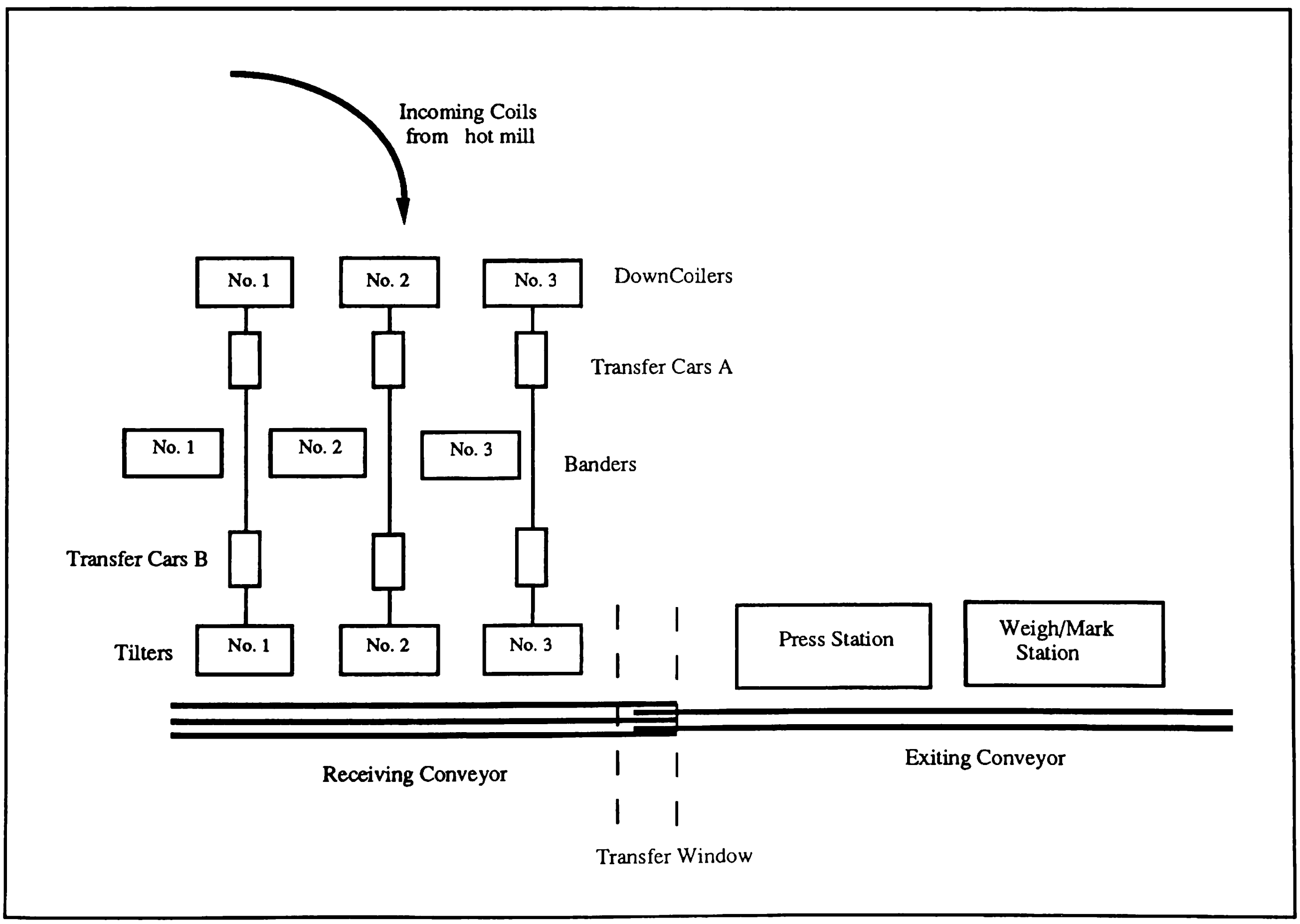

FIGURE 1

After 60 coils the cycle starts over again. The coils are placed on the fixed saddle set down point by the first transfer car (Transfer Car A), which then returns to the initial pick-up point to receive the next coil. Each coil is then picked up at the fixed saddle set down point by a second transfer car (Transfer Car B) and accurately positioned at the appropriate bander, where it will undergo one or more banding operations. When the banding operations are completed and the tilter is ready to receive a coil, the second transfer car takes the coil to the tilter located at the end of the banding line. As soon as the coil to be placed on the conveyor is lifted from the car by the tilter, the second transfer car returns to pick up the next coil arriving at the saddle set down point.

The tilter transfers and reorients the coil on the three-chain receiving conveyor. The coil cannot be transferred to the receiving conveyor unless this conveyor is stopped. Once the transfer is accomplished, the conveyor logic checks appropriate conditions before starting. These conditions include: tilter arm to be removed, coil is in the transfer window between conveyors, the downstream conveyor has a logic condition that does not allow it to be started, etc. If all conditions are satisfied, the receiving conveyor transports the coil until it reaches a stopping point located 20 feet downstream from the center of tilter No. 3.

The coil can only enter the transfer window between the receiving conveyor and the two-chain exiting conveyor if it can make a complete transfer to the exiting conveyor. If this cannot be accomplished, the coil will wait until the exiting conveyor can be moved ahead so the entire transfer can be achieved.

The exiting conveyor transports the coil to the Press station, the conveyor is stopped, and the coil is lifted from the conveyor and pressed. After pressing the coil, the conveyor is stopped again and the coil is lowered back onto the conveyor. The coil proceeds to the Weigh/Marking station. One foot before reaching the Weigh/Marking station, the conveyor slows down to facilitate accurate positioning. Once at the station, the conveyor is stopped, a hydraulic table lifts the coil off the conveyor, and the coil is weighed and marked. When this process is finished, the coils at the Weigh/Marking and Press stations are lowered back onto the conveyor. As soon as a coil is ready to make the transfer from the receiving conveyor, both conveyors start again and move the coils downstream. At the end of the exiting conveyor, the coils are transferred to a third intermediate conveyor to continue towards their storage location.

2.2 Goals and Objectives

Specific areas targeted by this phase were the following:

- Identification of potential bottlenecks for the banding, scaling, and marking area at the end of the hot mill.
- Identification of potential differences in coil flow rate from hot mill to transfer conveyor, depending on which banding lines are used.
- Utilization of the major processing units and material handling equipment involved in the coil handling.
- Identification of optimal process control logic for conveyor.
- Identification of optimal coil routing and throughput analysis for single, double, and triple-banded coils, and testing of the system's robustness under minimum, average, and peak loads.

Furthermore, the customer was interested in using this model for additional testing at the implementation phase, after the actual machine times would have been supplied, and operational training before and after installation. This is described in detail in Phase 2.

2.3 Methodology

The simulation model was created on a Silicon Graphics 3200 Series Workstation using AUTOMOD II. AUTOMOD II is a simulation language designed to specifically address material handling issues. With its built-in features, it captures the physical constraints of distance, space, and size in three dimensions. It also offers advanced features to allow the simulation of complex movement systems without the need to re-write the basic logic of, for instance, collision detection for AGV systems or accumulation conveyors.

The simulation model incorporated a level of detail well beyond that needed for evaluation of the physical process. It was included at this time to avoid having to re-write or modify the program to address issues pertinent to subsequent phases. This extra level of detail would also provide additional help when comparing the relative efficiencies of the different coil routings and programming of conveyor logic alternatives. Additionally the level of detail achievable through the graphics feature of AUTOMOD II took into account the long term use of this model as planned by the customer.

As is necessary when performing any simulation, several modeling assumptions were made:

- No equipment breakdowns are modeled at the banders, tilters, press, weigh/marking stations or material handling systems.
- No intermediate buffers are included along the car lines or conveyors.

Other assumptions related to the system such as physical spacing between the coils, etc., were derived from discussions between the customer and Daxus steel engineers. Proposals for further studies which would include the above mentioned assumptions are being discussed.

Before developing the model, detailed flowcharts were developed for the logic of entities in the model (refer to Figure 2) and for each piece of the material handling equipment. Some of these flowcharts also contained data on input rates, operations, process times, and other key parameters which were provided by plant personnel. These flowcharts, as part of the standard methodology used in Daxus simulation studies, are of extreme importance since they are the basis for communication with the customer, for development of the programming code, and for the verification process.

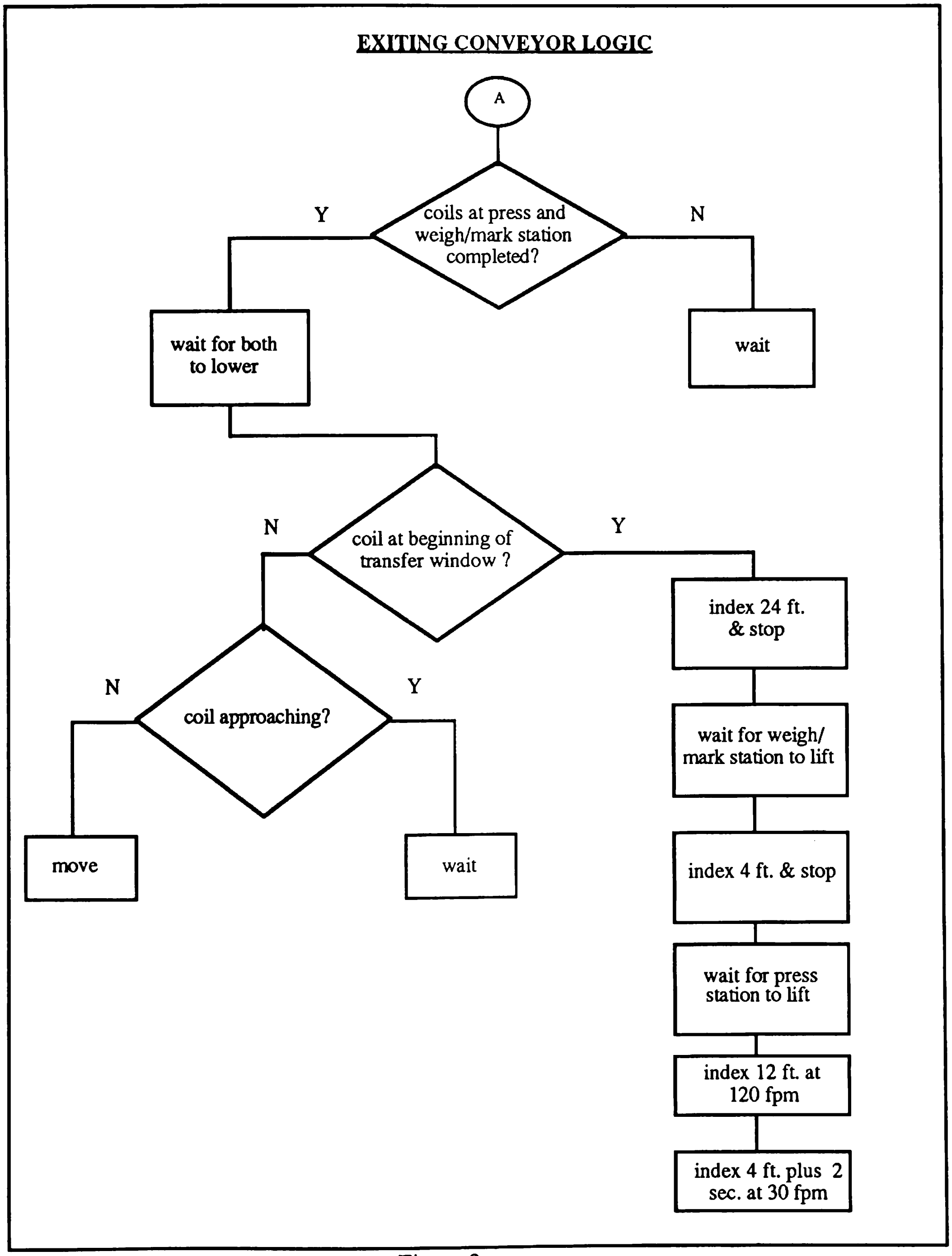

Figure 2

Once the initial model and the baseline logic structure were developed, the process of verification and validation continued as a joint effort between the simulation team and the customer. This iterative process allowed, among other things, refinement of the specific experiments to be carried out and an initial transferring of information and technology to the client's team.

2.4 Results and Recommendations

In this section, the major results of several simulation experiments performed on the Hot Mill Banding, Weighing and Marking Material Handling System are presented.

The first set of experiments indicated the origin of the bottleneck operation at the Weigh/Marking station. To obtain the required throughput level, it was necessary to reduce the marking time by 18 percent. This result forced the customer to go back to the equipment provider and review specifications for their best time estimate. It also brought about a decision making process that eventually redefined the quality and quantity of data to be marked on the coil.

Similarly, the analyses performed on the triple-banded coil runs showed that the use of only two lines at a time was not sufficient to support the backlog that occurred during peak production periods. This finding brought about the implementation of a new jockeying procedure that re-routed any overflowing coil from its original line to the backup line while maintaining the overall sequencing of banders. This first policy implementation succeeded in keeping the throughput at the desired level. However, the flow within the system was no longer smooth; all transfer cars became blocked for periods of time partially due to the extra delay at the bander and increased congestion at the tilters. Line 3, especially, exhibited this condition because of its relative position. The delay appeared in the second phase of the cycle and became more evident in the fourth phase. It was never recuperated due to the clearance required between different tilters and the individual tilter and their arms. As a consequence, an alternative procedure was implemented to run Lines 1 and 2 as the primary ones and keep Line 3 as backup.

Another set of experiments confirmed the system's capability to handle periods of time when surges of coils occur. The use of off-center-single bands as a minimum holding device for coils and minimum amount of data required at the Weigh/Marking station led to a satisfactory throughput. The low utilization at the Weigh/Marking station indicated the potential capability, under these particular circumstances, to add more data on the coil at that location without impacting production.

Finally, an overall analysis of the system showed the benefits of synchronizing the flow of the coils at the transfer window, Press and Weigh/Marking stations. This resulted in a new operational procedure opposite to what had been followed. Desynchronizing the flow only provides local short term optimization and very few extra coils in the long run. The time gained pushing those coils downstream was subsequently lost due to extra stops in the system to position incoming coils. If a shutdown or delay beyond those included in the distribution used for incoming coils were to occur, it is advisable to flush the system and restart at original conditions. The simpler logic required to maintain the system running synchronized was used as a blueprint to develop the PLC logic used at implementation time.

3 PHASE 2: ADDITIONAL EXPERIMENTS AND TRAINING ON THE HOT MILL BANDING, WEIGHING AND MARKING MATERIAL HANDLING SYSTEM

3.1 Description and Objectives

This second phase addresses the issues raised by both the customer and its electrical/machinery supplier. The objective of this second phase is to provide additional support to ensure that the planned design and modernization plan for the discharge end of the hot strip mill will meet the required throughput objectives. The additional support will focus on transferring information and technology to the customer's team. This support will include discussing the work that has been completed, updating and testing alternatives for the control system implementation and transferring the technology to plant personnel who support the practical operations of the Banding, Pressing, Weighing and Marking System.

3.2 Methodology

This phase has been divided into three stages: awareness training, what-if analysis, and simulation model customization and operations training.

3.2.1 Awareness Training

Awareness training focuses on training the customer's team to achieve a detailed understanding of the goals and objectives of the Phase 1 simulation analysis. It will also serve to acquire a detailed understanding and description of the manufacturing system analyzed by using process flow diagramming techniques, by reviewing the data used, and by reviewing the assumptions made in the simulation model. This stage establishes the groundwork for all future developments in this phase. The participation of all stakeholders in this phase of the project cannot be stressed enough. They need to provide their input while changes to the direction of the study can still be done efficiently. The participants will also acquire a better understanding of what they can gain from the study and what they must do to support the study.

3.2.2 What-If Analysis

As the electrical supplier defines the exact material handling system specifications to be used at the Hot Mill Banding, Weighing and Marking stations, these parameters will be incorporated into the simulation model. The objective is to determine if the actual times of the new equipment will satisfy the customer's production requirements. A number of experiments will be run with the simulation model, each having a pre-defined set of driving input data and scenarios that have been developed in conversations with the customer. A final report and a presentation will be the culmination of this stage of Phase 2 project activities, as well as a historical record of what has been done. The presentation will focus on a summary of Phase 2 activities, and most importantly, on the assumptions, final findings, recommendations, and general action plans required to implement the findings and recommendations.

3.2.3 Simulation Model Customization and Operations Training

As mentioned before, training is a key item to ensure future success for several reasons. In addition to the need that comes from the new sophistication in equipment and its maintenance, today's trend towards decentralized decision-making and participatory management requires shop floor employees to be familiar with problem solving techniques and group dynamics. Their operational decisions can have an immediate effect; therefore it is critical to give them the tools and the skills to assess the impact of their decisions.

This stage will encompass the transfer of the customized model to the customer, and training for on-site personnel. The customized model will include graphics and user interfaces required to facilitate a successful implementation and continued use of the simulation model. The simulation tool selected for this project and the experience level of the people who will become the users of this tool will have a direct impact on the requirements for this phase in the terms of the level of customization required. A user guide will be developed to describe the use, assumptions and constraints of the simulation model.

The training will focus on two areas: (1) running the simulation model in parallel with the electrical supplier's distributed microcontroller (DMC) to show the behavior of the system under a variety of conditions, and (2) training selected customer personnel on operational strategies and their impact on the overall system performance. The training course will acquaint the users with the use of the simulation model and what they can expect to gain from using it. The training will be "hands-on" and will provide the users with immediate results to what their decisions can accomplish and the extended consequences of these decisions on the whole system.

4 PHASE 3: CTV COIL TRANSFER SIMULATION STUDY

4.1 Description

This third phase focuses on the development and analysis of the operations that take place at the CTV Coil Transfer System located downstream from the Hot Mill Banding, Weighing and Marking Material Handling System. In addition to specific quantitative objectives, an equally important goal is to integrate the CTV model with the one developed in Phase 1 to permit a global evaluation of both strategic and operational practices for the whole line. The concepts of modularity already addressed in Phase 1 will be further developed so that from a programming and documentation point of view, there would be a minimal effort in linking the two separate models. Following is a description of the system to accompany Figure 3.

The scope of this phase starts at the feed conveyor delivering the coils to the two transfer/pick-up spurs that provide coils to the CTV coil handling system. The coils will be delivered to one of the two transfer/pick-up spurs utilizing the feed conveyor and will be routed using several strategies. As the coils are successfully positioned at one of the coil tilting mechanisms, the feed conveyor will be stopped so that each coil can be engaged and tilted to the upright position.

The coil will then be picked up by a transfer car and transported to the next set-down point. Here a second car or the original transfer car will take the coil directly to the CTV system pick-up point. In case no CTV vehicle is available at the pick-up point, the coil will be transferred to an alternate vehicle, which is on the opposite side of the CTV System Track. In this unlikely case, the coils will be routed to an alternative location. On their normal path, the CTV vehicle will take the coil out of the spur and to its regular storage location.

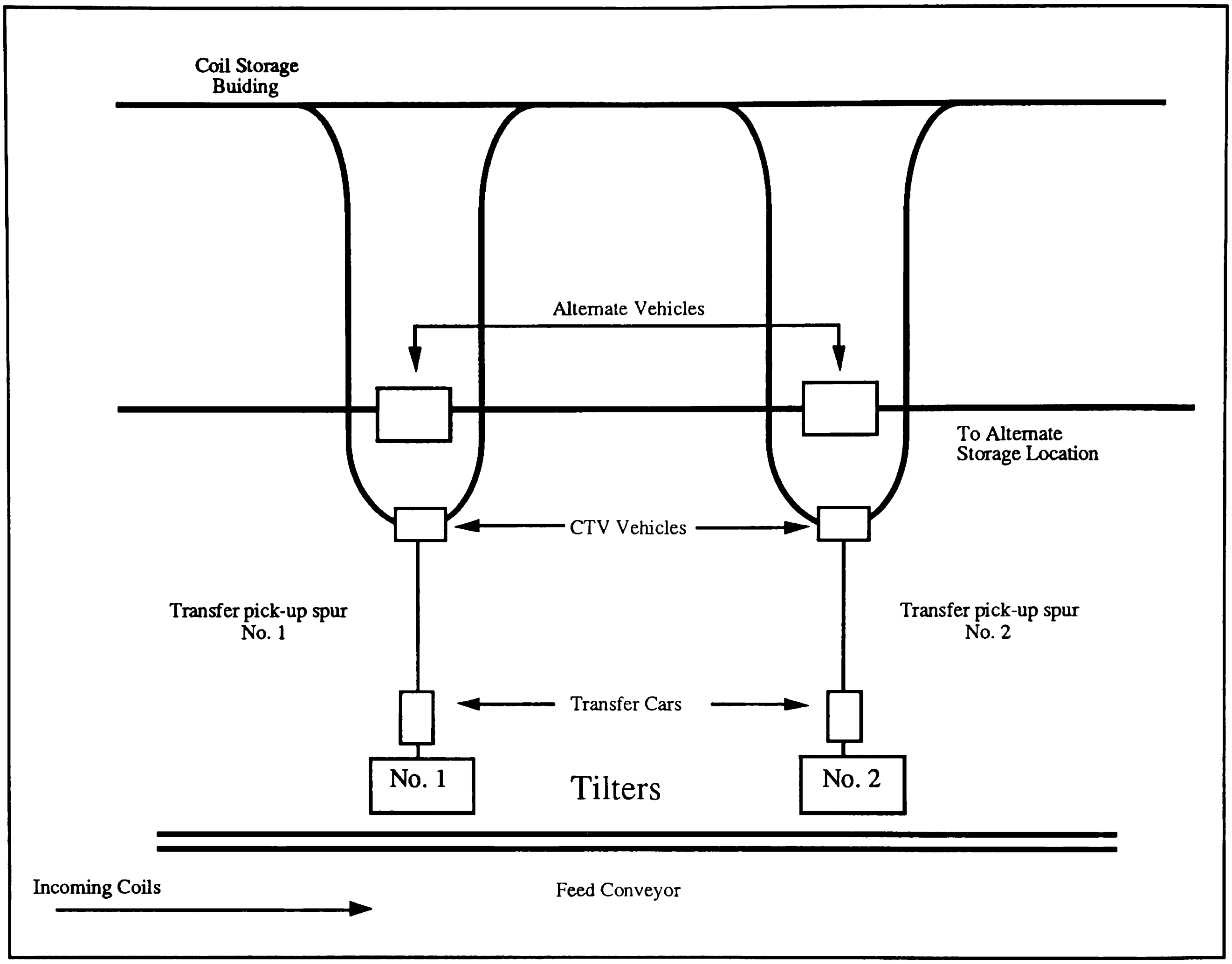

FIGURE 3

4.2 Goals and Objectives

Specific goals of this particular phase are the following:

- Identification of potential bottlenecks for the material handling system.
- Identification of coil rate differences due to different routing strategies, overall throughput, and minimum capability.
- Utilization of the major processing units and material handling equipment involved in coil handling.
- Identification of optimal conveyor speed.
- Identification of optimal number and location of transfer cars to be allocated between the tilting mechanisms and CTV System pick-up points.

In addition to these objectives, a second set of objectives includes the interaction of the two systems (Phase 1 and Phase 3). It is precisely at this stage that benefits from having addressed both the short and long terms issues associated with the customer's needs pay off. Although at the beginning of the project the specifications for this last phase were still far from concluded, it was possible to think ahead about the modularity needed so that at a later stage the two models could be connected to each other easily.

Issues such as choice of graphics scale (due to the nature of the package), development of top-down modular design and modules/macros for programming purposes, assignment and consistency of parameters at the highest level possible to facilitate access to the final user, etc., are all addressed in the first stage of the methodology used by Daxus to implement simulation projects. Although specifications are not always clearly defined at this first stage, just having issues identified establishes an internal structure where a variety of potential questions can be answered. Furthermore, it provides all parties with an understanding of what they can gain from the study and how they can support it.

In this particular study, the common transport conveyor which was the last piece of the simulation model addressed in Phase 1, was built with "hooks" so that minimum effort would be required to link it with the model developed for Phase 3. Similarly, concepts of "indexing" were laid out to reproduce the logic at the pick-up and drop off points for the transfer cars in the CTV Systems. This method minimized the amount of coding required to model stations with similar logic functions. Furthermore, all parameters used for internal calculations are accessible to the final user for modification and are not embedded in the code. Finally, careful documentation will provide a logical and consistent definition of code and parameters which, in turn, will facilitate the transition of the whole model to the final users.

5 CONCLUSIONS

Simulation tools provide great potential for organizations to remain competitive over the next decade and beyond. Performing simulation has resulted in an improved awareness of the many factors which impact system performance for the customer and Daxus. Simulation has also aided in understanding the many and complex relationships which coexist whenever a new system is to be implemented, as well as in implementing new operational policies and actual performance of the technology in the system.

Certainly, languages such as AUTOMOD II assist by minimizing the amount of basic programming and internal code structures required, while maintaining flexibility of code. Similarly, the high quality and realistic graphics become an invaluable verification, validation, and communication tool that address the needs of all customers. Elements like these allow the emphasis of the study to be shifted from coding to both planning and analysis.

Finally, it has been our experience that regardless of the simulation software used, a thorough understanding of the dynamics of the system analyzed is vital. In this case, Daxus experience in steel process and machinery provided alternatives in terms of operations and strategy and reduced the number of alternatives based on knowledge of similar systems. Another key area resides in a thorough first phase of a study, where the short and long terms needs of the customer are described. These goals, in turn, need to be translated into a well-defined structure for project management in terms of model development, communication, and documentation. This structure facilitates the review and prioritization of alternative analyses and the transfer from a recommendation phase to its implementation at the customer site. No effort should be spared here, because often the failure or success of a project is well contained within it.

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REFERENCES

AutoSimulations. 1989. *ACE Users Manual.* Autosimulations, Inc., Bountiful, Utah.

AutoSimulations. 1989. *Auto Mod II Users Manual.* Autosimulations, Inc., Bountiful, Utah.

Carson, J. S. 1989. Verification and Validation: A Consultant's Perspective. In *Proceedings of the 1989 Winter Simulation Conference*, Eds. Osman Balci, Randall P. Sadowski, Richard E. Nance

Doerr, R. H. 1991. Formula for Success. *33 Metal Producing*, January 7.

Law, A. M. and W. D. Kelton. 1990. *Simulation Modeling and Analysis*, Second Edition. New York: McGraw-Hill.

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