Proceedings of the 1998 Winter Simulation Conference
D.J. Medeiros, E.F. Watson, J.S. Carson and M.S. Manivannan, eds.

SIMULATION OF A LARGE-SCALE BREWERY DISTRIBUTION SYSTEM

K. Heinz Weigl

ESLA
Scheibengasse 5
A-1190 Vienna, AUSTRIA

ABSTRACT

This paper describes a simulation model of a large beverage distribution center. The brewery distribution center has a volume of 71,600 cubic meters and contains about 8,000 pallets. Every day 1,800 pallets are handled in or out of the system, and the object of this study was to verify the functionality of the automated storage and retrieval system and integrated conveyor system—including elevators connecting five levels of the distribution center. The complex system is modeled with the powerful simulation software Arena®. A brief discussion of the results is also given.

1 INTRODUCTION

During the conceptual design stage of a project to install a new AS/RS at the Eichhof Brewery in Luzern, Switzerland, the client, main contractor, and automation equipment supplier decided to use computer simulation as a tool to test the validity of the system design.

The equipment included a complex conveyor system—over 250 meters in length with more than 150 drive units over five levels—dealing with up to 1,800 pallets per day. This, combined with a new AS/RS for storage, covered an area of around 3,900 sq. meters. The Distribution Center is shown in Figure 1.

The brewery distribution system is required to store beverage bundles (supplied from production, train, or trucks) and to consign for delivery via train and trucks. The core of the distribution center is a four-level conveying system, conveying up to 800 different products into and out of a 7,600 pallet AS/RS system. The conveyor system is designed for a daily performance of 1,800 pallets in normal operation. Four automatic narrow-aisle cranes are installed in two aisles, each moving 300 pallets an hour. Ten rail wagons and 30 trucks are loaded and unloaded every day.

Euro pallets with different products are moved according to a load table—starting from three different input stations, production, trucks and train as shown in Figure 10, over elevators, powered roller conveyors, crossings, and transfer units to the identification point (I-Point) are shown in Figure 9. The reason is to identify paired pallets (same product, and AS/RS area) for transport via elevators to the pickup station of the narrow-aisle crane. Only pallets with the same product and area can be picked up together by the narrow-aisle crane, shown in Figure 8. This is also a requirement for the output movement from the store to the consignment area and train loading.

The goal of the simulation study was to identify the following:

- Measure the utilization of individual elements of the system, such as the elevators, rail-guided vehicles, and narrow-aisle cranes
- Identify bottlenecks and highlight integration effects
- Highlight congestion in individual sections of the conveyor system
- Examine breakdown scenarios
- Analyze strategies to increase pair pallet movement of narrow-aisle cranes

Figure 1: Eichhof Luzern Distribution Center

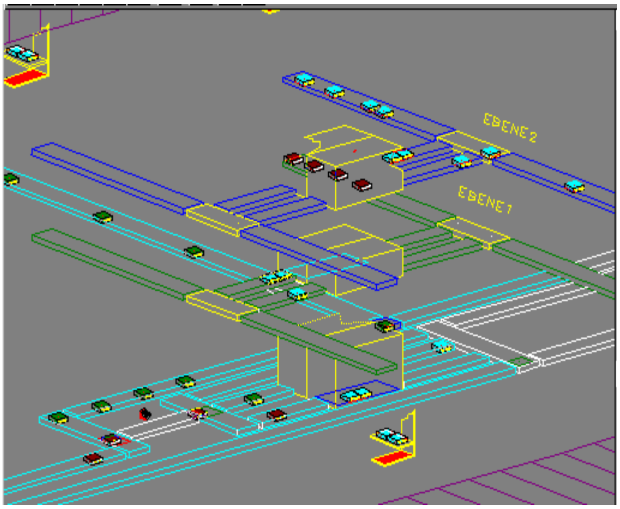

Figure 2: Animation of the Main Conveyor System

2 CARRYING OUT THE SIMULATION STUDY

The simulation tool Arena (including the Input and Output Analyzers) was used to perform the simulation study. The main steps of the study are as follows:

- Analysis of the input data
- Design of the model concept
- Development of the simulation model
- Analysis of output data

Different load tables with the product range, plant dimensions, detailed performance data of the individual transport equipment (such as velocities, accelerations, decelerations, drop-down, and pickup times), as well as the complex logic of the crossing sections were analyzed. This data was stored in a database accessible via a menu system before starting the simulation runs.

Prior to starting the model, a detailed concept was developed based on architectural and functional drawings and the model detail required by the end user. The complex logistics of pickup, drop-down and movement operations of elevators, conveyors, and narrow-aisle cranes required development of models for each individual component to establish the necessary detail to provide the required characteristics. A 3D AutoCAD® drawing, shown in Figure 2, was made which showed a simplified view of the storage area and a more detailed view of the core conveyor system. Each section of the conveyor offers space for a certain number of pallets and is divided into individually powered segments moving individual and paired pallets to the next destination. The logic for the elevators was designed to move two pallets synchronously in reverse direction in order to save pickup times on one end of the elevator. This was necessary due the system load and the available space on some rolling conveyor segments.

The detail of the conveyor system with two crossing sections and individually powered segments in level 1 is shown in Figure 3. The capacity of the powered rolling conveyors F24, F25, F17, and F18 is designed for eight pallets; each unit is divided into three individually powered sub-units moving two and four pallets synchronously. Pallets of the same type are transported in pairs by either elevator SF3 or SF4, unloaded onto conveyors F15 or F16, and move over crossing section K5 to either F17 or F18. An example of the detailed movement and its phases is shown in Figure 4. Each section of rolling conveyors F17 or F18 is an individually powered segment moving one or two pairs of pallets at the same time. This detailed situation was modeled with Arena's powerful BLOCK/UNBLOCK combination for each individually powered conveyor unit.

Two levels connected with the two elevators SF3 and SF4 were designed as shown in Figure 3. Both levels have two pickup and two drop-off stations for the narrow-aisle cranes RGB1- RGB4.

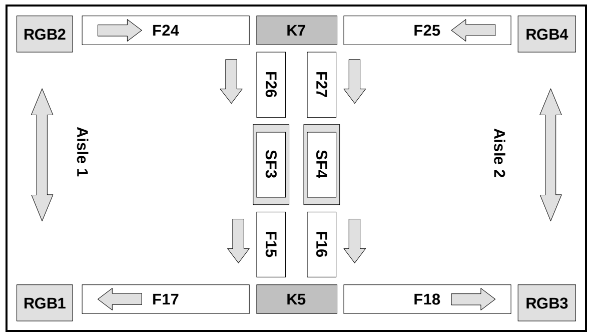

Figure 3: Crossing Section with Individual Powered Segments

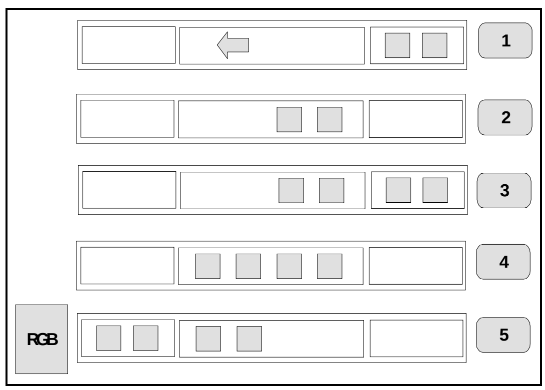

Figure 4: Detail and Phases of Movement on F17

Complex control logic is also required at the I-point, where a scanner identifies all input pallets and controls the definition of the storage area and the allowed pair mix of pallets, preventing single-pallet movements of the narrow-aisle crane. The 3D movement of the narrow-aisle crane was split into three independent elements, each carried out by a guided transporter in x, y, z direction and then synchronized. A random-number-based calculation of the storage position (depending on the type of pallet) was carried out. The crane was modeled using three Arena transporters (Transfer panel) to deal with the three elements of movement, since the narrow-aisle crane has to move different distances with different velocities after picking up the pallets, depending on the storage area and level of the conveyor system. Figure 5 shows the principle of the concept of the narrow-aisle movement.

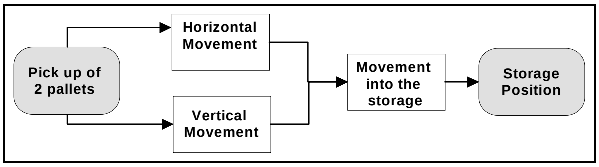

Figure 5: Concept Movement of Narrow-Aisle Crane

The synchronization of the individual movement in horizontal and vertical directions, each with individual velocities, acceleration, and deceleration, is modeled with control entities and a MATCH block. Loading and unloading times are also taken into account. The storage system is divided for each aisle into sections A, B, and C served by one narrow-aisle crane (NAC). (See Figure 6.)

Pallets from the three different sources are scanned at the I-point. One major requirement of the end user was that there should never be a situation when the main conveyor from the production line is blocked by incoming pallets from the train or trucks. A specific logic was designed to cover this requirement of the system. The rotation table located at the crossing section feeds the main conveyor from production and the conveyor served by an elevator from the truck area. The rotation table blocks or unblocks the movement of an even number of pallets coming from the production line, depending on the congestion factor of the input conveyor (Figure 7). To model this, a sub-model with one of Arena's continuous features (the DETECT block) was developed to create (dependent on the actual congestion factor) a controlled entity, setting the allowed number of pairs of pallets coming from the production main conveyor. Different congestion factor values were evaluated during the experimentation phase.

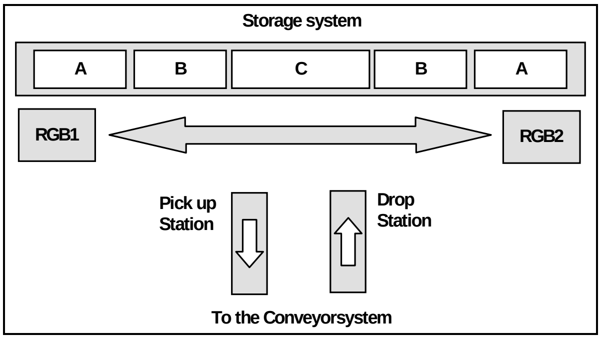

Figure 6: Schematic Picture of Storage and Aisle 1

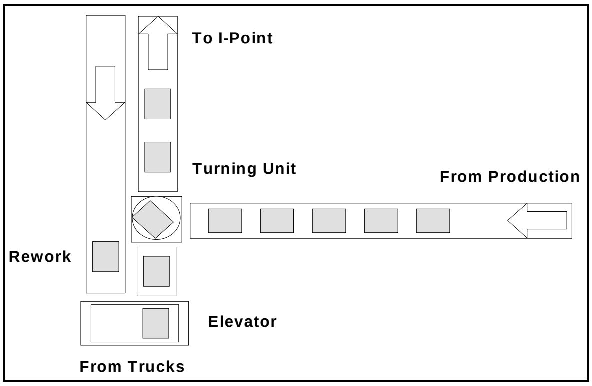

Figure 7: Schematic Picture of the Rotation Table

The system was designed to offer an efficient material-handling system with scope for future expansion.

Figure 8: One of Four Narrow-Aisles with Crane

Figure 9: Conveyor System with I-Point

3 THE SIMULATION MODEL AND RESULTS OF THE STUDY

The simulation model is broken down into different sub-models describing the complete system. Figure 2 shows the animation of the core conveyor-elevator system with different levels. From the main level, where the scanner is positioned, the pallets move in pairs via two elevators to the next two levels above, feeding the four pick-up points for the narrow-aisle crane. For each aisle, two pickup and two drop-down stations are placed asymmetrically on each of the levels. Each of the aisles are divided into two sections, each with a narrow-aisle crane and individual unloading and loading stations. After unloading two pallets, the narrow-aisle crane has to move vertically to load the next pair of pallets for storage.

Individual animated statistics are placed on the overall layout. These include histograms for the usage of each individual narrow-aisle crane, the number of pallets in the system in different sections, and the congestion level of different conveyor units and rail-guided vehicles.

With Arena, all complex situations could be modeled easily. The results of the simulation study surprised the end user and the main contractor. Although the system design could handle the required throughput of pallets, bottlenecks at different times of the day occurred in unexpected areas.

We simulated breakdowns on one of the four narrow-aisle cranes to find out what effect breakdowns would have on the complete conveyor system.

We also studied breakdowns on elevators SF3 or SF4, because they transport all pallets either in the warehouse or from the warehouse.

We did not simulate truck movements and allocation to the bays (see Figure 12); we only know the frequency and the number of pallets coming into the system delivered by train, truck, or production. There is no interface to the outside transportation network.

More than 500 simulation runs were carried out with these results:

- The narrow-aisle cranes were underutilized
- The input and output pallets could be processed in the required time span; however, during breakdowns, pallets coming from the production, train, and truck areas should be handled alternately for maximum throughput
- The buffer sections, with a few exceptions, have sufficient capacity
- The rail-guided vehicle QVW2 will be a bottleneck unless a higher velocity can be obtained
- The elevator SF3/4 will be a bottleneck during breakdowns of other units, and breakdown strategies need to be developed, see Figure 13.
- One I-point (scanner) is sufficient, but strategies for building pallet pairs are necessary
- Elevator SF1 will be a bottleneck if only one pallet can be handled at a time.

The results showed, that the system was very robust in being able to cope with the peaks and troughs of pallet inputs and outputs anticipated. (Figure 11)

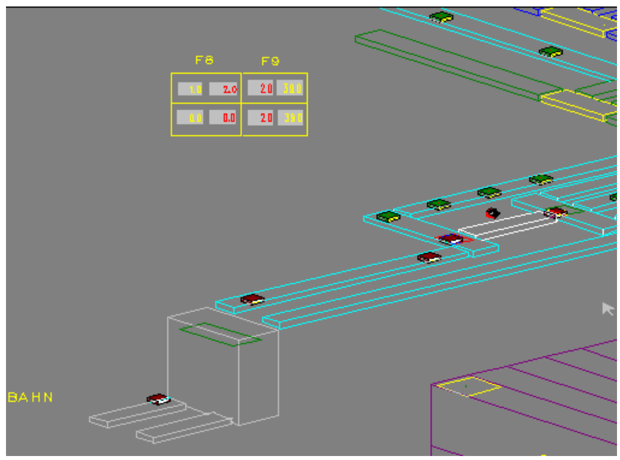

Figure 10: Loading Area Train and I-Point

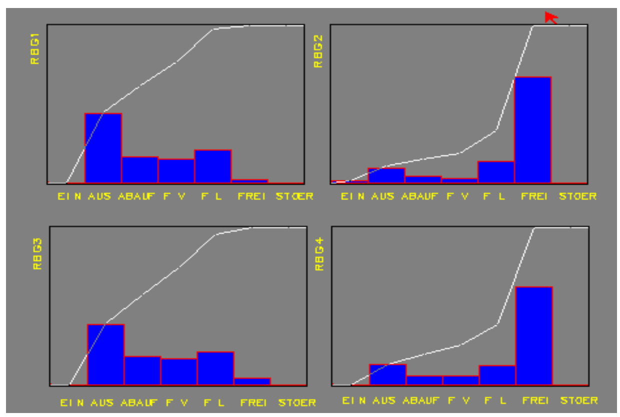

Figure 11: Histograms of the Aisle Crane Usage

The identified and unexpected bottlenecks were later confirmed by the designers of the system, and feasible modifications to the design were tested and incorporated into the final system.

The simulation model was also used by the control-system designers, which resulted in reduced installation and commissioning time. The simulation project provided them a greater understanding of the system characteristics through the need to collect more detailed information, and analyzing the performance thus reduced the risk of unexpected problems in the design. After installation, a comparison of simulation results with real output was found to be 100 percent accurate.

Customer´s comments: We reduced our risk using simulation, and we had more insight in the behavior of the system compared with analytical methods.

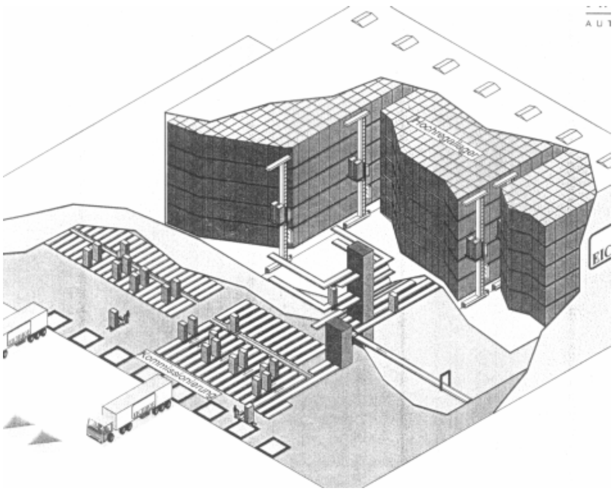

Figure 12: General View of the Distribution Center

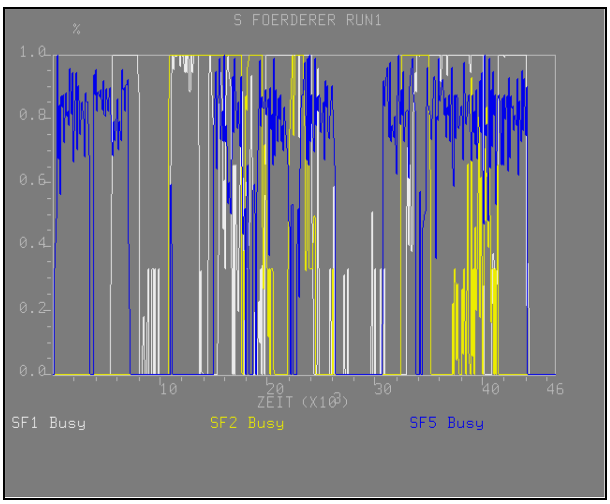

Figure 13: Utilization Plots of Elevators SF3 & SF4

ACKNOWLEDGMENTS

I thank the company Eichhof Brewery in Luzern for permission to publish this paper and Systems Modeling for support during the last 12 years. The project was also supported by the staff of Salomon Automation in Graz, Austria.

Arena is a registered trademark of Systems Modeling Corporation. AutoCAD is a registered trademark of Autodesk.

REFERENCES

Pegden, C.D., R. E. Shannon, and R.P. Sadowski, 1990. *Introduction to Simulation Using SIMAN*, McGraw-Hill, New York, NY.

Law, A. M. and W. D. Kelton, 1991. *Simulation Modeling & Analysis*, McGraw-Hill, New York, NY.

Muller, D., 1989. “AS/RS and Warehouse Modeling.” In *Proceedings of the 1989 Winter Simulation Conference.*

Kelton, W. D., R. Sadowski, and D. Sadowski. 1998. *Simulation with Arena*, WCB/McGraw-Hill, New York, NY.

AUTHOR BIOGRAPHY

K. HEINZ WEIGL is currently a consultant in the field of manufacturing and logistic systems and lecturer at the Technical University Vienna and Dresden and the University of Economics in Vienna. He received his M.Sc (Dipl. Ing.) in Electrical Engineering in 1980 and his Ph.D (Dr. techn) in 1992 from the Technical University of Vienna. He was employed by Siemens AG for five years in the high-voltage motors division in Germany. In 1994 he founded the European Simulation and Logistic Academy (ESLA) in Austria.