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SIMULATION OF BULK FLOW AND HIGH SPEED OPERATIONS

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ABSTRACT

Simulation modeling can be highly effective for solving problems found in the food, beverage, consumer products, and pharmaceutical industries. The flow of material or fluid in these industries is often described as bulk flow, continuous, semi-continuous, or high-speed. Traditional discrete event modeling tools do not speak well to these industries, because they are focused on the pieces/parts paradigm. The nature of bulk or fluid manufacturing problems calls for a unique simulation architecture that is adaptable to many different applications.

SDI Industry is a simulation tool which is built on top of the popular Extend + Manufacturing™ simulation application, and it provides a unique architecture and approach for modeling bulk, continuous, batch, and high speed operations. SDI Industry is used to evaluate scheduling strategies and plant configurations, find bottlenecks and improve throughput. Simulations of continuous, batch and high speed processes can incorporate dynamics like changeovers, breakdowns, shifts, and material related characteristics.

SDI Industry provides an integrated database and a framework for rapid modeling of industrial operations. This framework guides model building at four levels: equipment, operations, systems, and plants. The database and components at all levels are reusable for application to new plants. See Figure 1 below.

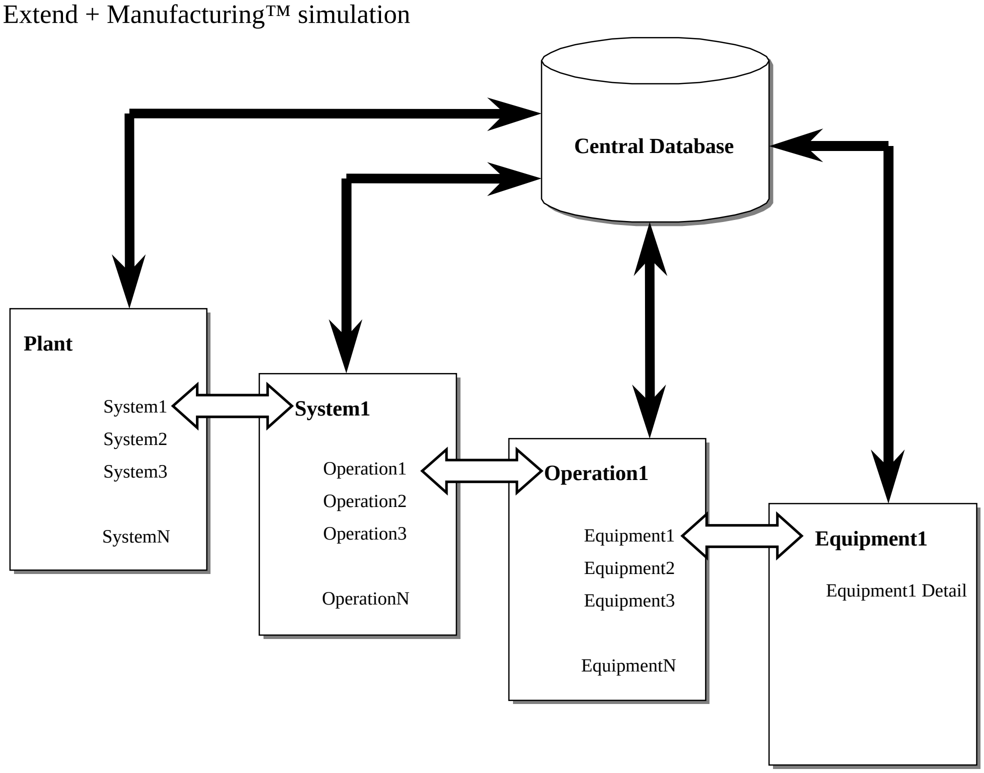


Figure 1: SDI Industry Hierarchy

1 INTRODUCTION

If you take a stroll down an aisle at Wal-Mart, you are confronted with a myriad of products which are found in bottles, tubes, jars, and various other containers. Plants which make these items are comprised of "making" or "processing" operations followed by high speed packaging operations.

Making produces bulk materials, pastes, or liquids by mixing and processing ingredients in steps that are characterized as continuous, semi-continuous, or batch. The physical gear in such operations typically consists of tanks, conveyors, mixers, dryers, extruders, and pipes. Downstream from the making operation is packaging, where material is filled at high speed into containers, then sealed, labeled, and palletized. Making operations produce different flavors of base product, while packaging operations further differentiate that product by packing into different containers.

The way in which important factors interact with each other through time in a making/packing operation makes simulation the tool of choice for evaluating problems and predicting the effect of design or reengineering decisions. In particular, simulation is well suited to study the logistical problems of these systems, such as plant configurations, scheduling, and capacity.

Unfortunately, in using simulation for logistic-related problems, practitioners have had two kinds of tools to choose from, and neither has met their need well. On one side are physical process modeling tools, which are best used to study the thermodynamic and physical properties of the material being processed (such as viscosity, compressibility, enthalpy, etc.). Physical process simulation systems address the continuous nature of the bulk flow problem, but the resolution required to capture important events results in cumbersome, inefficient, and slow-running models. This makes the use of continuous equations inappropriate for application to logistical problems.

On the other end of the spectrum are classical discrete event modeling systems, which are best used for logistical problems, but are inappropriate and slow for modeling the flow of bulk material or the high speed of packaging operations. A common approach for dealing with bulk material in a discrete event system is aggregation. This approach requires assigning a certain quantity of material to each discrete entity, and then treating each entity as a portion of flow. This leads to inaccuracy and loss of detail, and potentially slow models (Sturrock and Drake, 1996).

SDI Industry provides an answer to the bulk process and high-speed flow problem. It is designed for the modeling of such processes, and it is compatible with the existing architecture of Extend, so blocks from within the Extend environment can be used as well. In addition, SDI Industry is a framework that supports rapid model building of bulk, discrete event, or combined systems.

2 OVERVIEW OF SDI INDUSTRY

SDI Industry is a graphical, interactive, industrial simulation program built on top of the popular Extend simulation package, which is developed by Imagine That, Inc.. SDI Industry has evolved from Simulation Dynamics, Inc.'s extensive model building experience in the food, consumer products, and pharmaceutical industries (Siprelle, 1995).

SDI Industry provides Extend with a structure that enables rapid modeling of industrial processes. It provides a hierarchical framework of model templates; flow blocks to model material flows; control blocks to manage the flow; and an integrated database in which to store management information.

SDI Industry introduces a structure to general model building that exploits the hierarchical nature of Extend. This structure makes it easier to rapidly develop reusable models and model components. The task of model building with SDI Industry is divided into four defined hierarchical levels: Equipment (or process); Operations; Systems; and Plant. Each model level has its own template that guides construction, and process management blocks which control the process at that level and interface with the levels above and below.

SDI Industry's flow blocks model any kind of material flow, from parts and pieces to bulk flow and high-speed production. Flow blocks convey rate information between blocks, account for mass, and facilitate blocking and starving mechanisms through an advanced message-passing system. This message-passing system is fully compatible with the existing Extend message architecture (Lamperti and Krahl, 1997). In addition, flow can be converted back and forth between items and bulk flow. For example, a tote container of toothpaste can be treated as an item when you are manipulating the tote, and then converted to a bulk material to flow through packaging processes. Tubes of toothpaste can be aggregated at a palletizer, and pallets can be sent forward as items.

Levels within SDI Industry are designed so that standardized controllers handle issues specific to each level. Equipment level controllers deal with the dynamics of processes such as failure, repair, and batch cycle control. Operation Level controllers manage changeovers and set process characteristics such as bin sizes or equipment rates which may be based on material characteristics. System level controllers specify and read production/shift schedules, and coordinate operation startup and shutdown sequence as product changes occur. Plant level controllers manage distribution of product between systems, and coordinate their schedules.

SDI Industry incorporates an integrated relational database that is used to store and manage data centrally. A central database eliminates the need to search for critical data buried in the model. Standardized tables within the database support the data requirements of the control blocks at each level. Materials and Brands Tables provide information about the products to be run; an Equipment Failure Table provides Time Between Failure and Time To Repair data; Changeover Tables provide matrices of changeover times; Shift Schedule Tables provide alternative crewing schedules; and Production Schedule Tables provide specific run sequences. Report Tables can be customized to gather information as the model runs.

3 BUILDING A MODEL

A complete model built using SDI Industry is presented to show how models are constructed.

3.1 Plant Level

Figure 2 shows a model of a plant comprised of a Raw Material system, 2 Making (processing) systems, a Distribution system, 3 Packing systems, and finished SKU Storage. Each of these systems is contained in a hierarchical block. Since these blocks are hierarchical, we can double-click on a system, like the block labeled

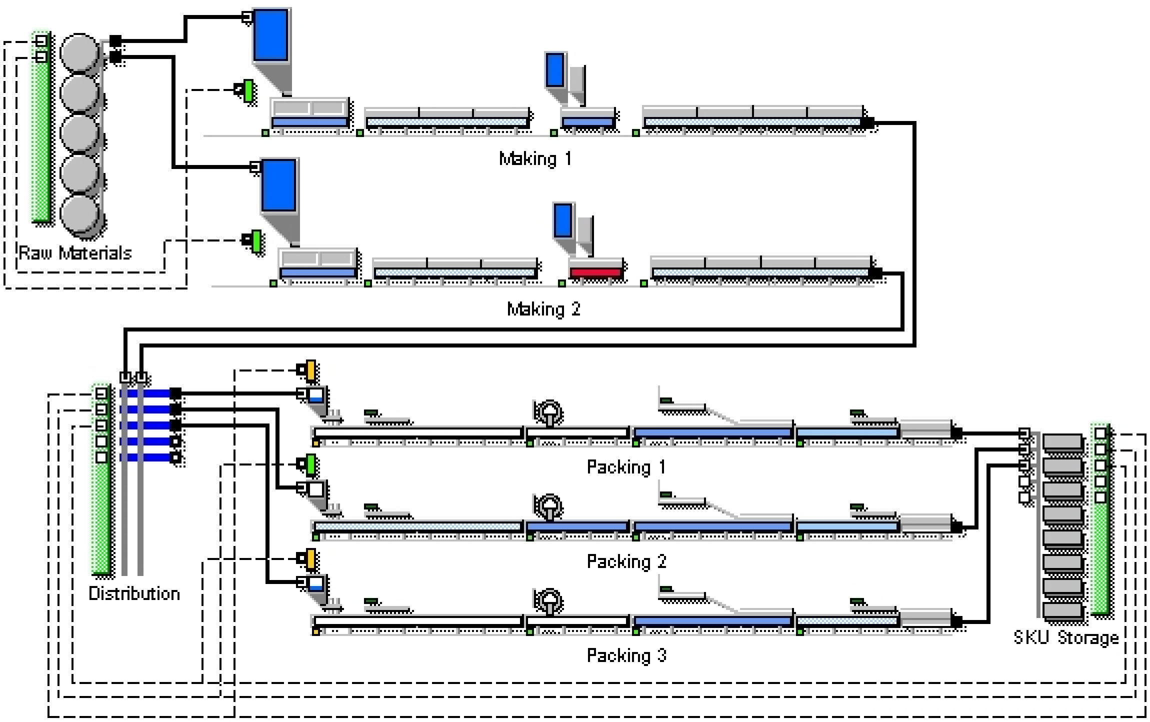
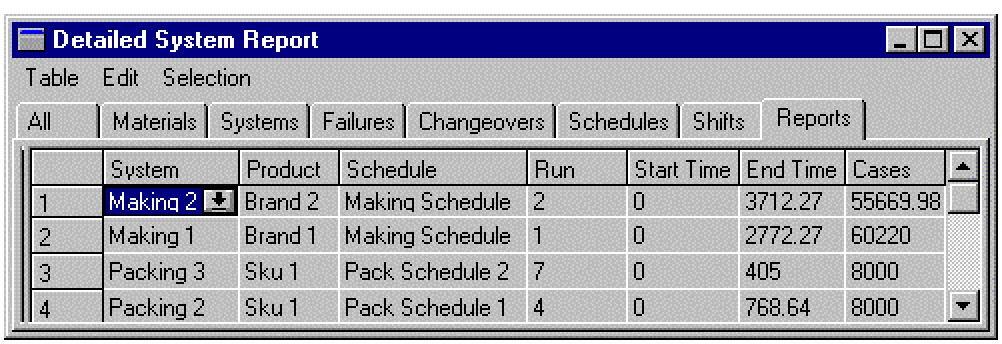


Figure 2: View of Complete Plant


Detailed System Report
Table Edit Selection
All | Materials | Systems | Failures | Changeovers | Schedules | Shifts | Reports

	System	Product	Schedule	Run	Start Time	End Time	Cases
1	Making 2	Brand 2	Making Schedule	2	0	3712.27	55669.98
2	Making 1	Brand 1	Making Schedule	1	0	2772.27	60220
3	Packing 3	Sku 1	Pack Schedule 2	7	0	405	8000
4	Packing 2	Sku 1	Pack Schedule 1	4	0	768.64	8000

Figure 3: Detailed System Report

"Making 1," to expose the details of that system. The system hierarchical blocks can be easily duplicated to add new Making or Packing lines.

A Detailed System Report from the database is shown in Figure 3. The model database can be opened to view tables or configure custom reports from the Extend menu. Tabs within the database are used to group similar kinds of tables. Drop-down menus facilitate selection of different systems and materials within the tables.

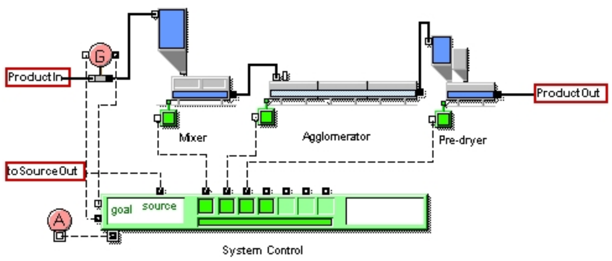


Figure 4: System Level Detail View

3.2 System Level

Double-clicking on the Making 1 system hierarchical block reveals the underlying detail shown in Figure 4. Making 1 consists of three operations; a Mixer, an Agglomerator, and a Pre-dryer. The System Control block manages the flow of product through these operations based upon a production and shift schedule selected within the controller. The total amount of product produced by the system is monitored, and changeovers triggered as production goals are met.

Schedules can be built in a standard format with the assistance of a wizard or populated with data directly from an Excel spreadsheet. SDI Industry supports the concept of dependent schedules, so that runs within the Packing schedule can be fed by runs within an upstream Making schedule. The database view in Figure 5 shows a typical Making schedule.

Making Schedule

Table Edit Selection

All | Materials | Systems | Failures | Changeovers | Schedules | Shifts | Reports

	Production Run	System	Product	Start Time	Goal
1	1	Making 1	Brand 1	0	60000
2	2	Making 2	Brand 2	0	30000

Figure 5: Typical Making Schedule

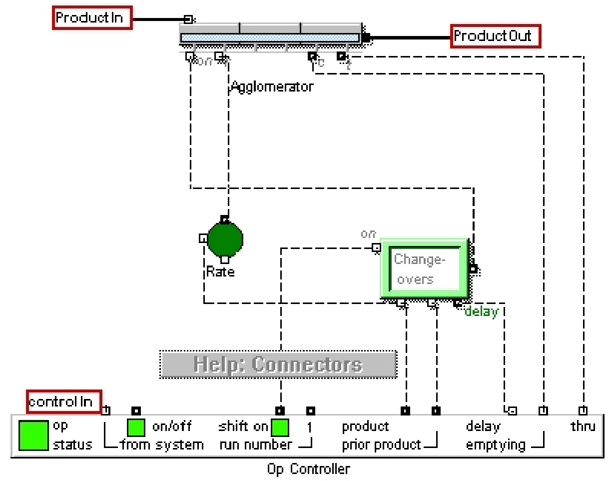


Figure 6: Operational Detail View

3.3 Operation Level

Each of the Operations is a hierarchical block. Double clicking on the Agglomerator block reveals the details of the Agglomerator operation, shown in Figure 6. The Operation Controller block at this level passes the prior and current product data and shift status information down to the Equipment level, and passes operation status information back up to the System Level. The Changeovers controller determines the changeover time associated with product changeovers as they occur. Figure 7 shows the changeover matrix referred to by this

Changeovers

Table Edit Selection

All | Materials | Systems | Failures | Changeovers | Schedules | Shifts | Reports

	From Sku	To sku1	To Sku 2	To Sku 3	To Brand	To Brand
1	From Sku 1	0	12	13	0	0
2	From Sku 2	21	0	23	0	0
3	From Sku 3	31	32	0	0	0
4	From Brand	0	0	0	0	120

Figure 7: Equipment Changeover Detail View

controller. The Rate controller uses the product SKU number to lookup the appropriate production rate for this Operation.

3.4 Equipment Level

Double-clicking on the Agglomerator block reveals the Equipment detail shown in Figure 8. This detail shows the flow blocks which model the actual operation of the Agglomerator. The Agglomerator is a constrained process with a defined material capacity, which can be modeled with just two flow blocks. The Process controller manages the Constraint block based on signals it

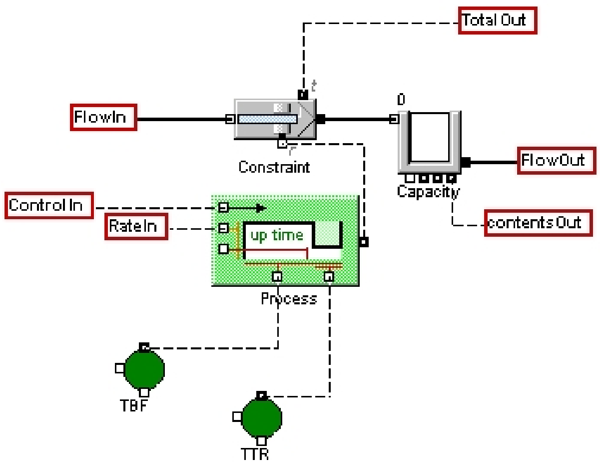


Figure 8: Equipment Level Detail View

receives from the TBF and TTR controllers and the operation controller. These signals are converted into rate information for the constraint block. Figure 9 shows the database input screen for inputting the failure data for the equipment in the model.

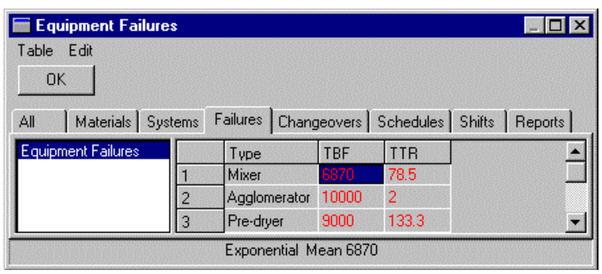


Figure 9: Equipment Failure Detail View

3.5 Example Summary

This model could be used to evaluate system reliability, test alternative scheduling algorithms, fine-tune distribution control strategies, determine the optimum size of in-process inventories, and study system constraints and the impact of rate changes.

Any of the levels shown here can be copied and pasted into new models, and then modified for application to other plants.

4 CONCLUSIONS

SDI Industry provides a unique new architecture specifically designed to address the needs of bulk and high speed consumer product producers. Simulation Dynamics has been using this tool kit to bring targeted solutions to their clients for over four years. Now SDI Industry brings the power of this architecture to your desktop. A companion product, *SDI Supply Chain*, is under development for extending this architecture to encompass the entire supply chain of a plant.

REFERENCES

Krahl, D. 1994. An introduction to Extend. In *Proceedings of the 1994 Winter Simulation Conference*, ed. J.D. Tew, S. Manivannan, D.A. Sadowski, and A.F. Seila, 538-545. IEEEE, Piscataway, NJ.

Siprelle, A. J. and D. J. Parsons. 1995. Modeling a bulk manufacturing system using Extend. In *Proceedings of the 1995 Winter Simulation Conference*, ed. J. D. Tew, S. Manivannan, D. A. Sadowski, and A.F. Seila, 813-817. IEEEE, Piscataway, NJ.

Sturrock, D. T. and G. R. Drake. 1996. Simulation for high-speed processing. In *Proceedings of the 1996 Winter Simulation Conference*, ed. J. M. Charnes, D. J. Morrice, D. T. Brunner, and J. J. Swain, 432-436. IEEEE, Piscataway, NJ.

AUTHOR BIOGRAPHIES

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