Simio 2021 May Student Competition

Demand Driven Materials Requirement Planning (DDMRP) Problem

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Overview

The Simio Shelving Shop is a shelving manufacturer and wholesaler specializing in several types of shelving units with design variations. The shop is currently experiencing low order fill rates (stockouts), affecting the shop's bottom line. Management recently hired an outside consultant to provide recommendations for revamping the inventory and buffering system. The consultant recommended a new dynamic buffering and inventory paradigm, Demand Driven Materials Requirement Planning (DDMRP), to address the rampant stockout issue.

The factory currently uses static buffer levels, where areas have a fixed amount of raw material buffered, and the factory maintains a fixed number of each product ready to ship. The current buffering method, combined with variations in lead time and quality throughout the factory and its suppliers, results in frequent stockouts of finished goods and raw material. Management embraced the consultant's recommendation to incorporate a DDMRP buffering solution into the factory because they are convinced that a dynamic buffering solution will improve selected Key Performance Indicators (KPIs), especially fill rate and average inventory cost. As a secondary objective, management also seeks better methods of monitoring risk in the buffer levels, which the DDMRP buffer profiles will provide.

The directive is to set up dynamic DDMRP buffers in the factory. This will include leveraging pre-existing data from Sales, Quality, Manufacturing, and suppliers to first determine the locations of the buffers, then fine-tuning the buffer parameters to improve the selected KPIs. After the buffers are integrated, management wants to predict the anticipated change in the factory's KPIs. Additionally, management would like to reevaluate potential suppliers, which have varying lead times and product quality. This assessment will include recreating optimal buffers for the potential suppliers to determine the impact each supplier could have on the company's fill rate and average inventory costs.

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Problem Description

Product Descriptions

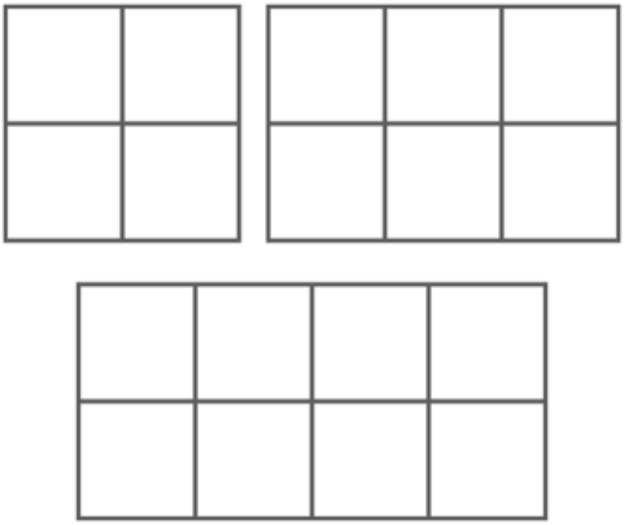
The Simio Shelving Shop specializes in cellular shelving units, with 1-foot by 1-foot compartments. There are six different shelf types, or products, with varying quantities of compartments and different types of wood, as shown in Table 1 below.

Table 1: Product Part numbers by shelf configuration and wood type

		Shelf Configuration		
		2x2	**2x3**	**2x4**
Wood Type	**Birch**	B22	B23	B24
	Oak	O22	O23	O24

Each product is framed by four pieces of wood on the top, bottom, left, and right and is backed by a panel. The middle shelving grid varies by each design type. Show below in Figure 1, is a front view of each of the three shelf designs.

Figure 1: The front-facing view of each shelf configuration: B22/O22 top left, B23/O23 top right, B24/O24 bottom



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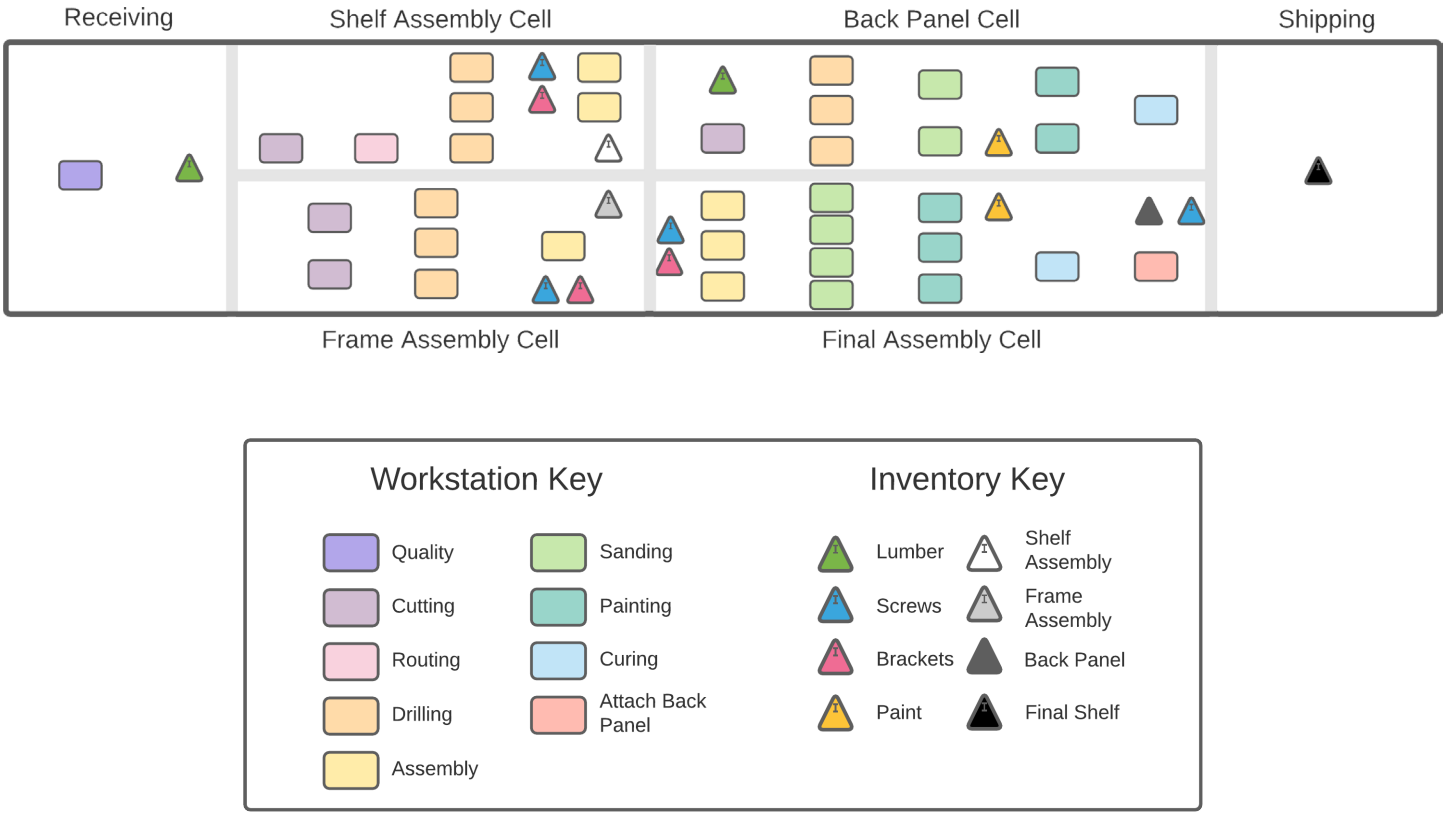
Facility Layout

The manufacturing facility is 129 meters long and 35 meters wide. To account for margins on the drawing, the size of the transparent layout image should be specified as 130 meters by 26.71 meters when importing into Simio. The facility uses a cellular layout with four cells, plus a Shipping Area. Aisles divide these cell locations. The Receiving Area accommodates the receiving dock, quality inspections, and raw material storage. Material flows from the Receiving Area to one of the four production cells: Shelf Assembly, Frame Assembly, Back Panel, and Final Assembly. After material flows through each of the production cells, the final assemblies are delivered to the Shipping Area to fulfill product demand for the day. Figure A shows the facility layout. A supplemental image file of the layout is provided with the attachments.

Figure 2: Simio Shelving Shop Facility Layout



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Manufacturing Process

All shelving units are split into three sub-assemblies: a frame assembly, a shelf assembly, and a back panel. Each sub-assembly is manufactured in its own cell, which includes individual stations for the value-added processes. Materials required for assembly are consumed at the corresponding station. For example, wood for the shelf assembly is consumed at the cutting station. You can find the material requirements in the BOM Matrix. The three sub-assemblies meet at a fourth cell where the final product is assembled. In each cell and station, products and subassemblies waiting in buffers are selected on a FIFO basis, where ties are broken by shortest processing time.

The frame assembly consists of four pieces of wood acting as the outer structure that holds the shelves. In the Frame Assembly Cell, the wooden boards must be cut to the correct length of the shelf design and then have pilot holes drilled for assembly. After each of the boards have been cut and the holes drilled, the frame is assembled using screws and brackets. Time studies have shown that the processing time of the cutting and drilling process for each frame varies by shelf configuration, but that the frame assembly time does not vary by shelf configuration. These times can be found upon investigation of the provided historical processing data.

The shelf assembly is made up of wood planks that become the grid structure within the frame. In the Shelf Assembly Cell, the shelf assembly adheres to the following steps in order: cutting, routing, drilling, assembly. When starting with the full, uncut wood board, this process is similar to the frame assembly cutting process. However, unlike other cutting processes where there is not enough remaining wood to be reused, after cutting the wood for the 2x4 shelf designs there is enough remaining scrap wood for it to be used elsewhere. This scrap wood plank goes into a special inventory exclusively used by B22 and O22 shelf assemblies, depending on the wood type. To maintain compliance with internal policies, this scrap wood plank cannot be used elsewhere in the facility, only for B22 and O22 shelf assemblies. Workers first use the half-planks of wood before resorting to full wood planks when cutting wood for a B22 or O22 shelf assembly but will only use this wood if there are at least two scrap pieces of the proper wood type available. When scrap wood is used in this way, the number of cuts is decreased, which decreases the overall processing time. This difference can be seen in the processing data. Cutting time also varies by shelf configuration and must be investigated in the processing data.

After the planks are cut for the shelf assembly, the shelves are notched at the routing station so they will sit together when assembled. A notch must be added at each intersection where one shelf plank meets another shelf plank and will be added to both planks, so they interlock. The processing time to complete the routing for each assembly varies by shelf configuration and can be found through analysis of the data file attachment.

Once the notches are added to the shelves, pilot holes must be drilled for each screw required for assembly. Processing times vary by shelf configuration as given in the data file attachment. After the pilot holes are drilled, the planks of wood are then assembled into the shelf assembly. This processing time also varies by shelf configuration and will need to be acquired from the data file attachment.

The final components of the shelf are the back panels, which are added to the rear of the final shelf assembly. The back panels must be cut and have pilot holes drilled like the shelf and frame assemblies. The back panel is sanded, painted, then placed on a rack to allow the paint to cure. The time to cut, drill, sand, and paint back panels varies by the shelf configuration, and will need to be collected through investigation of the data file attachment. Painted parts must always be set aside to cure for at least 60 minutes, and there is only room for a maximum of 50 back panels at the curing station.

In the Final Assembly Cell, the frame and shelf assemblies are combined first. After being attached, the frame and shelf subassembly is sanded and painted, much like the back panel. The subassembly is then placed on a rack for a 60-minute cure time. The curing station racks can hold up to 40 subassemblies at a time. After the subassembly has cured, the back panel is attached. Attaching the back panel always uses eight #12 x 2-1/2" wood screws (MAT006). and the unit is moved to the Shipping Area. The processing times for the assembly, sanding, painting, and attachment of the back panel vary by the shelf configuration. They must also be collected through analysis of the data file attachment.

There are setup times associated with each of the manufacturing processes, which have been estimated as part of another project. The resulting times are provided in Table 2. When wood needs to be cut, the worker needs to take a moment to dust off the machine, secure the wood, and adjust the cutting instruments to the correct measurements each time the cutting process is started for an assembly. When pilot holes need to be drilled, there is a time associated with setting up the drill press. Prior

to any assembly step, the pieces are placed in a jig to be held in place while the parts are screwed together. This occurs at each assembly step and when the back panel is attached. Before sanding an assembly, the belt sander is checked and dusted off, and the belt is replaced as needed. Before painting, the paint applicator also must be inspected and potentially refilled before coating an assembly. Lastly, prior to curing, the worker must carefully place the assembly to avoid disturbing the paint.

Table 2: Estimated setup time by task

Task	Minimum Time (sec)	Average Time (sec)	Maximum Time (sec)
Assembly	8	10	12
Cure	12	15	18
Cutting	24	30	36
Drilling	16	20	24
Painting	16	20	24
Routing	16	20	24
Sanding	12	15	18

Employees

The Simio Shelving Shop retains 33 employees to work on the factory floor, one to work at each station except for the two curing stations, which are unmanned. Although many employees are trained in more than one station, they are assigned to a station at the beginning of each shift and work at that station for the entire day. Before starting work on a particular unit, they will travel to the necessary inventory locations to acquire the necessary materials. After they complete their work, they will also deliver materials, including completed subassemblies, to their next holding locations. The factory runs on a single shift, so all employees work Monday through Friday following a 8:00 am to 5:00 pm work schedule, with a one-hour lunch break from 12:00 pm to 1:00 pm.

Current State Buffering and Inventory System

The Simio Shelving Shop currently maintains many buffer locations around the factory, so workers do not need to walk long distances to pick up required materials. The list of buffers and the locations they serve are shown in the data file, while the physical locations can be viewed in the facility layout. Each buffer is treated separately for the purpose of material replenishment. Meaning, if there are multiple places where one type of material is stored, each storage location has an individual replenishment policy.

All buffers use a min-max reordering policy. Every day at 5pm after the required number of completed shelves are set aside to be shipped, the shop submits orders for raw material, subassemblies, and completed shelves. For raw materials, if the current quantity of a material in inventory is equal to or less than its reorder point, a raw material order is submitted to the proper supplier for enough additional units to make the raw material's inventory position equal to the raw material's order-up-to-level. Orders for subassemblies and completed shelving units are submitted internally if the current quantity of a material in inventory is equal to or less than its reorder point. In this case, the order quantity will be the material's order-up-to-level plus any unmet demand that is logged for the day, minus the current WIP and material already in inventory. After an order for subassemblies or completed shelves is submitted, each subassembly or completed shelf is treated separately for the purposes of movement throughout the facility. In the current state system, the reorder point and order-up-to-level are static for all materials, and their values are provided in the data file attachment.

Suppliers, Receiving, and Quality

After an order for raw material is submitted, the order will arrive after a variable lead time. Lead times will need to be investigated in the provided Supplier data. Suppliers are grouped into two categories: local and not local. Raw material ordered from local suppliers is picked up directly from the supplier Monday through Friday and arrives at the factory at 9:00 am. Raw materials shipped from non-local suppliers through third-party parcel delivery services are delivered at 11:00 am Monday through Friday. The list of suppliers and the raw materials they provide can be found in Table 3. After the materials are delivered, they are inspected for any defects at the quality station in the Receiving Area. The Simio Shelving Shop has high standards for its materials, so incoming materials are thoroughly inspected. After the inspection, the material that passed the inspection is placed at the appropriate inventory locations by the quality inspector before the next inspection. Scrapped material is returned to the supplier, and the cost of that material is refunded. The time required for the inspection varies by material and must be investigated in the data file attachment.

Table 3: Raw Material Data

Material	Material Description	Supplier	Local	Minimum Order Quantity	Cost per Unit ($)
MAT001	Birch 3/4" x 14" x 54"	Incity Timber	FALSE	100	$6.24
MAT002	Oak 3/4" x 14" x 54"	Highe's Lumber	FALSE	150	$7.61
MAT003	Birch Paint (gal)	Local Storage Hardware	TRUE	50	$23.00
MAT004	Oak Paint (gal)	Jone's Paint Store	TRUE	30	$27.00
MAT005	#8 x 1/2" wood screws	Building Center	FALSE	1000	$0.04
MAT006	#12 x 2-1/2" wood screws	King's Supply Company	TRUE	1200	$0.07
MAT007	Brackets	Club Hardware	FALSE	500	$0.52

Product Demand

Demand for each type of shelf varies. Customer orders for each product are received and aggregated by the Sales department throughout each day. At 5pm every workday, the demand report is sent to the Shipping Area to indicate the quantity of each product to be shipped that day. After receiving the report, the requested quantity of shelves is loaded and shipped to the appropriate retailers. Any demand that cannot be met with the current stock of each product will be shipped on a future workday. Units missed from previous orders are shipped before units on the demand report that day. Data from the Sales department must be investigated to ensure that variable and unpredictable demand is appropriately represented when conducting analysis on the Simio Shelving Shop's manufacturing process.

Future State Buffering and Inventory System

Simio Shelving Shop management wants to revamp the facility's buffering system by incorporating a DDMRP dynamic inventory system for each buffer. Management wants to integrate a buffer configuration that will maximize the shop's order fill rate and minimize the shop's average inventory cost. Management has also given permission for buffers to be created or removed, provided all necessary stations have access to the required material and all buffers utilize the DDMRP dynamic replenishment policy. For the dynamic inventory system, management agreed to move forward with the information provided by the consultant. The equations the consultant provided are below, while the buffer chart examples are in the data file attachment. To become more familiar with DDMRP, some self-led investigation might be necessary.

The consultant provided a recommendation on how to incorporate the dynamic buffers to integrate seamlessly with the current state inventory replenishment process. Each buffer could continue to be treated separately for material replenishment, and buffer contents could be evaluated each day after the orders for the day have been shipped. At the end of each workday, after orders are fulfilled, the new zone levels for each buffer could be calculated using the equations provided. After these calculations, the inventory position of each buffer could be evaluated and compared to the zone levels. If the contents of the buffer are less than the current level of the green zone, an order is submitted for additional units to make the material's inventory position equal to the top of the current level of the green zone. Management is also open to other methods of incorporating dynamic buffers into the system.

Buffer Profile Equations:

*Green Zone Profile= Max(MOC*ADU,LT*ADU*LTF,MOQ)*
*Yellow Zone Profile= LT*ADU*
*Red Zone Profile= LT*ADU*LTF*(1+VF)*

Where:

- ADU is the average daily usage of the item stored in that buffer. ADU is usually a time-varying, trending average.
- LT (Lead Time) is the time it takes ordered product to arrive in the buffer.
- MOC (Minimum Order Cycle) is the minimum time between placing orders. At the Simio Shelving Shop, the MOC is 1 day for all materials.
- MOQ (Minimum Order Quantity) is the minimum number of units that can be purchased from a supplier at one time.
- LTF (Lead Time Factor) is a user-assignable parameter used to fine-tune the size of the Green and Red Zone Profiles.
- VF (Variability Factor) is a user-assignable parameter used to fine-tune the size of the Red Zone Profile.

Buffer Height Equations:

Red Zone Height=Red Zone Profile
Yellow Zone Height=Red Zone Profile+Yellow Zone Profile
Green Zone Height=Red Zone Profile+ Yellow Zone Profile+Green Zone Profile

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Analysis and Problem Deliverables

The Simio Shelving Shop's main objectives are to maximize the facility's order fill rate and minimize its inventory cost by changing its inventory policy to a DDMRP dynamic buffering model. The facility defines its order fill rate as the number of units shipped on time divided by the total day's demand, and its inventory cost as the cost of all inventory in stock. Management is also interested in the improvement in two of its other KPIs, throughput and average unit production time. Throughput is defined as the number of shelves completed per unit of time. Currently, the average weekly throughput is between 600 and 620 shelves. Average unit production time is defined as the average time between the submission of an order for a shelf to the time the shelf is completed, including weekends and off shift time. The current average unit production time is approximately 46 hours.

Management would like the following deliverables to be provided in the final report: the buffer configuration, the predicted improvements to the facility's primary KPIs, buffer plots that show the project's success, and buffer plots for the 5 buffers with the highest average inventory costs. The buffer configuration should include all information required to incorporate the new system, especially the stations served and any modified parameters such as the lead time and variability factors for each buffer. The facility's predicted KPIs from the new inventory system should be compared to the values of the current state KPIs. The KPIs to include in the report are average inventory cost, order fill rate, throughput, and average unit production time. The buffer plots should be labelled with the material and inventory location to help management evaluate risk caused by levels of inventory in the buffers.

Metrics that interest management:

- Throughput
- Average unit time in system
- Workstation utilization
- Average inventory cost for each buffer
- Number of stockouts
- Unmet demand by day

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Questions to answer include:

- What buffer configuration would you recommend better meet the factory's objectives?
- What is the predicted change on the order fill rate and average inventory cost with the new dynamic buffer configuration?
- Which 5 buffers have the highest average inventory cost?
- Which 3 materials have the highest average inventory cost?

Challenge Problem

The contract with Highe's Lumber for oak planks will expire in three months, so management has tasked you with determining whether the Simio Shelving Shop should renew the contract or accept one of the contracts presented by two potential suppliers, Watson Lumber Company or Pacifica Timber. The Simio Shelving Shop has completed a trial period with each supplier to evaluate quality levels and provided the resulting data from the shop's ERP system. Because the potential supplier change would occur after dynamic buffers are integrated into the shop, management would like each supplier to be evaluated in conjunction with the dynamic buffers. Management has also dictated that the selected supplier must not have a negative impact on the shop's order fill rate. The trial period data for Watson Lumber Company and Pacifica Timber can be found in the Challenge Problem Data File.

Attachments

The link for the attachments and descriptions of the data contained in each data file can be found below.

https://cdn.simio.com/StudentCompetition/2021May_Data.zip

DataFile.xlsx

The Data File attachment contains data from various locations on the Simio Shelving Shop factory floor, in addition to some other information. Each sheet in the Excel Workbook is described on the next pages.

BOM Matrix. This sheet contains the matrix of the quantity of each part number required for each assembly and subassembly.

BOM Matrix Notes: In the Final Assembly Cell, the attach back panel station always consumes eight units of MAT006. The remaining units of MAT006 are used in the assembly station to attach the frame and shelf assemblies. All MAT005 and MAT007 are used at the assembly station.

Example BOM Matrix. This sheet provides an example and explanation of the information provided in the BOM Matrix sheet.

Current State Inventory Policy. This sheet contains the current state inventory configuration and replenishment policy parameters.

DDMRP Buffer Chart Examples. Contains the sample buffer charts provided by the consultant.

Processing Data. This sheet contains processing data collected from stations around the factory.

Quality Data. This sheet contains quality inspection data.

Sales Data. This sheet contains a report generated by the Sales department providing the number of products ordered by day.

Supplier Data. This sheet contains data on orders of raw material from suppliers.

ChallengeProblemDataFile.xlsx

The challenge problem data file contains data from the potential suppliers. Each sheet in the Excel Workbook is described below.

PT – Quality Data. This sheet contains quality inspection data from the trial period with Pacifica Timber.

PT – Supplier Data. This sheet contains data on orders of raw material from suppliers from the trial period with Pacifica Timber.

WLC – Quality Data. This sheet contains quality inspection data from the trial period with Watson Lumber Company.

WLC – Supplier Data. This sheet contains data on orders of raw material from suppliers from the trial period with Watson Lumber Company.

Image Folder

This folder contains the layout image files for importation into Simio.

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