The JOB SHOP GAME

This simple game was developed by
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The JOB SHOP GAME
Instructor Information

Objective of Game
The student will be able to understand how Drum-Buffer-Rope (DBR) scheduling applies to Job Shop environments.

Overview:
The game is played by releasing up to 36 Orders, one at a time, into the shop and sending them through four different Work Centers (A - D) to make the product. The Orders are monitored to determine how long it takes to get an Order processed from start-to-finish (flow time). The flow days are recorded on a chart. The results are analyzed.

Background:
In a Job shop environment, machines are organized in a functional layout (machines with similar processing characteristics are grouped together in a Work Center). Each Order that is released follows a specific routing (a processing sequence) through the Work Centers.

With the high variety of routings and loads (setup and run times), you have a complex environment which is extremely hard to schedule. The bottlenecks (constraints) seem to constantly shift, making it difficult to determine when Orders will be completed.

Even though Job Shop environments range from 'High Variety / Low Volume' (Unique One-of-a Kind, ex. a tooling shop), to 'Lower Variety / Higher Volume' (ex. a production shop where the parts for a set of products are made in batches on a regular basis), this exercise effectively demonstrates the applicability of DBR to all Job Shop environments.

Work Centers & Capacity:
For this exercise, our Job Shop has four (4) Work Centers (A - D) and each Work Center has one machine. The processing capability of each Work Center is specialized, so you can't use alternate routings.

Each machine has only enough capacity to perform one operation per day.

Products:
There are 36 Order cards and each Order card has a Product # (1 - 4) on it.

For the student who works in a High Variety / Low Volume environment, there are four product TYPES represented by the Product # (1 - 4) [ex. four different types of tools]. Each Order card represents a UNIQUE PRODUCT [tool] within each product type.

For the student who works in a Lower Variety / Higher Volume environment, there are four different PARTS represented by the Product # (1 - 4). Each Order card represents a different BATCH of each part.

Routings:

The process Routing, which represents the necessary sequence of Operations (the Work Center where each operation is to be performed) is on the Order Card. Orders must be processed by the Work Centers in the same sequence as the Routing.

Role Requirements:

The Instructor should assign students to the Scheduler, Work Center Operator, and Flow Control Monitor roles. The roles have the following requirements:

Scheduler - This game requires the Scheduler to be able to add up the buffer count and determine whether to release an order.

Work Center Operator - At the end of the day in scenario 3, the students will be required to indicate the number of 'B' operations that have not been completed on the orders in their queue. This will be indicated by either a closed fist for none, or the appropriate number of fingers.

Flow Control Monitor - Must be able to calculate the flow days for each Order card by subtracting the Release Day from the Shop Day.

Allow the students to select their own roles.

The Players & Duties:

Scheduler (One): When the Instructor calls out "Shop Day ...", the Scheduler makes a decision to Release/Not Release an Order card according to the specific scenario instructions. When the Instructor calls out "Write...", and the Order is going to be released, the Scheduler writes the Shop Day on the 'Release Day' line on the Order card. When the Instructor calls out "Pass...", the Scheduler passes the Order card to the queue of the initial Work Center (the first Operation).

Work Center Operators (Four): Each Work Center can only process a maximum of one Order per day. When the Instructor calls out "Shop Day ...", the Operator takes ONE Order card from their queue (if there are any Order cards in the queue), writes the Shop Day in the appropriate 'Routing Box' on the Order card. When the Instructor calls out "Pass...", the Operator passes the Order card on to the next Work Center queue on the routing, or to the Flow Control Monitor if the Order card is complete. For best results, the Operator should process all Orders in a 'First-In-First-Out' (FIFO) sequence [otherwise you end up with a FISH (First-In-Stays-Here) sequence.

Flow Control Monitor (One): Calculates the flow days for each Order card by subtracting the Release Day from the Shop Day in the last 'Routing Box' and writes the flow days on the 'Total Flow Days' line on the Order card. When each Scenario is complete, the Flow Control Monitor also plots the data from the Order cards - see Data Plotting instructions.

General Instructions:

The Instructor controls the rate of play and will call out Shop Days until all the Orders have been completely processed. Students will follow the cadence and not work ahead.

Preparing the Students:

In order to have the students perform the exercise correctly, the Instructor must make sure that the students understand what to do and when to do it. Clearly explain the responsibilities of each role and how to properly record data on the 'Order card' and Flow Days charts.

Also, the students must understand that they are not to work ahead or fall behind. Everyone must be in sync or the exercise will not demonstrate the desired points. Possibly consider explaining that the Instructor is like a Conductor and everyone must follow the beat or the resulting sound will not be beautiful music - just a lot of noise.

The Queue:

The queue in front of each operator is a piece of 8 ½ x 11 paper with the Work Center Letter written on it. Remind them to keep their orders in First-In-First-Out (FIFO) sequence and give them time, especially operator 'B', to stay organized.

The Order Card:

Below is an example of the Order Card. It contains the following items:

Product or Part: Labeled 1 - 4, this indicates either 1) which product type is represented (high variety/low volume environments) or 2) a batch of parts numbered 1-4 (lower variety/higher volume environment).

Release Day (Shop Day): When the Instructor calls out "Shop Day ...", the Scheduler makes a decision to Release/Not Release an Order card according to the specific scenario instructions. When the Instructor calls out "Write...", and the Order is going to be released, the Scheduler writes the Shop Day on the 'Release Day' line on the Order card.

Routing Box/Shop Day: When the Instructor calls out "Shop Day ...", the Operator takes ONE Order card from their queue (if there are any Order cards in the queue), writes the Shop Day in the appropriate 'Routing Box' on the Order card.

Last Operation Day minus Release Day: When the order is completed, the Flow Control Monitor will calculate the flow days for each Order card by subtracting the Release Day from the Shop Day in the last 'Routing Box' and writes the flow days on the 'Total Flow Days' line on the Order card.

Scenario Instructions:

This requires that the room remain quiet during the exercise so that all the students can clearly hear the instructions.

Scenarios Overview:

The first two scenarios are run in a Traditional Job Shop scheduling manner. Scenario #2 is a traditional job shop scheduling, but there is an attempt to minimize work in process at Work Center B. Scenario #2 may be skipped if time is short. Scenario #3 is a Drum-Buffer-Rope environment.

Scenario #1 Instructions:

The Scheduler should first shuffle the Order cards. The Scheduler will release one Order card each Shop Day until all Order cards have been released.

For each Shop Day, the Instructor will:
Call out the Shop Day (ex. "Shop Day #7")
Pause, then tell the students to write the number of the Shop Day (ex. "Write #7") on the next Order card in their queue waiting to be processed (using the FIFO method).
Pause, then tell the students to pass the Order card to the next Work Center on the Routing or to the Flow Control Monitor if the Order is finished (ex. "Pass the Order card")
At completion, record the data. (See 'Data Plotting Instructions')
At the completion, discuss with the students:
Ability to Promise Customer Delivery
Ability to predict Order Completion
What's holding you back?
How were your Flow Days (Lead Times)?
What did your Variability look like?
What changes did you see in your system comparing the beginning to the end?
Any Growth? Growth of what?
How would you compare your Capacity to your Workoad?
Comment on the Inventory in the System
Scenario #2 Instructions:
The Scheduler, with the help of the other members of the team, will use their intuition and the Routings to sequence the Order cards so that the bottleneck Work Center ('B') is not so plugged up with Inventory. The Scheduler will release one Order card each day just as in Scenario #1.
For each Shop Day, the Instructor will:
Call out the Shop Day (ex. "Shop Day #7")
Pause, then tell the students to write the number of the Shop Day (ex. "Write #7") on the next Order card in their queue waiting to be processed (using the FIFO method).
Pause, then tell the students to pass the Order card to the next Work Center on the Routing or to the Flow Control Monitor if the Order is finished (ex. "Pass the Order card")
At completion, record the data. (See 'Data Plotting Instructions')
At the completion of the second scenario, discuss the amount (insignificant or lack of) improvement when using intuitive scheduling.

Scenario #3 Instructions:
An explanation of Drum-Buffer-Rope (DBR) is given before the third scenario is run. Depending on the depth of the knowledge the students have of DBR, they may be able to analyze the results of the previous exercises and make a determination of the correct buffer size. If not, the Instructor will have to give an explanation and guidance. The buffer size should be no less than 4 and no greater than 6. See the 'Observations/Results' for Scenario #3.
The Instructor will ensure that the Scheduler arranges the Order cards in the same release sequence that was used in the previous Scenario. Explain to the students that the reason is to provide a direct comparison of results between

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the two scheduling methods. The Scheduler will release orders into the shop based on how much work is in the buffer. The amount of work in the buffer is defined as the number of Work Center 'B' operations which have not been completed for all Order cards on the shop floor. At the beginning of each Shop Day, when the Instructor says "Buffer Count", the Scheduler will count all the number of 'B' operations which have not yet been completed no matter where they are located (include un-completed B work on cards at the other Work Centers also). If the number of 'B' operations yet to be completed is less than the buffer size, the Scheduler will plan to release one Order card. If the number of 'B' operations is equal to or greater than the buffer size, the buffer is considered full and no Order card is released.

For each Shop Day, the Instructor will:

Call out "Buffer Count" and the students will raise one finger for each 'B' operation which has not been completed on the Orders in their queue - use a closed fist if they have none. The Scheduler will count the fingers and make a determination of whether or not to release an order for the day.

Pause

Call out the Shop Day (ex. "Shop Day #7")

Pause, then tell the students to write the number of the Shop Day (ex. "Write #7") on the next Order card in their queue waiting to be processed (using the FIFO method).

Pause, then tell the students to pass the Order card to the next Work Center on the Routing or to the Flow Control Monitor if the Order is finished (ex. "Pass the Order card")

At completion, record the data. (See 'Data Plotting Instructions')

At the completion of the third scenario, compare the results to the first two scenarios in the same terms used in Scenario #1.

Data Plotting Instructions:

There are two charts for plotting Order card data (see examples below).

I. 'No. Of Flow Days vs. Orders (in Release Day sequence)' (top chart)

This chart represents the number of Total Flow Days for each Order card.

A. Arrange the Order cards in sequence by Release Day. Each order will have its own column.

B. Plot the 'Total Flow Days' by putting an 'X' in the appropriate column at the 'Total Flow Days' height.

C. ex. the ninth Order released had Total Flow Days = 15

II. 'No. Of Orders vs. Flow Days (Distribution)' (bottom chart)

This chart represents the number of Order cards that have the same number of Total Flow Days.

A. For each Order card, put an 'X' in the column (starting at the bottom of the chart and working up) representing the 'Total Flow Days' for each order.

B. ex. Six orders had Total Flow Days = 7

Traditional Scheduling Example

Summary

Observations / Results:

Scenario #1: Using the traditional scheduling techniques, the first orders are processed in 4 days, but as more orders are released, the flow time increases and becomes highly variable, making order promising a risky proposition and causing a lot of padding to be added to the expected completion date to avoid late delivery. This results in lead times for the Customer getting longer and still missing delivery dates. In addition, WIP inventories continue to increase in front of the bottleneck Work Center ('B').

Traditional Scheduling Example

Scenario #2: Again, the results are about the same as Scenario #1. There will be no significant improvement and maybe even slightly worse results. (See 'Data Plotting Instructions - Traditional Scheduling Example')

Scenario #3: Using the Drum-Buffer-Rope (DBR) scheduling technique, the flow days range from 4 to about 10 with the most common values (the tallest columns) of 5 and 6, if the exercise is performed correctly. This results in short lead times for the Customer and no missed delivery dates, and very little inventory in the system at any one time. Note: If the buffer size is set to 4, the Constraint will occasionally run out of work, Throughput is decreased, and the flow days will be slightly higher. When the constraint runs out of work, the buffer should be increased by one. If the buffer size is 6 or higher, the inventory will be slightly higher and the flow days will increase. If the queue for Work Center 'B' never gets below 2, then the buffer is too big. A correctly sized buffer provides maximum Throughput with minimum Flow Days and Inventory. If the buffer is too small, Throughput decreases. If the buffer is too big, both Flow Time and Inventory increase.

DBR Scheduling Example

Conclusion:

DBR is an appropriate technique for scheduling a complex manufacturing environment.

(Results documented by Chuck Gauthier, Alpha West, Portland, OR, Summer 1998)

Advance Simulations

Luck of the Draw

Shuffle the Cards for Scenario #3: Clever students can spend a lot of time arranging the cards into a nice sequence. They may think that the performance of the system is because of their cleverness. Of course, cleverness is not always possible in real life. Buy shuffling the cards, you see that it is the DBR control that give the predictable outcome not cleverness (although, cleverness can give a slightly tighter flow day distribution when used with DBR).

Change Over

Inserting DBR on the fly: Often students ask the question, "How can I implement DBR in our Job Shop?" A fun simulation is to run Scenario #1 for 20 days which builds up a healthy Queue in the system and THEN implement DBR from Scenario #3. You have to hold back releasing work until the selected buffer size is reached. After that, things are smooth again. It shows very nicely on the flow day visuals.

Variability

Using Dice: After you gain proficiency in using the Job Shop game, you may want to move forward to some more complex models. The basic game is deterministic. That is, the only variability is the shuffle of the cards before the start of the game. This is not realistic. To simulate variability, you can give each Work Center a single die. Each day the Work Center rolls the die. If the roll is 2,3,4,5 or 6, the Work Center is productive that day (acts normally). If the roll is a 1, the Work Center is not productive (cannot do any work at all - cannot write a number). You may want to play this game yourself before working with the students. You will find that both Scenario #1 and Scenario #3 perform almost the same as before only with a bit more variability in the outcomes. The parallelism is surprising.

Kanban

Just In Time: Doing Kanban flow in a flow line is easy to watch. But, doing Kanban in a Job Shop is hard and takes a lot of careful control. If you are brave, you can try to do Kanban with the Job Shop Game as a comparison with DBR. I suggest using a Kanban size of two cards (one in process and one waiting). This way, the maximum theoretical work in process would be 8 cards. There are a lot of different possible outcomes depending upon your control of the system. In the Job Shop, cards often flow from two Work Centers to one Work Center. This leads to a decision of who gets to move there and who doesn't if the Kanban for the receiving Work Center is full. With students, this often becomes 'whoever is fastest'. As such, you can get a nice distribution with a few way out outliers. The key to running Kanban is the release of work. the scheduler calls out the day but only writes the release date if it is possible to release work on that day. Since this is similar to the rope in DBR, you will get a tight distribution of flow times. However, rather than having a safe feeling buffer, the work in process varies drastically and often approaches zero in Work Center B's queue. If you play Kanban with dice, you will surely starve Work Center B once or twice in 36 cards.

Dynamic Buffering

Advance Buffer Management: In general, buffer sizes are fixed. But, there are some cases where it is justified to change the buffer size (adjust up and down). One such incident is when the work load on the system shifts and causes a non-constraint to become more heavily loaded than the chosen constraint. When this happens, you have a choice to change the constraint of the company (not the recommended option since it changes the whole measurement system and subordination process) or to increase the buffer size to accommodate the temporary change in product mix. This is a hard thing to teach and difficult for students to understand, however, with the Job Shop Game, it is easy to demonstrate. Here is how. Create another Product #5 that flows to C->A->C->D. Take the basic 36 cards and shuffle them to play Scenario #3 as usual. The scheduler will insert the Product #5 card for the Product #2 card as follows: After the tenth day (and until the 25th day), every time a Product #2 card comes up, exchange it for the new Product #5. This will shift the system constraint to Work Center C temporally. If you have too small a buffer for the real constraint Work Center B, the buffer will not be enough to assure continued production on the constraint. Allow the students to determine how to increase the buffer size during the temporary shift in product mix such that Work Center B does not run out of work. Encourage them to return the buffer size to its original size after the day 25.

I hope you enjoy playing the Job Shop Game as much as I do. It is a robust exercise that really opens the eyes to the necessity of the rope in DBR. The cleaver instructor can use the Job Shop game (with variabilty) as an effective introduction to problems with Multi Tasking in Projects and the Critical Chain Project Management techniques.

Of course, I'm always looking for improvements. Please contribute your suggestions.

Dr. Holt

Support Materials:

- Blank Charts
- Basic Jobs (1-4)
- Advanced Jobs (5-8)