Manufacturing Simulation Game© 1997

Playing the Game

Props

1) One building block tower kit, consists of 21 block towers.
2) A stopwatch, needed to determine manufacturing lead time.
3) Measurement Chart, which is a dry erase board or flip chart to document the measurements and differences between the three simulations.
4) Calculator
5) Five 3 inch square pieces of paper with a blocked "X" on each of them.

The PLAYERS

Materials Manager: The Materials Manager **releases raw material to the first (green) assembly operation**. They will release columns of four black based towers then one white based tower. They will repeat this process four times until all twenty towers have been released. As they release each white base they are to say aloud, "Releasing first white base; second white base; third white base; or fourth white base." In both the "Push" and "Pull" sequences the materials manager will always make one tower base available to the first operation.

Green Assembly Operator: This operator places two green blocks on top of red blocks in a crisscrossing pattern to add strength to the tower.

Blue Assembly Operator: This operator places two blue blocks on top of green blocks in crisscrossing pattern to add strength to the tower.

Yellow/Blue/Yellow/Green Assembly Operator: This operator places two yellow blocks in opposite corners and fills remaining two corners with one blue block and one green block.

White Assembly Operator: This operator places two white blocks on top of the yellow/blue/yellow/green blocks.

Red Assembly Operator: This operator places two red blocks on top of white blocks in crisscrossing pattern to add strength to the tower. As each tower is assembled and placed into **Finished Goods** the Red Assembly Operator says aloud, "Completed first white base; second white base; third white base; or fourth white base."

Quality Control Inspector: This person's job is to visually inspect the towers for correct color sequence to the Master Tower. We all know how much value is added to a product by inspecting the product prior to shipping (none in most cases).

8 **Controller:** As the materials manager is signaling which white base is being released into production the Controller counts the number of black and white bases released into production and records the data on the Measurement Chart. The Controller should **not** count any unreleased raw material or finished goods as these are not considered work-in-process.

9 **Production Control Manager:** This person will be responsible for gathering the **historical data** of the manufacturing simulation game. As the Materials Manager is signaling which white base is being released into production; the Production Control Manager will start the stopwatch on the first white base and record the time of each white base released thereafter. As each white base reaches finished goods inventory then the Quality Control Inspector will **signal** which white base is being completed. The Production Control Manager will also record this time on the Measurement Chart.

10 **The Customer:** The customer is the **leader of the pull simulation game** and must become familiar with the remaining material in this manual so as to answer questions and probe for feedback from the other participants. This game can be somewhat unpredictable, as you will learn through the teaching process.

Starting the Game: "Push" Simulation

You (**leader/customer**) should go around the table and disassemble the master block to each of the five assembly operators in the sequence required to build one tower. Your discussion can be centered on internal customer and supplier relationships. Explain to the group you are asking for a prototype to be manufactured by them.

Release the raw material base and watch each assembly operator assemble in the correct color and method as discussed in the Player Section. This tends to eliminate questions on how to assemble the blocks. After they complete this **master tower**, approve it as a **quality prototype** by which all other production will be judged.. If it is not a quality product, then disassemble the tower and try it again until they get it right.

The reason for this prototype step is simple. First of all, it lets the assembly operators and the audience know who the customer is. A lot of firms and employees today do not know who the end customer really is. Therefore, identifying the customer and your mind-set is important. The other reason is that when I did the game in China, I had the bottleneck operator placing the four building-block pieces upside down. He would take the sub-assembled tower from his supplier (blue operator), assembling the blocks by pressing the top of the tower onto all four blocks simultaneously, and then flipping the tower over for the next assembly operator. Do not allow this to happen because, as it turns out, the bottleneck could move, depending on the physical dexterity of the other participants. Have each operator place their pieces on top of the tower as it progresses through the assembly process. This master tower allows you to change incorrect methods before starting the simulations.

Setting or Resetting the Game:

The next step is to set up the game. I carry the towers already assembled from the previous demonstration. Therefore, I have the participants pass the tower from finished goods backwards through the process, taking off their appropriate color and shape combination at each assembly operation. This will give each assembly operator the correct number of building blocks to be used. Have each of the manufacturing assembly operators start by disassembling the towers from finished goods to raw material bases. Once the blocks are in the raw material form, arrange the bases into four columns of five bases. **Each column will have four black bases and one white base. The white base should be the last one released for each column.**

Now is the time to explain to the participants the difference between the black base towers and the white base towers. Tell them the only difference is that the white base towers will be used by the Controller and Production Control Manager to determine the measurements of the manufacturing system. They also should be told to keep them in the correct sequence (four black and one white). If the towers get out of sequence, the timing and WIP values could be off for an individual timing.

Now it is time for the **fun part for the leader**. By this time one or all of the assembly operators have arranged the blocks to ease their assembly method. The leader's job is to say that we are manufacturing towers today and therefore, we do not have time to organize our workplaces. The leader is to go in front of each assembly operation and mess up their organized workplace pieces. This usually gets a good laugh out of the participants, and they will mess up their organized work station before you can get to them.

An organized work station is very important. We all recognize that an organized workplace makes a more effective worker. This demonstration needs to keep all of the variables between the "Push" and "Pull" to have the same frequency of occurring. **Therefore, do not let the operators organize their workstations in either simulation.**

Ask for any final questions on assignments. Tell the manufacturing operators to go **as fast as they can. The leader's** job is to go to the **bottleneck operation and keep the blocks in the proper sequence.** As the bottleneck operator gets behind, the feeder operation will overrun the bottleneck, thus getting the blocks out of the correct sequence (four black bases then one white base).

On your mark! Get set! Go!

Question (9): Ask the Quality Control Manager if all product meets the master tower sample?
Answer: If no defects are found, then tell the manufacturing people they have done a good job and you will purchase the entire order. If a defect is found, then the leader/customer is to reject all twenty pieces and tell the manufacturing people you refuse to pay for their hard efforts and will go to their competitor with future business.

Post the times on the Measurement Chart as shown below.

The Production Control Manager will fill in the Start and Finish times. Notice that the clock does not start until the first white base is released.

The Controller will fill in the work-in-process as each white block is released.

Calculate the average time to complete one tower and the range of time for one tower.

	PUSH					PULL			
	Start	Finish	Second	WIP		Start	Finish	Second	WIP
1	0:00	0:55	55	5	1				
2	0:19	1:34	75	9	2				
3	0:38	2:13	95	10	3				
4	0:56	3:12	136	15	4				

Calculate the average time = (55+75+95+136) / 4 = 90.25 seconds
Calculate the Range = (largest time minus shortest time) = (136-55) = 81

A **bottleneck** is a resource (man or machine) whose capacity is less than demand.

The leader should ask these series of questions.

Question (12): How do you think you did?
Statement (13): Manufacturing has a natural occurring phenomenon called a "Bottleneck."
Question (14): Who is the bottleneck operator?
Question (15): How can you tell?
Answer: It should be the Red/Blue/Blue/Green Assembly Operator, because the queue behind this operator is large as compared to the other operations. This operation will require more time to assemble four pieces than it does to assemble two pieces.

Question (16): Asked to the bottleneck operator. How did you feel as the towers started to pile up behind you?
Answer: Hopefully you will get an honest answer, and "nervous" best describes their feelings. But I have heard, "I was doing the best I could do" or "I did not care."

Question (17): If the Red/Blue/Blue/Green operator is the bottleneck, then which operation is second most important?
Answer: The Blue Assembly Operator and/or the Green Assembly Operator because they directly feed the bottleneck operation. If these operations shut down long enough to shut down the bottleneck operation, then the time that the bottleneck is down can not be made up. The Materials Manager releasing raw material is also important because if raw materials are not available to release, then the bottleneck operation could eventually shut down. The other two operations downstream from the bottleneck can make up time because their time to assemble is shorter than the bottleneck. These operations can experience temporary shutdowns without affecting the bottleneck, but could affect the total amount of work-in-process in the system.

The leader will refer to your Measurements Chart, and I will refer to the sample above.
Statement (18): Your average time is 90.25 seconds to complete a white base. Your range is 81 seconds to complete a white base.

Question (19): What do you think your time to complete another tower would be?
Question (20): If I were the customer, what would be the delivery time you would quote to me? The leader's job here is to play devil's advocate. If the group says the shortest time or the average time, then point out what happened to those late deliveries. As a supplier with late deliveries a customer will do business elsewhere. If the group says the longest time, then point out that their trend is getting longer and longer and you, the customer, need a good answer because the customer is rating your performance based on on-time-delivery.

Answer: There is no right answer. Given the data above, the process is out of control. If a range is more than half of the average, then the condition is obviously out of control. If more blocks for towers were supplied, then the times would get even longer. We recognize that this is historical data and that management will use this data to measure performance. The moral to the story is that we try to manage a process without recognizing that the process is out-of-control. So, for our example of the "Push" Manufacturing technique, we will settle for the average time, but understand that the process is out-of-control.

Question (22): What should be your investment in work-in-process?
Answer: The WIP trend is usually always headed in an upward direction. Explain that the average cost of a tower in WIP is $100 dollars per tower. In our example, we required from $500 to $1,500 of work-in-process capital.

Question (22): How much capital do you need to run this manufacturing business?
Answer: Like the time associated with quoting a manufacturing lead time, the WIP cannot be determined at this time. However, the upward direction it is headed usually indicates that someone has to increase the amount of investment associated with the manufacturing business and a WIP range value would indicate an out-of-control situation.

"Pull" Simulation Game

Now it is time to reset the game for the "Pull" Manufacturing Simulation.
Resetting the game is done the same way as setting up for the first "Push" Simulation.
Please refer to the Setting or Resetting the Game section of this manual for details.

Implement the Control:

Take the **Kanban cards** of the game and place them in **between each operation** (see step 5 in the prop's section). Explain that these are **kanban squares** and they are to be used to signal work required between operations. **If the square is empty, then do work to fill it. If the square is full, then do not work.** Actually I do allow for a queue of one tower in a kanban square after an operation, one tower in the kanban square before an operation, and one tower inside an operation being assembled.

Everything about the game is the same except that the **raw material is released only if the kanban square is empty**. The five assemblers do the same thing as before. Assemble a quality product as fast as they can. The leader will not be required to go to the bottleneck operation during the "Pull" simulation.. The Kanban cards will control the correct sequence of towers as they move from operation to operation. The leader should make sure that none of the operators have organized their workstation. If they have, then simply jumble the blocks in a pile. It is important to keep as many variables as possible in both simulation games. Ask for any final questions on assignments.

On your mark! Get set! Go!

Question (26): Ask the Quality Control Manager if all products meet the master tower sample?
Answer: If no defects are found, then tell the manufacturing people they have done a good job and you will purchase the entire order. If a defect is found, then the leader/customer is to reject all twenty pieces and tell the manufacturing people you refuse to pay for their hard efforts and will go to their competitor with future business.

Post the times on the Measurement Chart as shown below.
The Production Control Manager will fill in the Start and Finish time. Notice that the clock does not start until the first white base is released.
The Controller will fill in the work-in-process as each white block is released. A helpful hint is that the number is almost always five for each measurement (no more than six). Since there are five operations and five blocks in a column, then each time a white block is released there are some black blocks that are finished goods that are not counted.

Calculate the average time to complete one tower and the range of time for one tower.

PUSH	Start	Finish	Seconds	WIP
1	0:00	0:55	55	5
2	0:19	1:34	75	9
3	0:38	2:13	95	10
4	0:56	3:12	136	15

PULL	Start	Finish	Seconds	WIP
1	0:00	0:49	47	5
2	0:34	1:25	51	5
3	1:16	2:02	46	5
4	1:55	2:45	50	5

Calculate the average time = (47+51+46+50) / 4 = 48.5 seconds
Calculate the Range = (largest time minus shortest time) = (51-46) = 5

The leader should ask the same series of questions.

Question (28): How do you think you did?

Statement (29): Manufacturing has a natural occurring phenomenon called a "Bottleneck."

Question (30): Who is the bottleneck operator?
Question (31): How can you tell?

Answer: It should be the Red/Blue/Blue/Green Assembly . This operation will require more time to assemble four pieces than it does to assemble two pieces. Therefore, the other four operators had idle time on their hands waiting for the bottleneck operator to complete the tower assembly.

Question (32): Now with this idle time we could move some of the work performed by the bottleneck operator to balance the assembly line. Correct?

Question (33): Was there a lot of idle time with any operators?
Answer: Yes. Usually with the operators that have a two block assembly process.

Question (34): What can we now do with this idle time?
Answer: You would use these operators to perform other duties, such as preventative maintenance, cross training, and continuous improvements. The preventative maintenance an operator performs will make that operation less likely for breakdowns. The cross training makes the operator more valuable to the firm. A flexible person can move to another operation when a co-worker is out or when kanban signals require resources to move in the direction of the problem. I have heard several in the audience state a manpower reduction. This is not a bad answer, but I do not believe that it is the best answer. Keep in mind that a reduction in the work force sends a message to that work force on how management intends to view other continuous improvements. Since labor is approximately 5 to 15 percent of the cost of a product, realizing a labor saving may more than offset by deflating the morale of the work force. Use the resource of labor as experts in continuous improvement. They are experts at their operations and have many good ideas to reduce the process time of your product.

Question (35): What happens to our bottleneck?
Answer: It will move to another operation depending on how we redistribute the work of assembling towers. A bottleneck will always occur in a manufacturing sequence. If we relocate work or "break" the bottleneck we need to keep in mind that this is the correct thing to do, but we must determine where we moved the bottleneck.

Question (36): Where would we like to move our bottleneck operation?
Answer: The first operation in the process should be the bottleneck operation while balancing the other operations. This allows all other operations to experience temporary shutdowns without affecting the bottleneck. The Kanban Squares keep the work-in-process controlled between operations.

Question (37) Asked to the bottleneck operator: How did you feel as the towers started to pile up behind you?
Answer: Hopefully you will get an honest answer, and "not as rushed" best describe their feelings.

The leader will refer to your Measurements Chart and I will refer to the sample above.
Statement (38): Your average time is 48.5 seconds to complete a white base. Your range is 5 seconds to complete a white base.

Question (39): What do you think your time to complete another tower would be?
Question (40): If I were the customer, what would be the delivery time you would quote to me?
Answer: The biggest difference is that the participants will see that the average time and range are much closer together and easier to predict. Hence, the system is in better control.

Question (41): What should be your investment in work-in-process?
Answer: Consistent. The WIP trend is flat and predictable because it is controlled by the kanban squares. Comparing the two sets of data will lead one to believe that cash can now be freed up to purchase needed resources.

Question (42): Which method is easier, a "Push" system or a "Pull" system?
Answer: The "Pull" system is better.

The difference between the "Push" and "Pull" times (3:12 and 2:45) is a learning curve of assembling the towers the second time. I have actually seen the "Pull" total time longer than the "Push." This is usually attributed to a quality problem at the bottleneck requiring rework which did not occur in the push simulation. Even when this occurs the average time, range time, and work-in-process values are more consistent in the "Pull" simulation. Also from this are group discussions on how soon the problem was detected and the number of rework pieces that would be required in a push verse a pull system.

I have even had groups that think this is a parlor trick. Once in China, I asked which method was better? They said they wanted to reset the "Push" simulation to better their times. I told them they would not improve their average time, range time, and work-in-process values over the "Pull" simulation. We reset the game and did another "Push" simulation. They did improve their overall total time to assemble the towers. After all, it was the third time they had performed the simulation. But to their surprise, their average time, range, and work-in-process were still inconsistent, unpredictable, and out of control. They finally said that the "Pull" system was a better method of manufacturing.

Flexibility:

What happens if a certain machine experiences a breakdown? What happens if an operator fails to show up at work? In a push system, work-in-process is usually increased every where except at the bottleneck operation whose operator is absent. Occasionally, if the operation is critical, someone else with training moves into the position temporaily. But the operation they moved from suffers. I have seen management move operators in a push environment to help an operation that is behind schedule. Those reassigned operators are the same ones that are required to work overtime and Saturdays to catch up their own jobs later in the work week. This will build an anti-continuous improvement wall between management and the work force.

A flexible operator adds value to the firm. The most unused resource is the mind of the operator. It is critical in a pull environment that the operators be cross trained to work their assigned job plus one upstream and one downstream. A team will perform better that a group of individuals. As operators are cross trained, they will provide you with improvements of doing the work. It will also give the operator a better understanding of the responsibilities of quality from his customer and supplier. This operator becomes his own customer and supplier.

Now **reset the game one more time!**

You are going to simulate a pull system one more time. Once the towers have been disassembled, ask each assembly operator individually if they know how to perform the job of the operator up stream and down stream from them. Concentrate this question at the bottleneck and their internal customer and supplier.

Ask the bottleneck operator to get up and leave. You simply explain to the audience that this person called in sick this morning. This usually gives the operators on each side of the bottleneck a chance to stare at each other, and generates laughs from the audience.

Question (45): What do you expect the outcome to be?
Comment (46): The kanban will now signal the operators to move and flex in the direction where work is required. If the downstream kanban is empty then fill it. If the upstream kanban is empty then flex upstream.

On your mark! Get Set! GO!

With the bottleneck operator out of the picture and the kanban signals still in place, the operators will naturally flex up to the bottleneck when the simulation begins. Your job, as leader, is to make sure that they also flex down if the signals call for a move in that direction. Make all of the operators move to the work station which require work up or down stream. Remember, you now have two two operators putting on four blocks pieces and two operators putting on two block pieces. This is an imbalance of work content. Therefore, the bottleneck will move several times during this simulation.

Ask many of the same questions in the pull simulation sequence. Refer to the Simulation Highlights for the Leader: "Flexibility" section of this manual. The work-in-process is exactly the same as in the pull simulation since we did nothing to change it. You should expect about the same average time and range time as in the pull simulation. But since we changed the variable of the bottleneck operation you should expect an improvement. The idle time has changed to work time but is somewhat off set by operator confusion and movement to different work areas. In either case, the difference will be insignificant to a twenty percent reduction of the work force. The point we are trying to make is that flexibility allows the production to continue at the natural rate only if resources are trained to flex. It is important to have a flexible resource if you want to produce what the customer wants, when the customer wants it.

In a push system with no resource flexibility, inventory is the result, with hidden problems and cost. In a pull system with no resource flexibility, the line stops, but the problem of no flexibility is exposed and can be corrected. Therefore it is critical that flexible resources become part of your pull manufacturing implementation plan.