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A Simulation Tool to Compare MRP, JIT, AND TOC

The production planning and control philosophies are often taught with religious zeal. The instructors' commitment and belief in one system over another often loses objectivity. Therefore, it became necessary to develop a process that would demonstrate each of the methodologies in such a way as to show the students the advantages and disadvantages of each. Each system has been found to be more effective in some specific production situations over others. This appropriateness of fit comes through in the demonstration of the methodologies.

The most commonly used production planning and control methodologies are Material Requirements Planning (MRP), Just-in-Time (JIT), and Optimized Production Technology (OPT) with its updated version called Theory of Constraints (TOC). Appendix 1 shows some of the advantages and disadvantages of each of these systems. This is what the simulation tool discussed in this article attempts to draw out of the students.

The Simulation Procedure

The simulation is run on three different days; one day for each of the production planning philosophies demonstrated. Each simulation is preceded by a thorough discussion of the production planning methodology. MRP is usually the first discussed, since it is the most common in the United States. Following the discussion, the MRP simulation is run. Afterward, a case study is often used to cement the concepts into the memory of the students. Then, JIT is discussed, simulated, and demonstrated with a case. And lastly, TOC is taught in the same way. This article will not discuss the instruction of the production planning concepts, or the use of a case study. Instead, it will focus on the operation of the simulation.

Abstract

A simulation tool has been developed that allows for the comparison of the three most popular production planning philosophies: MRP, JIT, TOC. A mini production facility is set up and each of these production processes is demonstrated in the classroom or in seminars. Through this tool, students can see the advantages and disadvantages of each production planning environment.

The MRP Simulation

For all the simulation exercise, the class is assigned into the following departments:

Management (whose responsibility is observation, measurement, and improvement of the process)

Materials Movers (MM) (they handle all parts transfers between departments and from raw materials)

Quality (Q)

Shipping (S)

Production Department 1 (PD1)

Production Department 2 (PD2)

Production Department 3 (PD3)

The production sequence is MM-PD1-PD2-Q-PD3-Q-S.

1) The instructions for each department and for each simulation are given in appendix 2.

2) The production process is to fill out the “produced product” card shown at the beginning of appendix 2 according to the instructions. Each department is to set up an “IN” box, an “OUT” box, and, in the case of inspection and shipping, a “REJECT” box. The production process is run for five minutes and the department efficiencies are measured. Then the class is given time to make changes to the process, within the rules specified on the following sections. The five minute production process is repeated to see if the changes have made any improvements. This sequence can be repeated four or five times, each time improving and refining the process.

MRP Simulation Procedure

Step(I) Set up Procedure:

Assign Departments and hand out instruction sheets

Supply raw materials to Materials Movers

Setup someone in management to time the production process (5 minute days)

Setup product throughput counters for each department to track throughput performance

Step (II) Run process for 5 minutes

Step (III) Check:

Efficiency of each Department

Output performance for each Production Department

Step (IV) Discuss:

Methods to improve the “system”

Allow them to:

- set up work-in-process inventories
- hire more movers and inspectors
- setup a rework department
- train and cross-train
- communicate between departments

Do not allow them to:

move equipment or departments

change lot sizes

send rejects back to previous work stations

What are the real problems with efficient Department performance?

Step (V) Make improvements that management agrees to that will improve the “numbers”

Step (VI) Repeat steps II through V watching improvement each time

Step (VII) Wrap-up discussion

How have we improved the production process?

What are the shortcomings of labor efficiency as a performance measure?

What has happened to inventory levels?

What has happened to the non-value-added functions (overhead)?
 What improvements have been made through the use of a MRP style production process?

MRP Measurements

Measures of Efficiency and Performance:

- PD 1 Throughput - Number of units placed in the "out" box of this department during the production cycle
- PD 2 Throughput
- PD 3 Throughput

Measures to be used for comparative purposes in later simulations:

- Inspection Rejects
- Shipping Rejects
- PD 1 WIP
- PD 2 WIP
- PD 3 WIP
- Inspection WIP
- Other WIP
- Shipped
- Number of overhead personnel

Typical improvements recommended by the students to improve departmental throughput and efficiency include:

- Quality Training and cross training
- Inventory Build-up
- What Happens to Rejects
- Improve Communications between inspection and the departments
- Bell Ringer to identify materials ready for transfer
- Rework Department
- Reengineer some of the process steps
- Hire more movers and inspectors

In the end, only departmental throughput and efficiency matter. The other measures listed above are for future comparative purposes only. A successful MRP simulation is one where these two measures have been improved, usually at the cost of increased inventory and overhead.

The JIT Simulation

In the JIT simulation, the class starts out from the same spot that they started from in the MRP simulation. They are instructed about their new objectives and restrictions, and they are told that the production process has now changed somewhat, but it is up to them to figure out how. The assignment sheets are handed out with new assignments given to each student (see appendix 2). Then the class is given up front time to make changes to the production process before the first simulation is run. The first run of the MRP simulation is the data used as the starting point for the JIT simulation. The first JIT simulation is the second run in the JIT series of improvements.

In the JIT simulation the following are changed:

(Please note the new inspection procedure for JIT in appendix 2).

JIT Simulation Procedure

Step(I) Same as MRP but the following is added:

- Open the class for discussion focusing on the new performance measurements
- Permit changes to the production process

Step(II) Run process for 5 minutes
 Run a marked unit through the system and measure product cycle time

Step(III) Check:
 Output performance for the production process

- Throughput to Customer
- Reject percentage of each phase
- WIP levels
- Cycle Time

Step(IV) Discuss:
 Methods to improve the "system"

Allow them to:

- Move work-stations closer together (reorganize)
- train and cross-train
- communicate between departments
- in-line quality training
- convert job functions
- change the way job functions are performed
- change the production level

Do not allow them to:

change lot sizes - initially force them to enlarge lot sizes but in later simulations allow them to reduce the lot size

What are the real problems with efficient throughput performance?

Step(V) Same as in MRP

Step(VI) Same as MRP

Step(VII) Wrap-up discussion

How have we improved the production process?

Discuss waste elimination and inventory reduction.

What has happened to the non-value-added function (overhead)?

What improvements have been made through the use of a JIT style production process?

What are the shortcomings of materials efficiency as a performance measure?

Note the following types of improvements and compare them using the numbers with the MRP simulation:

- Quality Training and cross-training
- Sequencing
- Job function changes - no inspectors
- Multiple production lines

Two production lines (Quality and Rework become a line)

- Batch size reductions
 - Eliminate rework
 - Cross training - employees at end support front
 - PD 2 writing sequence changed
- Transfer in the way work should be done
- Shut down phasing out of the production process early to reduce WIP
- In-line corrections
- In-line quality
- Bottleneck identification
- Kanban control on WIP

Attempt to:

Eliminate all WIP

Eliminate all Waste (extra functions)

JIT Measurements

Measures of Efficiency and Performance:

- Shipping Throughput
- Inspection Rejects
- Shipping Rejects
- PD 1 WIP
- PD 2 WIP
- PD 3 WIP
- Inspection WIP
- Other WIP
- Total Product Cycle Time
- Number of overhead personnel

Measures to be used for comparative purposes in other simulations:

PD 1 Throughput - Number of units placed in the "out" box of this department during the production cycle

PD 2 Throughput

PD 3 Throughput

At the end we want to demonstrate:

- High levels of total throughput as measured by customer shipments
- Low total cycle times
- The elimination of all WIP
- The elimination of all Waste (extra functions)
- Low reject counts
- Low overhead (excess personnel)

The TOC Simulation

In the TOC simulation, the class again starts out from the same spot that they started from in the MRP simulation. This is because most TOC implementations start from MRP, not from JIT. It also helps to establish a common basis for comparison.

The students are again instructed about their new objectives and restrictions, and they are told that the production process has now changed somewhat, but it is up to them to figure out how. The assignment sheets are handed out with new assignments given to each student. Then the class is given up-front time to make changes to the production process before the first simulation is run. The first run of the MRP simulation is the data used as the starting point for the TOC simulation. The first TOC simulation is the second run in the TOC series of improvements. In the TOC simulation the following are changed:

(Please note the new inspection procedure from TOC in appendix 2).

TOC Simulation Procedure

Step (I) Same as in MRP except the following is added:

- Open the class for discussion focusing on the new performance measurements
 - analyze the process and attempt to identify any bottlenecks
- Permit changes to the production process

Step(II) Run process for 5 minutes \bar{n} same as in JIT
Run a marked unit through the system and measure product cycle time

Step(III) Check:

- Output performance for the production process
- Throughput to Customer
- WIP levels
- Operating Cost

Step(IV) Discuss:

Methods to improve the "system"

Allow them to:

- train and cross-train
- communicate between departments
- in-line quality training
- convert job functions
- change the way job functions are performed
- change the production level
- change lot sizes

Do not allow them to:

move work-stations closer together (reorganize)

What are the real problems with efficient bottleneck performance?

Step(V) Same as MRP

Step(VI) Same as MRP

Step(VII) Wrap-up discussion

How have we improved the production process?

Discuss bottleneck efficiency and inventory reduction.

What improvements have been made through the use of a TOC style production process?

What are the shortcomings of bottleneck efficiency as a performance focus?

Note the following types of improvements and compare them using the numbers with the MRP and JIT simulation:

- Batch size reductions
- Redefinition in the way work should be done
- Reduce WIP
- Bottleneck identification
- Prioritization of job functions
- Production wave performance
- Operating cost effects
- Throughput improvements

Attempt to:

Eliminate all WIP
Eliminate all Waste (extra functions)
Make the bottleneck as efficient as possible

TOC Measurements

Measures of Efficiency and Performance:

- Shipping Throughput
- Inspection WIP
- Other WIP
- PD 1 WIP
- PD2 WIP
- PD3 WIP
- Operational Costs

Measures to be used for comparative purposes in other simulations:

- Inspection Rejects
- Shipping Rejects
- PD 1 Throughput - Number of units placed in the “out” box of this department during the production cycle
- PD 2 Throughput
- PD 3 Throughput
- Total Product Cycle Time
- Number of overhead personnel

At the end, we want to demonstrate:

High levels of total throughput as measured by customer shipments
Low operating costs
Low inventory levels

A SAMPLE SIMULATION

The resulting data from one of the simulation series is as follows:

MRP Simulation- Run #	1	2	3	4
* PD 1 Throughput	20	20	42	50
* PD 2 Throughput	19	30	51	55
* PD 3 Throughput	0	20	36	50
Shipped	0	14	20	45
Inspection Rejects	20	5	3	2
Shipping Rejects	0	1	3	2
WIP	6	38	70	95
Direct Labor	3	3	6	8
Overhead Personnel	3	3	4	4

Production emphasis was placed on the items with the “*”. As expected, department throughput (labor efficiency) improved from run 1 to 4, at the cost of increased overhead and increased inventory.

JIT Simulation-

Run #	1	2	3	4
* Shipped	0	30	60	75
* Inspection Rejects	20	0	0	0
* Shipping Rejects	0	0	0	0
* WIP	6	3	2	0
Direct Labor	3	3	6	6
Overhead Personnel	3	3	0	0

As expected, the emphasis on product shipped and inventory minimization (materials efficiency) resulted in specific improvements in the areas. The costs of this efficiency was labor inefficiency because the work loads were unbalanced and occasionally there were workers with nothing to do.

TOC Simulation -

Run #	1	2	3	4
* Bottleneck Throughput	19	30	50	0
* Shipped	0	30	50	50
Inspection Rejects	20	10	7	8
Shipping Rejects	0	4	6	5
WIP	6	13	22	30
Direct Labor	3	3	6	6
Overhead Personnel	3	3	3	3

and Inventory Management Journal, Second Quarter, 1986, Volume 27, Number 2, pp. 22-29.

Plenert, Gerhard J., and Terry Lee, "Optimizing Theory of Constraints when new product alternatives exist", Production and Inventory Management Journal, Third Quarter, 1993, Volume 34, Number 3, pp. 51-57.

Plenert, Gerhard J., "Optimizing Theory of Constraints when multiple constrained resources exist" European Journal of Operations Research, October 1993, Vol. 70, pp. 126-133.

Plenert, Gerhard J., "Successful factory management systems" Produktiviti, Bil. 42. Jul/Ogos, 1992, pp. 2-6.

Plenert, Gerhard, The Plant Operations Handbook, Business 1 IRWIN, 1993, Homewood, Ill.

Plenert, Gerhard J., "Three different concepts for JIT", Production and Inventory Management Journal, Second Quarter, 1990, Vol. 31, No. 2, pp. 1-2.

Plenert, Gerhard J., "What manufacturing resources are critical?" Produktiviti, Bil. 42. Jul/Ogos, 1992, pp. 14.

Plenert, Gerhard (1995) World Class Manager, Rocklin, CA: Prima Publishing.

Plossl, G. W., and O. W. Wight, Production and Inventory Control: Principles and Techniques, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1967.

Shingo, Shiego, Non-Stock Production: The Shingo System for Continuous Improvement, Productivity Press, Cambridge, MA, 1988.

Appendix 1

Comparisons Between MRP, JIT, and TOC -

Feature/Function	MRP	JIT	TOC
Complexity			
Computer	High	None	Medium
Mathematical	Minimal	Minimal	High
Usage	Complex	Medium	Complex
Installation			
Conversion			
from EOQ	Simple	Simple	Simple
from MRP		Difficult	Medium
Data Prep.	Complex	Medium	Complex
User Disruption			
from EOQ	Major	Medium	Major
from MRP		Major	Major
Cost			
Systems	High	Medium	High
Plant	Low	High	Low
Flexibility			
Operation	Rigid	Rigid	Simulation
Product	High	Low	High
Scheduling	High	Rigid	Medium
Quality			
Integration	Minimal	High	Minimal
Productivity			
Labor	High	Low	Low
Materials	Medium	High	Medium
Machinery	Low	Low	High
Production			
Batch Sizing	Rigid	Rigid	Flexible
Lead Time	Long	Short	Medium
Order Track	Detailed	None	Detailed
Shop Layout	Open	None	Open
Inventory	High	Low	High
Setup Time	High	Low	High
Resource	Labor	Materials	Machinery

Manufacturing

Discrete	Good	Good	Good
Process	Poor	Good	Good
Mk to Stk	Good	Good	Good
Mk to Ordrr	Excellent	Good	Good
Mk to Ordrr	Excellent	Good	Good
Repetitive	Good	Excellent	Good
Non-Rep.	Good	Poor	Good
Capacity Loading			
Flexibility	High-Labor	Minimal	High/Machine
Cost			
Control	High-Batch	Minimal-Avg.	Medium
Measurement	Labor/Materials	Over-All	Medium
Purchasing			
Lead Time	Long	Short	Long
Scheduling	Easy	Annual	Medium

Appendix 2

Simulation Process for MRP, JIT and TOC

The Produced Product – Side A

A	B	C	D	E	F	G
H	I	J	K	L	M	
N	O	P	Q	R	S	T
U	V	W	X	Y	Z	

Side B

1	2	3	4	5
6	7	8	9	10

The Instruction Sheets for MRP, JIT and TOC Simulation -

INSTRUCTIONS TO MATERIALS MOVER

In our production system, we move materials from:

- Production Department (PD) 1 to PD 2
- PD 2 to Inspection (I)
- Inspection to PD 3
- PD 3 to Inspection
- Inspection to Shipping (S)

You are to move sheets from PD 1 to PD 2 whenever a full lot of five sheets is placed in the Move Location. If there are less than five sheets, don't move them until there is a full lot of five. All stations have locations to put the incoming materials.

Move from PD 2 to I in lots of five.

I have two move locations. Out to PD 3 and out to S. Move sheets placed on either of these locations to their proper destination. There is no lot size on these transfers.

PD 3 output is to be moved to I only in lots of five.

NO DISCUSSION OF TASKS IS ALLOWED !!!!!

INSTRUCTIONS TO PRODUCTION DEPARTMENT (PD) 1

You are to fill in the first 13 boxes on side A with the letters A through M. Write carefully and neatly, using printed capital letters.

Take empty sheets (the raw materials) as you need them, but your production lot size is five. When you have processed five sheets (a full lot), put the completed lot on the "move" space.

If you ruin a sheet, complete your work on it anyway and send it through the system.

NO DISCUSSION OF TASKS IS ALLOWED !!!!!

INSTRUCTIONS TO PRODUCTION DEPARTMENT (PD) 2

You are to fill in the second 13 boxes on side A with the letters N through Z, BUT YOU MUST WRITE THEM BACKWARDS, starting with Z in the last box, and working backwards until you finish with N in the 14th box. Write carefully and neatly, using printed capital letters.

Your raw materials is a partially filled-in sheet coming from PD 1. If you have no raw material to work on, wait until you do. You can take sheets as you need them from your "IN" location, but your production output lot size is five. Each time you have processed five sheets (a full lot), put the completed lot on the "move" space.

If you ruin a sheet, complete your work on it anyway and send it through the system.

NO DISCUSSION OF TASKS IS ALLOWED !!!!!

INSTRUCTIONS TO PRODUCTION DEPARTMENT (PD) 3

You are to fill in the ten boxes on side B with the numbers 1 through 10. Write carefully and neatly, using printed capital letters.

Your raw materials is a partially filled-in sheet coming from PD 2 and inspection. If you have no raw material to work on, wait until you do. You can take sheets as you need them from your "IN" location, but your production output lot size is five. Each time you have processed five sheets (a full lot), put the completed lot on the "move" space.

If you ruin a sheet, complete your work on it anyway and send it through the system.

NO DISCUSSION OF TASKS IS ALLOWED !!!!!

INSTRUCTIONS TO THE INSPECTION DEPARTMENT FOR THE MRP SIMULATION

You are to check sheets coming from Production Department (PD) 2, then inspect again after PD 3. Put all rejects on the "reject" location, and acceptable product in the proper "out" location, either to PD 3 or to Shipment. The materials mover will come by from time to time to empty out

your out boxes. In inspection, check for the following quality characteristics: All characters must be completely inside the boxes Letters must be well-formed capital letters .

The letters O and Q must be fully closed, with no open spaces in the circle

Right

O Q

Wrong

O Q

The numeral "1" must be formed as shown below whenever it appears

Right

1

Wrong

1 1 1

When you have completed the last inspection, put your initials on the space provided on B side of the paper before putting the finished product in the out to shipment location.

NO DISCUSSION OF TASKS IS ALLOWED !!!!!

INSTRUCTIONS TO THE SHIPPING

As materials arrive from the final inspection station, look over the sheets to make sure that Inspection didn't miss anything. You have been given a copy of the inspection instructions so you know what to look for. Also, make sure that the inspector has signed or initialed the inspection sheet .

If any sheet is defective in any way, including missing the inspector's initials, put it on the reject pile. Otherwise, it is accepted.

NO DISCUSSION OF TASKS IS ALLOWED !!!!!

CHANGES TO THE INSTRUCTIONS TO THE INSPECTION STATION FOR JIT

In inspection, check for the following quality characteristics:

All characters must be completely inside the boxes

Letters must be well-formed capital letters

The letter A must be fully closed, with no open spaces

Right

A A

Wrong

A A

The letter U cannot have a down-stroke to its right

Right

U

Wrong

U

The numeral 11 "4" 11 must be open on the top and closed on the bottom

Right

4

Wrong

4 4 4

CHANGES TO THE INSTRUCTIONS TO THE INSPECTION STATION FOR TOC

In inspection, check for the following quality characteristics:

All characters must be completely inside the boxes

Letters must be well-formed capital letters

The letter K must be touching, but not crossing

Right

K

Wrong

K K

The letter W must be rounded, not sharp pointed

Right


Wrong


The numeral 11"6"11 must have a small loop, not a large loop

Right


Wrong
