Merits and Limitations of Various Practical Approaches to Job Shop Production Management

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About Job Shops

- What is job shop?
- No single, universally acceptable definition of job shop
- Examples:
- Machine shops, fabrication shops, forge shops, mold shops, tool and die shops,
- Custom woodworking, architectural millwork,
- Repair shops, MRO units, etc.
- I often see job shops:
  - (1) Making a variety of products for small quantities, (2) Making a product only against a received order, (3) Making several distinct products simultaneously.

Job shop Features

- Small and mid-sized production units (in terms of size and revenue)
- High-variety, low-volume (HMLV) production
- Different routings for different types of products
- Make-to-order / engineer-to-order production
- Custom manufacturing (with major changes in product properties and process requirements)
- Order-driven production aiming to meet specific due dates of customer orders

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Job shop Features

- Several distinct jobs simultaneously progressing on shop floor while competing for shared resources
- Usage of multi-functional machines and multi-skilled workers for various operations
- Non-sequential operations of a job
- Acceptance of rush orders (jobs)
- Unexpected changes in job priorities

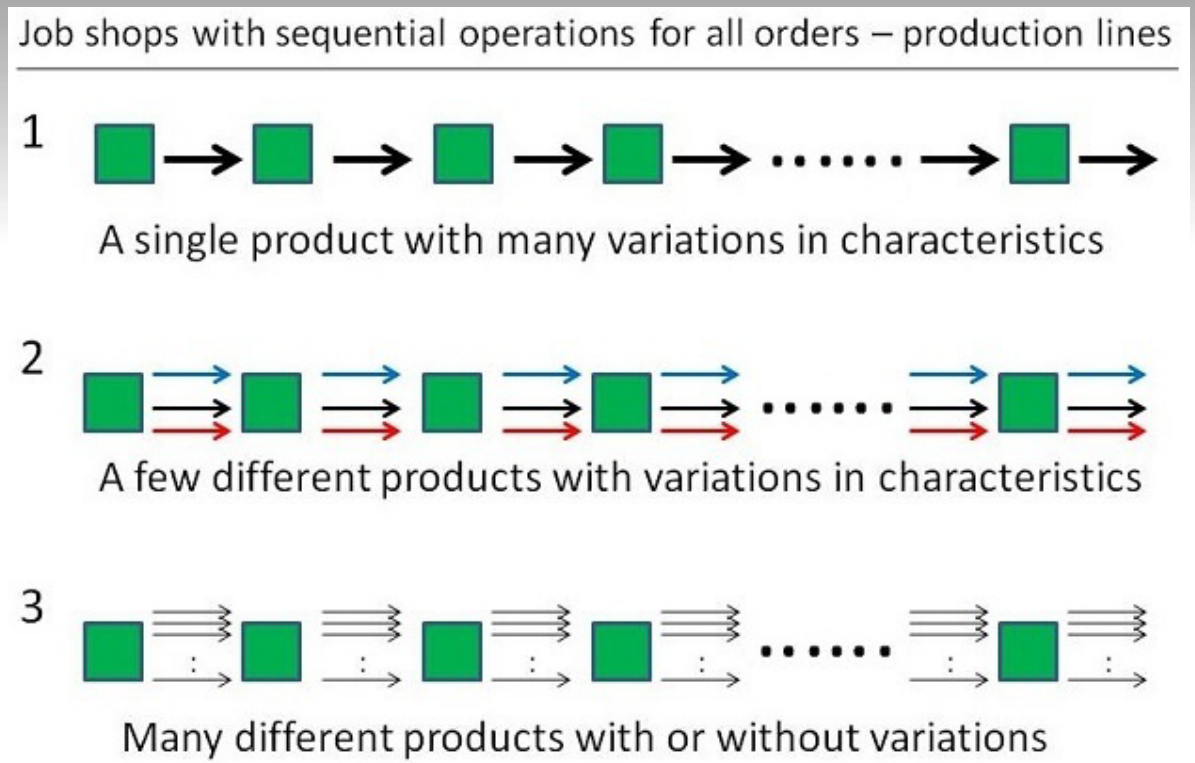
Material Flows in Job Shops

Three types of production systems in job shops:

1. A single production line
2. A set of parallel production lines
3. A system more complex than production lines with several products simultaneously moving through a network of work centers

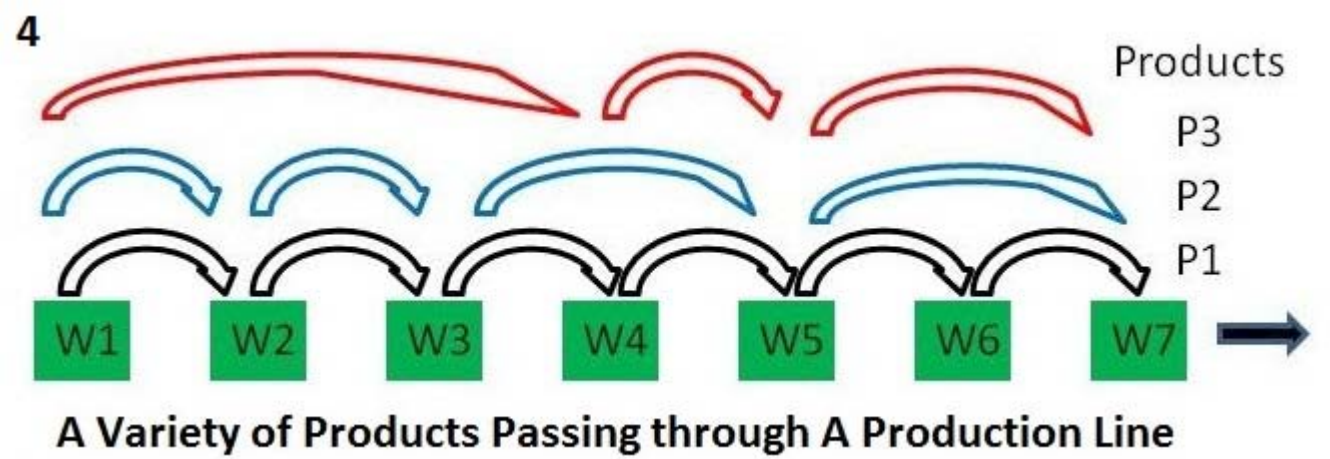
Material Flows in Job Shops

- A few types of linear production systems



Material Flows in Job Shops

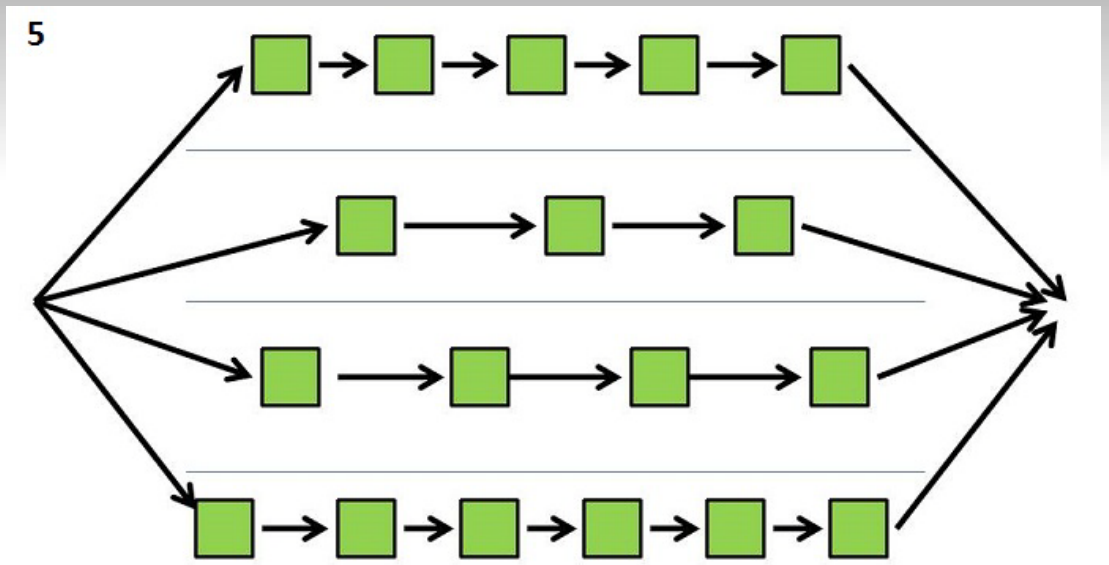
- A production line with products skipping some operations



A Variety of Products Passing through A Production Line

Material Flows in Job Shops

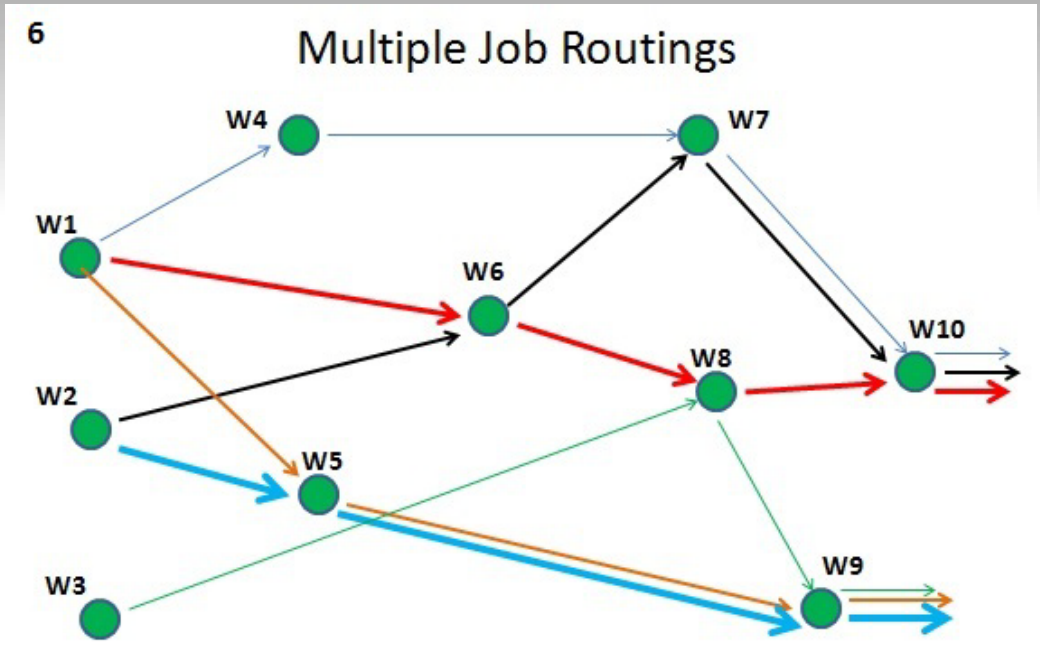
- A system with parallel, independent production lines for making a variety of products (product families)



Parallel Production Lines for Different Products

Material Flows in Job Shops

A network of work centers with each job passing through a sequence of work centers for process requirements



Material Flows through A Network of 10 Work Centers in A Job Shop

Complexity of job shop production

Due to customers:

- Customers place orders at unpredictable times for unpredictable quantities, process requirements and lead times.
- Unlike Toyota dealers, many job shop customers are quite authoritative and dominating.
- Customers may sometimes force changes in process requirements, quantities or job priorities.
- On-time delivery is very important for customers of make-to-order (MTO) shops.

Complexity of job shop production

Due to materials:

- For some raw materials, maintaining inventory in support of unpredictable demand may not be economically viable.
- A job shop may need to place an order for some materials only after receiving the corresponding customer order.
- Material procurement times may be long and/or uncertain with an adverse impact on production schedule and on-time delivery.
- Material requirements may not be stable over time due to varying product mix.

Complexity of job shop production

Due to the nature of workload:

- Large known variation in process requirements across orders
- Necessity to make products against received orders
- Various types of orders flowing through a network of work centers
- Rush orders and unexpected changes in job priorities
- Unexpected changes in quantities, process requirements and even resource requirements after orders are received

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Complexity of job shop production

Due to the nature of workload:

- Simultaneous production of many distinct, low-volume jobs (with different routings) and the resulting waiting at common work centers

- Precedence relations among operations of a job forming a network rather a sequence.

Complexity of job shop production

Due to resources:

- Multi-resource requirements of operations
- Limited resources including multi-functional machines and multi-skilled workers
- Possibility of different weekly working hours for resources
- Changes in available working hours due to machine breakdowns, maintenance, worker absenteeism, overtime, etc.

Need for Intelligent Production Control in Job Shops

In complex job shops, improvement of overall production performance needs more than:

- Improving leadership skills, communication, human aspects and working culture
- Performing each production operation efficiently
- Eliminating defects and reducing rework/rejections
- Minimizing setup times and material movement times
- Doing 5S and pull-based production control
- Visual management.

Various Methods for Production Control in Job Shops

Several approaches are available for production control with certain limitations. They include:

- Toyota production control methods (part of Lean)
- CONWIP (Constant WIP)
- Quick response manufacturing (QRM)
- Mixed Model Value Streams (MMVS)
- Theory of Constraints (TOC)
- Scheduling with whiteboards, Excel applications or project management software
- Finite capacity scheduling (FCS) or APS.

Lean Manufacturing Methods for Production Control

Line Balancing, Flow, Pull & Heijunka:

- Line balancing is relevant to a production line but inappropriate for job shops which are more complex than production lines.
- Flow is not economically viable in job shops where many different jobs simultaneously move along distinct routings and compete for shared resources.
- Kanban and heijunka are not much effective for high-variety production systems in general.
- All these methods are appropriate for production lines.

CONWIP Method for Production Control

- Stands for constant WIP (work in process)
- A production control method that is somewhat similar to kanban and aims to control total WIP in the system.
- Works with cards like a kanban method.
- Ensures that total WIP in production remains constant.
- Input to shop is directly controlled by release of output.
- Uses a fixed number of cards and assigns one of the cards to a part when material for the part is released to the first work center.

CONWIP Method for Production Control

- When a part leaves production system after its completion, the card attached to it will be returned to the card collection.
- A part is not released to shop floor until a free card is available.
- More effective than kanban for WIP reduction in multi-product parallel production
- Not very effective for large known variation in process requirements of products (with distinct routings)
- Ineffective for MTO production systems in general.

Quick Response Manufacturing

- Developed for MTO / ETO production systems
- Mostly focused on production control for reducing Manufacturing Cycle Time (MCT)
- Not focused on improving the speed or efficiency of individual operations
- Involves major restructuring of the system into product-oriented cells
- Production cells are created such that all operations of a product are done in a sequence of a few cells or even in a single cell.

Quick Response Manufacturing

- uses MRP for high-level planning and coordination of materials. (*HL/MRP in which routing of an order is viewed in terms of a sequence of cells*)
- Using estimated production lead times in individual cells, HL/MRP generates material release authorization times for products at every cell over the planning period.
- Within each cell, the cell team schedules its workload in more details, independent of other cells.
- POLCA (a material control method) is used to implement QRM on shop floor.

POLCA – A Material Control Method to Implement QRM

- POLCA - Paired-cell Overlapping Loops of Cards with Authorization
- POLCA is a sort of an extension of kanban control along with material release authorization times for cells generated by HL/MRP.
- POLCA controls the flow of orders across QRM cells.

POLCA – A Material Control Method to Implement QRM

POLCA Implementation:

- Suppose C1, C2, C3,....Cn are cells of a QRM production system.
- If Cj immediately follows Ci in the routing of a product, take into account the pair of cells Ci and Cj, denoted as Ci/Cj.
- List all such pairs of cells based on product routings.

POLCA – A Material Control Method to Implement QRM

- Suppose an order A has a routing in which cell Ci immediately precedes cell Cj. The processing for order A in cell Ci can be started only when

1. Material release authorization time (given by HL/MRP) for A at Ci has already passed

2. The total number of orders in cells Ci and Cj with routings in which Ci immediately precedes Cj is less than a pre-determined limit.

POLCA – A Material Control Method to Implement QRM

A few drawbacks of QRM implementation:

1. Dependence on weak MRP calculations for complex job shops
2. Difficulty with cell formation
3. Laborious material control on shop floor in POLCA implementation.

Mixed Model Value Streams

- Simplifies a high-variety production system.
- Products are grouped into families such that all products within a family have **very similar** process requirements.
- A production line is **dedicated** to each family.
- Each mixed model value stream has the following features and assumptions:
  a) It makes a variety of products in a product family (like wrenches of various dimensions) in small quantities to meet customer demand at right times.
  b) All these products usually pass one after another through the same sequence of operations.

Mixed Model Value Streams

c) The variation in process time requirements across products (of a family) is very limited.

d) Products on a MMVS have stable demands or their total demand is stable.

e) A common pacemaker exists for all the products in a MMVS.

- Lean methods for production control are quite effective for MMVS and they can make production management in MMVS easy and simple.

Mixed Model Value Streams

Some drawbacks of MMVS:

- It may not always be easy, economical or even feasible to reduce a complex HMLV system into a few mixed model value streams.
- Each mixed model value stream in the system needs dedicated resources.
- Many job shops like machine shops, fabrication shops, mold shops, print shops, etc are HMLV systems which cannot be easily transformed into MMVS.

Theory of Constraints (TOC)

- Developed by Dr. Eli Goldratt more than 35 years ago
- Got excellent recognition through his famous book on manufacturing, “The Goal”
- Applicable to a variety of production systems
- Based on a fundamental assumption that a production system has a single resource constraint and all other resources have sufficient capacity to fully support any feasible schedule on the constraint resource.
- Sets a major focus on the constraint resource to get the best out of the system.

Theory of Constraints (TOC)

- Drum-Buffer-Rope (DBR) is a method for implementing TOC in production systems.
- DBR schedules orders on the constraint and determines material release times for orders accordingly.
- Buffer times of orders before the constraint are used to ensure that constraint schedule is always protected.
- The buffer time will absorb uncontrollable natural variation in the system.
- Production is controlled by (1) the constraint schedule, (2) the corresponding material release schedule and (3) supportive buffer management.

Theory of Constraints (TOC)

- The basic idea of TOC is to keep the constraint resource busy always while controlling WIP in the system by releasing jobs at right times.
- DBR is simple and easy to implement.
- **Drawback**: It is not always easy and economical to ensure that a job shop has a single constraint resource with required subordination of all other resources.

Production Control Based on Excel & Whiteboard Schedules

- Many job shops try to control production with the help of schedules generated on whiteboards or in Excel.
- These schedules are generally either crude or narrowly focused at work center level.
- They are not based on rigorous scheduling logic.
- Their support to production control at plant level is not satisfactory in many job shops.

Production Control Based on Schedules Created by PM Software

- To control and manage high-variety production, some job shops use production schedules created by project management (PM) software.
- This practice is more prevalent among fabrication shops.
- Almost every PM software is developed as a tool mainly for scheduling a single project.
- PM software uses a scheduling method called Critical Path Method (CPM) which totally ignores resource requirements.
- Schedules from CPM-based PM software usually involve a lot of resource over-allocations.

Production Control Based on Schedules Created by PM Software

- Users of PM software adopt a manual resource leveling procedure to resolve all resource overallocations.
- This exercise can sometimes become laborious and time consuming and even prohibitive in job shops with limited resources.
- Usage of PM software for production scheduling in job shops is not efficient because resource capacities are limited.
- Examples of PM software: MS Project and Primavera.

Finite Capacity Scheduling (FCS) for Production Control

- FCS means scheduling without resource overallocation
- FCS is a rigorous, scientific approach to production scheduling subject to resource capacity and availability.
- FCS is an approach rather than an algorithm. The detailed logic of FCS can vary with application.
- FCS is computationally intensive. It has to be implemented on computer with the help of software.
- Many FCS software tools are available in the market for job shop production scheduling.
- Many ERP vendors claim their software contains a module for finite capacity scheduling.

Finite Capacity Scheduling (FCS) for Production Control

- Many manufacturing experts have been criticizing FCS for years for various reasons.
- FCS was not widely adopted in industries in the past because of several reasons including:

1. Difficulty to collect and maintain the required input data
2. Long execution times required by FCS software even on mainframe computers
3. High levels of rework and rejections in production
4. High levels of uncertainty and uncontrollable natural variation in the system

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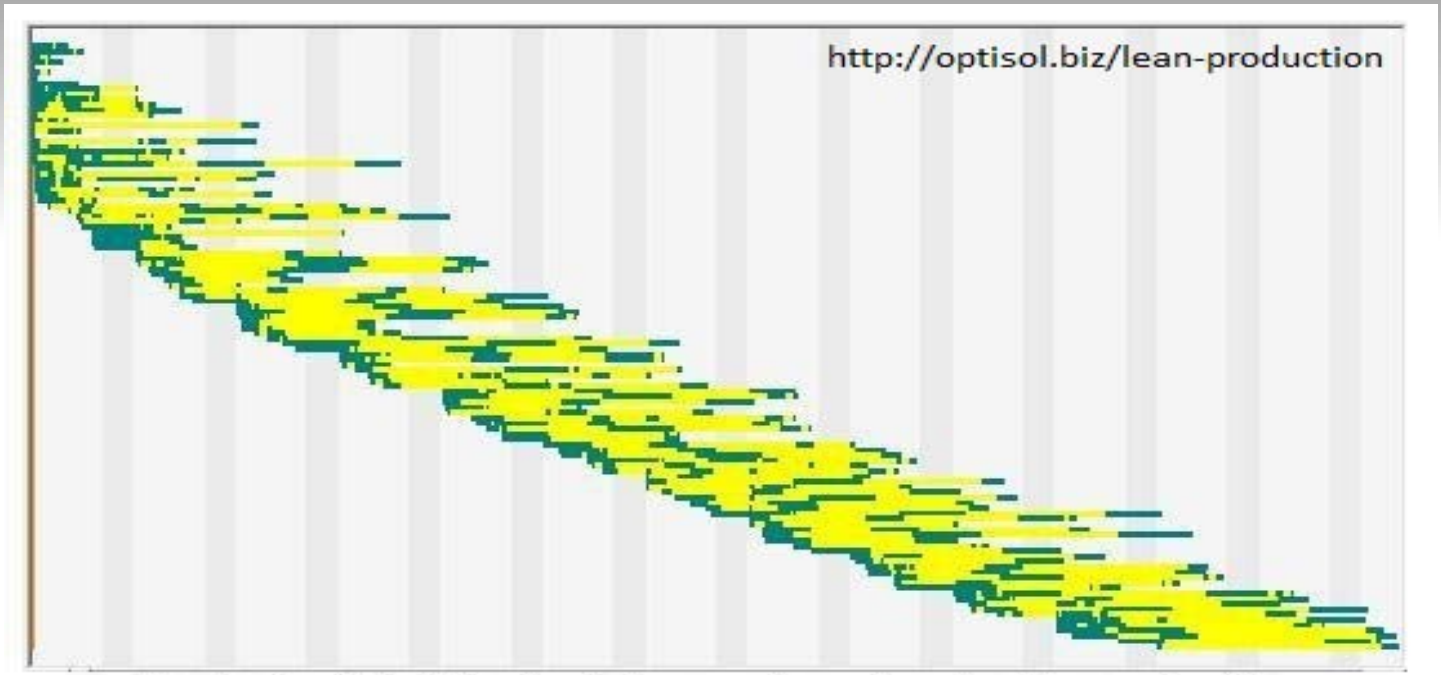
Finite Capacity Scheduling (FCS) for Production Control

5. Quick schedule revision was not practical
6. Inflexible schedules generated by FCS software
7. Cumbersome and unfriendly FCS software with a need for fixing many parameters
8. High price of FCS software.

- The current advancements in IT, improvements in production systems and the availability of shop floor data collection systems eliminated these drawbacks.
- Powerful FCS software is now affordable to even small job shops if the need is mainly to get a high quality schedule and quick schedule revision.

Finite Capacity Scheduling (FCS) for Production Control

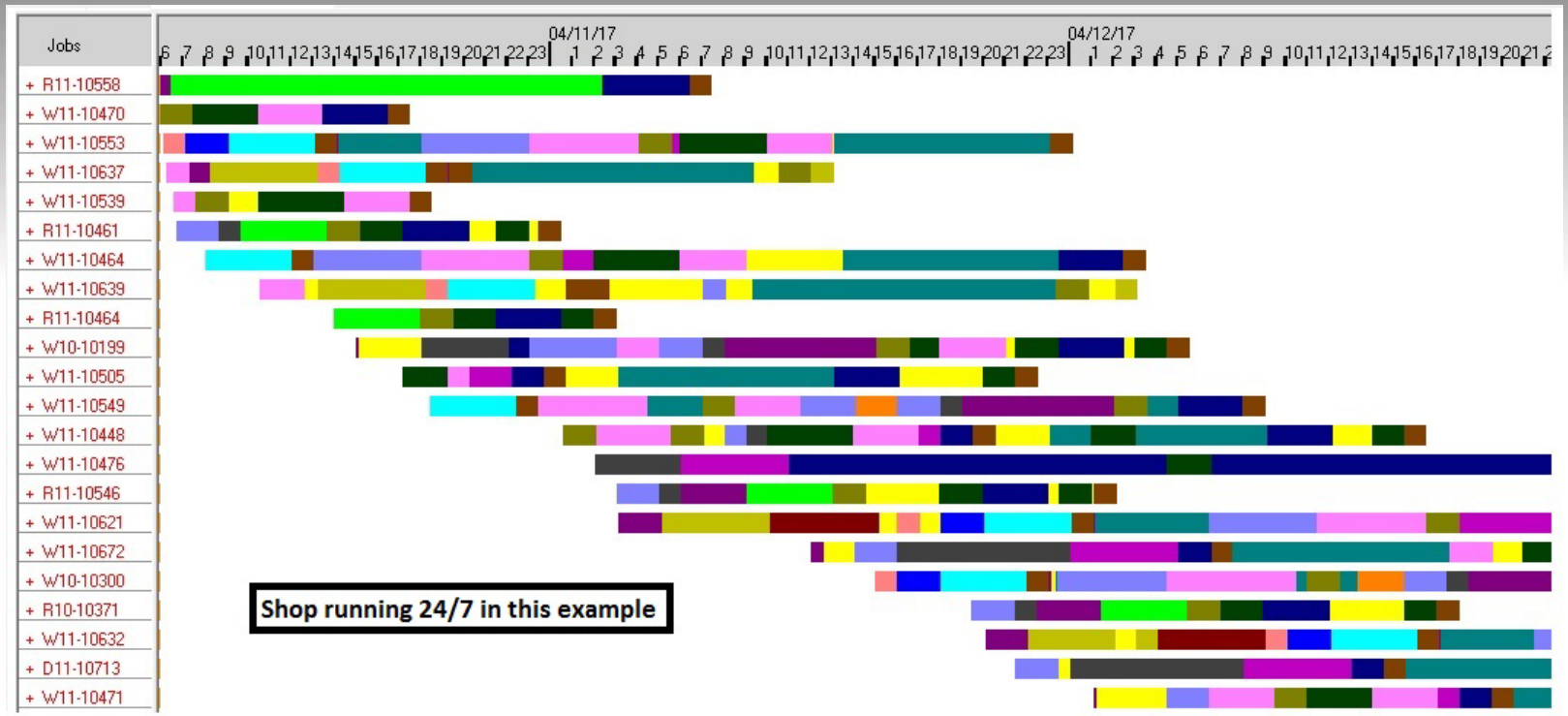
- Gantt chart of a production schedule for 1912 operations of 114 jobs created by FCS for a mold shop



Production Schedule when jobs are released to shop floor optimally

Finite Capacity Scheduling (FCS) for Production Control

A close look at Gantt chart of a job shop production schedule



Finite Capacity Scheduling (FCS) for Production Control

Functionality of FCS:

1. Estimates reliable lead times for new orders
2. Finds right start time for each work order
3. Generates explicit, operational level resource schedules for shop floor control
4. Supports fast, extensive and reliable what-if analysis of schedules
5. Helps identify permanent and temporary bottlenecks
6. Supports proactive capacity planning.

Finite Capacity Scheduling (FCS) for Production Control

High level benefits of FCS include improvement of:

a) On-time delivery
b) Throughput
c) WIP and production lead times
d) Overall resource utilization
e) Easier control and management of complex production.

- FCS compensates a major weakness of MRP for production planning and control in job shops.
- FCS can make production management simpler and easier in many small and mid-sized job shops.

Finite Capacity Scheduling (FCS) for Production Control

- Scheduling software tools for job shops include:
  - Preactor - www.preactor.com
  - Schedlyzer - www.optisol.biz
  - Tactic - www.waterloo-software.com
  - Asprova - www.asprova.com
  - PlanetTogether - www.planettogether.com
  - JobTime - www.jobtime.com

- The price, features, functionality, scope, logic and data requirements greatly vary with software. Some tools are very expensive.
- Some ERP vendors advertise scheduling modules of their ERP packages as scheduling tools for job shops.

Summary

- Job shops are very diverse and most of them are complex.
- It may not always be easy or economical to simplify a job shop.
- Production control and management is difficult in many job shops.
- There are several approaches to production control and management in job shops.
- Each approach has a limited scope of application in job shop environment.
- Any job shop has to select the right approach for itself.
- In the current IT era, FCS is quite promising for many shops. ■