Chapter 20

Finite Capacity Scheduling of a Flexible and Lean (FLean) Machining Cell

Acknowledgement
This chapter is based on work that I did when I was the Director of IE Research at Hoerbiger Corporation of America. This was my first industry job and a golden opportunity given to me by Hannes Hunschofsky, who was then the President of Hoerbiger Corporation of America. He invited (and challenged!) me to pilot the implementation of JobshopLean in their Houston, TX, facility. Had it not been for this job, I would never be where I am today – in industry doing hands-on projects to put my research into practice. Thank you, Hannes!

Background
Figure 1 gives an overview of a comprehensive approach that is followed for implementing JobshopLean in any high-mix low-volume discrete manufacturing facility, such as machine shops, forge shops, fabrication shops, mold shops, etc. At the core of this iterative approach is the expectation that a job shop (i) will utilize Production Flow Analysis and/or Group Technology to identify the stable part families in its product mix, (ii) will produce each part family that has a stable demand in a FLean (Flexible+Lean) manufacturing cell and (iii) utilize Finite Capacity Scheduling to schedule each cell on a daily shift-by-shift basis. *In theory*, every time that one loop of the process shown in Figure 1 is completed, it will result in the implementation of a stand-alone FLean manufacturing cell dedicated to producing a family of parts whose manufacturing requirements are completely satisfied by the cell, except for in-house support services like Maintenance or Tool Room and (external) vendor operations that simply could not be absorbed into the cell. *In reality*, numerous constraints may need to be broken to the extent that is possible. For example, it **is** possible to train operators to run different machines in a cell and to offer group incentives to those who work in a cell so they begin to work as a team to achieve metrics like on-time delivery and first-time quality rather than machine utilization or labor efficiency. However, it **is not** possible to incorporate a heat treatment furnace inside a cell next to a CNC (Computer Numerical Control) grinder. Typically, after several iterations of the process in Figure 1, a job shop will get divided into at least two areas: (1) One area consisting of several FLean manufacturing cells with each cell dedicated to a product family and (2) The other area being a "remainder job shop" that produces the parts in the product mix that are produced in small quantities, have low value and are ordered infrequently (aka "cats and dogs"), such as spare parts, prototypes for emergent business and one-off orders. By dividing the job shop into these two areas, (1) The FLean cells provide unquestionable quick response, high quality, team work and other benefits that are guaranteed by manufacturing cells and (2) Only a smaller non-cellular portion of the entire facility will continue to operate as a complex job shop which is always a challenge to schedule and control.

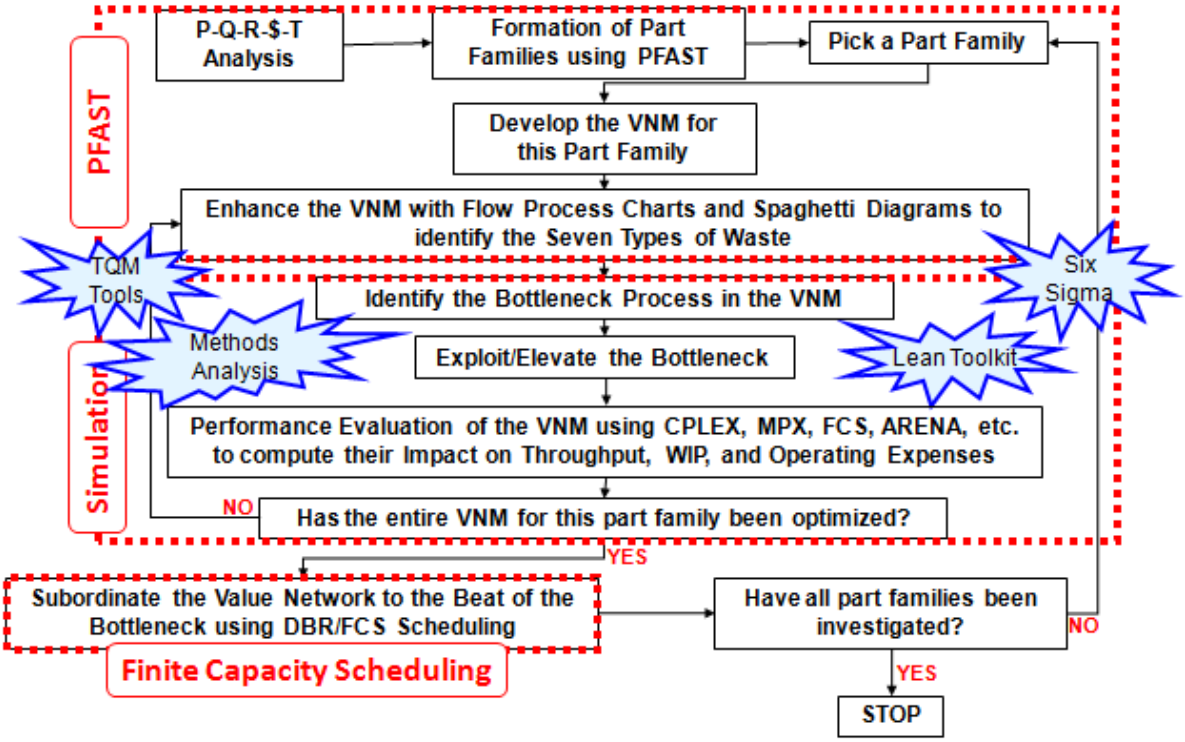

Figure 1 Comprehensive Approach for Implementing JobshopLean

What follows the Layout Design of a FLean Cell?

Numerous job shops continue to rely on their ERP systems to schedule (sic!) production, regardless of whether it is a single cell or the entire facility that is being scheduled. ERP systems are incapable of scheduling! Any ERP-generated schedule for a cell will have to be adjusted daily by experienced cell operators who can eyeball workloads (and capacity requirements) by just looking at the queue of parts in the cell. In the case of Hoerbiger Corporation of America in Pompano Beach, FL, Preactor (www.preactor.com) is the FCS (Finite Capacity Scheduling) tool being used in the main facility located in Pompano Beach, FL. The firm orders and their due dates quoted to customers are downloaded into Preactor from SAP (which is their ERP system). After the schedule is generated by Preactor, it is input to the MES (Manufacturing Execution System), FactoryViewer, which publishes twice daily a machine-by-machine sequence for producing orders loaded on every machine in the facility. Since every machine's operator must record the start/stop times for each order processed on their machine, the MES closes the loop between the daily schedule produced by Preactor and the real-time execution of that schedule. The complete daily schedule for a shop can be visualized using a Gantt Chart, such as the one shown in Figure 2 which was produced by Preactor.[1]

[1] Computer-aided scheduling facilitates Visual Management! For our Power Rings Cell, our IT staff had developed a robust user interface between the FCS (Preactor) and the MES (FactoryViewer) to standardize how the employees in the cell interacted with the daily schedule displayed on their computer monitors.

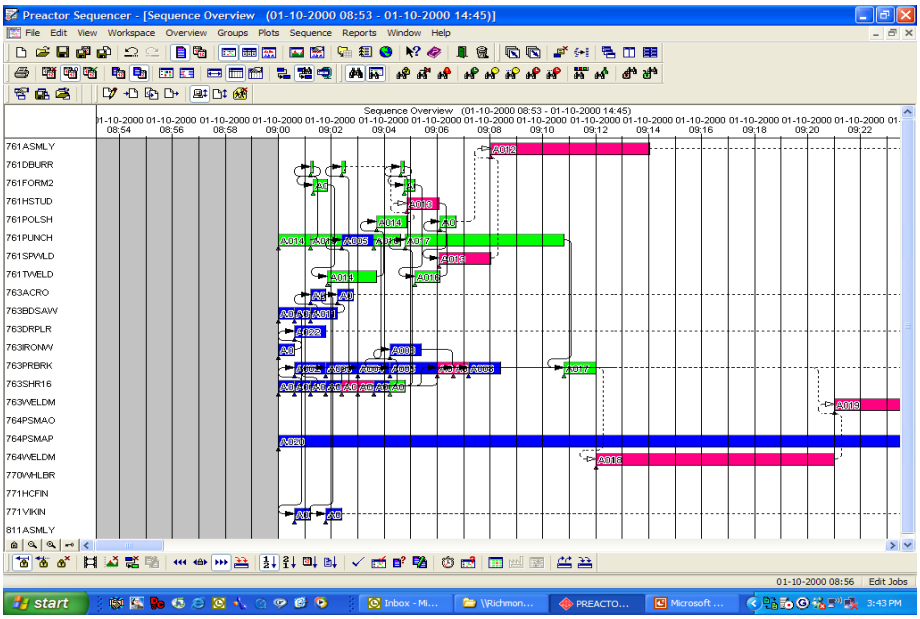

Figure 2 Gantt Chart Representation of a Production Schedule for Visual Management

Scheduling a <u>Single</u> High-Mix Low-Volume Cell

Per the methodology for implementing JobshopLean outlined in Figure 1, if a cell can be implemented so all value-adding operations to produce its part family are performed inside it, then its operations can be scheduled using a Finite Capacity Scheduler running on a stand-alone desktop in the cell. Having implemented a new layout for the Manual Packings Cell (MPC) in the Houston, TX, facility of Hoerbiger Corporation of America, the next step was to schedule daily operations in the cell. Depending on the complexity of the part family and the fluctuations in demand for the parts produced in the cell, a manual/visual system for scheduling the cell may have sufficed. One of our own cells, the Quick Response Cell (QRC), used a manual scheduling board that was populated with orders by an office manager based on his estimates of work load and available cell capacity. But I did not wish to schedule the MPC cell using ad-hoc manual cell scheduling methods. Because, if future cells had to share resources with this cell, then the schedules of those cells (and outside vendors too) would have to be coordinated with this cell's schedule.

Therefore, in this chapter, I will focus on the use of Finite Capacity Scheduling software for computer-aided scheduling of the MPC cell. The Manual Packings Cell (MPC) was essentially a small job shop. Therefore, effective scheduling would improve its performance and employee utilization. The complexity of scheduling even a small job shop with 4 or more machines used in various combinations makes it hard to generate, revise and maintain its daily schedule manually. Ask any IE graduate who has taken a course in Scheduling about how much time it took him/her to produce the schedule for a job shop consisting of just 3 machines producing 4 parts with different routings! In the case of the MPC cell, it had different equipment types, and in some cases, two machines of the same type that were capable of processing the same parts if the tools and fixtures were available. So, in order to complete the JobshopLean implementation process shown

in Figure 1, we undertook an exploratory proof-of-concept project to demonstrate the following operational scenario for the cell:

If the daily schedule that was issued to the cell at the start of the day was subject to change due to changing order priorities, machine breakdowns, rush orders, operator/s taken sick during the shift, due date changes forced by customers, etc., could we rapidly revise and re-generate a new schedule for the cell?

Why Schedlyzer Lite was Chosen over Preactor

Like all other ERP systems on the market, SAP uses MRP (Material Requirements Planning) for production planning and operations scheduling. MRP uses assumptions of infinite capacity, backward scheduling from customer due dates using fixed lead times, batch production, etc. So there was no question of using SAP for scheduling the MPC.

Although Preactor was being used successfully in our Pompano Beach facility, our current license and implementation was for a factory-wide installation. This licensing structure had resulted in a less than desirable pilot implementation of the SAP+Preactor+FactoryViewer system to manage the day-to-day operations of the Power Rings Cell in our Houston, TX, facility. Also, our Director of Manufacturing Systems, who was the architect of the integrated system being used in Pompano Beach, FL, had prior commitments that made him unavailable during the period when we wanted to do this project. Due to his time constraints, it was difficult to obtain a stand-alone license that would run on a desktop computer dedicated to the MPC.

Therefore, we decided to work with another FCS vendor, Optisol Inc. (www.Optisol.biz) and used their Schedlyzer Lite tool for the project. Schedlyzer Lite is easy-to-learn and allows a user-friendly VBA (Visual Basic) interface to be developed for shop floor employees. Its price tag easily makes it affordable to purchase a single license for a computer that can be dedicated to a cell. Its vendor, who is resident in Bryan, TX, boasts a track record of successful implementations in several job shops.

Figure 3 shows the VBA (Visual Basic) interface between SAP and Schedlyzer Lite that was developed by the graduate intern we hired to work on this project. Since SAP query authorization was not allowed for our project, a macro in SAP was adapted to automatically generate data for daily orders. First you would click on the button highlighted in **red** then click on the button highlighted in **yellow**. Voila, the Input Data File for Schedlyzer would be ready with data extracted from SAP!

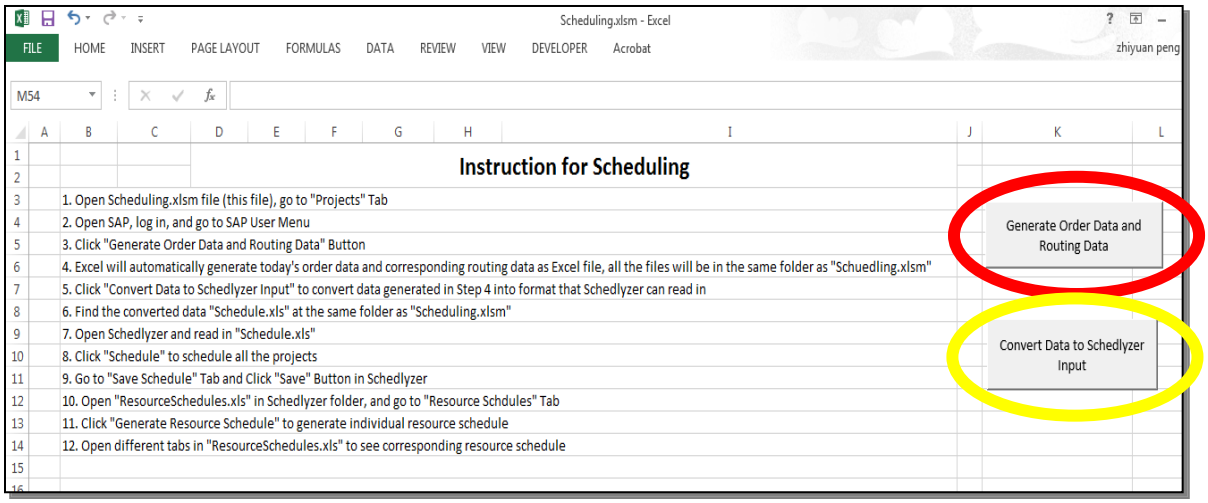

Figure 3 VBA Interface between SAP and Schedlyzer Lite

Next, as shown in Figure 4, we would open the Input Data File for Schedlyzer that was produced from SAP and, with one click on the "Schedule" button, we would schedule all jobs for production in the cell. By default, Schedlyzer Lite releases all jobs to complete by Earliest Due Date (EDD) subject to capacity constraints. Queues of jobs at individual machines are prioritized using the same EDD (Earliest Due Date) dispatching rule.

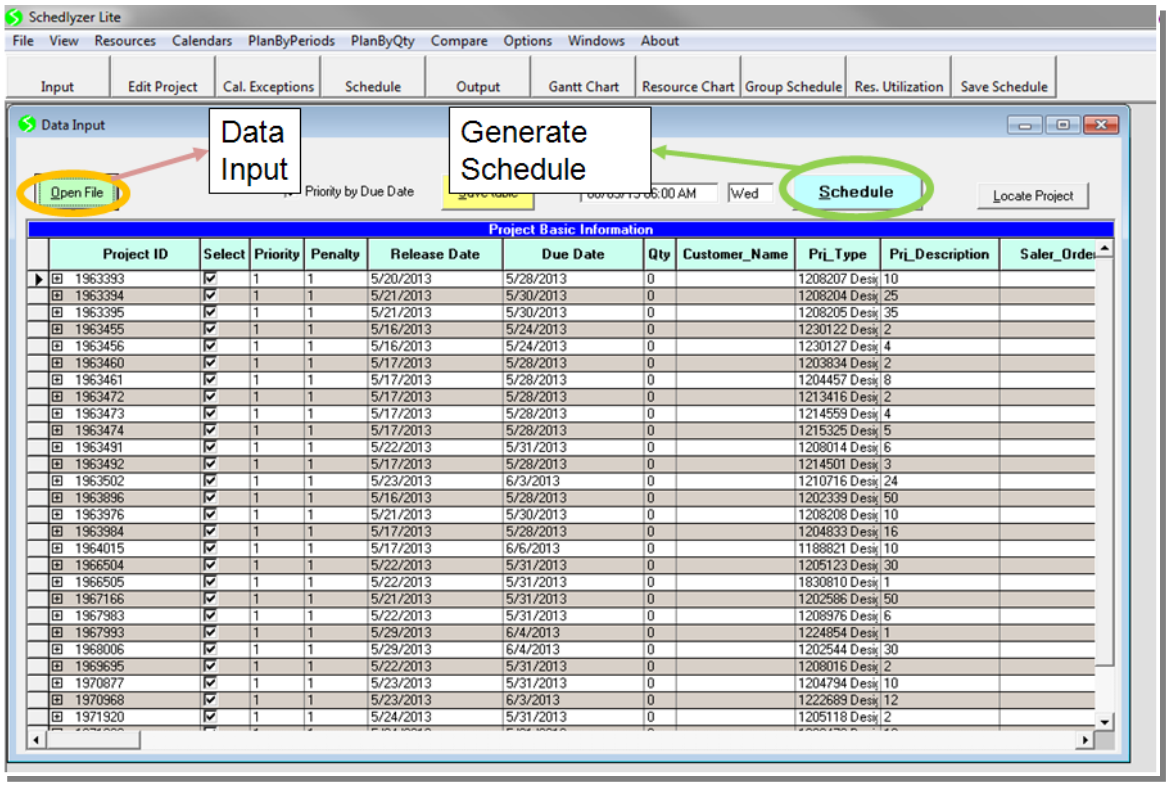

Figure 4 Schedlyzer Screen for Data Input

Figure 5 shows the Cell Schedule Summary screen in Schedlyzer Lite with detailed information on every job (Job ID, Job Start Time, Job Finish Time, Relative Earliness/ Lateness compared to Due Date, etc.). In the case of our pilot project, 30 jobs and 139

operations were scheduled to minimize the Average # of In-Process Jobs (WIP) to 8.2 orders. Some immediate benefits of this screen are that (i) it will help Customer Services to decide whether a new order could be finished by its customer-specified due date and (ii) it will tell the Shipping Department when to expect any order so it can be ready to start packaging it for shipment as soon as it arrived.

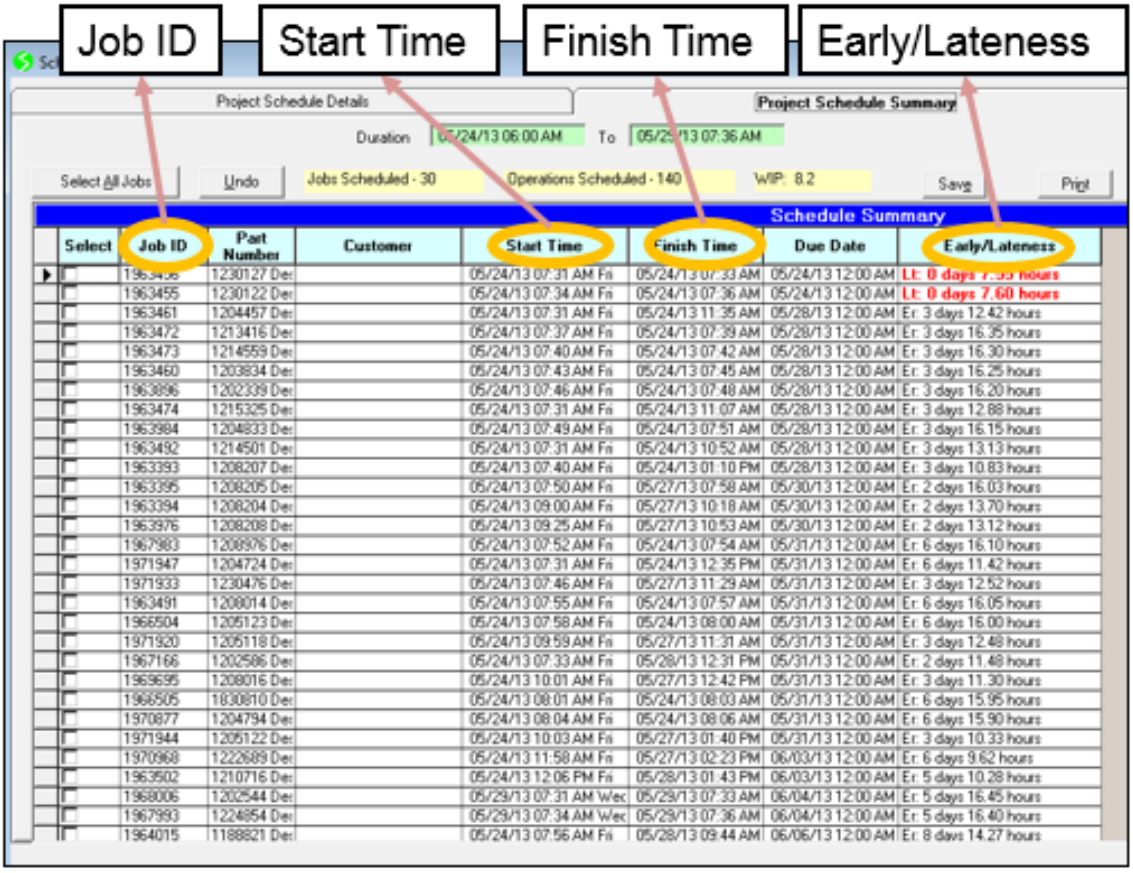

Figure 5 Cell Schedule Summary

Figure 6 displays the schedule for a particular machine. This is the preferred sequence in which jobs would be processed by that machine on any given day. For each job, its Job ID, Material Number, Operation # (with its expected Operation Start Time and Operation End Time), etc. is displayed. Thereby, the machine operator would have no doubt as to which jobs absolutely must be ready to run before/after another job. This schedule is the "drum beat"[2] to which everyone associated with the cell, such as the machine operators, material handler/s, the cell leader, office manager, etc. would march! Every violation of this daily sequence could be noted and initiate a problem-solving event (kaizen) that would start with the question, "Why did this happen?" being asked five times (aka Five Why's).

[2] For those readers who are familiar with the Takt Time counter that is mounted above an assembly line, the Gantt Chart display of the schedule for a high-mix low-volume cell serves the same purpose.

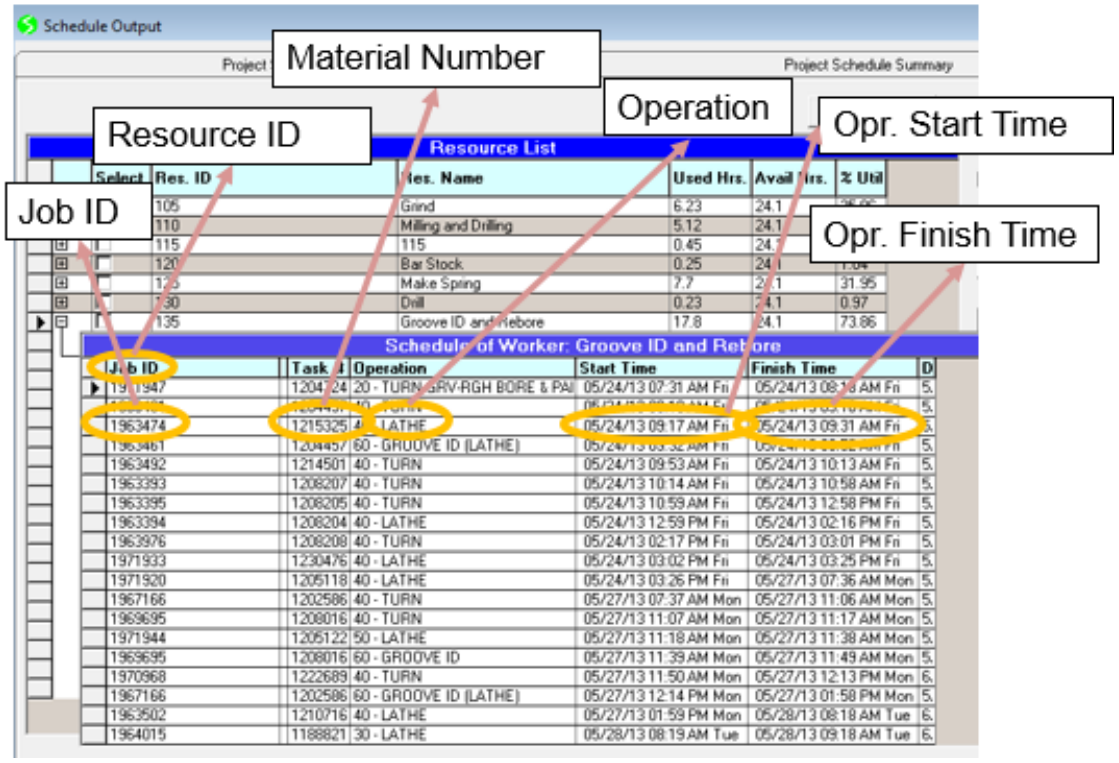

Figure 6 Schedule for a Specific Machine

Schedlyzer can also display the complete schedule for all active jobs run on all machines in the cell, either in a standard Gantt Chart format or produce an Excel spreadsheet equivalent of the Gantt Chart. Although not as visually pleasing, the spreadsheet showing the sequence of jobs, start/finish times, waiting times, etc. was preferred by the cell employees and Plant Manager!

Resource ID	Project ID	Material Number	Operation Desciption	Start Time	Finish Time	Ring Type
105	1971947	120472	30 - GRIND	05/31/13 08:19 AM	05/31/13 08:53 AM	Design:PACKING RING
105	1963461	120445	50 - GRIND	05/31/13 09:17 AM	05/31/13 09:27 AM	Design:OIL SCRAPER
105	1963474	121532	50 - GRIND	05/31/13 09:32 AM	05/31/13 09:41 AM	Design:PACKING RING
105	1963393	120820	50 - GRIND	05/31/13 10:59 AM	05/31/13 11:18 AM	Design:PACKING RING
105	1963395	120820	50 - GRIND	05/31/13 12:59 PM	05/31/13 02:08 PM	Design:PACKING RING
105	1963394	120820	50 - GRIND	05/31/13 02:17 PM	05/31/13 03:06 PM	Design:PACKING RING
105	1963976	120820	50 - GRIND	05/31/13 03:07 PM	05/31/13 03:26 PM	Design:PACKING RING
105	1971933	123047	50 - GRIND	05/31/13 03:27 PM	06/03/13 07:43 AM	Design:PACKING RING
105	1971920	120511	50 - GRIND	06/03/13 07:44 AM	06/03/13 07:50 AM	Design:PACKING RING
105	1969695	120801	50 - GRIND	06/03/13 11:18 AM	06/03/13 11:24 AM	Design:PACKING RING
105	1971944	120512	60 - GRIND	06/03/13 11:39 AM	06/03/13 11:53 AM	Design:PACKING RING
105	1970968	122268	50 - GRIND	06/03/13 12:14 PM	06/03/13 12:19 PM	Design:PACKING RING
105	1963502	121071	50 - GRIND	06/04/13 08:19 AM	06/04/13 10:04 AM	Design:PACKING RING

Resource Schedules | 105 | 110 | 115 | 120 | 125 | 130 | 135 | 145 | 150 | 155 | 180 | ...

Figure 7 Detailed Machine Schedule Output

How FCS Facilitates Waste Elimination

Scheduling a cell's operations using a FCS (Finite Capacity Scheduling) tool[3] would help any cell to reduce WIP, minimize job waiting, plan on-hand inventories of raw materials, anticipate short-term overtime needs, etc. For example, in this pilot project involving the MPCcell, the Schedlyzer schedule projected that we could reduce the number of in-process orders (WIP) from 59 orders to 15, which was equivalent to about $12000 based on the prices of those orders. That is because a schedule based on ***finite*** capacity constraints will never allow a pre-mature release of orders that will simply queue up in front of the bottleneck machine in the cell. This ability to check if an order will complete by its due date if released into a cell is especially useful if the current bottleneck machine is NOT the first machine used to process the orders. This is just one of many more benefits of effective scheduling using an FCS tool that are claimed by any FCS software vendor. But beware the hidden pitfalls and dangers of wanting to have those benefits when you **do not** (1) hire the personnel and (2) complete the pre-requisite tasks essential for the success of an FCS implementation!

Ensuring the Success of an FCS Implementation

You *must* implement the new layout for the cell in order to co-locate **all** the machines and their operators who will be responsible for completing orders loaded on the cell. In my entire career, I have not visited a single high-mix low-volume facility that had a correctly

[3] The well-known FCS tools on the market are Preactor (www.PREACTOR.com), Tactic (www.WATERLOO-SOFTWARE.com) and Schedlyzer (www.OPTISOL.BIZ). But I know of at least one precision machine shop that uses a DBR (Drum-Buffer-Rope) scheduling tool (http://www.dbrplus.com/).

designed layout! Due to a poorly-designed cell layout, *whenever there is a distance of separation between two consecutive operations that exceeds 3 feet*, the inter-operation transfer delays can result in disorderly flow of jobs that could destroy the best schedules generated by any FCS software.

You *must* have good data to input to the FCS tool. Any software, be it an ERP, FCS or MES, suffers from the GIGO (Garbage In Garbage Out) rule if it is provided bad data. You *have* to populate the routings for all the unique parts being produced in the cell with reasonably accurate setup and machining cycle times for all value-added operations performed in the cell. Instead of relying on Time Studies alone, you should use Group Technology and Pre-Determined Standard Times also to produce those standard times.

You need to have an in-house Production Controller and Scheduler to support the implementation. I firmly believe that this pilot project succeeded because of Clement Peng, the graduate intern from the Department of Industrial and Systems Engineering at Texas A&M University. He did most of the implementation work on this project in partnership with Dr. Prasad Velaga, who is the President of Optisol Inc. (www.optisol.biz), the vendor for Schedlyzer. Clement made the difference with his computer-skills and prior IE coursework related to scheduling. He demonstrated an excellent work ethic, aptitude and willingness to learn SAP and Schedlyzer on his own. He was determined to learn about and implement JobshopLean using computer tools like PFAST and Schedlyzer. Any company will need a full-time IE like him to make their FCS implementation a success!

Next, you need buy-in from the employees who will use the FCS. Software running on a cell computer, let alone someone's desktop in an office removed from the shop floor, will never be aware of all the disruptions that are bound to occur daily inside the cell.[4] No software could ever match the flexibility and response time that good cell operators can provide when any number of unscheduled disruptions, such as machine breakdowns, missing tools, defective parts requiring rework, scrapped parts and vendor delivery failures, render useless the current computer-generated schedule for a cell.[5]

Then, there is the need for top-down leadership by an individual who understands the technical and IT aspects of an FCS implementation. He/she must also ensure disciplined use of the system by the entire company. For example, in our Pompano Beach, FL, facility, our Director of Manufacturing Systems teamed with the Plant Managers of Plant 1 and Plant 3 to stress to the shop floor employees that the dispatch lists displayed at their machines ***had*** to be followed. Cell operators were forbidden to cherry-pick jobs out of the machine's dispatch list! Any FCS could quickly generate a new schedule after any disruption in a cell's day-to-day operations. Still, it would be the cell leader who must input the data to accommodate and/or override the existing schedule.

Conclusion

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[4] Do you forbid a machine operator from taking a restroom break just because the schedule generated by the FCS shows that he/she should be running Job X at that time?

[5] Will the computer be willing to report to work on a Saturday to get a rush order done and shipped to a key customer?

Lean, IT and flexible automation can co-exist with a motivated, talented and well-trained workforce in a cell, even more so in an entire high-mix low-volume manufacturing facility. Despite the incorporation of computer-aided data analysis and systems optimization, flexible automation, data analytics for production planning and control, etc., people and the standard Lean tools are going to be the foundation for successful implementation of JobshopLean. CIM (Computer Integrated Manufacturing) places an even greater reliance on employees and managers who can eliminate the myriad problems that arise when computer-generated shop schedules are disrupted by the vagaries of the dynamic shop floor.

References

Irani, S.A. (2012, October). *A Quick-Start Approach for Implementing Lean in Jobshops*. Gear Technology, 10-16.

Joshi, P. & Irani, S.A. (2013, April 1). *A Tutorial on Job Shop Scheduling (JSS) using LEKIN Academic Scheduling Software.* Presentation made at the First Lean and Flexible Conference in Houston, TX.

Mittendorff, P. (2013, April 1). *The Water Strider: How To Get the Right Material to the Right Machine at the Right Time per the Daily Schedule.* Presentation made at the First Lean and Flexible Conference in Houston, TX.

Irani, S.A. (2013, April 1). *What are the Wastes created by a Jobshop's ERP System?* Presentation made at the First Lean and Flexible Conference in Houston, TX.

Ellis, M. & Mittendorff, P. (2013, September 5). *Integration of MES (Manufacturing Execution System) with Material and Inventory Management.* Presentation made at the Second Lean and Flexible Conference in Houston, TX.

Irani, S.A. & Velaga, P. (2013, September 5). *Revisiting Time and Motion Studies: Implementing Lean Improvements for a High-Mix Low-Volume Flexible Manufacturing Cell.* Presentation made at the Second Lean and Flexible Conference in Houston, TX.

Irani, S. A. (2013, October). *Computer-aided Finite Capacity Scheduling of a Flexible and Lean (FLEAN) Machining Cell*. Gear Technology, 42-48.

(2011, August). *Preactor and Factory Viewer get Seal of Approval from Hoerbiger*. **Source:** http://www.preactor.com/Case-Studies/Case-Studies/Hoerbiger#.V0RodPkrK1t .

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