# NEW MODELS FOR PRODUCTION SIMULATION AND VALIDATION USING ARENA SOFTWARE

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**ABSTRACT:** Currently, Lean Manufacturing is a recognized topic in many research fields, which was once implemented only in an automotive industry initiated by Toyota. The simple concept of Lean is to remove different kinds of wastes in order to improve overall customer value. Information technology has played a important role in easing the researchers to integrate computer aided simulation into the lean production process. To add value in the process, one should concentrate on the machine capacity utilization, which can be assessed in providing the product within due date to the customer. To achieve the targets, different dispatching rules have been investigated, but due to rapidly change in demand, abrupt and unpredictable conditions on the shop floor, it is rather difficult especially for small based companies to practically implement it. Work Load Control (WLC) is a technique of load oriented order release which was first developed by Bechte, 1980. The purpose of this paper also enlighten two different WLC models i.e. Load limiting and Load Balancing.

**KEYWORDS:** Lean process, computer aided simulation, order release, Work Load Control

## 1. INTRODUCTION

The idea of Load Limiting in a shop is to limit the work-in-process inventory as low as possible in order to accomplish high workcentre utilization and a good management of orders flow through the factory. To release the job from the pre-shop pool we proposed the prioritization rule of the Total Work Content (TWC) time.

In addition the flow of work orders to and from the factory is controlled by measuring downstream and upstream inventory including planned and released orders. Using these control information inventories, lead times and due dates are planned applying the technique of load-oriented order release and performing backward scheduling with true lead times.

We have than compared the results with the benchmark of the results previously investigated WLC conceptualizes the job shop as a queuing system. In front of each work station, an arriving job finds a queue of jobs waiting to be processed.

The principle of WLC concepts is to control the length of these queues. The main instrument for this purpose is the release decision. The release decision allows a job to enter the queue of its first work station in the shop.

Once released, a job remains on the floor until all its operations have been completed.

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The progress of jobs on the shop floor is controlled by priority dispatching at each work station.

A hierarchical control concept emerges, with three levels which respectively relate to job entry, job release and priority dispatching (Figure.1).

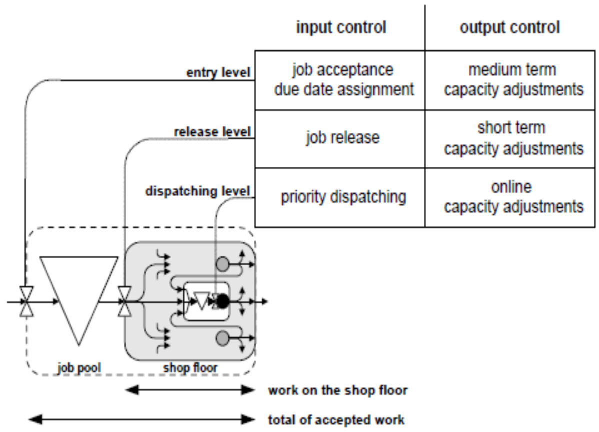


**Figure 1. Decisions place in WLC framework**

At each level, two means of control have been distinguished, input control and output control. Input control regulates the allowance of jobs to the next stage, respectively accepting jobs for entry into the pool, releasing jobs to the shop floor, and dispatching jobs for processing (thus allowing a job to enter the queue of its next operation).

Due to the great number of activities this task can hardly be solved as even large computers, in general, need many hours for this procedure.

The intended high, but hardly reliable, precision and the high cost of those deterministic systems just do not meet the reality of job shop manufacturing. Contrary to that, the techniques of load-oriented manufacturing control apply a statistical view of job shop manufacturing.

Evaluating the feedback records from the job shop input, output, inventory and average lead times of workcentres are monitored and compared to their planned values in a dynamic way. In addition the flow of work orders to and from the factory is controlled by measuring downstream and upstream inventory including planned and released orders. Using these control information inventories, lead times and due dates are planned applying the technique of load-oriented order release and performing backward scheduling with true lead times. The crucial point is that the system keeps actual lead times on a planned and predetermined level in a self-regulating way. The system also points out the bottlenecks and initiates capacity adjustments and due date changes if necessary.

The role of the ORR (Order Release Rules) methodologies within the general framework of a shop floor scheduling and control system is to manage the transition of production orders from the planning system to the execution phase. Production orders, that may be generated from a requirements planning system or directly originated from customers orders, arrive continuously at the production system over time, but the arrival itself does not necessarily involve the release of a job to the shop floor.

The major direct objectives of ORR are the control of WIP level and the workload balance both among machine centers and over time. In turn, these achievements can ensure both good shop utilization and improvements of the delivery performances.

Load-oriented manufacturing control has a planning system for three planning levels:

1. Order entry and mid-term capacity planning.

2. Order release and short-term capacity planning.

3. Operation sequencing.

**Order entry:** is initiated either by an MRP system or directly to satisfy any special demands. The generated orders define certain parts to be manufactured in certain quantities by passing several operations, as specified in the routings, and to be delivered to the receiving departments at certain order due dates. First of all the planned orders flow into the order stock (i.e. usually a database). Provided that the correct lead times for all operations are known, backward scheduling is performed and the resulting loads on all workcentres referenced are established using the process times of the routings. Taking into account the loads and scheduled operation dates of all orders planned and released earlier, the order due dates of the generated orders are checked against the available capacities. In case of overload, realistic due dates are offered and the affected bottlenecks are pointed at initiating capacity adjustments if possible. Thus order entry and mid-term capacity planning are conducted simultaneously for a planning horizon, which is about as long as the longest order lead times from generation to completion (e.g. 12 weeks are often sufficient).

**Order release**: takes place periodically (e.g. every week or every day) for all planned orders that should be started in the near future. Allocating the required raw materials, documents and supplies to the job shop order release, marks the actual irrevocable start of manufacturing the defined orders. At this point of time it is necessary to check whether the present situation allows the release of orders as scheduled earlier. Some capacities might have changed, unexpected bottlenecks might have occurred because of breakdowns, etc., raw materials might not be available, or some orders might have become unimportant with their due dates not yet revised. Furthermore it is very important to avoid unnecessary early order releases.

Control of the queues on the shop floor should result in stable and predictable station throughput times. Thus, an accurate release moment for each job can be determined to guarantee a good due date performance. However, it can be argued that a good timing of job release may conflict with realizing the norms for the workload on the shop floor.

Order release without considering the workcentre loads will result in unexpected bottlenecks and idle time. The technique of load-oriented order release selects those of the planned orders which are workable. It limits work-in-process resulting in controllable inventories and lead times. Furthermore it points at the momentary bottlenecks and initiates capacity changes if possible.

**Operation sequencing**: handles the queues of orders at the workcentres and decides on what operation to be processed next if several orders compete with one another. This decision frequently appears to be very difficult and aims at meeting certain due dates or preventing idle time at certain downstream workcentres for the present. There are numerous priority rules to solve this problem and to some extent they are rather complex and sophisticated but far from being practicable. Operation sequencing should take the scheduled operation dates as priorities. This will have the best results considering due date performance. In this case the priority rule applied is FIFO which gives best results in lead time accuracy.

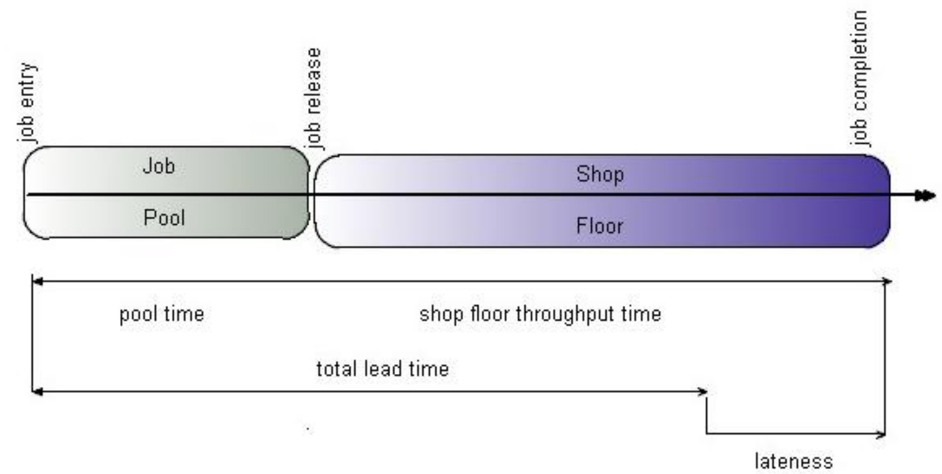


**Figure 2. Lead time components with controlled release**

**Shop Floor Configuration**

We have considered five stations for our problem in the shop floor, and on the basis of the routing parameters the job will be released to the corresponding station. Here, we have shown only one station to make it simple and understandable otherwise all of the stations have the same design parameters and blocks.

## 2. ABOUT ARENA SOFTWARE

Arena combines the case of use found in high-level simulators with the flexibility of simulation languages, and even all the way down to general-purpose procedural languages like Microsoft Visual Basic programming system or C if you really want. It does by providing alternative and interchangeable templates of graphical simulation modeling and analysis modules that you can combine to build a fairly wide variety of simulation models.

For ease of display and organization, modules are typically grouped into panels to compose a template. By switching panels, you gain access to a whole different set of simulation modeling constructs and capabilities. In most cases, modules from different panels can be mixed together in the same model.

Arena maintains its modeling flexibility by being fully hierarchical. At any time you can pull in low level modules from the blocks and elements panels and gain access to simulation-language flexibility if you need. For specialized needs, like complex decision algorithms or accessing data.

### 2.1 Components

*2.1.1 Modules*

The basic building blocks for Arena models are called modules. These are the flowchart and data objects that define the process to be simulated and are chosen from panels in the project bar. Modules come in two basic flavors: flowchart and data.

*2.1.2 Flowchart modules* describe the dynamic processes in the model. You can think of flowchart modules as being nodes or places through which entities flow, or where entities originate or leave the model. The basic flowchart modules available are Create, Dispose, Process, Decide, Assign and Record.

*2.1.3 Data modules* define the characteristics of various process elements, like entities, resources and queues. They can also set up variables and other types of numerical values and expression that pertain to whole model.

The basic process data modules are Entity, Queue, Resource, Variable, Schedule and Set. Flowchart and Data modules in a model are related to each other by the names for objects like queues, resources, entity types, and variables that they have in common.

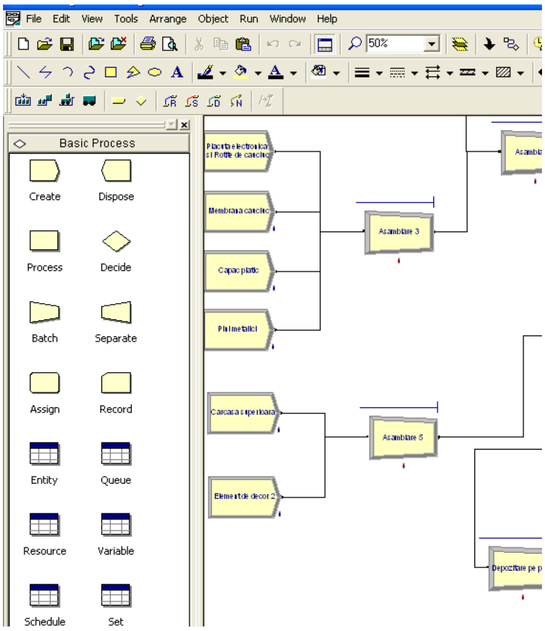


**Figure 3 Module of Arena**

## 2.2 Basic Definitions

### *2.2.1 Gross Throughput Time (GTT)*

Production orders, that may be generated from a requirements planning system or directly originated from customer orders, arrive continuously at the production system over time, but the arrival itself does not necessarily involve the release of a job to the shop floor. On the contrary, the orders are stored in a back log file, named “pre shop pool” (PSP), which actually decouples the planning system from the shop floor. In this sense, ORR procedures can be considered as the link between production planning and production control. The time an order spend in PSP and in the floor is refer to be Gross Throughput time.

### *2.2.2 Shop Floor Time (SFT)*

The time an order spend in the floor after releasing from the PSP is consider to be Shop Floor Time.

It includes the amount of time an order waited in the queue plus the processing time for the whole number of stations.

### *2.2.3 Output Levels*

Average daily output in the system, which entered the pre shop pool and processed through all of the stations, in terms of number of products and work content.

### *2.2.4 Percentage of (Tardy) Delayed Jobs*

Total number of Jobs which are late in comparison with the total number of processed jobs, measured in percentage. The mean conditional delaying will calculate the mean of all the jobs which are late.

The vast majority of ORR systems release jobs to the shop with the main aim of limiting workloads in the shop rather than balancing workloads among different work centers. The workload limiting mechanism is simple and produces an implicit workload balance among workcentres, because while no additional jobs are released to over-loaded workcentres, it is possible to release jobs to underloaded ones. (Perona and Portioli, 1998). Germs and Riezebos (2010) pointed out that the advantage from limiting workload on the shop is only obtained when the release mechanism also improves the balance of workload on the shop floor. In fact, they measure the effectiveness of workload control system as the ability of the system to balance workload on the shop.

## 3. THE ARENA MODEL

To give an idea for the model in Arena, only one model has been presented here which was designed in Portioli-Staudacher’s paper (2010), Load Limiting being simulated using this model.

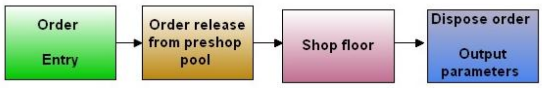


**Figure 4. Block diagram for the input/output of the ORR system**

**Table 1 Model Characteristics**

| | |
|---|---|
| Central control unit 25000 | Number of Stations 5 |
| Norm 640..14080 (with a difference of 480) | Production Capacity / Station / Day 480 minutes |
| Routing Length Deterministic routing | Operation Processing times 2-Erlang distributed |
| Inter-Arrival Time Orders enter the Pool at the beginning of each day | Release Period Length Once in a day |
| Priority Dispatching Rule First In First Out (FIFO) | Due Date Constant slack added (entry date + 20 days) |
| Jobs processing time / every station Lognormal: Mean = 32 min | Standard deviation |

### 3.1. Order Entry Phase

The first phase will create the job arrival rate into the system on the basis of the requirements given, it also assigns the value for due date, and different variables necessary to process later.

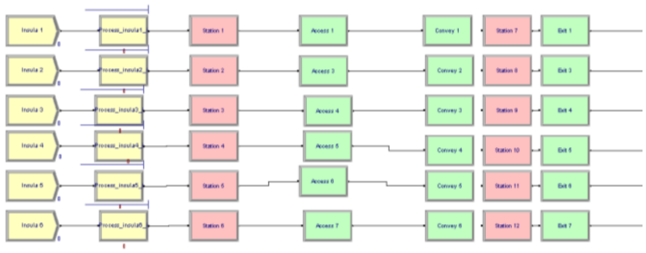

**Figure 5. Different blocks in the ARENA model with jobs entry and release from the system.**

The jobs created, will be released to the preshop pool if the total number of the jobs in the shop floor is less than the flow (in our case "Central control unit" = 25000), otherwise the job will be disposed off.

## 3.2. Order Release from Preshop Pool

The job is first hold for some duration and than all the five stations have been assessed for it's norm whether it has crossed the threshold value or not. If it fulfills the condition than the job is released to the Shop floor otherwise delayed for some duration and back to the hold panel.

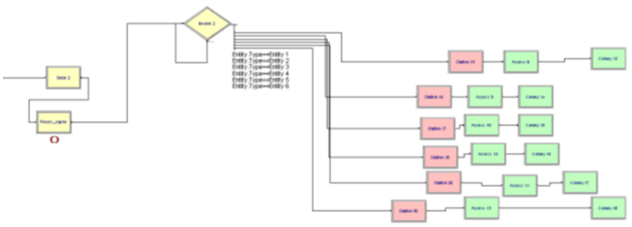

**Figure 6. Block diagram for order entry from the Preshop pool and release to the shop floor.**

## 3.3 Shop Floor

We have considered five stations for our problem in the shop floor, and on the basis of the routing parameters the job will be released to the corresponding station. Here, we have shown only one station to make it simple and understandable otherwise all of the stations have the same design parameters and blocks.

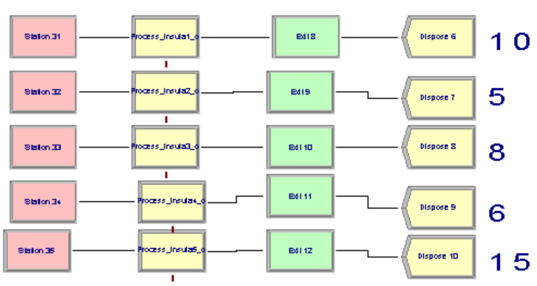


**Figure 7. Detailed block diagram for station 1 out of five stations.**

The details provided above is only for Load Limiting, we have also implemented the model in Arena for Load balancing which have different phases, blocks and panels. To get familiar with Arena and it's environment we have presented here only load limiting.

## 3.4 Record Output & Dispose of Orders

This phase will record all the required parameters like gross throughput time, shop floor time and Output. And, if there are some late jobs than those will be assigned late with its percentage tardiness and mean tardiness, finally the jobs will be disposed off.

# 4. SIMULATION RESULTS

This section discusses the results of simulation study for each of the parameters investigated. We start with an analysis of the workload norm because it has much influence on the results than any other parameter. We implemented for calculating norm, i.e. aggregate load norms. Figure 8 summarizes the results of the experiments with FCFS dispatching, along the x-axis are the values for shop floor time and along y-axis for gross throughput time (GTT), each norm contains overall averages of 45 runs.

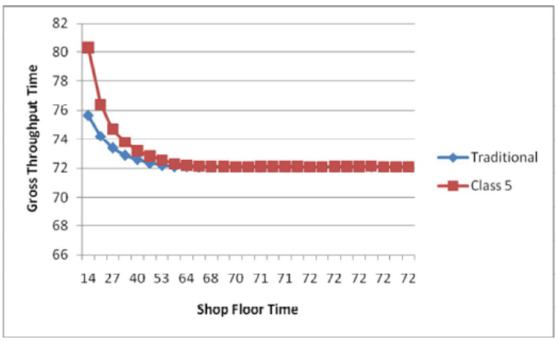


**Figure 8. Influence of norms on the two methods**

In Arena reports results are given at the corresponding norms with output in 'number of jobs', GTT & SFT are in unit 'hours'. Jobs arrive at the station on priority basis set by 5 classes; class means that the jobs are set by Easy, Easy-Medium, Medium, Medium-Hard, and Hard. Since the pipeline is 25000 with 5 stations, therefore the maximum number of jobs processed will be 5000 at each station. Nevertheless, we have tested norms greater than 5000 to assess the behavior of the system. We considered Gross throughput time (GTT) Percentage Delay, and Output as benchmark to compare both the situations and Shop Floor Time (SFT) as an intermediate variable. Figures 8 shows that, for norm 2000, the very first value, class 5 has greater GTT and it is due to the fact that first it will release all the jobs which has lower total work content and correspondingly achieving the lower SFT.

In the case of pure flow, therefore the jobs are arranged in the pre shop pool on the basis of due date without any classes, and this pre-arranged jobs will be released without following any criteria, is not like in the previous method and are not presented here.

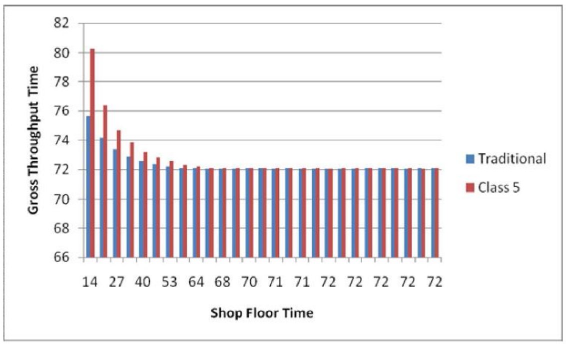


**Figure 9. Histogram view for the influence of norms on two different methods**

As the values for the norm are tightened, GTT for class 5 bisects the other curve and hence this method shows a better performance later than the traditional method in combination with larger shop floor time.

For better visualization, the same data is presented as a Histogram in Figure 9, which also shows better performance of the Class 5 at tightened norm considering GTT, SFT and Output.

## 5. CONCLUSIONS

The simulation results compares both the methods with the traditional one and shows that the release methods do have the capabilities to balance loads, which indicates that the pure job shops can be modeled as a simple flow shop.

As flows are completely single directed it appears to be important to estimate the influence of job release on the direct load of each station, and it proved to be useful to adjust the aggregate load of stations and increase visibility. Evident, the aggregate workload and the shop load do not appropriately indicate the future flow of work to a station in the case of job shops.

Queues are easily managed through a FIFO rule, thus resulting in an easier scheduling and expediting every stage is not longer required.

## 6. REFERENCES:

►Bechte, W., *Theory and practice of load-oriented manufacturing control*. International journalof production research, 26 (3), 375-395, 1998.

► Betrand, J. W., Van Ooijen., H:P:G., *Workload based order release and productivity. A missing link. Production planning and control*, 13 (7), 665-678, 2002.

►Breithaupt, J., Land, M. and Nyhuis, P., *The workload control concept. Theory and practical extensions of load oriented order release. Production planning and control*, 13 (7), 625-638, 2002.

►Kelton, D. *Simulation with Arena*, Second Edition. ISBN-13: 9780072507393
Publisher: McGraw-Hill Science/Engineering/Math

►Land, M.J., Gaalman, G.J.C., *Performance on workload control concepts in job shops. Improving the release method*. International journal of production economics, 56-57, 347-364, 1998.

►Melnyk, S.A., Ragatz, G.L., *Order review/release systems: Research issues and perspectives*. International Journal of Production Research, 27 (7), 1081-1096, 1989.

►Mohd Azrin Bin Mohd Said, Napsiah Binti Ismail. *Improvement of Production Line Layout Using Arena Simulation Software*, Applied Mechanics and Materials (Volumes 446 - 447), DOI 10.4028, /www.scientific.net/AMM.446-447.1340, 2014

►Muhammad Marsudi, Hani Shafeek, *The Evaluation of Production Line Performance by Using ARENA – A Case Study*. World Academy of Science, Engineering and Technology International Journal of Mechanical, Aerospace, Industrial and Mechatronics Engineering Vol:7 No:9, 2013

►Oosterman, B., Land, M. and Gaalman, G., *Influence of shop characteristics on workload control.* International journal of production economics, 68 (1), 107-119, 2000.

►Perona, M., Portioli, A., 1998. *Impact of parameters setting in load oriented manufacturing control*. International journal of production economics, 55 (2), 133-142.

►Portioli-Staudacher Alberto, Tantardini Marco. *Lean implementation in non-repetitive companies: a survey and analysis*. International Journal of Services and Operations Management, Volume 11, Number 4/2012, pp. 385-406, DOI 10.1504/IJSOM.2012.046076, 2012