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# MAXIMIZING THROUGHPUT: THE VALUE OF DISPATCHING RULES

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Manufacturing is an important part of Canada's economy, representing 11% of its Gross Domestic Product (GDP) as of August 2014 [1]. Due to globalization, many Canadian manufacturing industries face new challenges and, to remain globally competitive, they need to become more efficient [2]. Industry Partner A[1] was seeking efficiency gains by implementing Operations Research (OR) methods in their job-shops, particularly for their production scheduling. A job-shop is a type of manufacturing process in which small batches of a variety of custom products are made. As in many production models, it has a number of machines or resources on which the production work is processed. In job-shop scheduling, each job consist of several operations, each completed using a specific machine or resource for a set amount of time. The flow diagram in Figure 1 illustrates a hypothetical example of a job-shop. Each job has a due date by which time the job is ideally completed. At each machine, there are queued jobs waiting to be processed and a dispatching rule is implemented as a scheduling method to determine which queued job should be 'dispatched' for processing.

Andrew Brown, a graduate student at the University of Waterloo, was asked by Industry Partner A[1] to analyze various dispatching rules and propose a method that reduced the number of late jobs as part of his Masters dissertation under the supervision of Dr. Stan Dimitrov [3]. Hossein Abouee-Mehrizi, an Assistant Professor, ensured the content of this case complemented his course on scheduling theory.

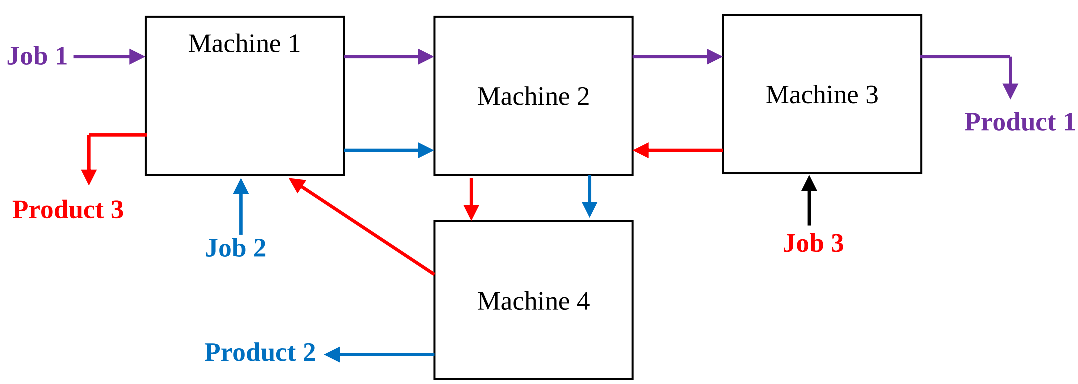


**Figure 1–Example of a job-shop process flow diagram**

[1] The identity of the company has been withheld at their request.



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## Operations Research and Dispatching Rules in the Industry

Operations Research (OR) is a discipline focused on the use of analytical methods to improve decision-making [4]. Job-shop scheduling is an optimization problem within operations research in which a variety of jobs need to be completed on various machines in a limited amount of time. A common scheduling technique is dispatching rules. A dispatching rule uses a specific set of criteria to determine the highest priority job among the queued jobs. Dispatching rules can range in complexity and are an important part of job-shops. They are used in a variety of industries such as manufacturing, taxicabs, emergency couriers and plumbing services [3].

## Situation of Concern

Industry Partner A was interested in analyzing their production scheduling methods in order to increase overall efficiency. This was important for continuous improvement and to remain competitive within the industry. In order to have a third party analyze their job-shop scheduling techniques, the company provided a sample set of production data[2] to Andrew Brown which included 467 jobs as well as processing time, machine IDs and respective due dates (Exhibit A).

### Requirements for Industry Partner A

The two Key Performance Indicators (KPIs) of interest to the company were the percentage of late jobs and the maximum lateness across all jobs. It is possible to have a scheduling method that reduces the percentage of late jobs but increased the maximum lateness. For this reason, the company specified that both KPIs should show improvement (a reduction). In addition, Industry Partner A used a human implementable method at the time of assessment, therefore a new scheduling method also had to be human implementable. A method is human implementable if it usable by schedulers with minimal training using existing scheduling equipment such as work-in-progress lists or job boards [3]. This was preferred since the company did not want a scheduling method that required new software implementation, refusing work, subcontracts, equipment acquisitions, substantial retraining or major corporate restructuring.

The job-shop uses a printed list of jobs to determine the schedule. They are printed per machine and several managers and production scheduling specialists as well as supervisors are required to make scheduling decisions. It is possible to alter the order of jobs that appear on these reports in order to implement another dispatching rule. This is the extent of the technology change the solution could require of Industry Partner A.

The aforementioned setup is human-implementable; the scheduling is done by people with the use of computers only being needed to generate a report.

[2] Data presented in this case study has been scaled and does not represent actual operations.

## The Push for Human Implementation

The major requirement for Industry Partner A was to have the new scheduling method be human implementable. This means implementing a solution that is minimally disruptive to the previously mentioned scheduling arrangement. Throughout their experience, there were three main reasons that prompt this requirement: transparency, unexpected problems and employee involvement.

**Transparency:** Most job-shop algorithms required extensive computations, so the reasons for the choices made by these algorithms were often opaque. When changes were required, the industry partner determined that this opacity made it difficult to alter a pre-existing schedule. In contrast, human implementable methods were simpler to understand and thus schedulers could easily analyze them against other manufacturing requirements, such as preventative maintenance.

**Unexpected Problems:** Job-shop algorithms cannot generally capture enough of the complexity and instability inherent in scheduling a real job-shop [5]. Industry Partner A knew that the shop floor changed quickly with new orders, machine break downs, etc. Job-shop algorithms typically created complete schedules, which specified the start and stop times for all jobs in progress; however, the latter half of a completed schedule often needed to be changed. The company concluded that human implementable scheduling methods were better at accounting for unexpected problems since scheduling choices were made in real time.

**Employee Involvement:** It was discovered that employees rarely criticized an OR computer generated schedule. Hence, employee criticism and suggested changes were often overlooked. After being overlooked often enough, employees stopped offering input, acquiescing to the schedule regardless of their better judgment. While using their computer scheduling system, Industry Partner A discovered this employee acquiescence and they found that employee involvement in many other aspects of production declined, negatively affecting production as a result [6]. For this reason, the company wanted the new scheduling method to allow employees to be informed of changing situations so they could easily make, contribute to, or criticize scheduling choices.

## Problem Statement

Andrew Brown needed to analyze the provided production data and propose a new scheduling method. This recommendation had to reduce the number of late jobs and minimize maximum lateness as well as meet the company's requirements. The solution could not involve a significant software change or addition in resources.

## References

[1] Statistics Canada, "Monthly gross domestic product by industry at basic prices in chained (2007) dollars – Seasonally adjusted". Internet. http://www.statcan.gc.ca/daily-quotidien/141031/t141031a001-eng.htm. [Accessed November 10, 2014].

[2] CMC, 2012. Manufacturing Our Future: A Manufacturing Action Plan for Canada. Tech. rep., Canadian Manufacturing Coalition.

[3] Andrew Brown, "Dispatching Work: Finding the best dispatching method for real job-shops". Masters Dissertation. Department of Management Engineering, University of Waterloo. 2014.

[4] Informs, 2014. "What is Operations Research?" Internet. https://www.informs.org/About-INFORMS/What-is-Operations-Research. [Accessed November 28, 2014].

[5] McKay, K., Safayeni, F., Buzacott, J., 1988. Job-shop scheduling theory: what is relevant? Interfaces. 18 (4), 84-90.

[6] Industry Partner A, 2013. Private communication with a manager from the industry partner.

## Exhibit A – Production Data[2]

The full set of production data is provided in an Excel file as part of this case study (Filename: WCDE-00336 Production Data). An example of the format and information provided in this file is shown in Table 1. The precedence constraints come from the order a job appears in the file, hence a job must be completed from top to bottom as it appears in the file. For the example below, job 1 must be completed in the order of machines M8, M5, M34, M30 then M5. One note is that there are re-entrant jobs which mean that a job can visit the same machine more than once, such as job 1 needing Machine 5 twice. To account for down time, the number of processing hours per day that Industry Partner A uses for their planning is 80% of the true capacity of each machine.

**Table 1 – Subset of production data (Job 1 example)**

| *Job* | *Release Date* | *Due Date* | *Machine No.* | *Processing Time (hours)* |
|---|---|---|---|---|
| 1 | 01-Oct-12 | 04-Dec-12 | M8 | 18.35 |
| 1 | 01-Oct-12 | 04-Dec-12 | M5 | 5.63 |
| 1 | 01-Oct-12 | 04-Dec-12 | M34 | 14.24 |
| 1 | 01-Oct-12 | 04-Dec-12 | M30 | 1.47 |
| 1 | 01-Oct-12 | 04-Dec-12 | M5 | 20.32 |

The following assumptions were taken regarding the provided production data:

- Each machine works 2 shifts of 7.5 hours per day Monday-Thursday, with 1 shift on Friday; this does not account for down time
- An operation cannot be preempted; once processing begins on an operation, it cannot be stopped until complete
- Each machine can work on one, and only one, operation at a time
- Each job can be processed on one and only one machine at a time
- Setup times are included in the processing times and they are not sequence-dependent
- One work day (7.5 hour time period during operational hours) is required to transport a job between different machines
- Re-entrant jobs are permitted which means two or more operations of a job may be processed on the same machine