Dual-resource Constrained Scheduling for Quality Control Laboratories

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Abstract: This work presents a novel formulation for quality control laboratory scheduling considering both equipment and analysts as constraints. The problem is modelled as a dual-resource constrained flexible job shop problem. The formulation considers analyst's tasks in multiple time points during the processing of samples. The mathematical model is implemented as a mixed integer linear programming model (MILP) aiming to minimize makespan. Two sets of instances for the scheduling problem are developed and solved. The first instance consists on a small example that illustrates the proposed formulation and is solved to optimality. The second instance mimics the real industrial problem and shows the challenges resulting from growing complexity.

Keywords: Scheduling; dual-resource constraint; quality control; flexible job shop; mixed integer linear programming.

1. INTRODUCTION

Recent trends are shifting industry's paradigms and enabling companies to cut on costs and save time on both services and production, through better planning and human-machine interfaces, better production control, raw material availability control, inventory levels, and energy consumption, Rüßmann et al. (2015). With the right decision making in place, customer and suppliers relations can be significantly improved and, with the increase in profit margins companies have the flexibility to better fulfil their social and environmental responsibilities.

Although all industry sectors are affected by these changes, one where it is inevitable is the chemical sector. Chemistry 4.0, involving the chemical and pharmaceutical industries is experiencing changes with great potential impact, Falter et al. (2017). With the electric car, a decline in demand for many chemical products, such as gasoline-resistant plastics, oil and fuel additives, is expected. Similarly, in the pharmaceutical subsector with the patent expiration and price controls increasing in Europe and the US, profit margins are under threat, Maslaton (2012). The prospect of these changes pressure companies to invest and try to find solutions, both in process improvement and product portfolio diversification.

It is within Industry 4.0 scope, and more specifically Chemistry 4.0, that the scheduling and rescheduling problem arises. To improve plant productivity, and having data from demands and plant state, it is possible to make planning decision to optimize future outcome, corresponding to either minimize costs and/or maximize revenues.

Quality control (QC) laboratories are one of the key structures in many chemical process industries. Because they are upstream and/or downstream operations (suppliers to manufacture and/or close to the point-of-sale), a loss in efficiency may compromise production start or delay shipments, Maslaton (2012). Therefore, QC laboratories have been appointed as an area where scheduling could have a very high impact on efficiency, Schäfer (2004).

This work focuses on QC laboratory scheduling considering both equipment and analysts as constraints. To do so, a mathematical formulation of a dual-resource constrained flexible job shop problem is proposed, where assignment of jobs to equipment and analysts is performed in order to minimize maximum completion time. The peculiarity of the model is that it considers analysts' tasks, not only in mounting and dismounting but in specific time points during processing. The mathematical model is implemented as a mixed integer linear programming model (MILP). To the best of our knowledge the mathematical formulation developed and application to the QC laboratory scheduling has not been presented. Additionally, two sets of instances were developed. One as an illustrative example, solved to optimality. The other to simulate a real industrial problem.

The remainder of this study is organised as follows. The rest of this section gives a review on related work. Section 2

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