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Job keeping strategies for rebalancing assembly lines during epidemic outbreaks

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RESUMO

Em circunstâncias estáveis, linhas de montagem comumente empregam trabalhadores com diferentes capacidades e os designam às estações de trabalho, onde realizam um determinado conjunto de tarefas especializadas várias vezes ao dia. No entanto, em uma situação de disrupção da demanda (algumas indústrias afetadas pela pandemia do COVID-19), a atual taxa de produção levaria ao acúmulo de estoques. Uma alternativa simples para lidar com essas quedas de demanda e os custos contínuos da força de trabalho é demitir funcionários. No entanto, isso também implica em custos econômicos e sociais. Como alternativa, podem ser feitos acordos para reduzir a carga de trabalho com uma dedução proporcional nos salários. Em casos em que a força de trabalho é heterogênea, pode ser particularmente difícil tomar decisões sobre a redução da carga de trabalho individual. Propomos uma abordagem que considera explicitamente a manuntenção de empregos, minimizando os custos totais de mão-de-obra em uma linha rebalanceada. Soluções que evitam inconveniências e custos associados à rotatividade de funcionários podem ser encontradas, com gastos levemente maiores com a folha de pagamento.

PALAVRAS CHAVE. Rebalanceamento de linha de montagem, Trabalhadores heterogêneos, Disrupção da demanda.

SE - Aplicações de PO/Analytics no combate ao COVID-19, retomada da economia e implicações nas cadeias de suprimentos, POI - PO na Indústria

ABSTRACT

In stable circumstances, assembly lines commonly employ workers with different capabilities assigned to stations, where they perform a given set of specialised tasks multiple times a day. However, under a situation of demand disruption (e.g. the case of some industries under the COVID-19 pandemic), the current overproduction rate would lead inventory levels to soar. A simple alternative to cope with these demand drops and ongoing workforce costs is to dismiss employees. Nevertheless, this also implies economic and social costs. Alternatively, agreements can be made to reduce workload with a proportional deduction in wages. In the case of heterogeneous workforce, decisions on workload reduction can be difficult to made, and that is why we propose an approach to preserve jobs while minimising the total labour costs in the rebalanced line. We can find solutions that avoid inconveniences and costs associated with a future workforce renovation, with only a slightly higher payroll.

KEYWORDS. Assembly line rebalancing. Heterogeneous workers. Demand disruption.

SE - OR/Analytics applications in the fight against COVID-19, economic recovery, and implications for supply chains, POI - OR in Industry

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1. Introduction

Assembly lines are manufacturing systems commonly applied to high-volume industries of standardised products. They are generally dedicated to produce homogeneous goods, a characteristic that is convenient for mass production. In academic research, assembly lines have originated a combinatorial problem widely discussed in the literature [Battaïa e Dolgui, 2013]: the Assembly Line Balancing Problem (ALBP).

In its simplest form, several simplification hypotheses are considered [Baybars, 1986] to define the so-called Simple Assembly Line Balancing Problem (SALBP). The SALBP consists in assigning a set of tasks to stations, whilst respecting constraints imposed by a precedence graph. Furthermore, these stations must be organised in a straight, serial line producing a unique model of a single product. The most studied objectives in a SALBP are the minimisation (i) of the number of stations (SALBP-1) or (ii) of the cycle time (SALBP-2).

Industrial assembly lines usually rely on fixed physical layouts, which can be hard to rearrange. Furthermore, it is often the case that the workforce is trained to conduct specialised tasks. Therefore, it is usually unrealistic to implement a (re)balancing solution from scratch without reckoning the active workforce and line configurations [Corominas et al., 2008]. This adaptability issue gives rise to a natural extension and more generalised version of ALBPs: the Assembly Line Rebalancing Problem (ALRP).

Other impractical simplification hypotheses are assuming that any task can be processed at any station and task processing times are independent of the station, which assumes that all tasks are performed by identical workers. Having a heterogeneous workforce means that task processing times are dependent on the worker assigned to perform them. This problem, named Assembly Line Worker Assignment and Balancing Problem (ALWABP), has been proposed by Miralles et al. [2008] and widely applied to sheltered work centres.

These problem variants were addressed in stable and mostly predictable conditions [Becker e Scholl, 2006]. In late 2019, however, the COVID-19 has been identified in Wuhan [Hui et al., 2020]. Few months later, in early 2020, it had become a global pandemic, leading many countries to adopt strict social measures to slow down the virus propagation and prevent infections to spread. The imposed restrictions impacted the demand of some manufactured products negatively, pushing industries to apply collective leaves. After this period, nevertheless, production levels could not be maintained at the usual rate due to inventory capacities and raw material scarcity. In order to avoid massive unemployment rates, governments allowed companies to make agreements with their workers by reducing labour hours with a proportional deduction in salaries. In April, 2020, the Brazilian government passed a temporary legislation (the MPV 936/2020) to permit workload reductions of 25%, 50%, 70%, or even more depending on the situation [Brazilian Ministry of Economy, 2020].

Motivated by these facts, in this paper, an approach to rebalance assembly lines with a heterogeneous workforce is proposed. It focuses on the integration of rebalancing and worker assignment problems under scenarios with an acute decline in demand, considering the conservation of a heterogeneous workforce and social distancing recommendations. As in the original SALBP, we consider a serial line producing a unique model of a single product.

The proposed approach is presented in Section 2, highlighting advantages associated to workforce conservation in assembly lines under a temporary demand disruption. Lastly, Section 3 ends this paper with concluding remarks and a discussion on further research directions.

2. Proposed Approach

Let us imagine an assembly line operating before the outbreak. The approach consists in initially taking into account such stable circumstance, in which the line is running under regular

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conditions with a given balancing solution. A set of tasks must be performed to assemble a product, they must respect precedence relations in their execution order, and the precedence graph is known. The current balancing solution with a defined cycle time that meets the demand is given. In this scenario, the company might be using an optimal SALBP-1 configuration for a known stable demand, and therefore the sum of task duration times assigned to the same station/worker does not exceed the defined cycle time.

At the moment that this assembly line was implemented, the workforce could be considered homogeneous. Nonetheless, due to initial training and intensive repetition, these workers became specialised in a subgroup of the task set. Changing their assignment at this point would slow down the line's pace. Therefore, depending on the heterogeneous worker, each task has a different processing time. Job rotation schedules alleviate this effect, but they are routinely conducted between neighbouring stations, thus the difficulty often remains if workers are assigned to tasks originally assigned to stations far from their own.

Under the demand disruption scenario caused by a pandemic, the initially defined cycle time must be proportionally increased to cope with the new production rate. Additionally, social distancing rules must be applied in order to follow health recommendations, i.e. allowing extra physical space between workers. This can be done by "eliminating" intermediary stations, and introducing gaps between operating stations with a consequent reduction in production capacity.

Finally, recognising that this epidemic outbreak is a temporary situation is an important assumption. Usually, a sinking market demand would be followed by company announcements on downsizing their workforce by means of mass lay-off and involuntary furloughs. Such kind of reaction has certainly been triggered by the recent COVID-19 outbreak, but in the context of manufacturing industries, these drastic measures are being carefully evaluated: since governments allowed companies and employees to accommodate workload reductions with a proportional wage deduction in mutual agreements, these industries have ample incentives to conserve its workforce during this upheaval.

The most straightforward approach would be simply dismissing workers up to a point that the remaining ones would be enough to keep up with the shrunken demand, which implies in high dismissal costs and even higher rehiring, training, and loss of product quality standards in the near future. Alternatively, the well-trained workforce can be maintained for further production re-establishment with reduced workloads. This later approach also has a positive social impact: none of the employees would lose their jobs in the midst of an economic crisis. It follows that incorporating job keeping strategies is a desired characteristic. In the proposed approach, it means that each worker should be hired at least once a week. For each day, a shift option is chosen to define its working hours duration. Furthermore, different workload reduction rates are applied to each worker, which may imply in a more vigorous use of some workers over the others.

Nonetheless, these viable advantages come along with two drawbacks: the possibility of a slightly increased cost in salaries and the computational burden in solving the problem. The total contracted hours may not be used for all workers, with conceivable payments for non-worked hours, which leads to minor inefficiencies when compared to the more simplistic approach. Lastly, whereas it is relatively easy to solve a SALBP case with specialised algorithms to contemplate the enlarged cycle time, it might be much harder to simultaneously decide the assignment of tasks to worker, workers to stations and days of the week, as well as the selection of workload reduction and shifts options to workers and days of the week. Even though workload reductions and shift options with different duration can be selected, the exigence of hiring each worker at least once a week must be satisfied. For the proposed approach, it is assumed that the balancing decision is a

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temporary short-term plan due to the uncertainty associated to the context. It is also considered that the cost of any worker is identical. Hence, by formulating a mathematical model with the objective of minimising the required working hours among employees, the proposed approach can be tested and solutions analysed.

3. Conclusions

As the current circumstance is predicted to be a temporary setback, the proposed approach of making agreements with workers to reduce labour hours with a proportional deduction in salaries allows a trade-off that is concerned with for both sides. With industries because rehiring a well-trained, heterogeneous workforce may be troublesome and costly in terms of product quality standards and retraining. Also with employees because they are able to keep their jobs whilst partially receiving a monetary compensation on the financial default they would experience.

The existing literature focuses on heterogeneous workforce assignment and assembly line rebalancing separately. The approach herein proposed tries to integrate these problems for industries facing demand disruption scenarios. We propose a problem in which workload reductions must be applied to workers with different capabilities while avoiding dismissals. The situation under study includes line size reductions to impose social distancing rules and lower production rate requirements.

Preliminary tests conducted with a mixed integer programming (MIP) model evidenced that it is possible to maintain the entire workforce employed for reduced demands with slightly higher costs on wages when compared to the dismissal scenario. Further research should focus in establishing a solid framework on how to conserve workforce during temporary disruptive circumstances with practical and industrial needs.

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