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Pareto Optimal Material Allocation Mechanism

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Abstract : Scheduling problems have been studied by the algorithmic mechanism design research from the beginning. This paper is focusing on a practically important, but theoretically rather neglected field: the project scheduling problem where the jobs connected by precedence constraints compete for various nonrenewable resources, such as materials. Although the centralized problem can be solved in polynomial-time by applying the algorithm of Carlier and Rinnooy Kan from the Eighties, obtaining materials in a decentralized environment is usually far from optimal. It can be observed in practical production scheduling situations that project managers tend to cache the required materials as soon as possible in order to avoid later delays due to material shortages. This greedy practice usually leads both to excess stocks for some projects and materials, and simultaneously, to shortages for others. The aim of this study is to develop a model for the material allocation problem of a production plant, where a central decision maker—the inventory—should assign the resources arriving at different points in time to the jobs. Since the actual due dates are not known by the inventory, the mechanism design approach is applied with the projects as the self-interested agents. The goal of the mechanism is to elicit the required information and allocate the available materials such that it minimizes the maximal tardiness among the projects. It is assumed that except the due dates, the inventory is familiar with every other parameters of the problem. A further requirement is that due to practical considerations monetary transfer is not allowed. Therefore a mechanism without money is sought which excludes some widely applied solutions such as the Vickrey–Clarke–Groves scheme. In this work, a type of Serial Dictatorship Mechanism (SDM) is presented for the studied problem, including a polynomial-time algorithm for computing the material allocation. The resulted mechanism is both truthful and Pareto optimal. Thus the randomization over the possible priority orderings of the projects results in a universally truthful and Pareto optimal randomized mechanism. However, it is shown that in contrast to problems like the many-to-many matching market, not every Pareto optimal solution can be generated with an SDM. In addition, no performance guarantee can be given compared to the optimal solution, therefore this approximation characteristic is investigated with experimental study. All in all, the current work studies a practically relevant scheduling problem and presents a novel truthful material allocation mechanism which eliminates the potential benefit of the greedy behavior that negatively influences the outcome. The resulted allocation is also shown to be Pareto optimal, which is the most widely used criteria describing a necessary condition for a reasonable solution.

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