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Enhancing the Performance of Automatic Logistic Centers by Optimizing the Assignment of Material Flows to Workstations and Flow Racks

Authors : Sharon Hovav, Ilya Levner, Oren Nahum, Istvan Szabo

Abstract : In modern large-scale logistic centers (e.g., big automated warehouses), complex logistic operations performed by human staff (pickers) need to be coordinated with the operations of automated facilities (robots, conveyors, cranes, lifts, flow racks, etc.). The efficiency of advanced logistic centers strongly depends on optimizing picking technologies in synch with the facility/product layout, as well as on optimal distribution of material flows (products) in the system. The challenge is to develop a mathematical operations research (OR) tool that will optimize system cost-effectiveness. In this work, we propose a model that describes an automatic logistic center consisting of a set of workstations located at several galleries (floors), with each station containing a known number of flow racks. The requirements of each product and the working capacity of stations served by a given set of workers (pickers) are assumed as predetermined. The goal of the model is to maximize system efficiency. The proposed model includes two echelons. The first is the setting of the (optimal) number of workstations needed to create the total processing/logistic system, subject to picker capacities. The second echelon deals with the assignment of the products to the workstations and flow racks, aimed to achieve maximal throughputs of picked products over the entire system given picker capacities and budget constraints. The solutions to the problems at the two echelons interact to balance the overall load in the flow racks and maximize overall efficiency. We have developed an operations research model within each echelon. In the first echelon, the problem of calculating the optimal number of workstations is formulated as a non-standard bin-packing problem with capacity constraints for each bin. The problem arising in the second echelon is presented as a constrained product-workstation-flow rack assignment problem with non-standard mini-max criteria in which the workload maximum is calculated across all workstations in the center and the exterior minimum is calculated across all possible product-workstation-flow rack assignments. The OR problems arising in each echelon are proved to be NP-hard. Consequently, we find and develop heuristic and approximation solution algorithms based on exploiting and improving local optimums. The LC model considered in this work is highly dynamic and is recalculated periodically based on updated demand forecasts that reflect market trends, technological changes, seasonality, and the introduction of new items. The suggested two-echelon approach and the min-max balancing scheme are shown to work effectively on illustrative examples and real-life logistic data.

Keywords : logistics center, product-workstation, assignment, maximum performance, load balancing, fast algorithm
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