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Quantifying picker blocking in a bucket brigade order picking system

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ABSTRACT

Bucket brigade is a linear order-picking process with one loading station and one unloading station. Here we model and quantify picker blocking in bucket brigade order picking systems (OPSs). A bucket brigade improves throughput and reduces variability in OPSs. However, each order picking trip fills different orders and creates workload variation per order. We show that bucket brigade order picking experiences picker blocking when there is a workload imbalance per pick face. We derive a closed-form solution to quantify the level of blocking for two extreme walk speed cases. Additional simulation comparisons validate the picker blocking model which includes backward walk and hand-off delays. We identify the relationship between picker blocking in bucket brigade OPSs and picker blocking in a circular-aisle abstraction of OPSs in which backward walk and hand-off delays as well as forward walk speed are considered. Our analytical model and simulations show that aggregating orders into batches smoothes the workload variation by pooling the randomness of picks in each order and that slowest-to-fastest picker sequencing modulates picker blocking between two pickers, *i.e.*, the interaction between neighboring pickers.

1. Introduction

Distribution centers (DC) receive products from suppliers and fulfill orders for customers. Order picking refers to the process of retrieving items from storage locations to fulfill customer orders. Tompkins et al. (2003) report that OPSs on average consume 55 percent of a retailer DC's operational cost. This cost will likely be higher for an OPS under pressure to absorb demand variability from market fluctuation (Hong et al., 2012b) and to resolve skill discrepancy from frequent workforce changes (Bartholdi and Eisenstein, 1996a). A bucket brigade strategy is useful for order picking both in warehouses and many types of manufacturing processes. Its characteristics of high throughput and a self-organizing property allow workforces to be organized with a minimal level of managerial planning and oversight. In this paper, we refer to the combination of flow-rack shelving (Fig. 1(a)) and the bucket brigade strategy discussed in Bartholdi and Eisenstein (1996a) as a bucket brigade order picking system (OPS). We define the bucket brigade OPS as a linear order-picking process with one loading station and one unloading station (Fig. 1(b)). Pickers travel through an aisle to retrieve items from shelves and place them in a bin (or tote) on a conveyor.

The picking area is divided into "zones" in which a picker picks a batch (or order). However, unlike other types of zone picking, the boundaries between the zones are continuously updated to maintain high utilization of the pickers and to minimize the work in process (WIP). The picker in the first zone, the most upstream picker, picks an item and places it in the tote assigned to a particular batch (Fig. 2(a)). Then the upstream picker moves to the next pick face to continue processing the batch (Fig. 2(b)) by picking at subsequent pick faces until meeting a downstream picker who has no assigned tote. At this point, the upstream picker hands off the current tote and returns to the loading station, or meets another upstream picker. If this individual is not the most upstream picker, after handing off the tote, the upstream picker moves backwards to meet a picker further upstream (Fig. 2(c) and (d)). Upon finally meeting an upstream picker, the now-downstream picker takes over the upstream picker's tote and walks forward until either meeting another downstream picker without a tote, or reaching the unloading station (Fig. 2(b) and (d)). The last downstream picker releases the completed batch to the unloading station and moves backward to take over a new tote (Fig. 2(c)). This so-called dynamic pick-and-pass process eliminates the need for workload balancing and minimizes WIP (Bartholdi and Eisenstein, 1996a).

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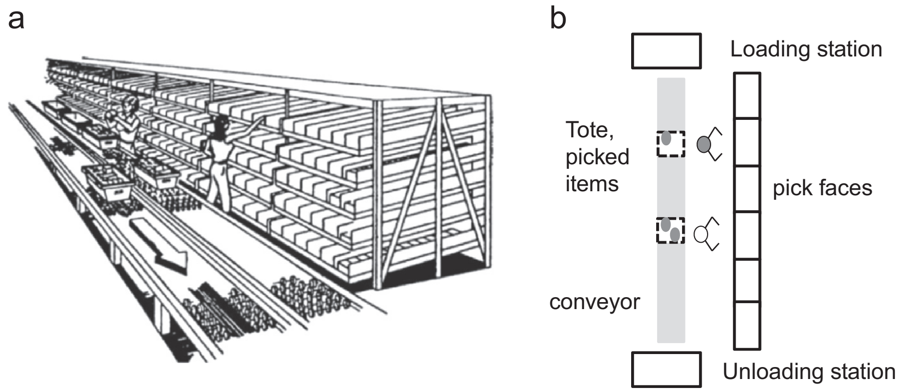

Fig. 1. A flow-rack OPS: (a) physical layout; and (b) top view.

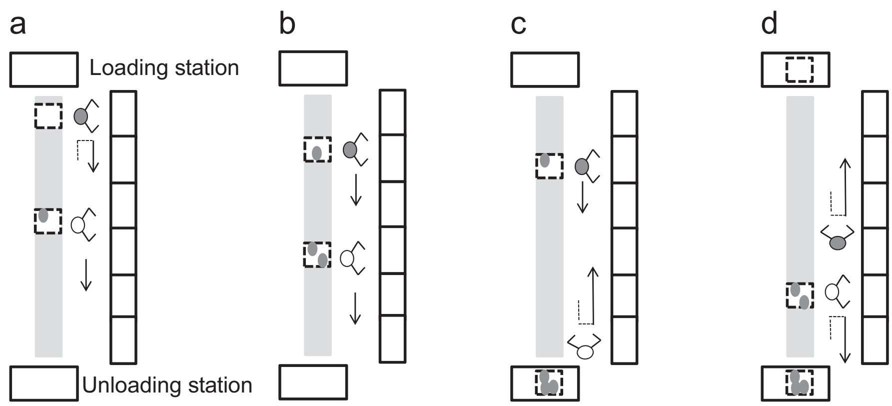

Fig. 2. A series of bucket brigade order picking operations: (a) an upstream picker takes a tote from a loading station and a downstream picker travels forward while picking; (b) both pickers travel forward and pick items; (c) a downstream picker unloads a tote and travels backward; and (d) a downstream picker takes over a tote and an upstream picker hands off a tote.

In a bucket brigade OPS, randomness and the imbalanced workload between pickers cause picker blocking. For example, an upstream picker in Fig. 2(b) attempts to move forward to the next pick face, which can be occupied by a busy downstream picker (Fig. 3(a)). In this example, *picker blocking* occurs when the upstream picker cannot hand off the current batch to the downstream picker, because the downstream picker is currently picking, and the upstream picker cannot pass the downstream picker, because the pickers' sequence must be maintained. In addition, pickers stand idle when the hand-off process is synchronized improperly. If an upstream picker in Fig. 2(d) is picking when a downstream picker encounters the upstream picker (Fig. 3(b)), the downstream picker must wait until the upstream picker completes the pick and *hand-off delay* occurs.

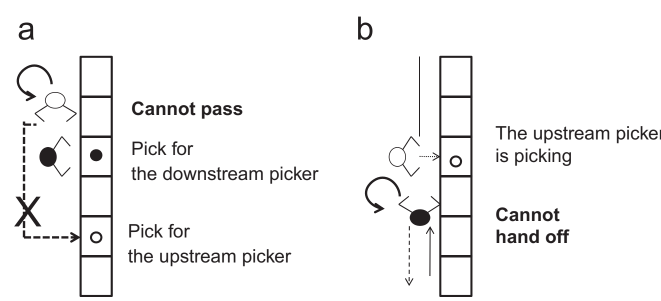

Fig. 3. Delay situations in bucket brigade order picking: (a) picker blocking; and (b) hand-off delay.

Blocking delays and the resulting hand-off delays occur (Bartholdi and Eisenstein, 1996a), when pick requirements are random over pick locations. Picker blocking in bucket brigade order picking has received little attention in the literature, with a few notable exceptions (Armbruster and Gel, 2006; Armbruster et al., 2007; Bartholdi and Eisenstein, 1996b, 2005; Bartholdi et al., 2001); however, this research has focused on operational rules or conditions that lead to reasonable overall operational performance in diverse settings. A clearly defined analytical model for upstream blocking delays is needed and we provide one such model in this paper.

We develop a model for picker blocking with unique characteristics specific to bucket brigade order picking by measuring and tracking the distance between order pickers. Further, we analytically investigate two extreme conditions of very-fast and very-slow forward walking speeds and discuss simulation studies to identify picker blocking patterns for typical forward and backward walk speeds including hand-off delays. Our simulation study also analyzes how picker blocking in a bucket brigade OPS occurs due to variations in the hand-off times between pickers, backward work speed, batch picking, and workforce staffing. Finally, the simulations compare bucket brigade and a circular-aisle OPSs abstraction in terms of picker blocking and the impacts on workload balance.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature and describes the picker blocking issues. Section 3 analyzes picker blocking in bucket brigade order picking. Section 4 introduces analytical models for picker blocking. Section 5 details the picker blocking *via* simulation studies. Section 6 concludes.