論　文　の　要　旨

題　目　A Study on Bucket Brigade for Cellular Production Systems with Worker Collaboration and for Order Picking Systems with Order Batching
(作業者協力を伴うセル生産システムとオーダーバッチングを伴うオーダーピッキングシステムに対するバケツリレーの研究)

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The bucket brigade concept, widely employed in production and order picking systems, dynamically arranges human labor and workloads. According to this concept, in a production or picking line, once the last worker or picker finishes their task, they move to the position of the second-to-last worker or picker to take over the work of the upstream worker or picker and continue the process. Consequently, the second-to-last worker or picker moves to the position of the third-to-last worker or picker to take over their work, and so on, until the first worker or picker introduces new work content into the production or picking line. Previous studies have shown that the bucket brigade concept allows for the achievement of the maximum possible production rate compared to various other methods of organizing human labor and workstations.

Cellular bucket brigade production system is proposed to reduce the unproductive walk-back behavior of workers in the traditional bucket brigade production system. In a bucket brigade production system, workers often walk back to retrieve additional work content from upstream workers, which can be time-consuming as they traverse the entire production line. The idea of the cellular bucket brigade production system is to distribute work content on both sides of an aisle. Each worker assembles an item on one side of the aisle while proceeding in one direction, and assembles another item on the other side while proceeding in the reverse direction. When workers need to retrieve additional work content, they only need to walk across the aisle instead of along the entire picking line. Compared to the traditional bucket brigade production system, the cellular bucket brigade production system significantly improves production efficiency.

Worker collaboration approach proves to be valuable in enhancing the efficiency of the cellular bucket brigade production system by reducing pickers' blocking time. A cellular bucket brigade production system is consistent with several workstations. And one workstation is only available for one worker to process item due to the space and tools limitation. However, when a worker needs to move to the next workstation but finds it occupied by a downstream worker, the worker experiences blocking. The worker collaboration approach facilitates collaboration among workers by enabling them to share space and tools at certain workstations. This approach effectively minimizes blocking time in the cellular bucket brigade production system, thereby enhancing production efficiency.

Order batching method addresses the challenge of small-sized orders in the bucket brigade order picking system. Small-sized orders significantly impact the system's efficiency as pickers must make multiple trips

to fulfill these orders, resulting in inefficiencies. The order batching method resolves this issue by grouping small-sized orders into batches, allowing multiple orders to be fulfilled in a single trip. This approach improves the efficiency of the order picking system.

Conveyor system reduces the walk time of pickers in the bucket brigade order picking system by assisting them in transporting totes. After picking all items in an order, pickers still need to walk to the unloading station to unload the totes associated with that order. Additionally, after handing over the tote to the second picker, the first picker must traverse a considerable distance back to introduce a new tote, resulting in unproductive walking behavior during the loading and unloading processes, which affects the overall efficiency of the system. Introducing a conveyor system to transport totes from the loading station to the first picker and from the last picker to the unloading station significantly reduces the walk time of pickers, thereby improving the efficiency of the order picking system.

This dissertation proposes two collaboration models for the cellular bucket brigade production system from different perspectives to enhance production efficiency. One problem addressed is the underperformance of existing collaborative models in achieving higher throughput in some cases due to design limitations. Another issue is the complexity of worker operation principles and the occurrence of many unproductive movements. A comparison between the proposed and existing models demonstrates significant improvements in throughput figures achieved by the proposed models.

In this dissertation, an order batching model is proposed to enhance the productivity of bucket brigade order picking systems when encountering small-sized orders. The previous model batched orders by minimizing batch completion time, but this approach proved challenging due to the complexity of the bucket brigade order picking system, especially when dealing with non-identical pickers. Consequently, the previous model relied on estimated completion time formulas, leading to errors and blocking issues in the order picking system. To address these challenges, this study proposes the Balanced Batching Model for Bucket Brigade (BBMB). Previous research indicates that bucket brigade order picking systems achieve maximum productivity when they are balanced, with balanced work content directly contributing to system balance. Building on these concepts, the BBMB model batches orders by balancing work content in the order picking system. The BBMB model has demonstrated increased productivity in bucket brigade order picking systems when handling a large number of small-sized orders. Compared to the previous model, the BBMB model reduces blocking time percentage from 4.46-12.5% to 0.26-5.66% in various simulation experiment scenarios.

In this dissertation, an enhanced bucket brigade order picking system with a conveyor is proposed to mitigate unnecessary walking behaviors of pickers in bucket brigade order picking system. The proposed order picking system incorporates a conveyor system to assist pickers in transporting totes that have completed order picking to the unloading station and to introduce new empty totes. By doing so, the proposed order picking system reduces the average total walking time cost by 36.64% and increases productivity by 9.65%.

Keywords: Bucket brigade, production system, worker collaboration, order picking system, order batching, conveyor