

Cost and Throughput Modeling of Manual and Automated Order Fulfillment Systems

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(ABSTRACT)

The e-commerce revolution has brought about the need for more efficient order fulfillment. Guidelines are needed to determine the order fulfillment system design, and whether a manual or automated system should be implemented. A spreadsheet-based descriptive model has been developed based on demand levels, labor rates, and order sizes. We propose to combine the descriptive model with simulation output to demonstrate reactions of the system to fluctuations in demand, labor rates, and order sizes. The ultimate research goal is to provide a design aid to companies engaged in order fulfillment systems, emphasizing the decision of whether or not to automate the sorting process.

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Chapter 1

Introduction

Sortation systems are becoming more and more common in distribution centers. With the explosion of the e-commerce revolution, more emphasis is placed on customer delivery. Customers have high expectations for internet delivery. The orders are becoming smaller. Where a bricks-and-mortar company might send a case of one item to the retailer, an e-business will have many orders with one or two different items each. Customers use the World Wide Web for convenience, but are often disappointed by poor delivery performance. For instance, the Christmas season of 1999 was disastrous for many e-businesses. These companies were not prepared for the mad rush of customers to the internet. A research study of 50 e-commerce sites showed that 20% of packages ordered arrived late or never made it [38].

E-businesses soon recognized that on-time delivery could be achieved if distribution centers (DCs) became more efficient. Sortation systems are proving to be a way to achieve the desired levels of efficiency. Catalog distributors also use sortation systems as a means to sort through thousands of orders efficiently. In fact, sortation systems are becoming common in every type of fulfillment centers.

1.1 Distribution Center Description

In order to fully understand the role of sortation systems in distribution centers, an overview of the entire distribution system should be understood as well. Distribution centers generally consist of five main areas: receiving, the reserve area, the forward area, packing, and shipping. Areas such as inspection, returns, and administration are part of the system as well.

In the receiving area, trucks bring shipments in to be unloaded and placed in the reserve area. Paperwork is completed, and samples are removed for inspection. Cases of items are then placed in storage locations in the reserve area. In this area, different types of storage assignment policies are used, including dedicated storage, random storage, and class-based storage. Items remain in the reserve area until they are needed in the picking or forward area.

The forward area is the storage area where cases are opened and items are removed as needed. Pickers receive a list of orders to be picked in a certain time period (wave). They travel up and down aisles, picking items from cases as needed. As in the reserve area, several types of picking configurations can be seen. In addition, pickers use many differing methods to collect items for orders. There are three main types of order-picking: zone picking, batch picking, and picking single orders to totes. Items travel from the picking area to the packing area via conveyors or totes.

Sortation occurs at this stage in the distribution process. The amount of sortation required depends heavily on the type of picking used. For instance, batch picking requires much more sortation than single-order picking. Once sorted, the orders are packaged and sent to the shipping area. In this area, packages are separated into trucks for final distribution (e.g., UPS, RPS, USPS, common carrier, etc.). Figure 1.1 illustrates the flow of a distribution center.

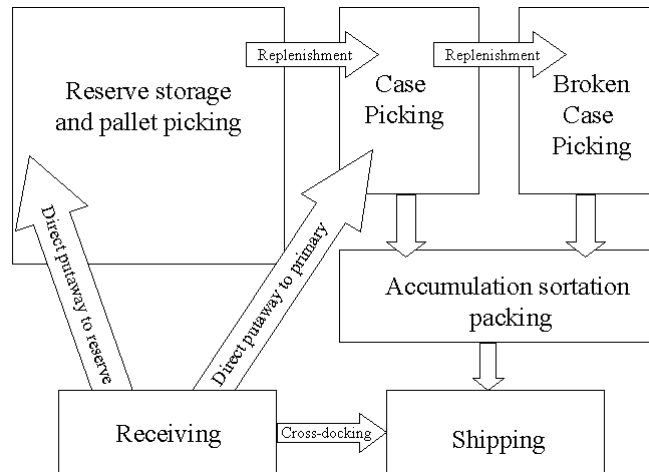


Figure 1.1: Distribution Center Flow [40].



Figure 1.2: Packing Sorter Installation [1].

1.1.1 Sortation System Description

Sortation systems are conveyor systems that circulate around packing areas. Items arriving from the picking area of the DC are inducted onto the conveyor and then sorted to the correct packing station based on their respective order number. The drop mechanism is instructed to discharge the item to a particular packing station by a computer system. Sorters of this type can sort between 100 and 400 items per minute, depending on their size and conveyor speed. Figure 1.2 shows the installation of a packing sorter.

Now that companies realize that sortation systems can be the answer to their efficiency problems, several questions should be answered. Sortation systems are large and expensive,

and may not be feasible for the company considering it. The first consideration the company must make is the feasibility of the system. The size of the required system, as well as the number of employees needed to operate the system must be considered. This requirement can help determine if automated sortation will be more cost effective than manual sortation. After determining if the system should be implemented, smaller decisions such as the number of orders filled per wave must be answered.

Wave Size

The common method of dividing orders within a distribution system is to utilize waves. A wave is basically a period of time in which a group of orders is either picked, sorted, or packed. A wave can range in length from 20 minutes to 2 hours, depending on the capacity of the sorter, the number of employees, and the volume of products. Waves are used to balance the workload in the picking and packing areas as well as to synchronize these activities [7]. Workers only work on the orders assigned to that particular wave.

Wave length is an important factor in distribution system design. Studies have been conducted to determine when the next wave should be released into the system and how this affects the throughput of the system. Varying wave lengths can have an effect on picker's and packer's efficiency, as well as the size of the sorter that would be required. In this research, we focus on the effects of wave length on system cost.

Setting the wave length can have a significant effect on a system configuration. For instance, a short wave length results in less efficient pickers, since the number of orders that can be batched is smaller. However, a packer may be more efficient in the manual system since he is receiving fewer orders. A long wave length allows for more intelligent batching, therefore increasing the pickers' efficiency. Longer wave lengths also result in larger sorters, which effects the capital costs of the system.



Figure 1.3: Tilt-tray Sorter [3].

1.2 Types of Sortation Systems

There are several types of sortation systems, each based on their configuration and uses. The most common are tilt-tray sorters, bomb-bay sorters, and cross-belt sorters. A company will select one of these types of sorters based mainly on the nature of the product needing sortation. For instance, a product such as a comforter can handle a drop from a tilt-tray or bomb-bay sorter, while a cross-belt sorter would be best suited to handle items that are more fragile, such as a video tape or compact disc. A tilt-tray sorter is shown in Figure 1.3.

Each automated sortation system consists of three parts: the conveyor (including trays or belts), the induction area, and the packing area. The induction station includes a chute, conveyor, or staging area for parts arriving from picking and a platform for the workers. Sortation systems can have one induction station or split stations to increase productivity. At the induction station, items arrive from the picking area, and inductors place items onto the trays so that the scanner can read the item information from its label. The scanner then sends this information to the computer. Induction stations and packing stations are shown in Figures 1.4 and 1.5, respectively.

The part then travels on the conveyor to the pack station designated by the central computer



Figure 1.4: Induction Station [2].



Figure 1.5: Packing Station [2].

system. As the item arrives to the pack station, it is discharged to a chute leading to the packing work area. There are generally several chutes coming into one pack station. Each chute can hold several orders, or a single order depending on how the system is configured. From this area, the parts are packed by order and the packaged orders are sent to the next processing area (typically shipping).

Automated sortation systems can be used for several purposes. The most obvious use is sorting items to be packaged. However, many companies use the system to sort returned items back into picking zones or rows. Another common use is sorting packages to be shipped.

Automated sortation systems can either be designed to accommodate recirculation or not. Recirculating systems allow items to travel around the conveyor several times to allow sortation lanes to accommodate more than one order per sorting wave. This type of system is commonly used in shipping areas. In a recirculating system, the number of lanes is typically less than the number of orders. Recirculation is therefore necessary since each incoming item will not find an available lane. Another reason for using a recirculating system is to use the loop to accumulate all items in an order before the order is assigned to a lane.

The focus of this research is on non-recirculating systems (NRS) used in packing areas. In this type of system, the sortation conveyor is empty before reaching the induction station again since each sortation lane accommodates only one order per sorting wave.

In Chapter 2, literature related to distribution systems and sortation issues is discussed. This chapter provides a general overview of distribution research as well as specific research related to automated sortation.

Chapter 2

Literature Review

Because literature concerning sortation systems is somewhat limited, an overview of warehousing and distribution systems research will be reviewed. This list includes general warehousing issues, storage policies, automated storage/retrieval systems (AS/RS), order-picking, sortation systems, and conveyor systems.

This overview will provide background and insights into research that has taken place up to this point, and will lead to the need for research into sortation system design concerns.

2.1 General Warehousing

According to Cormier and Gunn [11] there are three major warehousing problems: throughput capacity, storage capacity, and warehouse design. Much effort has been placed on maximizing throughput. Batching and picking policies, as well as storage assignment policies, have been aimed at this objective. Storage capacity models, on the other hand, have been developed with the objective of minimizing total discounted costs. Other objectives in these models include minimizing material handling costs, inventory costs, and holding costs.

Cormier and Gunn [11] review research relevant to each of these warehousing problems. They conclude that the model used in the decision-making process should be determined

based on the type of decision that is being made. For instance, a strategic decision that will have a long-term impact, such as storage capacity design, should use an optimal model if possible. Although models that yield optimal results are more complex and difficult to solve, the effort is justifiable based on the importance of the decision. In contrast, an operational decision such as assignment of products to storage areas may be more suitable for a good, fast decision from a heuristic.

Gray *et al.* [24] developed a method of warehouse design using a hierarchical approach. Their research studies the entire design and operation of the system. Decisions such as layout, equipment, storage, order-picking, and technology are considered. Since the entire design is too complex to be determined by a single model, the method used is a hierarchical decision structure. The main decision levels include facility design and technology selection, item allocation, and operating policies. Within these levels are smaller decisions such as assigning items to zones, order batch sizes, and other similar decisions. The solution to this problem is found by iterating between the three main levels until a solution is found that minimized the total cost. This decision structure considers the interaction and fundamental relationships between each decision as well as the individual decisions. The authors propose using the analytical models within each level of detail to eliminate poor solutions. Once this is completed, simulation can be used to examine the subset of solutions reasonably.

Cormier and Gunn [10] developed a discounted cost model that establishes a warehouse size and inventory policy. Under the assumption of constant demand, this model integrates the two factors to determine a design that is optimal for both. The model resulting from the coordination of warehouse sizing issues with inventory policy is best applied at the conceptual stage of design, mainly due to the simplifying assumptions made.

Distribution design can also involve determining the optimal number of distribution centers for a particular company. Erlebacher and Meller [19] developed a model that solves a location-inventory problem with a large number of customers. This model will determine the optimal number and locations of DCs, and which customers should be served by each DC based on inventory costs as well as transportation costs. Because of the difficulty of this problem, a heuristic procedure was developed to solve the problem.

Recently, van den Berg completed a literature review survey of warehousing systems [41]. This review summarizes new methods, technologies, and models used to deal with customers that are requesting smaller orders and shorter response times. In order to improve accuracy and quality, warehouse operations must be improved to respond to these changes. Literature related to the planning and control of warehousing systems was reviewed.

Planning of warehouse operations consists mainly of storage location policies. Decisions related to storage location include how products are distributed throughout the warehouse, what products are clustered, how products should be stored in order to balance workload, and the assignment of products to locations. Distribution of products into order-picking areas and reserve areas, as well as order-picking methods in these areas has been studied. Correlated products that are often ordered together can be clustered in order to reduce travel time. Research regarding the proper amount of clustering and its effects has been conducted. Storage assignment policies that have been developed will be discussed in a later section of this review.

Control of warehouse operations include batching of orders as well as order-picking routing and sequencing. Batching orders reduces the average travel time per order. Routing and sequencing orders in an intelligent manner can also reduce the travel time required to pick orders. Methods of batching, routing, and sequencing orders will be discussed in the review of order-picking techniques.

Many methods used to reduce travel time and increase throughput have been discussed in this literature review. However, little research has been completed concerning the use of automated sortation systems to increase throughput. Automated sortation systems allow the use of more sophisticated order-picking techniques that have been proven to reduce travel time required to pick an order. Although research regarding automated sortation systems exists, to our knowledge no research has shown when this type of system should be implemented based on throughput and associated costs.

2.2 Storage

Warehouse objectives include maximizing space and minimizing travel time required for order-picking operations. Storage policies can have a significant effect on these objectives. There are three main storage policies commonly used in practice: randomized storage, dedicated storage, and class-based storage. With randomized storage, parts are placed in a location based on available storage space at the time of storage. Over time, even if parts are assigned to the closest open location, the distribution of parts over the warehouse appears random [6]. With dedicated storage, parts are assigned a particular location in the warehouse, where each location is dedicated to one part. Class-based storage assigns locations to parts based on a class of items with similar properties (e.g., demand, product type, and size).

Although dedicated and class-based storage policies can reduce material handling distances by locating fast movers at locations close to the input/output point, a tradeoff must be made between this reduction and the amount of storage space required for these policies. With randomized storage, items can be placed in any available location. In dedicated and class-based storage, a certain amount of excess storage space has to account for variations in demand. Randomized storage requires a much smaller amount of excess space than either dedicated or class-based storage. Malmberg [29] developed a model that determines the space requirements for a randomized storage system based on a probability distribution based on item activity levels. This model allows for a detailed analysis of the tradeoffs between using randomized or dedicated storage policies. An application of this model for a 25-aisle storage system resulted in lower average retrieval costs for randomized storage in certain scenarios. With randomized storage, this analysis also resulted in space requirement savings of an average of 30% of that required using dedicated storage [29].

Optimal arrangement of stock in the order-picking area depends on several factors: size requirements, correlated products, demand frequency, and type of order-picking used. Elsayed [17] examined four heuristic algorithms for order-picking using an automated storage and retrieval system. Each algorithm seeks to minimize material handling distance in a picking

tour. This problem is harder since the order-picker must perform a tour instead of an out-and-back trip as in the reserve area. Storage in order-picking areas will be discussed further in the review of order-picking.

Another method of storage is COI-based storage assignment. Cube-per-order index (COI) is the ratio of the amount of storage space required for a particular SKU to the order frequency [9]. In this storage assignment policy, items with low COI ratios are stored closer to the input/output point than items with high COIs. The effects of this storage assignment policy with different routing methods will be discussed in the order-picking review.

Larson *et al.* [28] developed a heuristic approach to warehouse layout in a facility with class-based storage. This heuristic consists of three phases: Phase 1 (determination of aisle layout and dimensions), Phase 2 (assignment of material to a storage medium such as a flow rack in the forward area or the reserve area), and Phase 3 (allocation of floor space). Floor space is allocated based on the storage medium. The use of a class-based storage policy provides flexibility to deal with demand fluctuations, and allows for decreased travel time and material handling costs without leaving as much excess storage space as a dedicated storage policy requires. Significant reductions in material handling distances are a result of using this heuristic warehouse layout approach.

2.2.1 Automated Storage and Retrieval Systems

An automated storage and retrieval system (AS/RS) is a storage system that is guided by a set of rails on which machines move to and from storage racks on a fixed path [40]. AS/RS can perform single or dual command operations. In a single command operation, a location is visited and either a pickup or a delivery is executed. In a dual command operation, both a pickup and a delivery are executed in the same cycle. AS/RS cranes are unique because they can travel horizontally and vertically simultaneously. This can help to reduce material handling times, especially in very high racks.

Hausman, Schwarz, and Graves [25] studied optimal storage assignment policies with automated warehousing systems such as AS/RSs. They considered random assignment, turnover-

based assignment, and class-based turnover assignment. Analytical expressions were developed to determine the travel time for each system. It was found that turnover-based assignment results in significant reductions in travel times in an AS/RS. Elsayed [17] developed four algorithms (discussed further in order-picking review) that seeked to minimize total costs of picking orders within a warehouse that utilizes an AS/RS.

Bozer and White [6] developed design algorithms to determine the near-minimum number of orderpickers for several system configurations. Each configuration is some version of an end-of-aisle AS/RS. Configurations include one aisle per picker or multiple pickers per aisle. The algorithm attempts to minimize the number of pickers subject to system throughput, storage capacity, and constraints on resources that must take on integer values. This design algorithm can be used to evaluate system configurations when used with a cost model.

Meller and Mungwattana [33] developed analytical models to determine the throughput of multi-shuttle AS/RSs. Multi-shuttle systems increase throughput, resulting in cost savings up to a point where the capital investment exceeds this savings. In addition, several operating policies were modeled to evaluate the performance of the policy. For instance, the nearest neighbor policy and reverse nearest neighbor policies were examined. Each reduced the travel time between storage and retrieval locations. By increasing the number of commands per cycle and using intelligent storage and retrieval strategies, significant increases in throughput were seen over single-shuttle AS/RSs.

2.3 Order-picking

2.3.1 Order-picking Methods

Order-picking is the most time consuming activity that takes place in the distribution process. According to Drury [16], it may account for up to 60% of all labor activities. This activity is also quite costly, making up approximately 65% of the warehouse's total operating cost [12]. Because of these alarming statistics, order-picking has become a popular research field. The majority of this research focuses on minimizing the total travel distance

in a picking tour, or a set of orders picked at a particular time. Many methods of reducing this distance have been examined. Some methods involve sequencing the pick tour in order to provide a tour with the shortest possible distance. Others have attempted to solve this problem by optimally storing items in the picking area. Finally, methods of order-batching are used to develop efficient pick lists.

2.3.2 Definitions

In order to fully understand the research encompassing order-picking strategies, several terms should be defined.

Traversal: Aisle travel policy that requires the picker to enter the aisle at one end, pick all items from that aisle, and exit the other end without reversing.

Return: Aisle travel policy that allows the picker to enter and leave the aisle at the same end.

Largest Gap: Aisle travel policy where pickers use a return policy, but in the first and last aisles entered, the picker travels to the position of the largest gap between the two adjacent locations in the aisle [15].

I/O Point: Area in the warehouse where pickers receive picking lists and drop off completed orders (see Central Depot).

Central Depot: Specified location in a picking area where pickers pick up order lists and drop off completed orders.

Picking Tour: The sequence of locations at which items are picked to fill a specified number of orders.

Order-picking By Order: Method where pickers in the warehouse pick one order at a time.

Batch Picking: Method where pickers in the warehouse pick items needed for several orders, accumulating the orders with other pickers after all items have been picked.

Sort-While Pick: Method where pickers retrieve items needed several orders and sort items into orders as they are picking.

2.3.3 Routing Policies

Routing policies determine the sequence used to pick parts to complete orders on a pick list. Several routing policies have been developed over the years. However, many of these policies are not commonly used in practice because they are not well known. Policies have been examined and evaluated for between-aisle travel and within-aisle travel.

There are two basic routing policies: the traversal policy and the return policy. Goetschalckx and Ratliff [22] developed an optimum traversal aisle model for picking within the aisle. This model was compared to the routing policy used commonly in practice, the ‘Z’ pick policy. This policy requires pickers to visit slots within aisles in a Z-pattern, stopping at only the locations of items on the pick list. The ‘Z’ policy is commonly used because only one picking pattern is required for every pick tour. In order to compare the two policies, the authors determined the length of the optimal Z-pattern tour, which is normally determined arbitrarily (i.e., non-optimally). The Z-pattern tour was outperformed by the optimum traversal aisle model by an average of 12% [22]. The optimum traversal aisle model was also studied with the all return model. While both models using optimum traversal instead of ‘Z’ pick were superior, the traversal policy has a shorter pick tour in all practical situations.

Caron *et al.* [9] combined a COI-based storage policy with different routing policies. This storage policy assigns items with a low ratio of required storage space to order frequency close to the I/O point. COI-based storage and random storage are combined with traversal and return routing policies. With COI-based storage, traversal routing policies generally outperform the return policy. Return policies outperform traversal policies in situations when the number of picks per aisle is low or there are many picks in few aisles (skewed inventory curves). With random storage, traversal is at least as good as return. The authors concluded that the average number of picks in an aisle is a key factor in determining the best routing policy with COI-based storage.

Ratliff and Rosenthal [39] developed an algorithm to determine the optimal picking route that minimizes the picking time. Their method uses graph theory to find a minimum length tour subgraph from a graph with vertices representing each pick location and aisle end, and edges representing distances between each vertex. For a rectangular warehouse, the runtime of this method increases linearly in the number of aisles.

Routing orderpickers was again studied by DeKoster and Van Der Poort [14] in order to compare an extended version of Ratliff and Rosenthal's optimal order-picking route with a commonly used S-shape heuristic. The algorithm developed by Ratliff and Rosenthal was extended to the case with a central depot. The authors determined that the major factors affecting the performance of the routing policy are the savings in time traveling in and out of aisles, and the warehouse layout. The layout can affect the time needed to enter an aisle. For instance, a wide aisle usually means an order-picking truck will travel in and out, and saving trips in and out of the aisle can considerably reduce the travel time. The optimal order-picking model developed by DeKoster and Van Der Poort outperforms the S-shape heuristic. When the number of stops per aisle is larger, the heuristic is only slightly worse than the optimal policy.

Another strategy being used to minimize travel distances or times for picking tours is the addition of cross aisles [14]. Cross aisles may be added in order to provide intermediate entry and exits points in an aisle. Cross aisles provide flexibility in the picking route, as well as shorter travel distance opportunities. The authors warn against adding cross aisles excessively, as this may actually increase travel time due to walking across extra aisles. Additional costs such as the cost of increasing the facility size or lost storage space may make this option unattractive. Their experimentation showed that the addition of cross aisles reduced the tour distance by up to 30% [14]. In fact, the only case shown not to reduce this distance is one in which only one pick per aisle is required.

2.3.4 Storage Policies

Efficient product layout is key in the reduction of travel time in pick tours. Jarvis and McDowell [26] take a different approach to the order-picking efficiency problem by attempting to optimally locate the items as opposed to developing an optimal picking tour. Results showed that the shape of the inventory curve has the greatest impact on the time and distance required to complete the pick tour. For instance, if the curve were skewed so that one product makes up a large proportion of the orders to be picked, fewer aisles must be traversed.

2.3.5 Order-Batching Policies

Order-batching is another method of reducing travel time in picking operations. According to DeKoster *et al.* [15], many companies batch orders according to a first-come, first-serve (FCFS) policy. This policy clusters orders as they arrive to the picking area. They argue that a more intelligent method of order-batching will result in significant reductions in travel distances. Several heuristic algorithms, including seed algorithms and savings algorithms were tested and compared with the FCFS policy of order-batching. The authors developed robust algorithms that did not depend on the type of order, size of order, material handling systems, or capacity of the warehouse.

According to De Koster *et al.* [15], seed algorithms begin by selecting a seed order, and adding consecutive orders until the picker's capacity is full. Orders are added based on either the minimum distance from the first order, the number of aisles to be visited, or the order that will save the most time when compared to picking the same orders separately. Savings algorithms base the orders added to the batch by the amount of time savings resulting from batching those orders. Using both S-shape and largest gap routing rules, the different algorithms were compared and evaluated based on total average travel time [15].

The results [15] from extensive simulation experimentation indicate savings algorithms proved to be superior when the number of orders per batch is small or the largest gap routing rule is used. Seed algorithms are superior when the S-shape strategy is used. Seed algorithms

should also be used if there are many orders in the batch, simply due to the amount of calculations that must be made.

Gibson and Sharp [21] also present order-batching procedures based on heuristic algorithms. They used spacefilling curves (SFC) to batch orders. This method compares the closeness of each item in an order to all other items in the order. Each item is assigned a rank, and using the minimum and maximum item rank in an order, all orders are compared in the same way. The results of the order comparison determine the rank of the entire order. Once the orders are ranked, a FCFS method is used to batch the orders on the sorted list. This method completes a batch by taking orders off the sorted list until the desired batch size has been reached.

Another method Gibson and Sharp developed was the Sequential Minimum Distance (SMD) batching heuristic [21]. This method uses a greedy algorithm to place orders in batches. Orders are placed by the distance from the seed order to each of the other orders. Many factors were manipulated to determine their effects on the algorithms (FCFS, SFC, and SMD). The FCFS method remained fairly consistent regardless of most factors. However, skewed item location did significantly reduce the tour lengths. This effect was even more noticeable with SFC and SMD (up to a 44% reduction). Results in [21] showed that the SFC method is preferable with Euclidean, rectilinear, and Chebyshev metrics, but SMD is superior when using the aisle metric to measure the distance between orders.

2.3.6 Combined Methods of Travel Distance/Time Reduction

It is not uncommon to combine a variety of methods commonly used to reduce travel distance in picking operations. As mentioned earlier, COI-based storage combined with intelligent routing policies was proven to reduce travel distance even more so than with using either method individually [9]. Also, within aisle and overall routing algorithms, such as optimum aisle traversal using an all traversal or return routing policy, have been combined to reduce distances in routing sequences.

Finally, Daniels *et al.* [13] used a method of inventory assignment in conjunction with picking

sequences to determine ways to reduce travel distances. The inventory assignment method the authors developed takes advantage of new technology as a way to locate inventory. Computer tracking of inventory allows for storage of items in multiple locations, therefore giving the sequencing algorithm more choices of locations from which to select items. The Traveling Salesman Problem formulation is modified to include the decision of which inventory location or locations should be visited in the tour. Several order-picking methods were modified, including the Modified Nearest Neighbor method, the Shortest Arc method, Randomized Construction, and Tabu Search. In each method, the sequence is determined by the lowest cost based on travel time or distance to the inventory location. At each move, the computer updates the inventory to reflect the quantity retrieved.

2.3.7 Comments

Order-picking methods can have a significant impact on the need for sortation. Although the improved routing of orderpickers can provide substantial gains in efficiency, routing policies may not be the area with the largest potential gains. The area with the largest potential gains may be using order-batching methods. If no batching of orders is performed, a worker will have to make a stop at a location to pick an item each time that item occurs in the separate orders. However, if batch picking is used with large numbers of orders, substantial gains in picking will result since multiple visits to the same location over multiple orders will be batched into one visit. With batching, sortation systems will be required in order to achieve the desired throughput. While sortation systems are large and expensive, the increased throughput often justifies the purchase of such a system. We now review research on sortation systems.

2.4 Sortation Systems

As mentioned earlier, only a small amount of research has been published concerning sortation systems. This section reviews the work that has been completed to date.

2.4.1 Recirculating vs. Nonrecirculating Shipping Systems

Bozer and Sharp [8] provided insights into design alternatives of shipping sortation systems. Several different design factors and control strategies were evaluated based on throughput. Both recirculating and nonrecirculating systems were examined. Many systems were compared on the basis of the performance measure, throughput ratio, which is the ratio of observed throughput to maximum throughput.

In a shipping sortation system, if the destination shipping lanes do not have enough capacity, the throughput ratio can be increased by recirculating items. However, if the lanes will hold many items, recirculation does not increase the throughput ratio very much. For a given lane capacity, increasing the lane capacity further causes the relative improvement in throughput to decrease in recirculating systems. If lane capacity is increased to very high levels, little or no improvement in throughput is shown.

Through simulation experiments, results in [8] showed that increasing the number of lanes while holding the lane capacity constant does not greatly affect throughput ratio for recirculating systems, but decreases throughput ratio for nonrecirculating systems.

Bozer and Sharp [8] also examined the effects of clustering items into lanes. A group of clustered items have a better chance of being sent to a particular set of lanes rather than having equal probability of being sent to any of the lanes. In other words, the assumption of uniformity in lane assignment no longer holds. Items arrive in clusters for many reasons. Clustering generally occurs because of the methods of order-picking, labeling, or unloading of items. Usually when items are clustered, the subset of lanes to which the clustered items are sent varies over time in order to balance the lanes. However, in rare cases where one subset of lanes tends to receive more clusters, the system will have to be modified in order to achieve balance. The clustering phenomena has a negative impact on the system. With a nonrecirculating system, clustering drastically reduced the throughput capacity. Clustering also reduces the throughput in recirculating systems, but the effect is not as extreme unless the lane capacity is small.

A final sortation system design aspect that was explored in [8] was the control strategy where

the decision to divert was made at the actual divert point as opposed to the induction point. With small lane capacities, the throughput was improved using this method in a recirculating system. However, with large lane capacities, little or no improvement was shown.

2.4.2 Recirculating Systems in Shipping Systems

In [7], Bozer, Quiroz, and Sharp focused their study to recirculating sortation systems to determine the effects of the lane assignment and wave release strategies. Simulation was used to obtain the throughput ratio based on different combinations of several factors, including the distribution of orders in a wave, the number of sortation lanes, the lane assignment strategy, and the wave release strategy.

The alternative lane assignment strategies tested were the “order completion enforced” strategy, the “order completion relaxed” strategy, the “advance priority ranking” strategy, and the “incidental assignment” strategy. “Order completion enforced” means that all of the totes in an order must be on the conveyor loop before the order is “eligible” for lane assignment. “Order completion relaxed” means that lanes can be assigned as soon as the first tote of the order is on the conveyor loop. “Advance priority ranking” assigns orders as soon as the location of all the totes in the order is known. “Incidental assignment” means that each tote is scanned at the scanner before the lanes, and if it belongs to an eligible order, and if a lane is unassigned, a lane is assigned to that order.

The wave release strategies studied by Bozer *et al.* [7] included overlapping and non-overlapping waves. The non-overlapping waves strategy was used as a base comparison since it is the most conservative strategy. Waves are overlapped by allowing the release of the next wave when a predetermined percentage of the previous wave of orders has been diverted into the assigned lane. This method reduces idle time, but may cause congestion.

The conclusions of the study in [7] showed that the best lane assignment strategy based on throughput was “incidental assignment.” Overlapping waves appeared to be a good strategy, using 90% or more as the predetermined percentage diverted as defined above.

An analytical model of sorting time in a recirculating sortation system was developed by

Johnson [27]. He compared two common sorting strategies: fixed priority schemes (FPS) and the next available rule (NAR). FPS sorts the orders from largest to smallest or vice versa on some measure. For instance, the “advance priority ranking” is a fixed priority scheme, using a priority index to sort orders. NAR does not use a predetermined sorted list, but rather uses information based on the system as the assignment must be made. An example of NAR is the “incidental assignment” strategy. In Johnson’s model, the spread and gap were used to determine the total expected sorting time. Spread is the time required to sort an individual order, and gap is the time between the completion of one order and the beginning of the next order. The analytical model, combined with simulation, showed that NAR outperforms FPS (which formalizes the simulation results presented in [7]. This outcome was significant since most companies use a fixed priority scheme. However, the effect of using a particular lane assignment strategy is less obvious when lane blocking occurs.

Meller [30] studied the lane assignment problem with recirculating systems. An algorithm was developed to optimally assign orders to lanes. This algorithm minimizes the maximum time that any item is recirculating on the conveyor subject to constraints such as lane capacity, one order per lane, and proper order sequencing within a lane for LIFO (last in-first out) truck loading. The algorithm developed shows that by optimally assigning orders to lanes on the basis of the random item arrival sequence, the throughput of the system can be increased.

2.4.3 Non-Recirculating Systems in Order Fulfillment

Few papers exist that study solely non-recirculating sortation systems. This system is different than nonrecirculating systems. In this type of system, the inducted items are not allowed to recirculate, therefore each item must be diverted to a lane on the first trip around the conveyor and thus, no conveyor blocking can ever occur. However, in the nonrecirculating systems studied by Bozer *et al.* [7], items must recirculate in a loop if the accumulation lane is full. This loop is separate from the accumulation lane and acts simply as a queue that allows the following items to attempt to be inducted.

One of the first papers that looks at non-recirculating systems provides an analytical model of system throughput based on different induction configurations. Meller and Johnson [31] developed this model based on a queueing approximation. Non-recirculation is ensured by making the maximum number of items in a wave equal to the number of bays or chutes. A variety of system configurations were modeled, including fast induction (faster than the speed of the conveyor) and slow induction. Side-by-side (SBS) as well as split induction stations (SPL) were also examined. Finally, the system was analyzed when a tote setup time was included. In all cases, inductor blocking was modeled.

Inductor blocking occurs when the inductor has to wait for a full tray to go by before an item can be inducted onto an available tray. For instance, if there are several inductors at one station, the first inductor will see only empty trays, and will be able to induct at his maximum rate. However, the next inductor down the line will see some full trays that have been loaded onto by the first inductor, and will have to wait for the next empty tray. This continues down the line, with the last inductor at the station seeing the fewest empty trays.

Side-by-side inductors work on a single platform at one end of the conveyor, while split inductors have multiple induction stations, usually equally spread around the loop. At each station, multiple inductors may be working. The advantage of splitting inductors is a reduction in conveyor blocking, and increased throughput when the conveyor is the bottleneck. Many induction layouts were modeled and simulated to determine the throughput capabilities. In addition, multiple inductors were simulated at the same rate and at different rates. In all cases, the analytical model provided very accurate approximations [31].

Results from their model [31] showed that splitting induction stations only increases throughput appreciably with fast induction (i.e., the conveyor is the bottleneck), and the maximum possible throughput is two times the speed of the conveyor (this is only achievable with many SPL stations). The model also shows that sortation systems work best when item commonality between orders is present.

Meller and Johnson [32] also developed a preliminary design model for non-recirculating sortation systems. Their model utilizes a mixed-integer program to minimize non-recirculating system costs subject to a throughput constraint and a wave time constraint. They examined

key parameters such as the number of bins and induction stations to determine the system design that would minimize the total system cost. The number of bins limits the number of orders that can be simultaneously sorted as well as the time to sort a wave. The wave composition also affects the total sortation time. Wave composition algorithms should take advantage of the item commonality within a wave.

2.4.4 Conveyor Systems

Conveyor theory is an important basis for understanding sortation systems. Work completed in the late seventies and early eighties analyzed closed-loop conveyor systems. The conveyor system consists of a single loading station, a single unloading station, belts, and a conveyor to transport and hold parts.

Modeling Material Flow with Difference Equations

Muth [34] first analyzed closed-loop conveyor systems using difference equations. He expressed continuous material flow in terms of space and time in order to determine the compatibility of sets of conveyor parameters with operating requirements. Once these conditions were established, a set of compatible conveyor parameters and operating requirements can be selected in order to minimize costs subject to certain constraints. An extension to this analysis included the discrete material flow case [35]. Another extension modeled random material flow [36]. In this model, the amount of material unloaded from the conveyor was defined by a difference equation. Results from this model proved that adequate conveyor capacity can minimize the variance in the output flow.

Modeling Conveyors using Queueing Theory

El Sayed *et al.* [18] used multiple channel queueing theory to develop performance measures for closed-loop conveyor systems with Poisson inputs and outputs. They investigated conveyors with two types of arrivals, singlets and doublets, and two-channel unloading stations.

Singlets are one arrival, while doublets are two simultaneous arrivals. Expressions for performance measures such as the probability that all channels are idle, the probability of a lost item due to busy channels, and the expected number of units in the system were established. The conveyor design can then be optimized by minimizing the probability of lost arrivals. This can be done by maintaining a low value of doublet arrivals and decreasing the number of singlet arrivals. Obviously, if the probability of both types of arrivals are decreased or at low values, there will rarely be a lost arrival. Conversely, the expected number of units in the system can be increased by maintaining a high value of doublet arrivals while increasing the number of singlet arrivals.

Proctor *et al.* [37] again used queueing theory to study systems with three service channels and dual input. Homogeneous servers (equal rates) and heterogeneous servers (unequal rates) were both studied. Cases where unserved units were either lost or allowed to recirculate were examined. Conclusions showed that as more doublet arrivals occurred, system performance improved. System performance measures include the probability of the system being idle, the expected number of units in the system, the probability of a lost item, and the probability that the first server is busy. System performance improves as the probability of lost items, an idle system, and a busy first server decrease.

Regardless of the type of arrival, conclusions showed that utilization of the service channels decreased according to their order in the loop. In other words, the first server was utilized more than the second. Results showed that recirculation improved system performance but does not affect server utilization [37].

Chapter 3

Problem Statement

3.1 Tradeoffs Between Automated and Manual Sortation

Although sortation systems increase the throughput of a distribution center, it is not always feasible for a company to implement this type of system. Many factors must be carefully weighed when making the decision to purchase a sortation system. Tradeoffs exist between the capital cost of the automated system and the labor savings usually realized with respect to a manual system. The capital costs include the hardware, software, and square footage needed to operate the system. The labor includes the pickers, packers, and inductors.

While picking efficiency can increase with the sortation system, the labor savings may not be enough to justify the cost of the sorter. An average tilt-tray sorter (including variable costs) can cost \$250,000 to \$1,000,000 depending on the number of chutes, pack stations, and induction stations. Pack station costs for manual and automated systems are quite different as well. A pack station for a manual system includes a basic table and any accessories needed to hold boxes, tape, and other items used in the packing operation. However, a pack station for an automated system includes all this plus the chutes leading from the sorter trays to the packing tables. In addition, labor is required for induction in an automated system and

no induction is needed in a manual system.

Some companies are physically required to use a sorter. For instance, at the distribution center for Nine West, there simply was not enough room to add more pickers to increase throughput. The addition of a tilt-tray sortation system allowed the company to add a new line of accessories to its distribution center while remaining in its current location [5]. For companies like Nine West, keeping the sorter within their budget is still important. The focus of their decision should be placed on the configuration and size of the sorter.

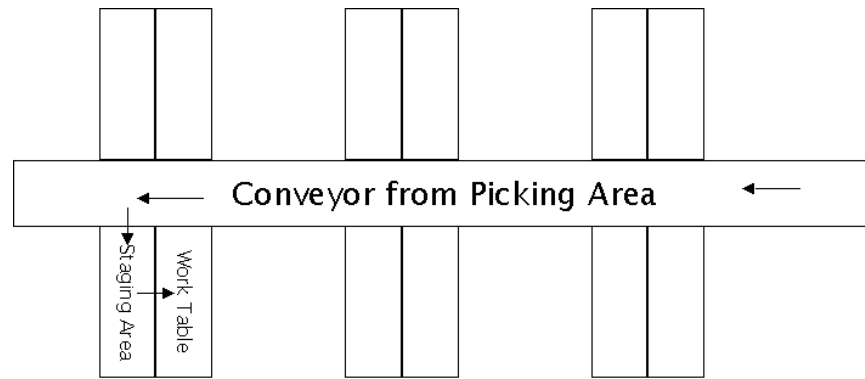
Many companies base the decision to buy a sorter on return-on-investment (ROI) [20]. After determining the throughput that could be achieved with such a system, the ROI can be calculated. If the ROI is not feasible to the company, the sortation system should be abandoned for a manual sortation system. This decision is especially important for some start-up internet companies who are struggling to make a profit.

Figure 3.1 shows a diagram of a manual sortation system. Parts arrive on a conveyor from the picking area (usually in totes), where they travel to a packing station. The worker then removes a tote and places it out of the way until he or she can complete the previous set of orders. Once the orders are boxed and ready to ship, the worker (usually) places the box onto another conveyor leading to the shipping area (sometimes the conveyor is directly beneath the incoming conveyor to save space, as in Figure 3.1).

Figure 3.2 shows a diagram of an automated sortation system. Section 1.2 provided a detailed description of the flow in this system.

3.2 Research Goals

Automated sortation is becoming a popular way to deal with efficiency problems in growing DCs. E-commerce businesses, such as *toysrus.com*, use sortation systems to provide direct delivery of high volumes of small orders. Many e-businesses model their DCs after catalog fulfillment centers. These companies have been using practices that provide good examples of quick delivery and efficiency for years. Catalog companies such as J. Crew and L.L. Bean



Packing Stations

(packers select items from staged totes for each boxed order)

Figure 3.1: Manual Sortation System.

use sortation systems to increase their throughput. Of course, these companies are now also using the internet to collect orders. Sortation systems are also being found in third-party logistics providers. Companies who need to accommodate heavy volumes of products, such as Nike, use sortation systems to increase throughput as well. It is obvious that a wide variety of companies are considering the conversion from manual to automated sortation systems. This shift in technology presents a need for a tool to provide guidelines for implementing such a system.

The purpose of this research is to provide a method to answer three main questions regarding the selection of a sortation system. First, the company should determine if the sortation process should be manual or automated. This question is answered by looking at all tradeoffs between manual and automated systems, and then determining which system is more cost effective. Second, if an automated system is preferred, the company should determine if this system is feasible based on their current economic situation. Third, the system should be designed in order to meet the specific needs of the company, such as room for growth, peaks in demand, product volume, the types of products that will use the sorter, and square footage available in the facility. All these factors must be considered when designing the sortation system. In this analysis, economic factors as well as the throughput of the system are considered.

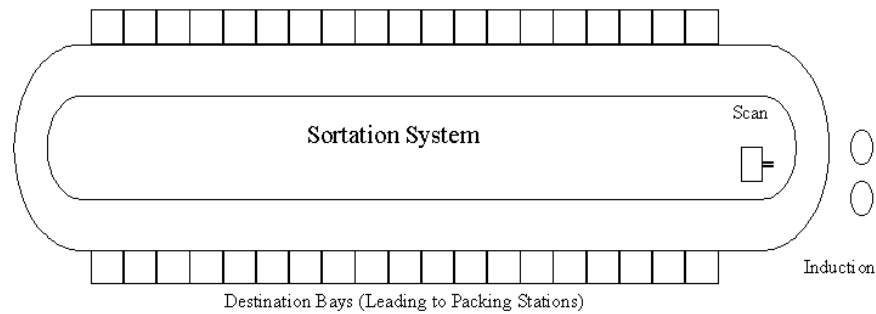


Figure 3.2: Automated Sortation System [27].

3.3 Theoretical Efficiency Curve

In order to understand the relationship between the two main costs of a system, picking and packing labor, an efficiency curve was developed. An efficiency curve depicts the important relationship between the picking standard and the packing standard. Namely, for a manual sortation system, as the batch size being picked increases, the packing standard will decrease. For instance, if the pickers pick individual orders, instead of batches, the packers have nothing to sort through, and therefore their packing standard is very high. In contrast, if a large batch is picked from zones, the packers may have many orders' worth of items to sort through before they can begin packing the orders. On the other hand, for the automated sorting system, the packing standard will remain approximately constant for all levels of picking standards due to the sortation performed to the orders as they arrive to the pack stations. That is, regardless of how the orders are picked, they will arrive to the pack stations in terms of orders already sorted.

These relationships for manual and automated systems are carefully reflected in the model so as to make an accurate comparison between the two systems. For each efficiency curve, several common wave lengths are examined. Figure 3.3 illustrates efficiency curves for automated and manual sortation systems over a range of wave lengths.

Points on the curve for a wave length represent a change in order-batching for the pickers. As more orders are batched together, the pickers' efficiency increases, but the packers' efficiency decreases. This is represented in Figure 3.3 by having the picking standard increase while the packing standard decreases.

It is important to note the relationships between the various curves as well. As the wave length increases, we can still assign the same number of orders to each picker. Since the number of orders the packer must sort through remains the same, the packing standard will remain the same. However, due to the longer wave, the picker assignments can now be improved. That is, since there are more orders to choose from in a longer wave, the assignment of orders to pickers can be made to improve the picker's efficiency. Thus, the curves shift simultaneously upward and to the right.

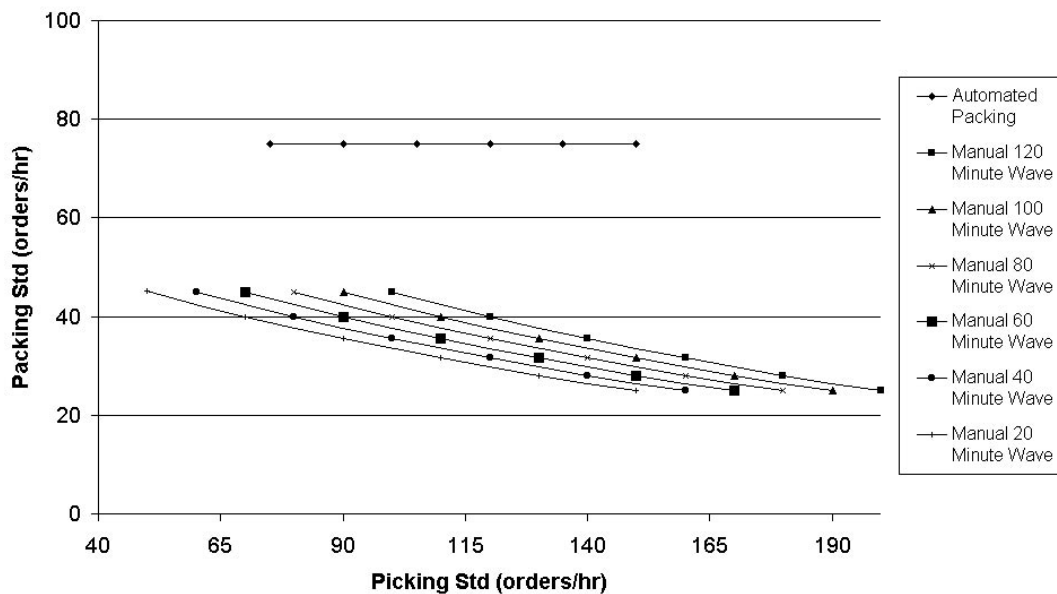


Figure 3.3: Manual and Automated Efficiency Curves.

In Figure 3.4 the same relationship is presented, as well as an additional relationship in the automated system. Realistically, if the wave length increases, the packing efficiency will decrease slightly for the automated system as the picking standard increases. Although the sorter works at a constant rate, the packers will be required to move between more packing

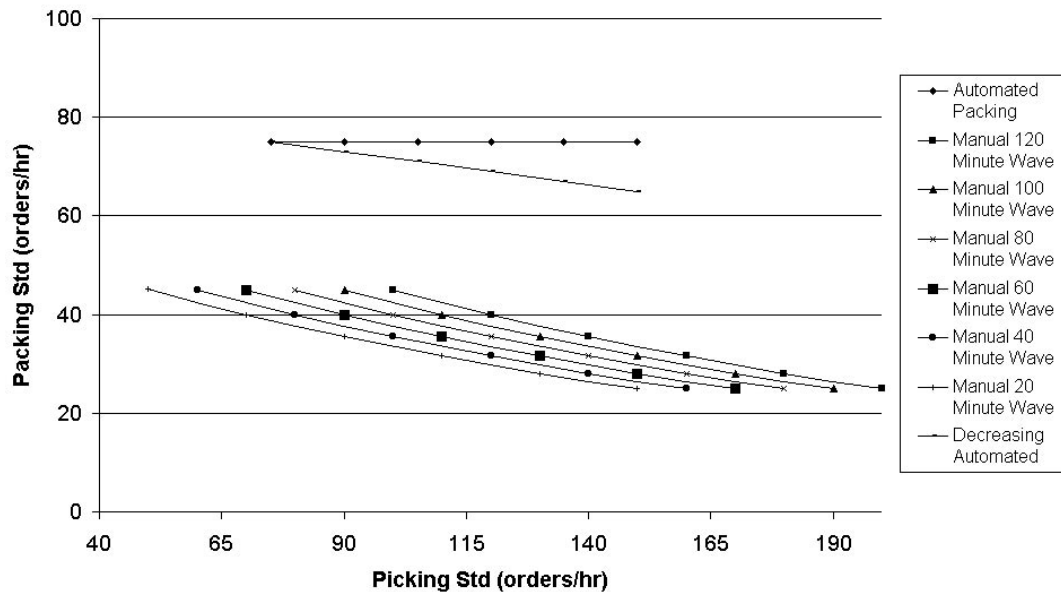


Figure 3.4: Decreasing Automated Efficiency Curves.

stations. Due to the randomness of order-completion times, this will cause the slight decrease in the packing efficiency.

3.4 Actual Efficiency Curve

Although we believe the relationships represented in the theoretical efficiency curves presented in the previous section exist, it is important to examine them in an actual or simulated context. Time study data are presented in Appendix A and simulation results are presented in Appendix B. The purpose of this section is to present our results and compare the theoretical efficiency curve with an actual one.

3.4.1 Picking Efficiency

With an effective sortation system, picker efficiency in the DC can increase. Since the sorter can efficiently sort many orders at once, the pickers can use more of a batch picking technique.

It has been reported that batch picking can save approximately 40% of required labor [23]. This technique will save walking time by allowing the pickers to retrieve identical items for several orders at once, instead of traveling to its location each time an order requires that item.

In order to verify the relationship between order-batching and picking efficiency, several experiments were completed. First, a time study was conducted in order to obtain realistic data demonstrating the benefit of batching orders. This time study was conducted at Cross Creek Apparel in Mount Airy, North Carolina. Twenty orders were picked in several different batch sizes, and travel times were recorded for each set of orders. The data collected is tabulated in Table 3.1 and is presented graphically in Figure 3.5. In Figure 3.5, the scaled number of stops is simply the number of stops from Table 3.1 scaled for presentation purposes. As can be seen, when no batching is performed (batch size equal to one), the picker must make multiple stops at a SKU location each time that SKU appears in an order. However, as the amount of batching increases, the number of stops and the travel time for the entire picking tour decrease since the picker can pick for several orders at that particular SKU's location. Notice when all orders are batched together (batch size equals all 20 orders), the number of stops exactly equals the number of SKUs, therefore minimizing the total travel time. The picking time study results are presented in full in Tables A.1 through A.4 in Appendix A.

Although this time study verified that batching orders increases picking efficiency, it does not account for different inventory arrangements. For instance, one distribution center might put the items that account for 80% of the items picked in the 20% of the picking area closest to the

Table 3.1: Cross Creek Picking Efficiency Data.

Batch Size	Total Time (min)	Number of Stops	Number of SKUs
20	38.35	300	300
10	54.82	354	300
5	67.35	393	300
1	99.44	437	300

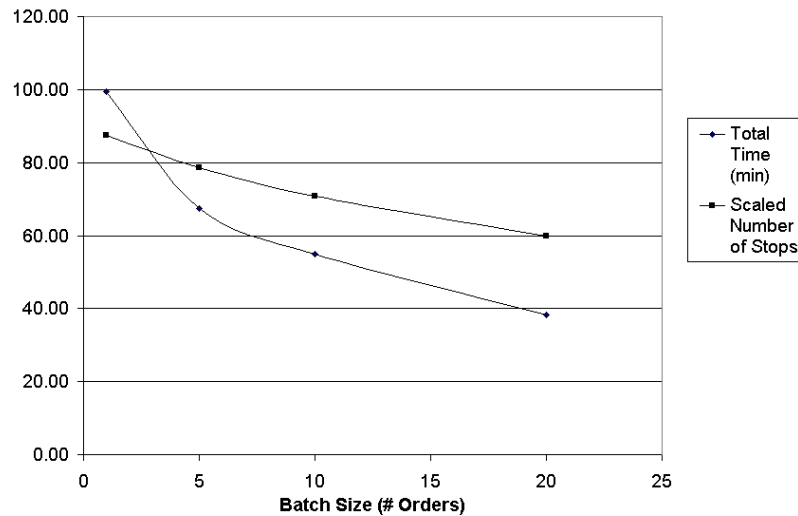


Figure 3.5: Effects of Batching Orders on Travel Time.

I/O point. However, other distribution centers might arrange the items evenly throughout the picking area. In order to capture the effects of several configurations, a simulation study was conducted.

The picking simulation was designed to capture the effects of batching on picking efficiency for three different inventory curves: 80/20, 60/40, and 50/50. In the simulation, a single picker is given batches ranging from 1 order to 150 orders. An average of 3 items per order was used to represent an average-sized order placed on the internet. A pick list of all items to be picked in the batch is generated, and then the row each item is in is determined. The picker then uses a traversal strategy to retrieve items in the pick list. The picking time per order is calculated and compared for each batch size. Simulation results are presented in full in Tables B.1 through B.6 in Appendix B.

Figure 3.6 shows this relationship between batch size and pick time per order for each of the three inventory curves. From this graph we can see that the picking time decreases rapidly over small batches and then tapers as the batch size increases. As expected, the 80/20 curve has a smaller picking time decrease than the 50/50 curve. An 80/20 curve has most of its items concentrated in a small portion of the picking area, so batching orders will not be as effective with this setup than with a 50/50 curve. In a 50/50 curve, the picker will save more

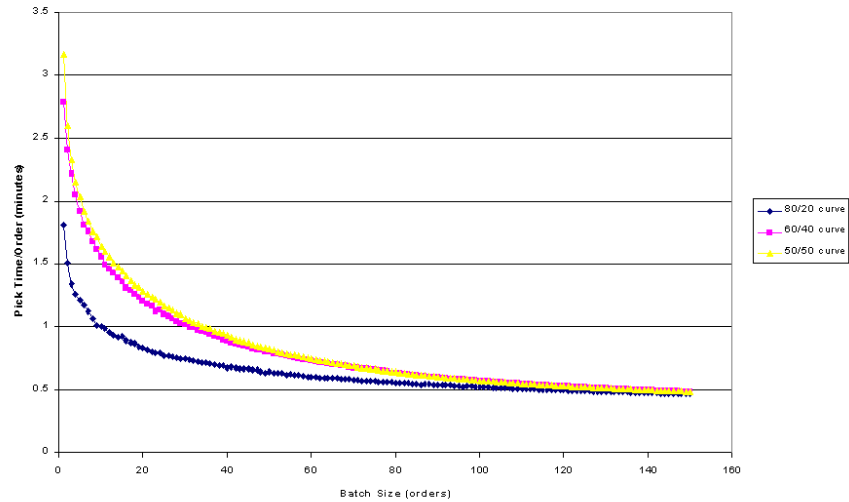


Figure 3.6: Picking Rates vs Batch Size.

aisle travel since the items are spread evenly throughout the picking area. For instance, with a single order in a batch, the average pick time per order over 100 replications was 1.81 minutes for an 80/20 curve, 2.78 minutes for a 60/40 curve, and 3.16 minutes for a 50/50 curve. After increasing the batch size to five orders, the average pick time decreases to 1.21 for the 80/20 curve, 1.92 for the 60/40 curve, and 2.03 for the 50/50 curve. The improvement is then 0.59, 0.86, and 1.13, respectively. The 80/20 curve will be the curve considered in all calculations from this point on. This curve is indicative of most companies and storing items based on turnover is used in most picking areas.

Not only can order-batching be effective with automated sortation systems, but also with manual systems. As the wave length increases, the picker can be more selective in the orders that are batched. Orders can be batched within a wave to decrease picking time per order, but also across wave length increases. A longer wave length provides more orders for the picker to select from when batching. The batches can be formed in a way that reduces the picking time even further. For example, selecting orders with items in a few rows that are close together, or a zone, can further reduce picking time. This type of batching was not included in the simulation, but results were estimated using the picking time study results combined with the simulation results as described next.

Table 3.2: Wave Length Effects on Picking Efficiency.

Wave Length (minutes)	Rate Increase from Previous Wave (%)
20	N/A
40	14.04
60	8.21
80	5.83
100	4.52
120	3.69

The picking time study results were gathered for pick lists separated by zones. Each zone represents a portion of the picking area with rows that are close together, therefore reducing the distance that must be traveled in each picking wave. From the results gathered in this time study, a reduction in picking time when using zone picking was estimated for wave length increases from 20 minutes to 120 minutes. The results from this calculation provided the shift in efficiency curves for each wave length. This shift shows the efficiency gains from intelligent batching while keeping the number of orders a packer is responsible for the same. Table 3.2 shows the percentage increase in picking rate based on the wave length increase. Notice that as the wave length increases, this percentage decreases due to the fact that more aisles will be entered for longer wave lengths.

3.4.2 Packing Efficiency

Packing efficiencies vary based on wave length, batch sizes, and whether a system is automated or manual. In general, as the batch size increases, the packing efficiency decreases. However, the system configuration has a large effect on the amount of efficiency lost by batching orders. For instance, an automated system does not lose much efficiency when orders are batched, especially if waves are overlapped. A manual system loses a great deal of packer efficiency with each increase of batch size.

Automated Systems

Packers in an automated system are usually assigned to several pack stations. Each pack station can have one or more bins where the items for an order fall from the sorter trays. When a bin is ready to be packed, a light or a similar indicator alerts the packer that that bin is ready. Packers may have to walk between several pack stations to reach a bin that is ready to be packed. Because of this, as the packer is assigned more and more pack stations, this results in more and more walking. The amount of walking that is required results in a slight packing rate decrease.

As mentioned before, the decrease in packing rates due to walking between pack stations varies greatly based on the wave setup. If waves are not overlapped, the packer must wait for bins to become ready to be packed. Items arrive to the bins at some time period between the beginning of the wave and the end of the wave. However, with waves overlapped, the packer would not have to wait for bins to become ready to be packed. Some of the bins should be ready at the beginning of the wave, and by the time the packer has completed those bins, the packer should not have to wait for other bins to receive all the items in the order.

Both overlap scenarios discussed above were modeled using simulation. The wave overlap situation was modeled as if there were complete overlap. In other words, all bins are ready at the beginning of the wave, so no time is spent waiting for bins to become ready to pack. The packer simply packs the first bin and then walks to the next bin. With no wave overlap, the packer must wait for the orders to become ready to pack, then decide which order should be packed next. In the simulation model developed, the packer packs an order, then checks the indicators to see if any other orders are ready to be packed. If no orders are ready at that time, the packer waits until the next order is ready and walks to that bin. However, if one or more orders are ready, the packer walks to the closest bin that is ready and packs the order. In this situation, the time spent waiting for orders to get ready and walking between bins decreases the packing rate.

Figures 3.7 and 3.8 present the amount of orders that can be packed in a wave for both

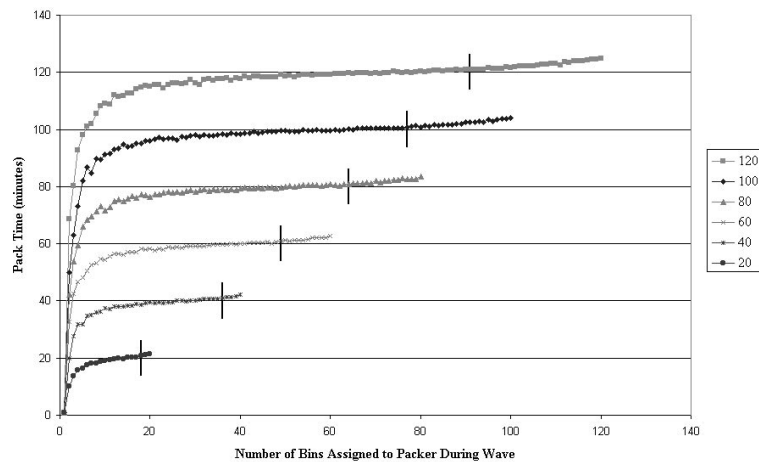


Figure 3.7: Number of Orders vs Total Pack Time (No Overlap).

overlap scenarios. The vertical lines on each curve in Figure 3.7 represent the maximum bin assignment that can be completed within the wave length for no overlap. Figure 3.8 also illustrates this result for the no overlap scenario, but also illustrates the results with overlap. Note that due to the minimum amount of walking, the expected packing rates with complete overlap are higher than the expected packing rates with no overlap. Also, the packer can sometimes pack more than the expected amount due to randomness present in the simulation model. Overall, since the walking time between one bin is so small, the decrease in packing efficiency as the wave length or batch size increases is not significant under complete overlap.

Manual System

With a manual sortation system, as the batch size delivered to the packer increases, the packer's efficiency will decrease. The packer is responsible for sorting through the orders before packing them. As the batch size increases, sorting the items down to individual orders becomes more and more difficult. A time study was conducted at Cross Creek Apparel to verify the relationship between batch size and pack time per order. In this study, twenty orders were picked and brought to the packing station. These orders were divided into random batches of 20, 10, 5, 4, and 2 orders and the sort and pack time was recorded for each batch. Using this data, the packing time was estimated for batches of different sizes.

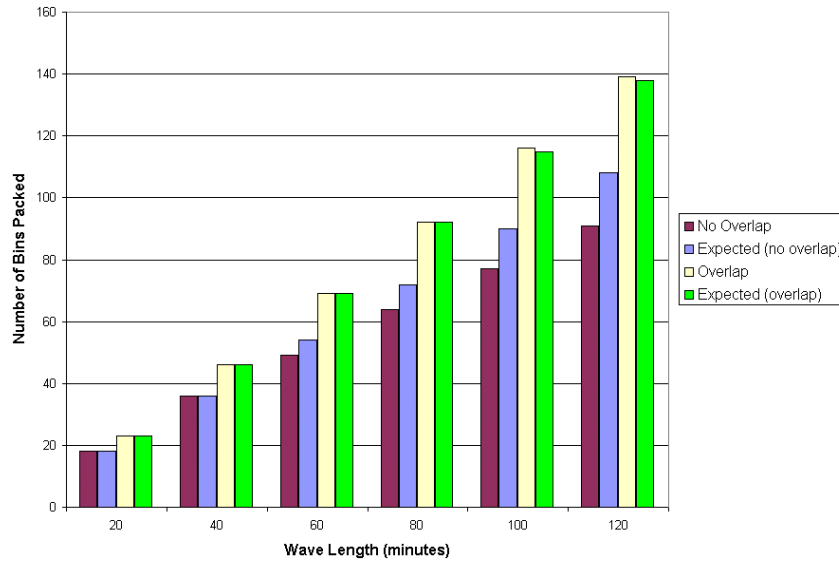


Figure 3.8: Number of Bins Packed.

The packing time study data is shown in Figure 3.9.

3.5 Forming the Efficiency Curve from Simulation Data

Once all simulation and time study data were collected, the information was used to develop the actual efficiency curve. First, the picking rates were determined for each wave length using the zone picking time study data. That is, the estimated gain in efficiency due to batching orders over a longer period of time was determined from the time study data, where the zone picking method provides information about the gain of intelligent batching. In addition to the picking rates, the time to pick the orders assigned to the picker that is associated with that particular rate was calculated. Using this time, the highest possible rate that can be achieved in a wave was determined. For instance, a picker working within a 20-minute wave can pick a certain number of orders in slightly less than 20 minutes. Therefore, this picking rate was used as an upper bound for a 20-minute wave. The corresponding manual packing rate was then determined by taking the rate that corresponds with the same batch size. We assume that the picker and packer work with an identical batch size, however, the pickers will be assigned more batches in order to even out the work within a wave (since,

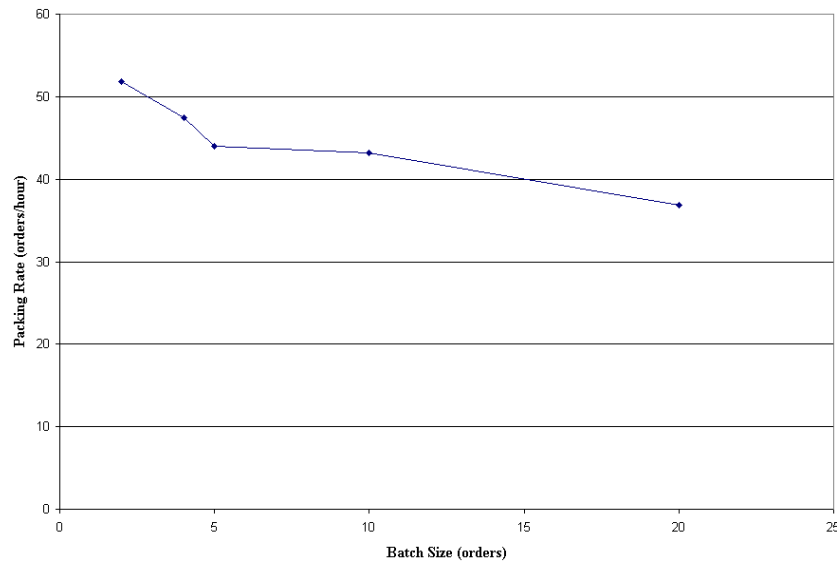


Figure 3.9: Packing Time Study Results.

in general, pickers work at a higher rate than packers). For example, consider a wave with a batch size equal to 34 orders. Pickers can work at a rate of 99 orders per hour and packers can work at a rate of 41 orders per hour given this batch size. This system would require more than twice as many packers than pickers working at this rate.

To obtain other picking and packing rate combinations for the manual system, we selected six rate combinations for each wave length. In other words, for each wave length, the maximum number of orders that can be picked within a specified wave length was determined, and the corresponding picking and packing rates were obtained for this batch size. This was chosen as the sixth combination on the curve (i.e., the point furthest to the right on the efficiency curve). The other five combinations were developed by dividing the total time so that the first combination completes six batches of a size that can be picked in one-sixth of the wave length, the second combination completes five batches of a size that can be picked in one-fifth of the wave length, and so forth. The packing rates are then determined by the rate at which that batch size can be completed. These combinations were used for both the spreadsheet model and the efficiency curve. However, every combination of picking and packing rates were used to develop the curve more accurately. In other words, batch sizes ranging from one to the maximum number of orders that can be completed within a wave

were simulated to fill in points between the six points evaluated in the spreadsheet model. This process was completed for every wave length considered.

The automated system curve was developed in much the same way. However, since picking and packing are not dependent on one another, they were selected separately. For each wave length, a corresponding picking and packing rate were again calculated. The batch size corresponding to the highest time under the specified wave length (or highest efficiency) was used as input in the spreadsheet model for the picking rate. The packing rate was determined for each wave length independently. The picking and packing rates for each wave length were then plotted.

Data used to develop the efficiency curves is presented in Appendix B for different levels of picking and packing rates. In particular, Tables B.1 through B.3 present the picking rates and times generated for each batch size. Table B.4 presents the packing rates and times for manual packing system simulations, and Tables B.5 and B.6 present the packing results for simulated automated systems. This will be discussed more thoroughly in Chapter 6. Tables B.7 and B.8 summarize the efficiency curve data for manual and automated systems, respectively.

3.6 Picking vs. Packing Efficiencies

Now that the relationships between batch size and picking efficiency and packing efficiency have been verified, the relationships between picking efficiency and packing efficiency can be verified as well. For an automated system, as the wave length increases, more orders are batched, therefore increasing the picking efficiency. Since the sorting is automated and at a constant rate, the packers can pack at approximately the same rate regardless of the number of orders batched together. Figure 3.10 shows the system with waves that overlap completely. This system results in an efficiency curve similar to the theoretical curve in Figure 3.3. The packers' rate has only a slight decrease as more and more orders are batched. This decrease is due to walking time between bins or pack stations.

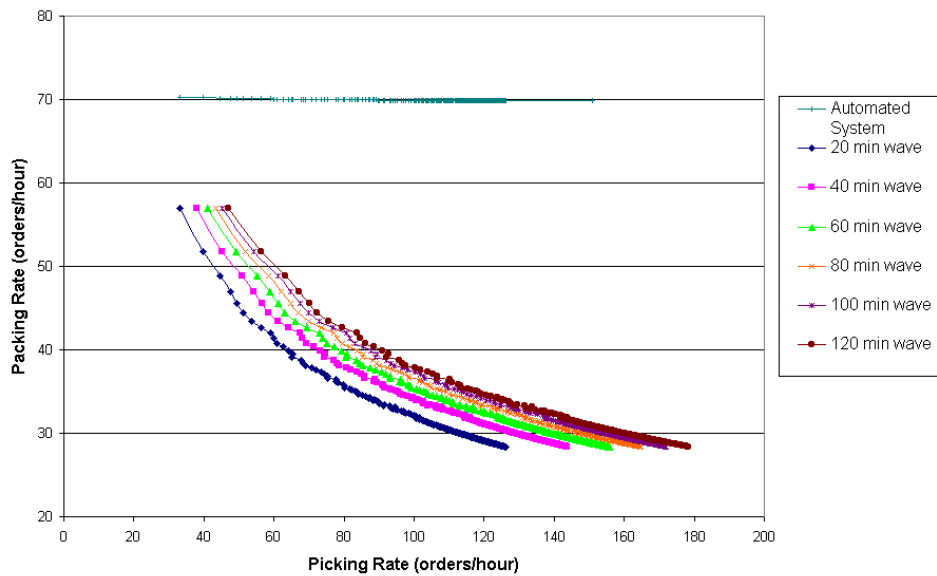


Figure 3.10: Actual Efficiency Curve with Complete Wave Overlap.

Figure 3.11 shows the system with waves that do not overlap. Notice the automated curve this figure has a dramatic decrease in packing efficiency as the picking efficiency increases. As discussed before, the decrease is due to the amount of time spent waiting for bins to become ready to pack and walking from bin to bin. In this situation, the packer may have to travel between several pack stations in order to reach the next bin that is ready to pack.

Figure 3.12 shows the packer efficiency decrease in the automated system due to walking times only. Notice the difference between the decrease from Figure 3.11, where waiting times are also included. Figure 3.12 illustrates how much time is spent walking if bins are packed randomly among the packer's assigned work stations. This graph would be similar to a system with partial overlap, where several bins are ready, but at different locations in the worker's area.

To summarize, the theoretical curve developed in Section 3.3 is a good estimate of the actual efficiency curve, especially in the case of wave overlap. Due to obvious benefits, and low marginal cost, we will proceed using the assumption that waves overlap in the remainder of this study.

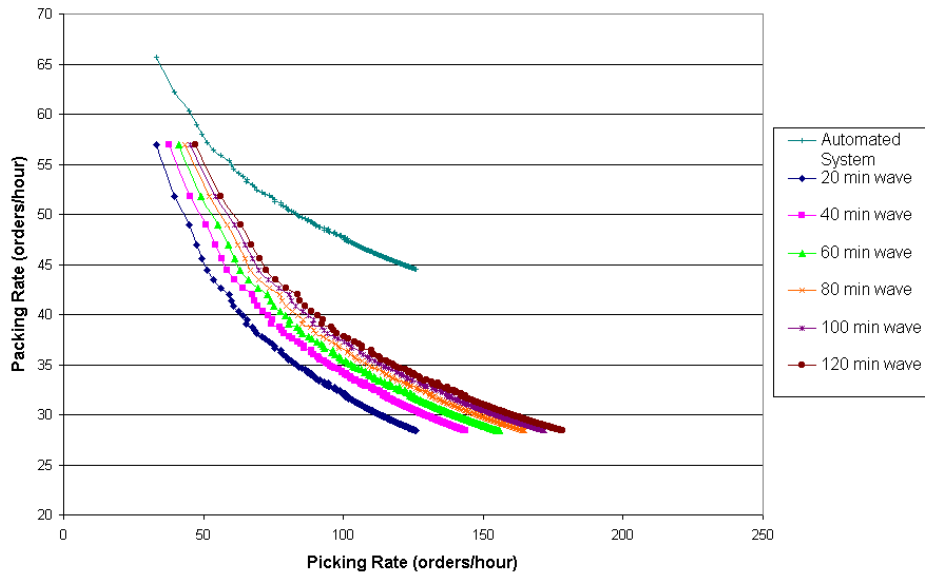


Figure 3.11: Actual Efficiency Curve with No Wave Overlap.

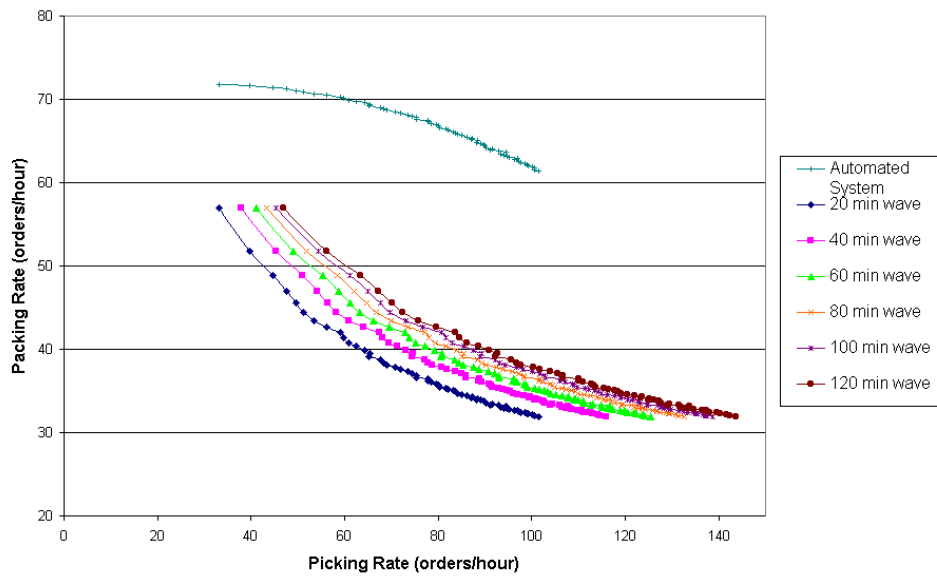


Figure 3.12: Actual Efficiency Curve with No Wave Overlap (Decrease due to Walking Times Only).

3.7 Company Data and Modeling

The primary goal of this research is to develop a model that will be useful to companies needing to make a decision about their sortation system design. A company in this position would provide input data for a deterministic spreadsheet model, discussed thoroughly in Chapter 4. This input data includes the average hourly demand, the estimated costs of the sorters they are considering, as well as any hardware, scanners, and control systems required to accompany this sorter. Other input data includes the labor costs of pickers, packers, and inductors, induction rates, and maximum and minimum picking and packing rates. Economic input data such as the interest rate and number of years of use are input in order to determine the capital recovery (A/P value).

Once this data has been input into the spreadsheet model, the total annual cost will be calculated for a variety of configurations. The least expensive configuration will be recommended as the system to implement. The recommendation includes all output data, including if the system should have manual or automated sortation. More detailed recommendations include the wave length, picker and packer rates, number of pickers, packers, and pack stations. In addition, automated systems must include data on the number of inductors and induction stations required to meet demand.

Although this recommendation is based on verified relationships between each parameter and actual company input data, stochastic picker, packer, and inductor rates, and the random locations of the items in each order produce different results each time simulations are run. Random effects are present within a company from minute to minute, so the recommended system must overestimate to allow for these effects. Therefore, after recommending a system configuration, a system simulation that uses the recommended configuration as input would be run to determine if the subsystems (picking, sorting, and packing) will meet the desired throughput. If throughput is met, the company can proceed and implement the recommended configuration. However, if throughput is not met, the subsystem that has not met demand must be reanalyzed.

In Chapter 4 we discuss our deterministic model of this order fulfillment system. Following

the development of the model, a sensitivity analysis is presented in Chapter 5 for key model parameters. Chapter 6 provides the details of our simulation methodology developed to test our deterministic model.

Chapter 4

Deterministic Model

In order to understand fundamental relationships between each factor in a sortation system, a descriptive spreadsheet model was developed. This model not only shows relationships within both automated sortation systems and manual sortation systems, but also serves as a tool for comparison between the systems. A range of parameters are used as input to determine the effects on the system. Parameters include factors such as demand rates, labor rates, fixed and variable costs, order sizes, wave size, and sorter capacity. That is, based on this deterministic input, the number of employees, packing stations, and induction stations required to meet demand will be determined. For each set of parameters, a total annualized system cost will be determined.

This chapter discusses the fundamental relationships between each parameter and variable in the system, as well as all notation, assumptions, and calculations made. Although manual and automated sortation systems are very similar, there are several key differences broken down in the following sections.

Wave lengths ranging from 20 minutes to 2 hours were tested, along with a range of picking and packing rates for each wave length. For these combinations of wave length, picking rate, and packing rate, a total annual system cost is estimated for each type of system. Results from each were compared in order to determine which sortation method is more appealing based on cost and throughput. The model provides guidelines for determining the size of the

system based on the number of packing stations and wave lengths. This tool will provide a starting point from which the decision to use automation can be made. Based on the current demand, labor rates and variable costs, and the fixed cost of a sorter, companies can use this guide to determine if automation is within the company's budget and space limitations.

We now present the descriptive model in more detail, explaining the fundamental relationships, presenting an example, and outlining our experiments.

4.1 Fundamental Relationships

There are several fundamental relationships that exist between the parameters and variables in the descriptive model. For instance, the numbers of required pickers, packers, and inductors are functions of the demand and the standard rate at which each type of worker performs. That is, the number of pack stations required is a function of the number of orders per wave, the number of orders per pack station, and the number of required packers. Likewise, the total annual labor cost is the sum of the labor costs for pickers, packers, and inductors, and the total annual cost of the system is the sum of the total annual labor cost plus the annualized costs of the sorter, pack stations, and induction stations. When examining a manual system, the total annual system cost is simply the cost of labor and the annualized cost of the pack stations. Costs associated with the picking area equipment are not considered.

Notation and mathematical expressions to illustrate these relationships are now presented.

4.1.1 Notation and Illustrated Relationships

Organization

- Labor costs for inductors, packers, and pickers, are denoted by the subscript ℓ .
- Fixed costs are denoted by the superscript C .

- Variable costs are denoted by the subscript c .
- Upper case variables denote system-wide variables.
- Lower case variables denote variables specific to manual or automated systems.

Notation and Definitions

The following notation and definitions are separated into parameters or variables used in both automated and manual system analysis and those used solely in manual or automated system analysis.

Automated and Manual Systems

- D represents the demand, in orders per hour.
- W represents the wave length, or the length of time (in minutes) over which a collection of orders are processed. This time is generally the same in all areas of the DC. The wave length is set at a certain length in order to balance activity between all areas of the DC.
- N_w represents the number of orders per wave. This is determined by multiplying the number of orders per hour by the wave length:

$$N_w = D * (W/60).$$

- N_o represents the average number of items contained in each order, whether the items are unique or identical.
- N_q represents the number of orders per pack station, or the capacity of the pack station. This is based on an average number of items per order, N_o .
- $p(n)$ represents the picking standard per hour, or the rate at which the workers pick items from cases when assigned n orders worth of items to pick.

- $q(m)$ represents the packing standard per hour, given in items per hour. This is the rate at which the workers pack items into orders when m orders are delivered to the packing station. This rate includes the final sort into orders (not including the automated sortation into packing stations), constructing boxes, packing the box or bag with items, fliers, and catalogs, and attaching the shipping label. This standard is generally much higher than the picking standard.
- r_p represents the number of required pickers, and is determined by the following:

$$r_p = \lceil D/p(n) \rceil.$$

- r_q represents the minimum number of required packers, and is determined by the following:

$$r_q = \lceil D/q(m) \rceil.$$

- n_q represents the minimum number of pack stations, and is determined by the following:

$$n_q = \lceil N_w/N_q \rceil.$$

- r_a represents both the actual number of required packers and the actual number of pack stations required. This is determined by the following:

$$r_a = \text{maximum}\{r_q, n_q\}.$$

- ℓ_p represents the annual labor cost per picker.
- ℓ_q represents the annual labor cost per packer.
- i represents the interest rate used to calculate the capital recovery factor (A/P).
- n represents the number of years of service used to calculate the capital recovery factor (A/P).
- A represents the annualized cost of a capital expense, P :

$$A = P(A/P) = P \left[\frac{i(i+1)^n}{(1+i)^n - 1} \right].$$

Manual Systems

- c_q^m represents the annualized cost per pack station. This is the variable cost associated with each pack station. This includes the packing tables and conveyors used in this area.
- T_ℓ^m represents the total annual labor cost. The following equation represents this cost for the manual system:

$$T_\ell^m = \ell_p r_p + \ell_q r_q.$$

- T^m represents the total annual cost of the system. The following equation represents this cost for the manual system:

$$T^m = T_\ell^m + r_q c_q.$$

Automated Systems

- c_q^a represents the annualized cost per pack station. This is the variable cost associated with each pack station. This cost includes the chutes or bins where parts are delivered, the pack station tables, and other associated equipment.
- s represents the speed of the conveyor in trays or items per minute.
- t represents the induction rate, or the rate at which workers place parts on the sorter in items per minute.
- x represents the total required induction rate over all inductors, in number of items per minute:

$$x = D(N_o/60).$$

- r_s represents the number of required induction stations. As mentioned before, induction stations can be either side-by-side or split. The number of induction stations depends on the total induction rate required, x , and the conveyor speed, s . The following

equation represents the number of required induction stations. The results from [31] are used, assuming each station represents a “fast” inductor (which could be one “fast” inductor or many slow inductors that represent one):

$$r_s = \begin{cases} 1 & \text{if } x \leq s, \\ \lceil x/(2s - x) \rceil & \text{if } x > s. \end{cases}$$

- r_t represents the number of required inductors. The number of inductors is dependent on the number of induction stations, the induction rate of each inductor, and the speed of the conveyor. The following expression ignores side-by-side inductor blocking since it cannot easily be represented in closed-form if the number of inductors for each station is greater than two (this will be addressed in Chapter 6):

$$r_t = \begin{cases} 1 & \text{if } x \leq t, \\ \lceil x/t \rceil & \text{if } t < x \leq s, \\ r_s * \lceil s/t \rceil & \text{if } x > s. \end{cases}$$

- c_t represents the annualized induction station cost. This is the variable cost associated with each induction station.
- C^s represents the annualized fixed cost of the sorter. This is the base cost of the sorter. When added to the variable costs mentioned above, the total hardware cost of the automated sortation system is determined.
- C_t^s is the total hardware cost of the automated sortation system.

$$C^s + r_s c_t + r_a c_q.$$

- ℓ_t represents the annual labor cost per inductor.
- T_ℓ^a represents the total annual labor cost. The following equation represents this cost for the automated system:

$$T_\ell^a = \ell_p r_p + \ell_q r_q + \ell_t r_t.$$

- T^a represents the total annual cost of the system. The following equation represents this cost for the automated system:

$$T^a = T_\ell^a + C_s + r_a c_q + r_s c_t.$$

4.1.2 Assumptions

- Each model input is deterministic and time independent. Most sortation systems are designed for particular peaks in demand (e.g., yearly, daily, or hourly volumes).
- Each capital cost is annualized using the capital recovery factor, A/P , where A is the annual cost given P , the present cost, with an interest rate of i , and n interest periods. These interest rates typically vary between 10% and 20% and n varies between 5 and 10 years.
- It is desired for the workload of pickers, packers, and inductors to be even.
- Wave lengths are the same in all areas of the distribution center (i.e., picking, sorting, and packing).
- The number of items per order is based on an average of 3 items per order. This can be changed, but represents the correct order of magnitude for many companies concerned with order fulfillment center design.
- For all sensitivity analyses and simulation data, we assume that there is overlap in waves. In other words, processing is completed on some or all of the orders in a wave before the next wave begins. However, we do discuss waves with no overlap briefly in the automated packing simulations in Chapter 5.
- Base levels of each parameter are presented in Table 4.1. The pack station cost for manual systems is much less than the cost for a pack station in the automated system. The sensitivity analysis varies each parameter from the base level and then varies combinations of these parameters to see the effects.

Table 4.1: Sortation System Costs [4].

Cost Parameter	Cost (\$)
Annual Labor Cost per Picker (ℓ_p)	30,000
Annual Labor Cost per Packer (ℓ_q)	30,000
Annual Labor Cost per Inductor (ℓ_t)	30,000
Pack Station Cost per Station (Automated System) (c_q^a)	10,000
Pack Station Cost per Station (Manual System) (c_q^m)	700
Sorter Fixed Cost (C_t^s)	250,000
Induction Station Cost per Station (c_t)	50,000

- The maximum throughput in a system with split induction stations is represented by the following equation:

$$\frac{2r_s}{r_s + 1} s \quad (4.1)$$

Relationship between Picking and Packing

As mentioned earlier in Section 3.1, an important relationship exists between the picking standard and the packing standard. In manual systems, as the batch size being picked increases, the packing standard decreases. However, in automated systems, as the batch size being picked increases, the packing standard will remain approximately constant in most systems due to the nature of the orders as they arrive to the pack stations. As was shown previously in Figure 3.3, this relationship must be carefully reflected in the manual system model so as to make an accurate comparison with the automated system model.

In Figure 4.1 the relationship between picking and packing efficiencies is shown in two ways in the automated system curve. Realistically, if a picker retrieves more and more items, the packing efficiency will decrease slightly for the automated system. Although the sorter works at a constant rate, the packers will be required to move between packing stations, set up more shipping boxes and inserts, and organize more orders. This will cause the slight decrease in the packing efficiency. Decreasing efficiencies are more prevalent in systems without overlapping waves. The straight line represents a system with overlapping waves. In this system, the amount of time spent walking is insignificant.

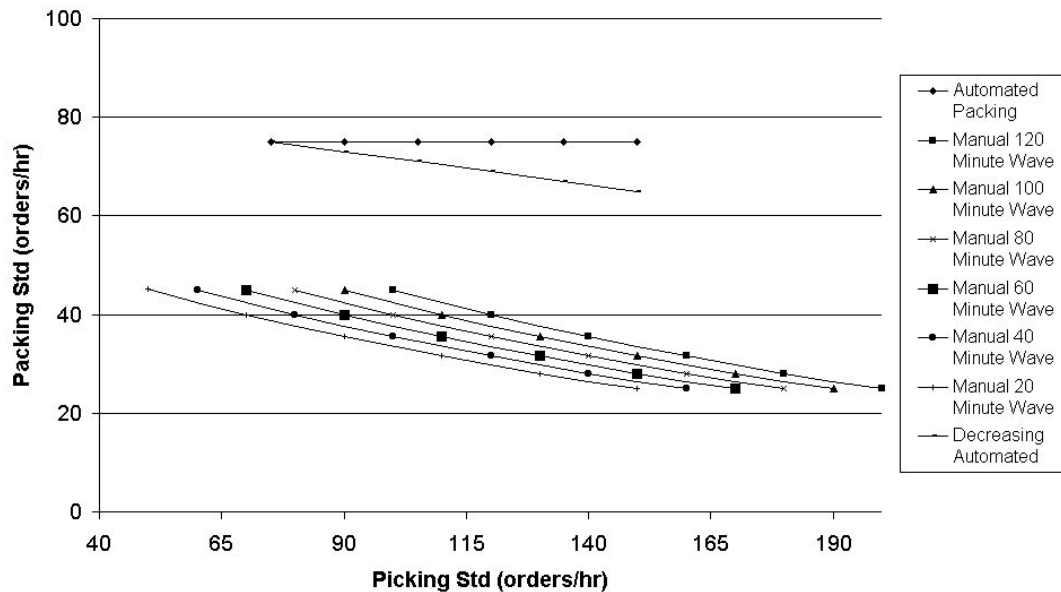


Figure 4.1: Decreasing Automated Picking Efficiency Curves.

Section 4.2 presents the relationships in the manual system. Characteristics and relationships in automated systems are discussed in Section 4.3. Example calculations for both a manual and an automated system configuration are presented in Section 4.4. Finally, a discussion of the experiments run for both systems is discussed in Section 4.5.

4.2 Manual Sortation System

A manual sortation system consists of all pickers, packers, and pack stations necessary to meet demand. Although automated systems also include pack stations, the manual pack stations are much less expensive. Manual pack stations include packing tables and all accessories, such as any shelves, dunnage holders, and other items used to pack boxes. A simple conveyor system usually accompanies the entire packing area, which can also be included in the pack station cost.

The picking and packing relationship for the manual system is very different than the automated system, thus requiring more calculations to be made. This relationship, discussed in

Section 3.3, requires a different range of picking and packing rates for each wave length. For instance, a 20-minute wave may only be able to pick from 75 to 125 orders per hour, while a 120-minute wave can pack between 135 and 185 orders per hour, based on the increase in efficiency due to intelligent order-batching. Therefore, for each wave length, the descriptive model tests a range of picking and packing efficiencies. The configuration in each wave that balances the number of pickers and packers in a way that results in the lowest total number of workers provides the best solution. Since the pack station cost in a manual system is so low, the number of pack stations tends to be irrelevant unless two picking and packing combinations have almost the same total number of employees.

4.3 Automated Sortation System

In the automated sortation system descriptive model, the input parameters include demand, picker, packer, and inductor rates, both fixed and variable capital costs, and the number of orders per pack station. The fixed cost includes the control system, scanner, and related hardware. Variable costs include the pack stations, induction stations, and trays or belts for the sorter. Pack station costs here include the chutes leading from the sorter to the pack station and all accessories, such as packing tables, conveyors, and shelving used at the pack tables. Automated systems must also consider the number of inductors and induction stations required to meet desired demand levels. Even though inductors usually work at a fast pace, the stations and additional trays or belts that must be purchased can be the additional cost that makes this system more expensive than a manual system.

Batch sizes increase as wave lengths increase with an automated sortation system. Since the sorter eliminates the effects of picking on the packing rates, the pickers can work at the highest rate possible. Packing rates remain fairly constant, with only a slight decrease in efficiency as the wave length or batch size increases. Also, since we are assuming that orders arrive to the pack station already individually sorted, the packer's rate will be much higher than a manual packer. The descriptive model takes all of these relationships into account, and calculates the total annual system cost for each of the common wave lengths (with only

one picking and packing rate combination for each wave length tested). The combination of higher picking and packing rates results in fewer workers for the automated system over its manual counterpart.

4.4 Example

In order to illustrate the relationships developed in the descriptive model, a numerical example is presented. In this example, a point was selected from the picking efficiency curve to demonstrate the differences between the manual and automated sortation systems. The picking efficiency curve in this example is presented in Figure 4.2. The manual curve is valid for a 20-minute wave length, while on the automated curve, the point at (75, 75) is valid for the 20-minute wave length. The manual system has a different curve for each wave length, because as picking efficiency increases with a longer wave length (i.e., more items can be collected at one location as the number of orders per wave increases), the packing efficiency decreases. In the automated picking curve, the picking efficiency increases as each wave length increases, while packing efficiency remains constant regardless. Although we have considered only one point from the manual curve and one point from the automated curve, the spreadsheet model will perform the following calculations for each of the six combinations of picking and packing rates in the wave length for the manual system, and for each wave length for the automated system.

For this example, the parameters in Table 4.2 were used to calculate the labor requirements and costs, the amount of hardware or size of the sorter, and the total annual system cost. The table is separated into parameters used in both manual and automated systems, followed by parameters unique to manual systems, and finally parameters used only in automated systems.

Table 4.2: Example Parameters.

Parameter	Symbol	Value
Demand	D	1100 orders/hr
Items/order	N_o	3 items
Wave Length	W	20 minutes
Orders/Pack Station	N_q	25 orders
Labor Cost/Picker	ℓ_p	\$30,000
Labor Cost/Packer	ℓ_q	\$30,000
Interest Rate	i	20%
Years of Service	y	5 years
Manual Picking Std	$p(n)$	50 orders/hr
Manual Packing Std	$q(m)$	45 orders/hr
Annualized Cost/Pack Station	c_q^m	\$234.08
Conveyor Speed	s	100 items/minute
Induction Std	t	20 items/minute
Picking Std (automated)	$p(n)$	75 orders/hr
Packing Std (automated)	$q(m)$	75 orders/hr
Labor Cost/Inductor	ℓ_t	\$30,000
Annualized Cost/Induction Station	c_t	\$16,720
Annualized Cost/Pack Station	c_q^a	\$3,334
Annualized Fixed Cost of Sorter	C^s	\$83,600

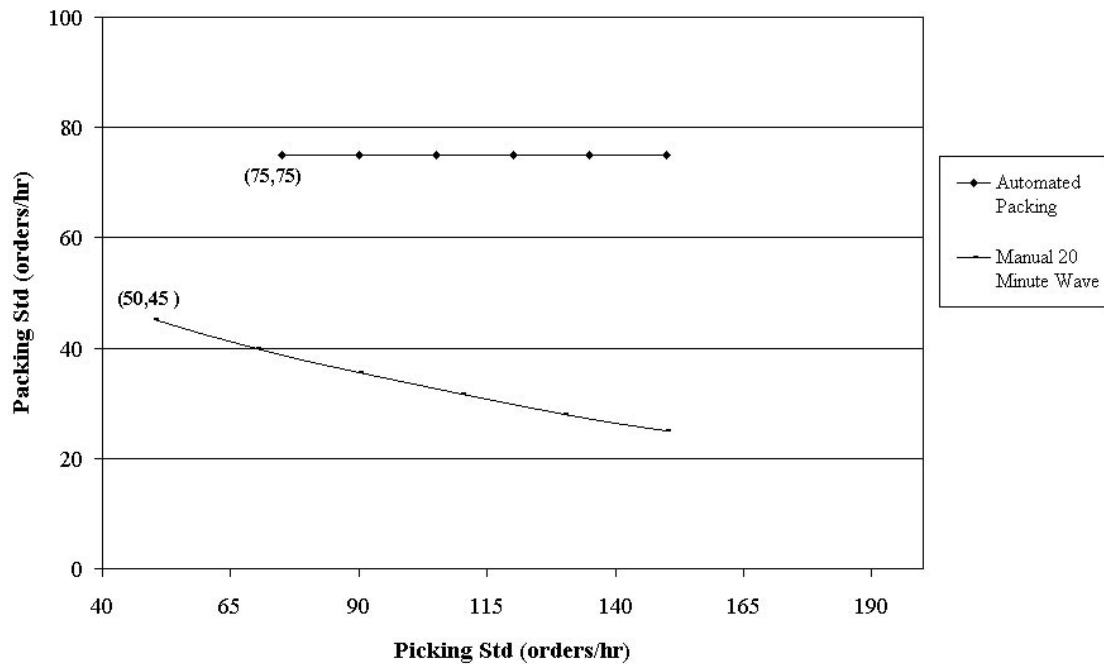


Figure 4.2: Example Picking vs. Packing Efficiency Curve.

4.4.1 Calculations

Sample calculations for a manual system with a 20-minute wave are presented in Table 4.3. Automated system calculations are presented in Table 4.4. Again, a 20-minute wave was used to make these calculations.

For the system, a basic tradeoff between the amount invested in automation and the amount of labor savings realized needs to be made. In this example, automation results in labor savings of \$420,000. However, the annual investment of the manual system is \$144,628 less than the automated system, mainly because of the expense of the pack stations, the sorter, and the accompanying hardware. Overall, this tradeoff suggests that an automated system should be selected, resulting in annual savings of approximately \$275,372.

Again, these calculations are repeated for all possible combinations. That is, for each combination of picking and packing rates within a wave for a manual system, calculations such as those in Table 4.3 are performed. This results in six identical sets of calculations for each

Table 4.3: Example Calculations for the Manual System.

Variable	Symbol	Formula Calculation	Value
Items/Wave	N_w	$(D * N_o * W)/60$ $(1100 * 3 * 20)/60$	1100
Pickers	r_p	$\lceil D/p(n) \rceil$ $\lceil (1100/50) \rceil$	22
Minimum Required Packers	r_q	$\lceil D/q(m) \rceil$ $\lceil (1100/45) \rceil$	25
Minimum Required Pack Stations	n_q	$\lceil N_w/N_q \rceil$ $\lceil (1100/75) \rceil$	15
Actual Number of Packers and Pack Stations	r_a	$maximum\{r_q, n_q\}$ $maximum\{25, 15\}$	25
Total Annual Labor Cost	T_ℓ^m	$\ell_p r_p + \ell_q r_q$ $30000 * (22 + 25)$	\$1,410,000
Total Annual Manual System Cost	T^m	$T_\ell^m + r_q c_q$ $1410000 + 25 * 234.08$	\$1,415,852

of the wave lengths considered. This equates to thirty-six total sets of calculations when 20-minute to 2-hour wave lengths are considered. The automated system calculations such as those in Table 4.4 are performed for each wave length considered in the model. This equates to six sets of calculations like those in Table 4.4 when 20-minute to 2-hour wave lengths are considered. The prescriptive deterministic model considers all possible combinations (e.g., forty-two total combinations when six batching levels and six wave lengths are considered) and uses the results from the descriptive model to determine the solution with the lowest annual cost. Results from experiments with a demand level of 1100 orders per hour are presented in Appendix C for both manual and automated systems. Notice that this example does not provide the best solution for either the manual or the automated system.

As we can see in the calculations in Table 4.4, although the capital investment of a sorter and more expensive pack stations is quite high, the labor savings are significant enough to make automation preferable. This will not always be the case. This example used a relatively low sorter fixed cost. In our following experiments with the model, we will consider many scenarios and cost ranges, as well as a variety of picking and packing efficiency curves.

Table 4.4: Example Calculations for the Automated System.

Variable	Symbol	Formula Calculation	Value
Items/Wave	N_w	$(D * N_o * W)/60$ $(1100 * 3 * 20)/60$	1100
Pickers	r_p	$\lceil D/p(n) \rceil$ $\lceil (1100/75) \rceil$	15
Total Induction Rate	x	$D(N_o/60)$ $(1100 * 3)/60$	55
Minimum Required Packers	r_q	$\lceil D/q(m) \rceil$ $\lceil (1100/75) \rceil$	15
Minimum Required Pack Stations	n_q	$\lceil N_w/N_q \rceil$ $\lceil (1100/75) \rceil$	15
Actual Number of Packers and Pack Stations	r_a	$maximum\{r_q, n_q\}$ $maximum\{15, 15\}$	15
Induction Stations	r_s	1, since $x < s$ 1	1
Inductors	r_t	$\lceil (x/t) \rceil$ $\lceil 55/20 \rceil$	3
Total Annual Labor Cost	T_ℓ^a	$\ell_p r_p + \ell_q r_q + \ell_i r_t$ $30000 * (15 + 15 + 3)$	\$990,000
Total Annual Automated System Cost	T^a	$T_\ell^a + C_s + r_a c_q + r_s c_t$ $(990000 + 83600 + 15 * 3344 + 1 * 16720)$	\$1,140,480

4.5 Model Experiments

Using the spreadsheet created to model this system, several experiments were tested. Different efficiency curves describing the relationship between picking and packing standards were input to determine the effect this curve has on the model. In addition, wave lengths of sizes varying from 20 minutes to two hours were tested. Each picking and packing standard was input for each wave length.

Additionally, for the automated system, two general relationships between picking and packing were investigated. First, picking standards were increased, while packing standards remained constant. This relationship assumes that the automated sorter adequately sorts the work to pack stations independently of the picking efficiency. Second, picking standards were increased, while packing standards slightly decreased. This relationship assumes that a decrease in packing efficiency would be attributed to the time spent by packers moving

between pack stations for multiple orders. Packers must move between stations since the packer can pack more orders in a wave than one station's capacity. This decrease can also be attributed to the amount of time needed to prepare shipping boxes and additional items placed in the box with the order, such as packing slips, inserts (magazines, coupons), and dunnage. This type of relationship is found in a system with no overlap.

The sensitivity analysis in Chapter 5 provides insight into how the input parameters interact with one another in each combination of picking and packing rates for both automated and manual systems. Each time a parameter is changed, a full set of model experiments is run to determine changes in the recommended system design.

Chapter 5

Sensitivity Analysis

In order to determine the effects of changes in each parameter, a sensitivity analysis was conducted. This analysis determined what parameter changes resulted in a shift to a different picking scheme and standard as well as the best overall solution for a wave length. This solution includes the type of system (automated or manual), the number of pickers, packers, and inductors (if an automated system is selected), the wave length that should be used, and the total annual cost for the system. Each parameter was increased and decreased until changes can be seen. In some cases, the amount of increase or decrease might be unrealistic, but still provides valuable information about the relationships within the model. Table 5.1 shows each factor that was changed and the anticipated effect it had on the decisions to be made.

Clearly, with as many factors and anticipated effects as are presented in Table 5.1, we cannot look at all possible combinations. Our methodology was to begin with the standard set of parameters for a problem and determine the solution. As mentioned above, the solution defines the type of system (automated or manual), the number of pickers, packers, and inductors (if automated), the wave length, and the picking methodology (as defined by the picking versus packing curves). We then changed a factor to determine the sensitivity of the solution to the factor.

Table 5.1: Sensitivity Analysis.

Parameter Changed	Anticipated Effect on Decision
Picker or Packer Cost	Wave Length, Automated vs Manual
Inductor Cost	Wave Length, Automated vs Manual (only if many inductors needed)
Automated Pack Station Costs	Wave Length, Automated vs Manual
Picker or Packer Std Rates	Number of Required Workers, Wave Length, Automated vs Manual
Inductor Rates	Number of Inductors, Wave Length, Automated vs Manual
Sorter Costs	Wave Length, Automated vs Manual
Demand	Everything
Wave Size	Everything

5.1 Methodology

The sensitivity analysis was conducted in the following manner. Five factors we deemed to be important were tested, including demand, sorter cost, labor costs, pack station costs (for the automated system), and induction rates. A full factorial experiment was completed, where each of the five factors was tested with each combination of the other factors. Table 5.2 shows the experiments run for a sorter cost of \$250,000. In this table, wave length is abbreviated WL and pack station is abbreviated PS. Similar test for sorter costs of \$500,000 and \$1,000,000 were conducted. A full table of experiments and results can be seen in Appendix D (Tables D.1, D.2, D.3, and D.4) for each of the five factors. Each experiment consists of using the experimental parameters as input data into the deterministic spreadsheet model, which then finds the best solution over the range of wave lengths and picking and packing efficiencies. The results from this experiment are the best automated and manual solutions over these ranges. From this information, we can see the effects on the solutions as well as the difference between automated and manual solutions. Also, we can make generalizations as to when automation is preferred over manual sortation, based on varying parameters.

Table 5.2: Sensitivity Analysis Experiments for Sorter Cost of \$250,000.

Demand Level (orders/hr)	Labor Cost (\$)	PS Cost (Auto) (\$)	Induction Rate (items/min)	Manual Best (\$)	WL Manual (min)	Automated Best (\$)	WL Auto (min)	Difference (M-A) (\$)
550	18000	2,500	20	350,661	100	389,104	120	(38,443)
550	18000	2,500	60	350,661	100	371,104	120	(20,443)
550	18000	10,000	20	350,661	100	451,072	20	(100,411)
550	18000	10,000	60	350,661	100	433,072	20	(82,411)
550	18000	20,000	20	350,661	100	477,824	20	(127,163)
550	18000	20,000	60	350,661	100	459,824	20	(109,163)
550	30000	2,500	20	578,661	100	557,104	120	21,557
550	30000	2,500	60	578,661	100	527,104	120	51,557
550	30000	10,000	20	578,661	100	650,640	80	(71,979)
550	30000	10,000	60	578,661	100	620,640	80	(41,979)
550	30000	20,000	20	578,661	100	693,824	20	(115,163)
550	30000	20,000	60	578,661	100	663,824	20	(85,163)
1100	18000	2,500	20	668,599	120	641,888	120	26,711
1100	18000	2,500	60	668,599	120	605,888	120	62,711
1100	18000	10,000	20	668,599	120	744,480	20	(75,881)
1100	18000	10,000	60	668,599	120	708,480	20	(39,881)
1100	18000	20,000	20	668,599	120	794,640	20	(126,041)
1100	18000	20,000	60	668,599	120	758,640	20	(90,041)
1100	30000	2,500	20	1,100,599	120	953,888	120	146,711
1100	30000	2,500	60	1,100,599	120	893,888	120	206,711
1100	30000	10,000	20	1,100,599	120	1,117,456	60	(16,857)
1100	30000	10,000	60	1,100,599	120	1,057,456	60	43,143
1100	30000	20,000	20	1,100,599	120	1,190,640	20	(90,041)
1100	30000	20,000	60	1,100,599	120	1,130,640	20	(30,041)
2200	18000	2,500	20	1,319,198	120	1,254,176	120	65,022
2200	18000	2,500	60	1,319,198	120	1,146,176	120	173,022
2200	18000	10,000	20	1,319,198	120	1,477,360	20	(158,162)
2200	18000	10,000	60	1,319,198	120	1,369,360	20	(50,162)
2200	18000	20,000	20	1,319,198	120	1,577,680	20	(258,482)
2200	18000	20,000	60	1,319,198	120	1,469,680	20	(150,482)
2200	30000	2,500	20	2,171,198	120	1,914,176	120	257,022
2200	30000	2,500	60	2,171,198	120	1,734,176	120	437,022
2200	30000	10,000	20	2,171,198	120	2,241,312	60	(70,114)
2200	30000	10,000	60	2,171,198	120	2,061,312	60	109,886
2200	30000	20,000	20	2,171,198	120	2,417,680	20	(246,482)
2200	30000	20,000	60	2,171,198	120	2,237,680	20	(66,482)
3300	18000	2,500	20	1,987,797	120	2,025,904	120	(38,107)
3300	18000	2,500	60	1,987,797	120	1,755,904	120	231,893
3300	18000	10,000	20	1,987,797	120	2,348,336	20	(360,539)
3300	18000	10,000	60	1,987,797	120	2,078,336	20	(90,539)
3300	18000	20,000	20	1,987,797	120	2,495,472	20	(507,675)
3300	18000	20,000	60	1,987,797	120	2,225,472	20	(237,675)
3300	30000	2,500	20	3,271,797	120	3,117,904	120	153,893
3300	30000	2,500	60	3,271,797	120	2,667,904	120	603,893
3300	30000	10,000	20	3,271,797	120	3,638,608	60	(366,811)
3300	30000	10,000	60	3,271,797	120	3,188,608	60	83,189
3300	30000	20,000	20	3,271,797	120	3,851,472	20	(579,675)
3300	30000	20,000	60	3,271,797	120	3,401,472	20	(129,675)

5.2 Results

As mentioned before, five main input parameters were tested in the sensitivity analysis of the prescriptive spreadsheet model. Of the five input parameters that were varied in the deterministic model, only four proved to be significant in determining whether a system should have automated sortation or not. The parameter that tended to not be significant was the induction rate since the number of inductors required in a system remains fairly low, even for a system with high demands. However, in experiments where a manual system has a relatively close cost to the automated system, the induction rate may end up being the deciding factor. This just proves that every input factor is important in some cases where the decision is more difficult. Results from demand levels of 550 and 3300 orders per hour are presented in Figures D.1 and D.4, where pack station costs are abbreviated as “PS Cost,” and labor costs are abbreviated as “L”. In each of these figures, the interest rate and life used are 20% and 5 years, respectively.

In what follows, each input parameter will be discussed in detail. Then the effects of varying parameters simultaneously will be discussed. For each separate parameter, the base case will be tested. The base case considered is a demand level of 1100 orders per hour, a sorter cost of \$250,000, labor costs of \$30,000 per employee, pack station costs of \$10,000 per pack station for the automated system and \$700 for the manual system, and induction rates of 20 trays per minute (items per minute). The total annual system cost for the base case is \$1,100,599 for the best manual system. This configuration requires 11 pickers, 25 packers, and 88 pack stations. The automated system for the base case costs \$1,117,456 with 11 pickers, 15 packers, 44 pack stations, 3 inductors, and 1 induction station. The manual system is recommended here, mainly due to the high cost of pack stations in an automated system.

5.2.1 Demand

Demand levels have the largest effect on a recommended system configuration. Intuition leads to the conclusion that at very low demand levels, automation would not be feasible for

a company. The cost of the sorter would add a significant amount to the total annual system cost, and greatly overshadows the cost of labor for a low demand. In contrast, at very high demand levels, the number of employees required to meet demand makes the total annual system cost for the manual system extremely high. Regardless of the sorter costs input, the labor costs remain a very high percentage of the total cost.

In addition to the base demand levels, three additional levels of demand were used to calculate the total annual system cost and determine labor, pack station, and induction station requirements. In general, increasing demand to 3300 orders per hour causes a large increase. With the same parameters, the manual system requires 33 pickers, 74 packers, and 264 pack stations at a cost of \$3,271,797. However, the automated system is still more expensive, at a cost of \$3,305,168. This configuration requires less workers (32 pickers, 44 packers, and 15 inductors), but requires 132 pack stations and 3 induction stations. The pack stations and induction stations cost approximately \$311,000 for the automated system, and the pack stations in the manual system are only \$20,600.

It would seem as though if demand were increased enough, labor requirements would be high enough to justify the capital costs involved in purchasing a sorter. However, the additional pack stations required make the automated system even less attractive. Induction stations would also need to be added to meet demand at high levels. Since it is very rare to have more than four induction stations, the requirement of more induction stations eventually requires another sorter due to size limitations.

Lowering demand to 550 orders per hour has a significant effect on the recommended system configuration. Large labor reductions are achieved when demand is lowered. The manual system requires only 5 pickers, 14 packers, and 37 pack stations in the recommended system at a cost of \$578,661. The automated system requires 5 pickers, 8 packers, 30 pack stations, and 1 induction station. Although this system reduces labor requirements by 5 workers, the \$150,000 saved does not make up for the cost of pack stations and the induction station.

By comparing Figures 5.1 and 5.2, we can see that demand has a large effect on the type of system recommended. In these figures, a negative (down) bar represents a manual system recommendation, while a positive (up) bar represents an automated system recommenda-

tion. In the system with low demand, automated systems are rarely recommended, but in systems with high demand, automation is recommended quite often. Keep in mind that the combination of other parameters, which will be discussed in Section 5.2.6, has an impact on this decision as well.

5.2.2 Labor Costs

Labor costs are a high percentage of the total annual cost of an order fulfillment system. For example, in the base case discussed above, the manual system requires 36 employees and the automated system requires 29 employees. Labor costs for each represent over 77% of the total annual cost. Therefore, when labor costs are reduced, it makes a significant impact on the system configuration and costs.

When labor costs are lowered to \$18,000 a year per employee in the base case, the total annual cost for the manual system is reduced to \$668,600 and the automated system is reduced to \$744,480. The manual system is more likely to be recommended at lower labor costs since the labor costs will be a lower percentage of the total annual cost.

With a labor cost per employee of \$33,000 a year, the manual system has a slightly higher total annual system cost of \$1,208,599, which is compared to the automated system at \$1,204,456. Any labor cost higher than this with the base case recommends an automated system since the savings due to labor increase while the other costs remain constant.

Looking at Figure 5.1, we see that although manual systems are usually preferred over automated systems, the labor cost can be the deciding factor. For example, with a low sorter cost of \$250,000, and a low pack station cost of \$2,500, the higher labor costs of \$30,000 result in the automated system having a lower cost than the manual system.

5.2.3 Pack Station Costs

Surprisingly, pack station costs have a significant effect on the total annual system cost. Automated systems require more expensive pack stations that hold more than one order,

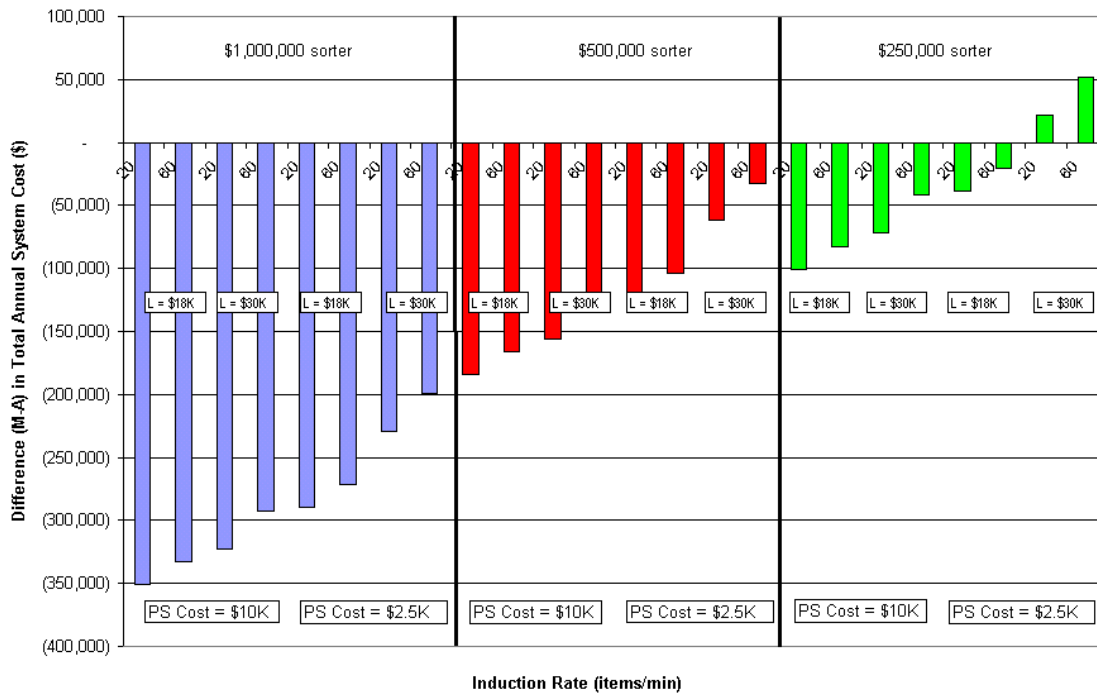


Figure 5.1: Sensitivity Data at Demand = 550 Orders/Hour.

usually containing several bins to hold the sorted orders. These stations are fairly expensive because of the equipment connecting the sorter to the bins. Manual systems require very simple pack stations, consisting of only a packing table and inexpensive accessories.

Since the manual pack stations are so inexpensive, the cost were not varied. However, three costs were considered for the automated system pack station costs. The base case of \$10,000 per pack station was raised to \$20,000 (not shown in Figure 5.1) and lowered to \$2,500 per pack station.

The base case requires 44 pack stations for the best automated system, at a total cost of \$294,272. A pack station cost of \$20,000 raises the total cost of pack stations to \$588,544. Lowering the pack station cost to \$2,500 per pack station lowers the total cost of pack stations to \$73,568, which results in the automated system being recommended. This automated system has a total annual system cost of \$953,888. At the highest pack station cost, none of the combinations result in a recommendation of automation. In fact, even with a \$10,000

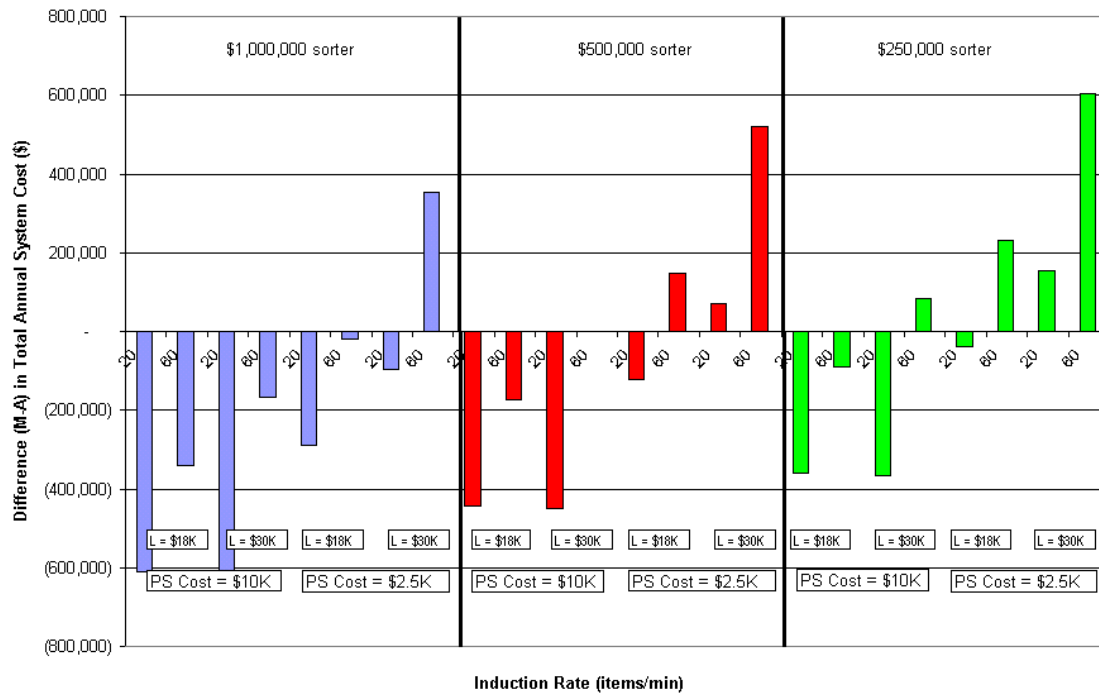


Figure 5.2: Sensitivity Data at Demand = 3300 Orders/Hour.

cost per pack station, only the combination of a low sorter cost, high labor cost, and high induction rate results in the recommendation of an automated system.

5.2.4 Sorter Costs

At relatively low demand levels, such as the base level of 1100 orders per hour, the cost of labor outweighs the capital costs involved with purchasing a sorter only if the sorter cost is low. The base sorter cost of \$250,000 is not low enough to outweigh the labor costs of a manual system. However, lowering this cost to \$199,500 will result in an automated system with a total annual cost \$30 lower than the manual system. Of course, this sorter cost is unrealistically low.

The three levels of sorter cost were \$250,000, \$500,000, and \$1,000,000. Each cost is annualized by a capital recovery factor (A/P) of 0.3344. Each cost increase makes it harder for the automated system to outperform the manual system, regardless of the demand level. Other

parameters must be adjusted to recommend the systems with higher sorter costs.

5.2.5 Induction Rates

At the base demand level of 1100 orders per hour and an induction rate of 20 items per minute, only 3 inductors are required, resulting in an automated system cost of \$1,117,456. With an induction rate increase to 60 items per minute, the system annual cost reduces to \$1,057,456, which is lower than the manual system cost of \$1,100,599. Although this parameter seems to make little difference in the system, it reduces the manpower requirements from 3 inductors to 1 inductor, for a savings of \$60,000. This is an example of how varying the induction rate can change the system recommendations when the two systems (automated and manual) have similar annual costs.

When demand levels are higher or lower, the two systems will have a larger gap in their total annual costs, making the induction rate parameter less significant.

5.2.6 Combination of Parameters

Sensitivity analyses showed that varying a single parameter may not change the recommended system configuration, but varying several parameters simultaneously has a significant effect on the system.

For example, at a demand level of 1100 orders per hour, a high sorter cost of \$1,000,000 and pack station costs of \$20,000 results in a manual system recommendation for every combination of other parameters tested. At high demand levels, with low sorter costs and low pack station costs (\$250,000 and \$2,500, respectively), the automated sortation system is recommended for every combination of other parameters, except with low labor costs and low induction rates. However, at the same demand level, a medium pack station cost (\$10,000) results in mixed recommendations that depend on the induction rate. A high induction rate results in an automated sortation system recommendation, while a low induction rate results in manual sortation.

A high demand level with a high sorter cost (\$1,000,000) and high or medium pack station costs always resulted in recommending the manual system. However, the same system with a low pack station cost varied based on the labor costs. Low labor costs resulted in a manual recommendation, while high labor costs resulted in an automated system recommendation.

At low demand levels, a high sorter cost results in a manual system in every experiment. A medium sorter cost (\$500,000), also results in a manual recommendation. Only at low sorter costs with low pack station costs and high labor costs (\$30,000) is the automated system recommended.

In general, we can see that although one parameter change might not be enough to cause the system recommendation to change, combinations may result in different configurations. A company can vary the costs to determine which would be more beneficial based on their needs.

5.3 Results for Order-Batching in a Manual System

In addition to the effects of changing parameter values, a sensitivity analysis was conducted to determine the effects of batching in both automated and manual systems. Order-batching has a significant impact on the resources needed to meet demand. This section describes the effects of order-batching as well as lengthening the wave in a manual system. First, however, we describe an approximate model to determine both the picking and packing rates, therefore providing the optimal level of order-batching.

5.3.1 Points Along a Curve

As discussed earlier, points on an efficiency curve (see Figure 3.3) represent a change in order-batching for a picker. Each point is a different picking rate that reflects the number of orders picked in a batch. As the batch size increases, the picking rate increases as well since the picker may be able to reduce the number of aisles traversed. This in turn will reduce the number of pickers required to meet demand, but will also increase the number of packers

required.

Because of this tradeoff, we experimented with different combinations of picking and packing rates for each wave length tested. The combinations varied from the picker's lowest rate to the highest, and then considered the packing rates associated with that batch size. From these combinations, we identified the lowest total annual system cost, and noted the tradeoffs that were made. The combinations represent the points on the curve for each wave length.

For instance, at the base demand level of 1100 orders per hour, a picking rate of 50 orders per hour requires 22 pickers and 25 packers. On the other hand, increasing the picking standard to 110 orders per hour requires only 10 pickers, but increases the number of packers to 35. In this case, increasing the picking rate (which results from a batch size increase) reduces the total annual system cost by \$57,659 since the increase in picking rate reduces the number of employees by 2, saving \$60,000, but it also adds 10 pack stations at an annualized cost of \$2,341. The addition of pack stations is insignificant in this situation, but would not be the case in an automated system with high pack station costs.

Since the number of pickers decreases with a picking rate increase (or batch size increase), the number of packers increases. Therefore, the level of each that minimizes the total annual system cost may not be the largest batch size. In fact, this would never be the case unless the packing rate did not decrease as rapidly as the picking rate increased. The addition of pack stations would also be important if the pack station cost were higher. In this example, the recommendation (from the 20-minute wave) is a picking rate of 70 orders per hour, which requires 16 pickers and 28 packers at a cost of \$1,326,554. This solution requires one less employee than the picking rate of 110 orders per hour.

Shifting Curves and Wave Length Increases

As the wave length increases, the manual efficiency curves shift up and to the right. The packing rate will stay constant, because the packers will receive the same proportion of orders in a wave (i.e., twice as much in a wave twice as long). However, the pickers become more efficient because they have a better selection of orders from which to batch.

For example, the 20-minute wave length has a picking standard of 50 orders per hour corresponding to the packing rate of 45 orders per hour. This level of batching is low since the pickers only have 20 minutes worth of orders to pick. This system requires 22 pickers and 25 packers at a cost of \$1,415,852. If the wave length increases to 60 minutes, the picking standard can increase because the pickers will batch in a way that will save multiple trips to one location or aisle. This level of batching has a picking rate of 70 orders per hour, with the packing rate remaining constant at 45 orders per hour. This level of batching requires only 16 pickers and 25 packers at a cost of \$1,240,300. By increasing the wave length by 40 minutes, the company would save \$175,552 annually. Again, when considering only the labor costs, the longer the wave length, the better the system cost.

Relationship Between Each Combination

Now that we have considered the two main relationships shown in the efficiency curves (i.e., shifting along the curve and shifting from curve to curve), we now consider the effects of the combined relationship. The shift along the curve represents batching levels, and a level which minimizes the total number of pickers and packers is the recommended combination of picking and packing rates at that wave length. Based on average picking and packing rates provided to us by distribution centers we have contacted, pickers can work at a much faster rate than packers. Reasons for this include the intelligent batching methods and pick rate increases due to improving order-picking technologies (e.g., pick to light) and the manual sorting required by packers. Also, the packers have more setup time and additional items to pack such as inserts or packing material.

Since pickers, in general, work at a faster rate than packers, the results show that a low or average picking rate is usually selected, since doing so will ensure the packing rate does not fall too drastically. Also, as the wave length increases, it appears that the batch size is typically reduced to maintain a high level of picking efficiency and improve the packing efficiency.

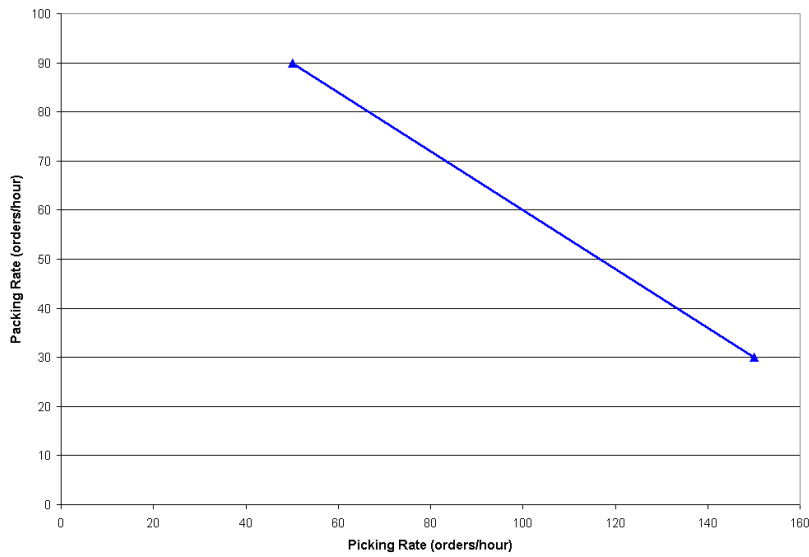


Figure 5.3: Estimated Picking vs. Packing Relationship.

5.3.2 Approximate Model to Determine Optimal Order-Batching

As discussed before, the biggest tradeoff exists between the picking and packing rates selected for the manual sortation system. Again, pack stations are the only other cost in this system, and their costs are low relative to the labor costs.

We have seen from simulation and verification of our theoretical efficiency curve that the relationship between picking and packing efficiencies is non-linear in general. However, the curve is nearly linear and can be estimated as a linear relationship as shown in Figure 5.3. From this relationship, we can predict the packing rate given a picking rate or vice versa. The following notation was used to estimate this relationship.

- p_1 is the picking rate in orders per hour.
- p_2 is the packing rate in orders per hour.
- \bar{p}_1 is the picking rate lower bound.
- \hat{p}_1 is the picking rate upper bound.

- \bar{p}_2 is the packing rate lower bound.
- \hat{p}_2 is the packing rate upper bound.
- D is the demand in orders per hour.
- z is the objective function value corresponding to the total number of employees.
- p_1^* is the picking rate that minimizes the objective function (unconstrained).
- p_2^* is the packing rate that minimizes the objective function (unconstrained).
- p_1^{min} is the picking rate that minimizes the objective function (constrained).
- p_2^{min} is the packing rate that minimizes the objective function (constrained).

The linear relationship between p_1 and p_2 is defined in (5.1) below. The slope, m , and intercept, b , are determined in terms of the problem parameters as shown in (5.2) and (5.3), respectively.

$$p_2 = \hat{p}_2 - (p_1 - \bar{p}_1) \left[\frac{\hat{p}_2 - \bar{p}_2}{\hat{p}_1 - \bar{p}_1} \right] \quad (5.1)$$

$$m = - \left[\frac{\hat{p}_2 - \bar{p}_2}{\hat{p}_1 - \bar{p}_1} \right] \quad (5.2)$$

$$b = \hat{p}_2 - m\bar{p}_1 \quad (5.3)$$

Thus, (5.1) can be written as shown in (5.4):

$$p_2 = b + mp_1. \quad (5.4)$$

Since this equation is linear, we know that it is a convex function. The objective function, z , where p_2 depends on the value of p_1 , is shown in Figure 5.4 for the data illustrated in Figure 5.3 and described in general by (5.5):

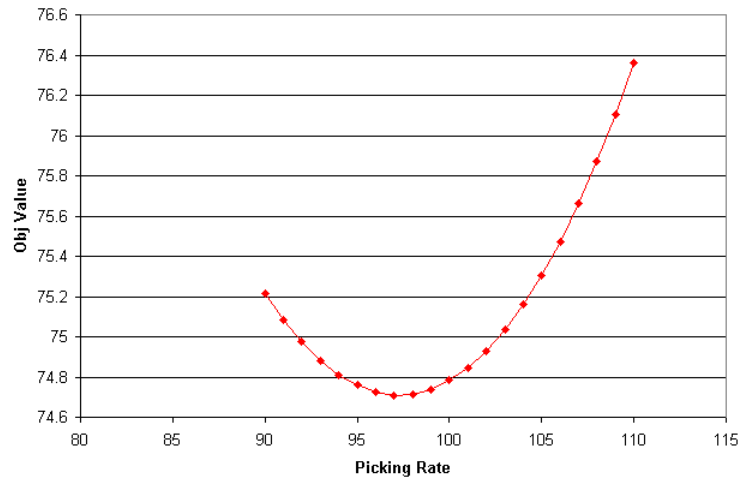


Figure 5.4: Picking Rate vs. Number of Employees.

$$z = \frac{D}{p_1} + \frac{D}{p_2}. \quad (5.5)$$

The objective function, (5.5), can be rewritten as follows by substituting for p_2 in (5.5) with (5.4). That is,

$$z = \frac{D}{p_1} + \frac{D}{b + mp_1}. \quad (5.6)$$

Note that we ignore the fact that the number of pickers and packers must be integer in (5.6). Examination of (5.6) leads to our first result.

Lemma 1 *Our objective function, represented by (5.6), is a convex function.*

Proof: A function $f(x)$ is convex if it is defined on a continuous interval and the second derivative $f''(x) > 0$ for all x on the interior of that interval. Therefore, we must solve for the second derivative of (5.6) as follows:

$$z' = \frac{-D}{p_1^2} + \frac{-Dm}{(b + mp_1)^2}; \text{ and} \quad (5.7)$$

$$z'' = \frac{2D}{p_1^3} + \frac{2m^2 D}{(b + mp_1)^3}. \quad (5.8)$$

Now, we must determine if $z'' > 0$ for all p_1 on the interior of the interval. Looking at the first fraction of (5.8), we know that demand, D , is always positive, as well as the picking rate, p_1 ; therefore, the first fraction is always positive. The numerator of the second fraction is positive since demand is always positive and m is squared. The denominator is less clear, but since $p_2 = b + mp_1$, we know that it is always positive since p_2 is always positive (packing rates must always be positive values). Therefore, $z'' > 0$, which completes the proof. ■

Since the objective function is convex, we know that the minimum exists at the point where the derivative is set equal to zero and solved for p_1 . Doing so and performing additional analysis leads to the following expression for p_1^* :

$$p_1^* = \begin{cases} \frac{-2bm - \sqrt{4b^2m^2 - 4b^2m(m+1)}}{2m(m+1)} & \text{if } m \neq -1, \\ b/2 & \text{if } m = -1. \end{cases} \quad (5.9)$$

Result 1 *The expression, (5.9), yields the optimal value for p_1^* when p_1 and p_2 are only constrained to be greater than zero.*

The proof of Result 1 is presented in Appendix E.

A surprising result that follows from Result 1 is that the demand level, D , does not play a factor in the optimal picking or packing rate for our system. We formally state this in our next result.

Result 2 *The optimal picking and packing rates, p_1^* and p_2^* , are not dependent on the demand level, D .*

Proof: The result is clearly true based on an examination of (5.9) and noting that neither b nor m are dependent on D . ■

Note that Result 1 is for the case where p_1 is only constrained to be greater than zero. However, we know that p_1 must also be between its lower and upper bound, \bar{p}_1 and \hat{p}_1 . If p_1^* is between the lower and upper bounds on the picking rate, then p_1^* is the optimal picking rate, i.e., $p_1^{min} = p_1^*$. However, if p_1^* lies outside of its bounds, then the nearest boundary to p_1^* is the optimal value for p_1 . That is, we will move along the curve that represents the objective function until we are feasible. This results in a shift of p_1 to the right if $p_1^* < \bar{p}_1$ and to the left if $p_1^* > \hat{p}_1$. This is represented in the following expression and formally stated in Theorem 1:

$$p_1^{min} = \begin{cases} p_1^* & \text{if } \bar{p}_1 \leq p_1^* \leq \hat{p}_1, \\ \hat{p}_1 & \text{if } p_1^* > \hat{p}_1, \\ \bar{p}_1 & \text{if } p_1^* < \bar{p}_1. \end{cases} \quad (5.10)$$

Theorem 1 *The expression (5.10) yields the optimal value for p_1^{min} when p_1 is constrained to be within (\bar{p}_1, \hat{p}_1) .*

Proof: Theorem 1 is illustrated by Figures 5.6, 5.5, and 5.7. Case 1 (Figure 5.5) represents a situation where the boundaries include the minimum, p_1^* , which is the optimal picking rate. Case 2 (Figure 5.6) is a situation where the picking rate boundaries are lower than the actual minimum of the objective function, resulting in an optimal picking rate of \hat{p}_1 . The boundaries of Case 3 (Figure 5.7) are higher than the actual minimum, resulting in an optimal picking rate of \bar{p}_1 . ■

In all cases, once p_1^{min} is determined, p_2^{min} is found by using (5.1). This analysis is helpful in estimating the optimal picking and packing rates if the workers' ranges were to increase or decrease in a manner where the slope, m , remains the same. For instance, consider a situation where the workers were at an optimal picking and packing rate and then the order-batching methods were improved, therefore increasing the pickers' upper bound. Suppose that this improvement in picking reduces the packers' lower bound by the same amount, since some packers will not be able to keep up at this higher rate. If the current range includes the objective function minimum, found by (5.9), then this change has no effect. If

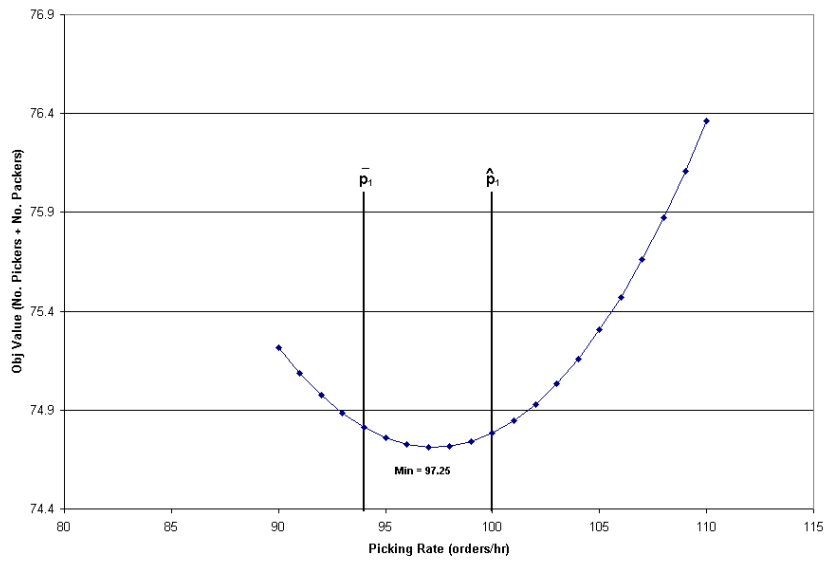


Figure 5.5: Case 1 — Minimum is Included in Picking Boundaries.

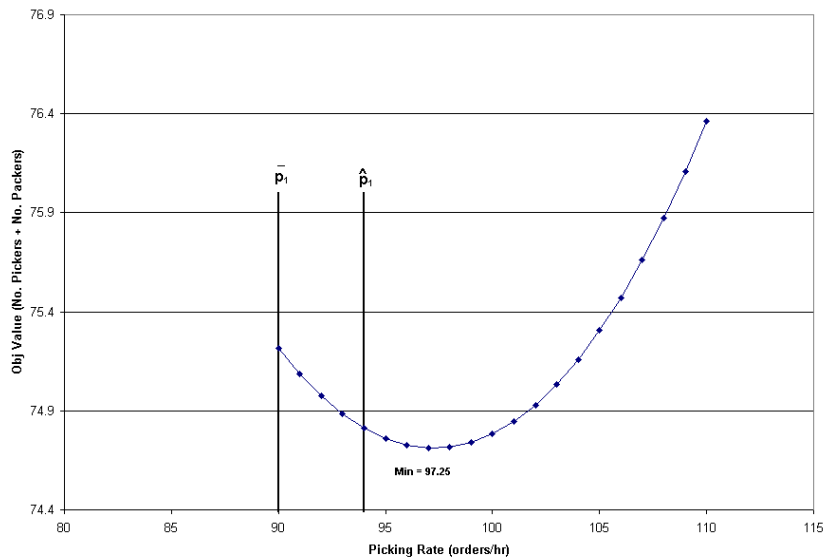


Figure 5.6: Case 2 — Minimum is Lower than Picking Boundaries.

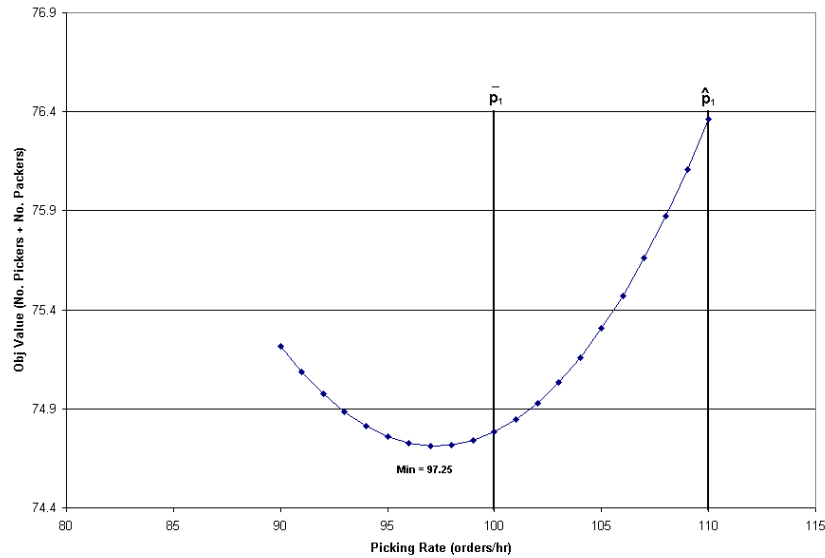


Figure 5.7: Case 3 — Minimum is Higher than Picking Boundaries.

the range is to the right of the minimum (i.e., picking rates exceed the actual minimum of the objective function), this shift in upper bound still has no effect on the optimal picking rate. However, if the range is to the left of the minimum, increasing the upper bound will shift the optimal picking rate to either the upper bound (if the minimum is still not included), or the actual minimum of the objective function. Similar results hold if the bounds decrease. The following example illustrates these results.

Example

To illustrate the behavior of optimal picking and packing rates, consider the following example. Table 5.3 provides several boundaries for picking and packing rates. Notice that p_1^* remains the same for each set of boundaries, since the boundaries are still of equal size (i.e., slope of (5.6) does not change). Figure 5.8 illustrates how the boundaries move around p_1^* . Picking boundaries of 90 and 110 orders per hour do not include p_1^* , but 70 and 100 do. As shown in Table 5.3, this results in an optimal picking rate of 90 orders per hour for the (90,110) boundaries, and 85 (the actual minimum) for the (70,100) picking boundaries.

Similar results do not hold for systems where the rates increase or decrease in a manner

Table 5.3: Example Picking and Packing Boundaries and Resulting Optimal Rates (m does not change).

\bar{p}_1	\hat{p}_1	p_1^*	p_1^{min}	\bar{p}_2	\hat{p}_2	p_2^*	p_2^{min}	z
90	110	85	90	60	80	85	80	94.44
90	120	85	90	50	80	85	80	94.44
80	110	85	85	60	90	85	85	94.12
70	100	85	85	70	100	85	85	94.12

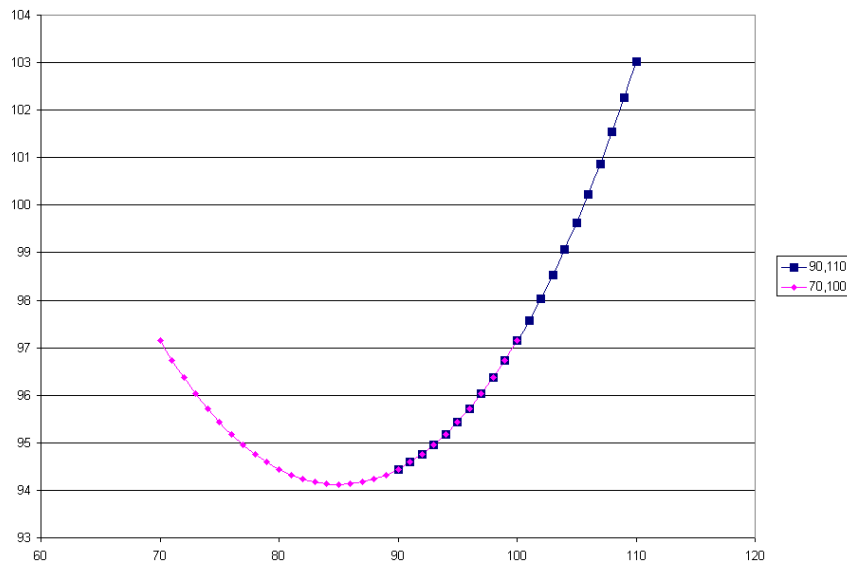


Figure 5.8: Example Objective Functions.

that changes the slope describing the linear relationship between picking and packing. It is difficult to predict the optimal picking rate for this type of increase or decrease. Using intuition, we can predict the reaction of a system with similar lower and upper bounds in much the same way as systems with identical slopes. However, when the boundaries do not overlap, this becomes more difficult. Consider the examples in Table 5.4. The first set of examples shows two similar boundaries, (50,100) and (50,100). Here, if we raise the picking lower bound while keeping the same packing boundaries, we expect that since the pickers are more efficient, we can allow the packers to move towards their upper bound, which does occur in this case. Lowering the picking lower bound would cause the optimal picking rate to increase, since the pickers are now less efficient. Using the same idea, however, by looking at the second set of examples in Table 5.4, the behavior of the picking and packing optimal

rates is not predictable. In the case where \bar{p}_1 is decreased from 75 to 70, the optimal picking rate should increase since the pickers are not as efficient. However, just the opposite happens. However, by increasing the packing rate lower bound in the last trial, the optimal packing rate does not increase as expected.

Table 5.4: Example Picking and Packing Boundaries and Resulting Optimal Rates (m changes).

\bar{p}_1	\hat{p}_1	p_1^{min}	\bar{p}_2	\hat{p}_2	p_2^{min}	z
50	100	75.0	50	100	75.0	106.67
55	100	74.4	50	100	78.4	104.75
45	100	75.7	50	100	72.1	108.33
75	100	75.0	40	60	60.0	120.00
70	100	71.9	40	60	58.7	123.74
75	100	76.4	45	60	59.2	119.67

In summary, our results with this approximate analytical model provide the foundation for evaluating changes in order-batching. In particular, a choice between increasing picking or packing efficiencies can be evaluated quickly with this model. Also, situations where increases in either or both do not lead to improvements in the system can be identified.

5.4 Results for Order-Batching in an Automated System

In an automated system, as the amount of batching increases, the picking rate will increase as well. However, increasing the batching has little or no effect on the packing rate. The automated sorter ensures that each packer will receive the orders at a constant rate. As the wave length increases, the batch size increases, since the pickers have a longer period of time to retrieve items for orders. At a wave length of 20 minutes, the picking rate is 75 orders per hour, requiring 15 pickers, 15 packers, and 3 inductors. The total annual system cost at this level of batching is \$1,140,480. With the wave length increased to 80 minutes, the picking rate increases to 120 orders per hour, therefore requiring fewer pickers. This system

requires 10 pickers, 15 packers, and 3 inductors at a cost of \$1,137,616. Savings of \$150,000 result from reducing the number of employees by 5, but the increase in pack stations from 15 to 59 at \$10,000 per pack station adds an additional \$147,136. The total savings from batching is \$2,864.

The system discussed above considered a system where no time was spent walking from bin to bin or between pack stations, and no time was spent waiting for orders to become ready to pack. The packing rate remains constant over each increase in picking rate. Therefore, the best solution from the experiments will occur at the best combination of picking rate and number of pack stations required. The solution that provides the best cost from these two factors will be recommended. For instance, in the base case, the solution with a picking rate of 105 orders per hour, packing rate of 75 orders per hour, and a requirement of 44 pack stations has a total annual cost of \$1,117,456.

However, if we now consider a system where the packing rate deteriorates due to walking and waiting times, such as a system with no overlap, the recommendation will be somewhat different. Now, we must consider the solution that minimizes the costs associated with pickers, pack stations, and packers, since the packing rate is no longer constant. At the same picking rate as the best automated solution where packing rate remains constant, the total annual cost is now \$1,147,456. This system requires an extra packer at \$30,000 due to the decrease in packing efficiency caused by walking times. In fact, from the simulation results, this decrease in packing efficiency can become quite pronounced as the wave length increases (see Figure 3.11).

Chapter 6

Throughput Simulation Results

After a company has provided input data such as their demand level, efficiency curves, capital costs, labor costs, and sorter speed, the deterministic spreadsheet model recommends a configuration. This recommendation consists of whether the system is manual or automated, the number of employees, the number of pack stations and induction stations, the picking and packing rates, and the wave length. This spreadsheet output then becomes the input for a throughput simulation. The throughput simulation determines if the demand can be met using the recommended configuration.

The throughput simulation is important for several reasons. First, any inaccuracies in the spreadsheet model can be discovered by running throughput simulations. The inaccuracies will manifest themselves as a system that does not meet demand. Second, the stochastic nature of the order fulfillment process can be modeled more accurately. Since stochastic factors degrade the performance of any system, our deterministic model is susceptible to the effects of stochastic factors. Third, the effects of rounding in the deterministic spreadsheet model can be quantified. Since many design parameters have been rounded to ensure sufficient capacity in the deterministic model, this additional capacity may or may not balance the negative impact of the stochastic factors.

The descriptive model provides a preliminary analysis of the system, ignoring all stochastic elements. This model defines a given situation with a particular set of parameters, such as

those used in the example previously presented. In order to develop a more realistic model of the sortation system, stochastic elements must be introduced.

Variability is present in almost every parameter represented in this model. Demand may have peaks or fluctuations based on the time of day, day of the week, or even the month or season. Additionally, while labor standards are set by the engineers, each worker will actually work at different levels. Although these types of variability are important, we do not consider them. Rather, we consider a peak wave size and equivalent workers all working at a minimum labor standard. However, we do incorporate randomness into wave composition and unit processing times.

The goal of the simulation study is to refine the data for the descriptive model and to give insights into the critical tradeoffs. This model allows the system to be examined under different parameters with stochastic processing times, demands, and other model inputs.

Since waves are being used, it is not necessary to model the entire system. With a wave, only items included in the orders in that particular wave may be processed, and processing cannot begin on items from the next wave until the current wave is completed. Therefore, there is little interaction between picking, sorting, and packing for one particular wave. Thus, three smaller systems, picking, sorting, and packing, may be simulated separately—although not independently, as will be discussed next.

As stated previously, the three sub-systems (picking, sorting, and packing) may be considered separately. The goal is to determine the throughput rate of a particular design and its associated wave length, while considering the stochastic elements of the system. Note that since many of the components of the system are integer in nature, the system determined from the descriptive model for a particular throughput rate may actually have a predicted throughput capability that is higher. Of course, the stochastic elements modeled in the simulation model have a negative effect on the throughput capability. The simulation model is used to gauge this effect relative to the target throughput by using the simulation model to measure the average total time required to pick, pack, or induct all orders assigned to the worker for a wave. The average total time and the maximum time can then be compared to the wave length for which the system was designed.

Each of the three sub-systems is somewhat different in the approach we have taken with it. In the picking sub-system we consider a rectangular picking area with an input/output point at one end of the area. Other researchers have considered such a layout (e.g., see [39]). In fact, fairly accurate analytical models exist to predict the time to pick a certain number of items. However, since we are concerned with the effects of variance, a simulation model is needed. Since each point on the picking efficiency curve is based on the throughput given a certain level of order-batching for the pickers, the analytical models are used to verify this point on the curve before beginning the simulation. In the simulation model, the items for orders are randomly generated and then batched for each picker based on the point on the curve of interest (i.e., how many orders' worth of items to pick in one batch). In many cases, more items are assigned to a picker than are necessary to meet throughput to make the data requirements more straightforward. Picking tours follow the traversal strategy.

The sorting sub-system only relates to the automated system, and only in terms of the induction process. The work by Meller and Johnson [31] provides an analytical model for inductors. The inductors can have different induction rates and can consider setup times if necessary. The total time to induct all items in a wave can be effectively estimated. For the most part, this analytical model has already been incorporated into our descriptive model (a modification to the material presented in Chapter 4 will be presented later in this chapter). Although comparing their work to simulation output proved this analytical model to be very accurate, it does not consider anything other than an average wave, and thus, simulation is needed.

The packing sub-system must consider both the manual and automated designs and is different from the other two sub-system simulations. The difference comes from the fact that there is not an analytical model to support the simulation model. However, this sub-system is also the simplest, with very few interactions to consider. That is, unlike picking or sorting where pickers and inductors interact with one another, for the most part packers at different stations do not interact — especially in the manual design. In the automated design, packers may interact with one another since two packers may, over different waves, pack at the same chute due to the stochastic nature of the system. However, we ignore the possibility in our

simulation model and simulate each packer independently. By varying the packing rates and walking rates in the automated system, the total time to pack all orders can be effectively estimated and the appropriate statistics constructed.

6.1 Methodology

The throughput simulation is performed for each subsystem: picking, sorting, and packing. However, simulations were not performed for manual sortation and packing. The picking simulation was run for the recommended wave length, picker rate, and batch size over 100 replications. For each replication, the total time to pick all items was measured. We collected statistics on the average, minimum, and maximum of this time. The picker utilization was also determined by dividing the total time spent picking all items for the batch by the wave length. For instance, if a picker took 118 minutes to pick all orders in a 120-minute wave, the utilization is $118/120$, or 0.9833 (98.33%). In addition, the number of waves where the items could not be picked within the wave was tabulated. Similarly, the packing simulation uses the recommended wave length, packing rate, and batch size as input, and calculates the amount of time spent packing the assigned orders for each replication. Again, various statistics over 100 replications were recorded. We assume that our manual sortation and packing estimates are valid, therefore only the picking subsystem is simulated for manual systems. The automated sortation is slightly different. Here, based on an induction rate, the effective rate for each inductor due to inductor blocking is calculated. Using this rate, the total number of items to be assigned to each inductor is determined. Again, statistics are collected for the induction subsystem over 100 replications.

6.2 Data

The tables in Section 6.2 present the data used in the throughput simulation runs. Data examples were generated in a manner that considers many different scenarios. For example, data that result in recommendations of manual and automated systems were generated. In

Table 6.1: Input Data for Deterministic Spreadsheet Model.

Trial No.	Demand Level (orders/hour)	Interest Rate (%)	Years of Service	A/P	Labor Cost (\$)	Pack Station Cost (\$)	Sorter Cost (\$)	Sorter Speed (tpm)	Induction Rate (tpm)	Picker Rate	Packer Rate
1	3000	0.1	10	0.1627	30,000	2,500	250,000	200	120	H	H
2	3000	0.2	5	0.3344	18,000	20,000	250,000	200	120	L	L
3	3000	0.1	5	0.2638	18,000	10,000	1,000,000	150	120	M	M
4	3000	0.1	10	0.1627	18,000	20,000	250,000	200	60	H	H
5	3000	0.2	5	0.3344	18,000	20,000	1,000,000	100	20	M	M
6	1100	0.1	10	0.1627	30,000	10,000	500,000	200	120	H	L
7	1100	0.1	5	0.2638	30,000	2,500	500,000	100	120	L	L
8	1100	0.2	5	0.3344	18,000	20,000	500,000	100	120	L	H
9	1100	0.1	5	0.2638	18,000	20,000	1,000,000	150	60	H	L
10	1100	0.1	5	0.2638	18,000	10,000	250,000	200	20	L	L
11	550	0.1	5	0.2638	30,000	2,500	250,000	200	120	H	H
12	550	0.2	5	0.3344	30,000	10,000	500,000	200	60	M	M
13	550	0.2	5	0.3344	30,000	10,000	250,000	150	60	H	H
14	550	0.2	10	0.2385	30,000	10,000	1,000,000	150	20	L	H
15	550	0.2	5	0.3344	18,000	20,000	1,000,000	100	20	M	M

addition, different demand levels were tested with high, medium, and low combinations of picking and packing rates. For each combination, a new efficiency curve and spreadsheet model were constructed from the simulated data. The construction of these curves and accompanying data is presented in Appendix F. In each table from this point on, the levels will be abbreviated as H for high, M for medium, and L for low. These scenarios ensure that the spreadsheet model is robust. Table 6.1 presents the input data for the spreadsheet model. Using the spreadsheet models adjusted by verification simulations, the recommendation for each set of input data is recorded in Tables 6.2 and 6.3. Tables 6.2 and 6.3 vary due to an assumption of whether or not overlapping or non-overlapping waves were used. The purpose of this distinction is to show the effects of overlapping on both the system configuration and the efficiency of the pickers and packers. All trials were performed for both types of waves. Table 6.2 presents the recommendations provided by the spreadsheet model for waves that overlap. Table 6.3 presents the recommendations for non-overlapping waves. Notice that the manual system is recommended more often given the same set of input data with non-overlapping waves. This is due to the fact that packing rates are lower in the automated system for non-overlapping waves because of the time spent waiting for bins to become ready to pack and walking time between bins that may be spread over a large distance. Systems with non-overlapping waves are not commonly used, but are presented here to illustrate the usefulness of the model in estimating throughput and picking and packing times for this type of system as well as systems with waves that overlap. In fact, systems with overlapping waves always result in a lower total annual system cost than systems without overlapping waves.

Table 6.2: Output Data for Deterministic Spreadsheet Model with Overlapping Waves.

Trial No.	Wave Length (min)	Picker Rate (orders/hr)	Packer Rate (orders/hr)	Required Pickers	Required Packers	Manual or Automated	Required Inductors	Required Induction Stations	Required Pack Stations	Total Annual System Cost (\$)
1	120	288.87	117.96	11	26	Automated	2	1	240	1,316,471
2	40	95.38	47.7	32	63	Automated	2	1	80	2,381,321
3	60	173.16	69.9	18	43	Automated	2	1	120	1,727,544
4	40	169.48	118.15	18	26	Automated	3	1	80	1,155,216
5	60	86.07	39.84	35	76	Manual	n/a	n/a	120	2,026,090
6	80	241.25	47.69	5	24	Automated	1	1	59	1,085,530
7	120	247.53	47.69	5	24	Automated	1	1	88	1,103,124
8	80	75.59	48.32	15	23	Manual	n/a	n/a	59	697,811
9	60	126.16	29.87	9	37	Manual	n/a	n/a	44	836,125
10	60	139.51	47.7	8	24	Automated	3	1	44	825,210
11	120	288.87	117.96	2	5	Automated	1	1	44	348,157
12	60	86.07	39.84	7	14	Manual	n/a	n/a	22	381,673
13	60	209.78	118.07	3	5	Automated	1	1	22	394,032
14	80	79.92	45.94	7	12	Manual	n/a	n/a	30	577,022
15	60	86.07	39.84	7	14	Manual	n/a	n/a	22	381,673

Table 6.3: Output Data for Deterministic Spreadsheet Model with Non-Overlapping Waves.

Trial No.	Wave Length (min)	Picker Rate (orders/hr)	Packer Rate (orders/hr)	Required Pickers	Required Packers	Manual or Automated	Required Inductors	Required Induction Stations	Required Pack Stations	Total Annual System Cost (\$)
1	40	169.48	83.45	18	36	Automated	2	1	80	1,761,373
2	100	91.43	28.99	33	104	Manual	n/a	n/a	200	2,512,816
3	60	86.07	39.84	35	76	Manual	n/a	n/a	120	2,020,159
4	20	113.45	93.21	27	33	Automated	3	1	40	1,313,020
5	60	86.07	39.84	35	76	Manual	n/a	n/a	120	2,026,090
6	40	169.48	33.85	7	33	Automated	1	1	30	1,368,334
7	120	247.53	30.62	5	36	Automated	1	1	88	1,463,124
8	80	75.59	48.32	15	23	Manual	n/a	n/a	59	697,811
9	60	126.16	29.87	9	37	Manual	n/a	n/a	44	836,125
10	100	91.43	28.99	13	38	Manual	n/a	n/a	74	931,665
11	20	113.45	93.21	5	6	Automated	1	1	8	444,415
12	60	86.07	39.84	7	14	Manual	n/a	n/a	22	381,673
13	20	113.45	93.21	5	6	Automated	1	1	8	450,639
14	80	79.92	45.94	7	12	Manual	n/a	n/a	30	577,022
15	60	86.07	39.84	7	14	Manual	n/a	n/a	22	381,673

Each system configuration was tested using simulation to determine if the desired throughput would be met. Although we have no way to simulate manual packing, the time study data should be sufficient for the manual system because of the method we used to determine the picking rate as discussed below.

In order to determine the picking and packing rates used in the manual system calculations, we had to decide which subsystem's rate, picking or packing, should be set first. By examining the efficiency curve in Figure 3.3, we see that picking and packing rates are dependent upon one another. Therefore, an equal batch size must be given to each subsystem in order to balance the workload within a wave. Because the picking rates are generally higher than manual packing rates, we determined these rates first.

Based on simulated picking times for different batch sizes, the largest batch that can be picked within the wave length was first determined. For example, consider a system with high picking rates and low packing rates, such as the system described in Trial 9 of Table 6.1. The recommended wave length for this set of parameters is 60 minutes. Using these input

parameters, the highest picking rate considered corresponds to a batch size of 210 orders. According to simulation data, this batch size can be completed in approximately 60 minutes. Batch sizes for each of the six combinations of picking and packing rates considered for a wave are set in much the same way. However, the time to pick all orders is divided by 6, 5, 4, 3, and 2 to determine the corresponding picking rate. Then, the picker is assigned 6, 5, 4, 3, 2, or 1 appropriately-sized batches depending upon the rate. The final batch size is chosen so that the total time to pick all the assigned batches is approximately equal to the wave length. For example, the first combination requires a batch size of 21 orders, and according to simulation data, this batch size can be completed on average in 9.99 minutes. Therefore, 6 batches of 21 orders should be able to be picked within a 60-minute wave. Similarly, the third combination requires a batch size of 36 orders, each being completed in 14.96 minutes. This means that 4 batches can be completed within 60 minutes. Six batches were considered in order to consider a wide range of picking and packing rates and numbers of employees. This method of batching orders determines the maximum batch size that a picker or packer can complete. The spreadsheet model then determines the best solution from this set of six combinations based on the total annual system cost.

In order to illustrate the excess throughput that can result from batching orders, we have calculated the required number of orders per picker and packer for each example trial, as well as the actual number of orders picked or packed as a result of order-batching. Table 6.4 presents this data for each trial, where the first fifteen trials are for systems with wave overlap, and the last fifteen are for systems without wave overlap.

The following example illustrates how setting either the picking or packing subsystem's batch size first affects the other subsystem. Consider the example summarized in Table 6.5. For Trial 2 with a system without overlapping waves, the best system cost occurs at a 100-minute wave, at the picking and packing rate combination which corresponds to a batch size of 26 orders. This batch size is taken from the efficiency curve and associated data developed from simulation experiments. Based on the picking time associated with this batch size, 17.06 minutes, the picker should be able to pick 5.86 batches within the allotted 100 minutes. However, we are not considering split batches, so the picker must be assigned an integer

Table 6.4: Effects of Order-Batching on Subsystem Throughput.

Trial No.	Orders Required per Picker	Batch Size per Picker	Batches per Picker	Total Orders per Picker	Orders Required per Packer	Batch Size per Packer	Batches per Packer	Total Orders Picked	Total Orders Packed	Orders Needed to Meet Demand
1	546	546	1	546	231	231	1	6006	6006	6000
2	63	63	1	63	32	32	1	2016	2016	2000
3	167	167	1	167	70	70	1	3006	3010	3000
4	112	112	1	112	77	77	1	2016	2002	2000
5	86	15	6	90	40	15	3	3150	3420	3000
6	294	294	1	294	62	62	1	1470	1488	1467
7	440	440	1	440	92	92	1	2200	2208	2200
8	98	17	6	102	64	17	4	1530	1564	1467
9	123	21	6	126	30	21	2	1134	1554	1100
10	138	138	1	138	46	46	1	1104	1104	1100
11	550	550	1	550	220	220	1	1100	1100	1100
12	79	15	6	90	40	15	3	630	630	550
13	184	184	1	184	110	110	1	552	550	550
14	105	22	5	110	62	22	3	770	792	733
15	79	15	6	90	40	15	3	630	630	550
1	112	112	1	112	56	59	1	2016	2124	2000
2	152	26	6	156	49	26	2	5148	5408	5000
3	86	15	6	90	40	15	3	3150	3420	3000
4	38	38	1	38	31	31	1	1026	1023	1000
5	86	15	6	90	40	15	3	3150	3420	3000
6	105	105	1	105	23	23	1	735	759	733
7	440	440	1	440	62	62	1	2200	2232	2200
8	98	17	6	102	64	17	4	1530	1564	1467
9	123	21	6	126	30	21	2	1134	1554	1100
10	142	26	6	156	49	26	2	2028	1976	1833
11	37	37	1	37	31	31	1	185	186	183
12	79	15	6	90	40	15	3	630	630	550
13	37	37	1	37	31	31	1	185	186	183
14	105	22	5	110	62	22	3	770	792	733
15	79	15	6	90	40	15	3	630	630	550

number of batches. Assigning the picker five batches result in 130 orders per picker, while six batches result in 156 orders. The demand level for this trial is 3,000 orders per hour, therefore in 100 minutes, 5,000 orders must be processed. The picking rate associated with an order batch size of 26 results in the need for 33 pickers, therefore each picker must be able to process 152 orders ($\lceil 5000/33 \rceil$).

Since 152 orders are needed to meet the required throughput, the picker is assigned six batches ($\lceil 152/26 \rceil$). The result of rounding the number of pickers and the number of batches assigned to each picker is an excess of 4 orders per picker and an expected throughput time equal to 102.4 minutes ($17.06*6$), which is also slightly over the wave length. The excess throughput over all pickers is then 132 orders when rounding is considered. That is, with 152 orders per picker and 33 pickers, the total throughput is 5,016 orders. However, the actual number of orders assigned to each picker, 156, results in a total throughput of 5,148 orders. The total excess throughput, without considering the effects of rounding the number of pickers required is 148 orders.

The packer is then assigned the same batch size of 26 orders, but since the packing rate is lower than the picking rate (time per batch equals 46.66 minutes with a low packing rate), the packer can only process 2 batches within the wave. Therefore, each packer is assigned

52 orders. The packing rate associated with a 26-order batch size results in the need for 104 packers. Again, this leads to a slightly higher throughput than the 49 orders required to meet demand ($\lceil 5000/104 \rceil$). The total throughput with this size batch is 5,408 orders, while the throughput required to meet demand is 5,096 (49×103). Notice that because of rounding this number is higher than the actual demand of 5,000 orders in the 100-minute wave. The excess when considering rounding is then 312 orders, while the total excess throughput is 408 orders.

Since the picking rates were set to be tighter, that is, to result in a total throughput closer to the actual throughput required, the packers pack much more than needed. This result is reassuring since we are not able to simulate manual packing. Therefore, even without simulation, we can confidently conclude that packers will meet demand.

We could reverse the order in which we set the rates, setting the packing rates first. Using the same input parameters, the spreadsheet model recommends a wave length for the manual system is 80 minutes. The demand level of 3,000 orders per hour requires that 4,000 orders be completed within the 80-minute wave. This system also requires 47 pickers and 89 packers. Since the packers are set first, their recommended rate corresponds to a batch size of 8 orders. This batch size requires each packer to process 6 batches, or 48 orders total within 80 minutes, since this picking and packing rate combination is the first of the six points on the efficiency curve that are considered. In order to meet demand, each packer must pack 45 orders ($\lceil 4000/89 \rceil$). The total throughput achieved by the packer is then 4,272 orders. The batch size of 8 orders assigned to each packer then results in an excess of 267 orders total when rounding is considered. Without considering the effects of rounding, the number of packers needed to meet demand results in an excess throughput of 272 orders more than the necessary 4,000 orders.

The pickers are assigned 11 batches of 8 orders (88 orders per picker), resulting in an excess of 2 orders per picker when considering the effects of rounding on the number of pickers needed ($\lceil 4000/47 \rceil$). The total excess with 47 pickers is 94 orders with rounding, and 136 orders without rounding the number of pickers needed. Again, this approach would virtually eliminate the need for picking simulations, since we are confident that throughput could be

Table 6.5: Example Effects of the Order of Setting Subsystem Rates for Example Trial 2.

Variable	Subsystem Set First	
	Picking	Packing
Wave Length (min)	100	80
Number of Pickers	33	47
Number of Packers	104	89
Batch Size (orders)	26	8
Batches per Picker	6	11
Batches per Packer	2	6
Total Picked (orders)	5148	4136
Total Packed (orders)	5408	4272
Required Picking Throughput (with rounding)	5016	4042
Required Packing Throughput (with rounding)	5096	4005
Required Throughput (orders)	5000	6000

met within the wave length, even though the entire assignment for that picker may not be feasible. Table 6.5 summarizes the results discussed above.

For the inductor simulation, our preliminary analysis indicated that throughput was not being met with the recommended system configuration. With experiments we were able to show that this was due to the fact that we ignored inductor blocking in our analysis. That is, if our system required 40 items per minute to be inducted and our inductors worked at a rate of 20 items per minute, our model would recommend two inductors. However, the model developed by Meller and Johnson [31] indicates that such a system could only achieve a throughput of 39.2 items per minute ($20 + 19.2$) due to the first inductor blocking the second inductor when the conveyor speed equals 100 trays per minute. We then decided to adjust our deterministic model to take inductor blocking into account. The adjusted model is presented in full in Appendix G and was used for all output data presented hereafter.

Finally, once the level of batching has been set appropriately, we are ready to simulate the system. The throughput simulation models provide the following output data, as shown in Tables 6.6 and 6.7. The output data for each replication is presented in Appendix F. Tables 6.8 and 6.9 provide information about the percentage of times that a subsystem completed the assigned work within the wave length allotted and within the wave length

plus 5 and 10 percent. In addition, the percentage of time spent idle is used to calculate worker utilization.

The inductors have unusually low utilizations in some cases due to the fact that the addition of one inductor adds a large amount of capacity since inductors work at such a high rate. For instance, one inductor may be capable of inducting 6000 items per hour, but might only be required to induct 2000 items in an hour based on demand. In Table 6.6, notice that Trials 6, 11, and 13 have extremely low induction times compared to the wave length. The reason for this is that only one inductor is assigned to the station, but the inductor can work at a rate that would provide much more throughput than actually needed. In fact, even with a higher coefficient of variation ($c.v. = 0.4$), the inductors meet demand in almost every case. Tables 6.10 and 6.11 compare the induction results previously shown with a low inductor coefficient of variation (0.2), to results with high inductor variation (0.4). Tables F.23 through F.24 present the breakdown of demand by inductor and induction station for both high and low coefficients of variation.

In each of the above fifteen examples, the recommended system configuration calls for only one induction station. In order to show that the induction model is appropriate for systems with more than one station, three examples were simulated with the results from the prescriptive model. These results are presented in Appendix G. Results shown here provide confidence that the induction model is accurate in predicting the number of inductors needed for sorters with higher capacity as well, since none of the total times to induct the required number of items exceeds the wave length.

Note that there are many cases in Tables 6.8 and 6.9 that appear to indicate the pickers or packers are not meeting throughput (since there is a high percentage of throughput times that exceed the wave length). However, by examining Table 6.4 we see that this throughput time is based on a number of orders much higher than the required throughput. These results constitute a worst-case scenario for the system. That observation leads us to also construct a best-case scenario as explained next.

Table 6.6: Output Data from Throughput Simulation Model (Overlapping Waves).

Trial No.	Wave Length (min)	Picking			Packing			Induction		
		Avg (min)	Min (min)	Max (min)	Avg (min)	Min (min)	Max (min)	Avg (min)	Min (min)	Max (min)
1	120	113.87	113.32	114.40	117.43	114.97	119.51	90.00	90.00	90.01
2	40	39.32	33.65	43.55	40.26	38.57	42.79	30.00	30.00	30.01
3	60	58.33	56.32	60.28	60.08	59.51	60.85	60.00	59.99	60.01
4	40	39.80	38.36	41.01	39.19	37.97	40.30	36.43	36.24	36.59
5	60	63.05	45.56	79.04	Manual	n/a	n/a	Manual	n/a	n/a
6	80	73.98	73.18	74.53	78.06	73.43	81.15	37.65	37.35	37.94
7	120	109.42	108.47	110.01	115.89	112.64	119.92	66.00	66.00	66.00
8	80	80.88	62.04	101.28	Manual	n/a	n/a	Manual	n/a	n/a
9	60	60.43	51.73	68.71	Manual	n/a	n/a	Manual	n/a	n/a
10	60	59.26	56.29	62.03	57.95	55.16	60.88	55.65	54.88	56.23
11	120	114.68	114.14	115.20	111.82	109.50	113.94	28.25	28.01	28.54
12	60	63.46	50.43	77.08	Manual	n/a	n/a	Manual	n/a	n/a
13	60	53.81	52.73	54.56	56.06	54.05	57.56	27.48	27.19	27.86
14	80	81.26	63.38	97.33	Manual	n/a	n/a	Manual	n/a	n/a
15	60	62.63	46.09	81.02	Manual	n/a	n/a	Manual	n/a	n/a

Table 6.7: Output Data from Throughput Simulation Model (Non-overlapping Waves).

Trial No.	Wave Length (min)	Picking			Packing			Induction		
		Avg (min)	Min (min)	Max (min)	Avg (min)	Min (min)	Max (min)	Avg (min)	Min (min)	Max (min)
1	40	39.66	38.45	40.81	40.88	38.10	43.70	30.00	30.00	30.01
2	100	102.55	75.10	121.92	Manual	n/a	n/a	Manual	n/a	n/a
3	60	63.37	49.37	76.44	Manual	n/a	n/a	Manual	n/a	n/a
4	20	19.89	16.82	21.65	20.66	18.54	22.48	18.23	18.09	18.39
5	60	63.37	47.12	80.23	Manual	n/a	n/a	Manual	n/a	n/a
6	40	37.71	36.29	39.24	40.86	35.46	45.16	18.80	18.52	19.13
7	120	109.42	108.47	110.01	120.64	109.78	127.49	66.00	66.00	66.00
8	80	79.40	54.63	96.46	Manual	n/a	n/a	Manual	n/a	n/a
9	60	59.40	50.41	70.55	Manual	n/a	n/a	Manual	n/a	n/a
10	100	103.25	62.26	120.64	Manual	n/a	n/a	Manual	n/a	n/a
11	20	19.53	17.29	22.20	20.85	18.80	23.46	4.70	4.55	4.80
12	60	62.35	48.06	79.60	Manual	n/a	n/a	Manual	n/a	n/a
13	20	19.58	17.88	22.04	20.76	18.03	22.81	9.16	8.95	9.35
14	80	80.40	62.49	94.39	Manual	n/a	n/a	Manual	n/a	n/a
15	60	61.93	47.31	84.98	Manual	n/a	n/a	Manual	n/a	n/a

Table 6.8: Results from Throughput Simulation Model (Overlapping Waves).

Trial No.	Picking				Packing				Induction			
	Util.	% Buffer			Util.	% Buffer			Util.	% Buffer		
		None	5	10		None	5	10		None	5	10
1	0.9489	0	0	0	0.9786	0	0	0	0.7500	0	0	0
2	0.9830	42	11	0	1.0066	56	2	0	0.7500	0	0	0
3	0.9721	1	0	0	1.0014	63	0	0	0.9999	4	0	0
4	0.9950	37	0	0	0.9799	3	0	0	0.9108	0	0	0
5	1.0508	69	53	36	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a
6	0.9248	0	0	0	0.9758	6	0	0	0.4706	0	0	0
7	0.9118	0	0	0	0.9657	0	0	0	0.5500	0	0	0
8	1.0110	55	34	21	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a
9	1.0071	55	23	4	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a
10	0.9876	27	0	0	0.9659	1	0	0	0.9276	0	0	0
11	0.9557	0	0	0	0.9318	0	0	0	0.2354	0	0	0
12	1.0577	69	57	36	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a
13	0.8968	0	0	0	0.9343	0	0	0	0.4580	0	0	0
14	1.0158	53	41	28	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a
15	1.0438	59	45	32	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a

Table 6.9: Results from Throughput Simulation Model (Non-overlapping Waves).

Trial No.	Picking				Packing				Induction			
	Util.	% Buffer			Util.	% Buffer			Util.	% Buffer		
		None	5	10		None	5	10		None	5	10
1	0.9915	0	0	0	0.9970	87	11	0	0.7500	0	0	0
2	1.0255	55	40	23	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a
3	1.0562	62	49	33	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a
4	0.9947	9	9	0	0.9837	92	29	2	0.9114	0	0	0
5	1.0561	63	51	37	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a
6	0.9427	0	0	0	0.9965	70	25	5	0.4700	0	0	0
7	0.9118	0	0	0	0.9970	70	2	0	0.5500	0	0	0
8	0.9925	48	29	18	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a
9	0.9900	29	18	6	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a
10	1.0325	61	41	25	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a
11	0.9763	4	4	1	0.9927	81	36	15	0.2348	0	0	0
12	1.0391	54	42	30	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a
13	0.9790	9	9	1	0.9884	81	41	7	0.4579	0	0	0
14	1.0050	51	32	15	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a
15	1.0322	54	43	25	Manual	n/a	n/a	n/a	Manual	n/a	n/a	n/a

Table 6.12: Output Data — Best Case Scenario (Overlapping Waves).

Trial No.	Wave Length (min)	Picking				Packing			
		Ratio	Avg (min)	Min (min)	Max (min)	Ratio	Avg (min)	Min (min)	Max (min)
1	20	0.9990	113.76	113.21	114.28	0.9990	117.32	114.86	119.39
2	40	0.9921	39.01	33.38	43.21	0.9921	39.94	38.27	42.45
3	60	0.9980	58.21	56.20	60.16	0.9967	59.88	59.31	60.65
4	40	0.9921	39.48	38.05	40.69	0.9990	39.16	37.93	40.26
5	60	0.9524	60.05	43.39	75.27	Manual	Manual	Manual	Manual
6	80	0.9977	73.82	73.02	74.36	0.9857	76.95	72.38	79.99
7	120	1.0000	109.42	108.47	110.01	0.9964	115.47	112.23	119.49
8	80	0.9586	77.53	59.47	97.09	Manual	Manual	Manual	Manual
9	60	0.9700	58.62	50.18	66.65	Manual	Manual	Manual	Manual
10	60	0.9964	59.04	56.08	61.81	0.9964	57.74	54.96	60.66
11	120	1.0000	114.68	114.14	115.20	1.0000	111.82	109.50	113.94
12	60	0.8730	55.40	44.03	67.29	Manual	Manual	Manual	Manual
13	60	0.9964	53.61	52.54	54.36	1.0000	56.06	54.05	57.56
14	80	0.9524	77.39	60.36	92.69	Manual	Manual	Manual	Manual
15	60	0.8730	54.67	40.24	70.74	Manual	Manual	Manual	Manual

In order to show the effects of order-batching on the system throughput, we have developed similar results with a best-case scenario. That is, we have multiplied each picking and packing time by a ratio of the number of orders required to meet demand to the number of orders actually picked. For instance, Trial 5 in Table 6.6 requires a 60-minute wave. The total pick time for 90 orders is 63.05 minutes, but only 86 orders were actually required. Therefore, we multiply 63.05 by $(86/90)$, or 0.9524, in order to obtain the best-case picking time of 60.05 minutes. Tables 6.12 and 6.13 present the output data based on this method, with the ratio used to determine the best-case time presented for each subsystem. Tables 6.14 and 6.15 present the results for this system in terms of the percentage of waves where the picking time exceeds the wave length. The induction data is not presented for the best-case scenario. Since inductors work in terms of items instead of orders, batching does not affect their throughput capabilities.

The simulations performed verified that the descriptive spreadsheet model is a good approximation in terms of the numbers of pickers and packers required to meet demand, as well

Table 6.13: Output Data — Best Case Scenario (Non-overlapping Waves).

Trial No.	Wave Length (min)	Picking				Packing			
		Ratio	Avg (min)	Min (min)	Max (min)	Ratio	Avg (min)	Min (min)	Max (min)
1	40	0.9921	39.35	38.15	40.49	0.9416	38.49	35.87	41.15
2	100	0.9713	99.60	72.94	118.41	Manual	Manual	Manual	Manual
3	60	0.9524	60.35	47.02	72.80	Manual	Manual	Manual	Manual
4	20	0.9747	19.39	16.39	21.10	0.9775	20.19	18.12	21.97
5	60	0.9524	60.35	44.88	76.41	Manual	Manual	Manual	Manual
6	40	0.9977	37.62	36.20	39.15	0.9662	39.48	34.26	43.63
7	120	1.0000	109.42	108.47	110.01	0.9857	118.91	108.21	125.66
8	80	0.9586	76.12	52.37	92.47	Manual	Manual	Manual	Manual
9	60	0.9700	57.62	48.90	68.44	Manual	Manual	Manual	Manual
10	100	0.9040	93.34	56.29	109.06	Manual	Manual	Manual	Manual
11	20	0.9910	19.35	17.13	22.00	0.9857	20.55	18.53	23.12
12	60	0.8730	54.43	41.96	69.49	Manual	Manual	Manual	Manual
13	20	0.9910	19.40	17.72	21.85	0.9857	20.46	17.78	22.48
14	80	0.9524	76.57	59.51	89.89	Manual	Manual	Manual	Manual
15	60	0.8730	54.07	41.31	74.19	Manual	Manual	Manual	Manual

Table 6.14: Results — Best Case Scenario (Overlapping Waves).

Trial No.	Picking				Packing			
	Util.	% Buffer			Util.	% Buffer		
		None	5	10		None	5	10
1	0.9480	0	0	0	0.9776	0	0	0
2	0.9752	33	6	0	0.9986	42	1	0
3	0.9702	1	0	0	0.9981	29	0	0
4	0.9871	22	0	0	0.9789	2	0	0
5	1.0008	53	35	16	Manual	n/a	n/a	n/a
6	0.9227	0	0	0	0.9618	0	0	0
7	0.9118	0	0	0	0.9622	0	0	0
8	0.9691	36	23	12	Manual	n/a	n/a	n/a
9	0.9769	36	9	1	Manual	n/a	n/a	n/a
10	0.9841	27	0	0	0.9624	1	0	0
11	0.9557	0	0	0	0.9318	0	0	0
12	0.9234	24	7	1	Manual	n/a	n/a	n/a
13	0.8936	0	0	0	0.9343	0	0	0
14	0.9674	41	27	5	Manual	n/a	n/a	n/a
15	0.9112	17	8	4	Manual	n/a	n/a	n/a

Table 6.15: Results — Best Case Scenario (Non-overlapping Waves).

Trial No.	Picking				Packing			
	Util.	% Buffer			Util.	% Buffer		
		None	5	10		None	5	10
1	0.9836	0	0	0	0.9388	4	0	0
2	0.9960	47	26	12	Manual	n/a	n/a	n/a
3	1.0059	43	33	19	Manual	n/a	n/a	n/a
4	0.9695	2	2	0	0.9615	63	9	0
5	1.0058	46	36	18	Manual	n/a	n/a	n/a
6	0.9406	0	0	0	0.9628	34	8	0
7	0.9118	0	0	0	0.9827	29	0	0
8	0.9515	28	18	5	Manual	n/a	n/a	n/a
9	0.9603	19	7	3	Manual	n/a	n/a	n/a
10	0.9334	16	8	0	Manual	n/a	n/a	n/a
11	0.9675	4	4	1	0.9785	70	26	7
12	0.9072	14	7	3	Manual	n/a	n/a	n/a
13	0.9702	3	3	0	0.9742	68	25	5
14	0.9571	31	13	5	Manual	n/a	n/a	n/a
15	0.9011	12	9	5	Manual	n/a	n/a	n/a

as their level of batching and corresponding picking and packing rates. Although the excess throughput resulting from batching causes some processing times to exceed the wave length, the order in which we set the picking and packing rates can reduce this to a minimum for one system. The method used here, setting the picking rates first, was useful since our packing times are estimated from time study data. The excess throughput in the packing system provides us with a buffer that increases the likelihood of meeting demand within the wave.

From the results shown in this chapter, we can see that rounding the number of pickers, packers, and orders in a batch has a significant effect on the system. Therefore, when performing this type of analysis for an actual company, the amount of rounding can be taken into consideration, and the company can decide if batch sizes are constant over the wave or whether they would be varied to meet throughput. This would not only allow matching the number of orders picked or packed to match the required throughput, but would provide the workers with a reasonable buffer within the implemented wave length.

In addition, we notice that pickers and packers working in shorter waves requiring smaller batches are susceptible to exceeding the wave length when picking or packing their assigned

batches. This is due to larger variance associated with a small batch. For instance, a picker with a batch size of 8 orders may have to travel into aisles spread throughout the picking area or may only have to travel through a few aisles relatively close together. This could be the difference between up to 24 aisles, or as few as one aisle. With a large batch size, however, the variance becomes much smaller since it is very likely the picker will visit a large number of aisles. This is true for both manual and automated systems, and, in general, does not make one system more attractive than the other. In such a case the batch size might have to be increased in order to lower the variance, which would increase the number of packers in a manual system. Another solution would be to assign more workers or provide a buffer within the wave length. Of course, since a manual system typically utilizes more pickers, the potential increase in pickers required for a manual system could be higher than for an automated system. Therefore, the simulation results suggest that the deterministic model appears to be conservative with respect to the benefits it calculates for automated systems in comparison with manual systems.

Finally, the simulation results verified that the adjusted model is very accurate in determining how many inductors are needed to meet throughput. This is true for both high and low coefficients of variation on the induction times.

Chapter 7

Conclusions and Future Research

7.1 Conclusions

Changes in the way companies do business have led to a need for more efficient order fulfillment systems. Again, automated sortation is one way to improve the efficiency of a distribution center, if designed correctly. Tradeoffs between picking and packing efficiencies must be clearly understood. In addition, the larger tradeoff between the capital costs involved with implementing an automated sorter and the labor savings it will reap must be carefully weighed. Other system parameters such as the wave length, size of the system (in terms of packing and induction stations), and design of the sorter itself (speed of the conveyor, capacity of each pack station, etc.) must be factored into the decision to implement a sorter as well.

The complexity of the relationships and combinations of parameters leads to the need of a guide to help a company determine if this investment is wise. Our research is an attempt to provide such a guide. Although some relationships are simplified, the prescriptive model developed provides cost estimates over a wide variety of parameters. This model provides the company with many feasible combinations, with the recommended system design being the one with the lowest total annual cost. However, the company can see how changing the wave length or picking and packing rates will effect the cost of the system. In addition, the

model illustrates the differences between manual and automated systems. For example, a manager could look at each combination of parameters' total annual cost for both manual and automated systems and determine very quickly if an automated system should be considered at all if every manual combination provides a much lower annual cost than the automated system.

Sensitivity analyses determined the effects of changing each parameter separately as well as in combination with one another. These analyses also provide insights into situations where one system would never be considered over another. For example, a system with very low demand would not implement an automated system design in most cases. We have also provided an analytical model to determine the optimal picking and packing rates for a manual system given a set of lower and upper bounds for each.

The relationships in the spreadsheet model were verified using simulation and time study data. This provides us with confidence that our model is accurate enough to make the decision as to whether manual or automated sortation should be used as well as an appropriate initial system design. However, systems with high variance may require adjustments to the output from the model.

Although we believe our model represents the most critical tradeoffs in the design of order fulfillment centers, we acknowledge the need for future research and discuss possible alternatives in the next section.

7.2 Future Research

Our model determines the best system configuration given a set of parameters. These parameters are all cost or throughput related. However, we should also consider parameters or constraints concerning the physical size of the sortation system. Most companies have a limited amount of square footage in which to put a sorter, so this constraint can be very important. For other companies, size is not an issue. This constraint should be taken into consideration when designing the sortation system. Some sorters have two levels, which

might add to the sorter cost, but keep the sorter within the space restrictions. Also, the cost of the floor space square footage used by the sorter should be taken into account in the objective function.

Another issue not addressed by our model is demand fluctuations. This tends to be a seasonal problem for most companies, such as clothing and catalog sales. For instance, if a new clothing catalog comes out, there might be a peak in demand for a few weeks. Another good example is the Christmas season. We have considered a system designed for peak demand, but there are also many lulls in most businesses. Therefore, the decision must be made as to whether to design for peak or average demand. A tradeoff can be made between the lost efficiency during the lulls with a sorter designed for peak demand and the overutilization of the sorter during peak demands for a smaller sorter design. However, some sort of compromise in the system design may be warranted for a system with only a few peaks and many lulls. For example, a company could design for the average or typical demand levels, and then hire temporary workers, set up additional manual packing stations, and possibly increase the sorter speed or utilize additional induction stations during the peak times.

Another possible alternative that we observed in industry is pre-sorting the items for packing stations in an automated system. Without pre-sorting, the maximum throughput in a two-induction station system is 1.33 times the speed of the sorting conveyor. In general, without pre-sorting, as shown previously in (4.1), the maximum throughput in a system with r_s induction stations is $(\frac{2r_s}{r_s+1})s$, where s is equal to the speed of the conveyor [31]. To increase throughput, pre-sorting is performed so that the items that belong in the bins before the next induction station are inducted at that station (to free all trays before the next induction station), allowing the system to achieve twice as much throughput in a two-induction station system, three times as much throughput in a three-station system, etc. However, the throughput increase achieved with pre-sorting must be balanced with its negative impact on picking since the possible picking batch combinations are reduced with pre-sorting.

Another limitation of our model is the method we used for order-batching in the manual system. We assigned each worker an equal-size batch, therefore sometimes exceeding the re-

quired demand level. This results in pickers and packers who cannot complete their assigned orders within the allotted wave length. However, we should consider alternative methods of batching. For instance, each picker could be assigned full batches until the last batch, when the batch size could be the remainder of the orders needed to meet demand divided by the number of pickers. Another solution would be to assign faster pickers more work in order to make the batches adequately sized for each worker.

Another limitation in our model is the estimation of the picking efficiency increase between wave lengths. This estimation was made based on our time study data. The picking simulation model should be modified to include intelligent order-batching methods such as those described in Section 2.3.5. This would more accurately reflect the benefits of increasing the wave length on picking efficiencies.

As one can see, there are many possible alternatives for future research on this topic. Addressing such research issues would likely result in a model that is more widely applicable and of more value to engineers in industry designing order fulfillment centers.

Bibliography

- [1] “Cleco Systems: Sortation: Tomorrow’s Technology Today!,” <http://www.cleco.nl/objects/images/sortation.jpg> (2000).
- [2] “Hanover Direct,” (2000).
- [3] “Rapistan Systems: Sortation Systems,” <http://www.rapistan.com/marketing/products/sorters/> (2000).
- [4] “Gross & Associates Rules of Thumb for Warehousing & Distribution Equipment Costs,” (2001), 7th Edition.
- [5] Anonymous, “Throughput Soars with Sorter,” *Modern Materials Handling*, pp. 69–70 (October 1999).
- [6] Bozer, Y. A., and White, J. A., “A Generalized Design and Performance Analysis Model for End-of-Aisle Order-Picking Systems,” *IIE Transactions*, 28, 4, 271–280 (1996).
- [7] Bozer, Y. A., Quiroz, M. A., and Sharp, G. P., “An Evaluation of Alternative Control Strategies and Design Issues for Automated Order Accumulation and Sortation Systems,” *Material Flow*, 4, 265–282 (1988).
- [8] Bozer, Y. A., and Sharp, G. P., “An Empirical Evaluation of a General Purpose Automated Order Accumulation and Sortation System used in Batch Picking,” *Material Flow*, 2, 111–131 (1985).
- [9] Caron, F., Marchet, G., and Perego, A., “Routing Policies and COI-Based Storage Policies in Picker-to-Part Systems,” *International Journal of Production Research*, 36, 3, 713–732 (1998).
- [10] Cormier, G., and Gunn, E., “Simple Models and Insights for Warehouse Sizing,” *Journal of the Operational Research Society*, 47, 5, 690–696 (1996).
- [11] Cormier, G., and Gunn, E. A., “A Review of Warehouse Models,” *European Journal of Operational Research*, 58, 3–13 (1992).
- [12] Coyle, J., Bardi, E., and Langley, C., *The Management of Business Logistics*, West, St. Paul, MN (1996).

- [13] Daniels, R. L., Rummel, J. L., and Schantz, R., "A Model for Warehouse Order Picking," *European Journal of Operational Research*, 105, 1, 1–17 (1998).
- [14] de Koster, R., and van der Poort, E., "Routing Orderpickers in a Warehouse: A Comparison Between Optimal and Heuristic Solutions," *IIE Transactions*, 30, 5, 469–480 (1998).
- [15] de Koster, R., van der Poort, E., and Wolters, M., "Efficient Orderbatching Methods in Warehouses," *International Journal of Production Research*, 37, 7, 1479–1504 (1999).
- [16] Drury, J., "Towards More Efficient Orderpicking," In *IMM Monographs 1*, Cranfield, UK (1988). Institute of Materials Management.
- [17] El Sayed, E. A., "Algorithms for Optimal Material Handling in Automatic Warehousing Systems," *International Journal of Production Research*, 19, 525–535 (1981).
- [18] El Sayed, E. S., Proctor, C. L., and Elayat, H. A., "Analysis of Closed-Loop Conveyor Systems with Mutiple Poisson Inputs and Outputs," *International Journal of Production Research*, 14, 1, 99–109 (1976).
- [19] Erlebacher, S., and Meller, R., "The Interaction of Location and Inventory in Designing Distribution Systems," *IIE Transactions*, 32, 2, 155–166 (2000).
- [20] Forger, G., "How Fingerhut Plans to Ride the Growth Curve," *Modern Materials Handling*, pp. 48–51 (June 1993).
- [21] Gibson, D. R., and Sharp, G. P., "Order Batching Procedures," *European Journal of Operational Research*, 58, 57–67 (1992).
- [22] Goetschalckx, M., and Ratliff, H., "Order Picking in an Aisle," *IIE Transactions*, 20, 1, 53–62 (1988).
- [23] Gould, L., "Increase Productivity by Choosing the Right Sortation Conveyor," *Modern Materials Handling*, pp. 54–56 (June 1991).
- [24] Gray, A. E., Karmarkar, U. S., and Seidmann, A., "Design and Operation of an Order-Consolidation Warehouse: Models and Application," *European Journal of Operational Research*, 58, 14–34 (1992).
- [25] Hausman, W. H., Schwarz, L. B., and Graves, S. C., "Optimal Storage Assignment in Automated Warehousing Systems," *Management Science*, 22, 6, 625–638 (1976).
- [26] Jarvis, J. M., and McDowell, E. D., "Optimal Product Layout in an Order Picking Warehouse," *IIE Transactions*, 23, 1, 93–102 (1991).
- [27] Johnson, M. E., "The Impact of Sorting Strategies on Automated Sortation System Performance," *IIE Transactions*, 30, 1, 67–77 (1998).
- [28] Larson, T., March, H., and Kusiak, A., "A Heuristic Approach to Warehouse Layout with Class-Based Storage," *IIE Transactions*, 29, 4, 337–348 (1997).

- [29] Malmberg, C. J., “Storage Assignment Policy Tradeoffs,” *International Journal of Production Research*, 34, 2, 363–378 (1996).
- [30] Meller, R. D., “Optimal Order-to-Lane Assignments in an Order Accumulation/Sortation System,” *IIE Transactions*, 29, 4, 293–301 (1997).
- [31] Meller, R. D., and Johnson, E. M., “Sortation Results for Split-Case Batch-Picking Systems,” Technical report, Department of Industrial Engineering, Auburn University (1999).
- [32] Meller, R. D., and Johnson, M. E., “Design of Split-Case Sortation Systems,” In *6th International Colloquium on Material Handling Research Proceedings*, York, Pennsylvania (2000).
- [33] Meller, R. D., and Mungwattana, A., “Multi-Shuttle Automated Storage/Retrieval Systems,” *IIE Transactions*, 29, 925–938 (1997).
- [34] Muth, E. J., “Analysis of Closed-Loop Conveyor Systems,” *AIIE Transactions*, 4, 2, 134–143 (1972).
- [35] Muth, E. J., “Analysis of Closed-Loop Conveyor Systems, the Discrete Flow Case,” *AIIE Transactions*, 6, 1, 73–83 (1974).
- [36] Muth, E. J., “A Model of a Closed-Loop Conveyor System with Random Material Flow,” *AIIE Transactions*, 9, 4, 345–351 (1977).
- [37] Proctor, C. L., El Sayed, E. S., and Elayat, H. A., “A Conveyor System with Homogeneous and Heterogeneous Servers with Dual Input,” *International Journal of Production Research*, 15, 1, 73–85 (1977).
- [38] Quick, R., “The Lessons Learned: The Rush to the Web Last Holiday Season Left Many Shoppers Fuming – And Many Web Sites Scrambling to Come Up With a Better Plan,” *The Asian Wall Street Journal*, pg. T9 (April 24 2000).
- [39] Ratliff, H. D., and Rosenthal, A. S., “Order-Picking in a Rectangular Warehouse: A Solvable Case of the Traveling Salesman Problem,” *Operations Research*, 31, 3, 507–521 (1983).
- [40] Tompkins, J. A., and White, J. A., *Facilities Planning*, John Wiley & Sons, New York, New York (1984).
- [41] van den Berg, J. P., “A Literature Survey on Planning and Control of Warehousing Systems,” *IIE Transactions on Scheduling & Logistics*, 31, 8, 751–762 (1999).

Appendix A

Time Study Data and Results

All time study data collected for picking and packing rates are presented in this appendix. Tables A.1 through A.4 present data for the zone picking time study. Each table represents a different level of order-batching. Table A.5 summarizes the results from this time study. In each table, SKU stands for stock-keeping unit. The letters A, B, C, and D represent different zones within the picking area. For each level of batching, the batches were separated into zones and the time to pick all items within that zone was recorded. The average time to pick each batch size was then determined and used to estimate the effects of batching from one wave length to the next (see Table 3.2).

Packing time study results are also presented in this appendix. In Tables A.6 through A.10, times are presented for several batch sizes. A set of orders comprising a batch were sorted and packed. This was completed 10 times per batch size, and the average time to pack each batch size was determined. Table A.11 presents the summarized data for this time study, including packing times, sorting times, and packing rates for each level of order-batching tested.

Table A.1: Zone Picking Time Study Data (Batch Size = 20).

Batch Size (no. orders)	Zone	Time (minutes)	Number of SKUs
20	A	9.43	82
20	B	6.34	26
20	C	12.72	113
20	D	9.86	79
20	Total	38.35	300

Table A.2: Zone Picking Time Study Data (Batch Size = 10).

Batch Size (no. orders)	Zone	Time (minutes)	Number of SKUs
1-10	A	6.98	46
1-10	B	3.15	11
1-10	C	8.62	65
1-10	D	7.96	50
1-10	Total	26.71	172
11-20	A	5.38	40
11-20	B	4.35	19
11-20	C	10.21	75
11-20	D	8.17	48
11-20	Total	28.11	182
10 orders	Average	27.41	
	Total	54.82	354

Table A.3: Zone Picking Time Study Data (Batch Size = 5).

Batch Size (no. orders)	Zone	Time (minutes)	Number of SKUs
1-5	A	6.19	38
1-5	B	2.50	11
1-5	C	5.35	31
1-5	D	4.89	31
1-5	Total	18.93	111
6-10	A	3.57	10
6-10	B	0.33	2
6-10	C	4.79	40
6-10	D	5.85	35
6-10	Total	14.54	87
11-15	A	3.22	18
11-15	B	2.15	11
11-15	C	7.43	41
11-15	D	3.53	21
11-15	Total	16.33	91
16-20	A	3.51	24
16-20	B	2.99	10
16-20	C	6.27	43
16-20	D	4.78	27
16-20	Total	17.55	104
5 orders	Average	16.84	
	Total	67.35	393

Table A.4: Zone Picking Time Study Data (Batch Size = 1).

Batch Size (no. orders)	Zone	Time (minutes)	Number of SKUs
1	All	8.50	49
2	All	4.09	41
3	All	2.61	26
4	All	2.73	6
5	All	3.60	11
6	All	4.52	21
7	All	5.75	13
8	All	4.01	36
9	All	4.67	20
10	All	3.97	11
11	All	9.04	19
12	All	6.65	14
13	All	5.47	16
14	All	4.29	18
15	All	5.68	24
16	All	3.30	14
17	All	5.19	28
18	All	4.82	18
19	All	6.09	30
20	All	4.46	22
Total		99.44	437

Table A.5: Picking Time Study Summary.

Zone A		
Batch Size	Time (min)	Total (min)
20	9.43	9.43
10	6.18	12.36
5	4.12	16.49
Zone B		
Batch Size	Time (min)	Total (min)
20	6.34	6.34
10	3.75	7.50
5	1.99	7.97
Zone C		
Batch Size	Time (min)	Total (min)
20	12.72	12.72
10	9.42	18.83
5	5.96	23.84
Zone D		
Batch Size	Time (min)	Total (min)
20	9.86	9.86
10	8.07	16.13
5	4.76	19.05

Table A.6: Packing Time Study Data (Batch Size = 20 Orders).

Batch Size	Orders Packed	No. Items	Sort Time	ST/Order
20	ALL	61	18:41.56	
20	ALL	61	16:35.37	
20	ALL	61	12:28.78	
	Average	61	15:55.24	00:47.76

Table A.7: Packing Time Study Data (Batch Size = 10 Orders).

Batch Size	Orders Packed	No. Items	Sort Time	ST/Order
10	11 through 20	29	06:51.72	
10	1 through 10	32	06:10.93	
10	odds	27	05:48.62	
10	evens	30	05:46.94	
10	1,20,2,19,3,18,4,17,5,16	28	05:08.97	
10	6,15,7,14,8,13,9,12,10,11	33	06:20.90	
10	1,3,4,7,18,19,10,12,9,13	25	03:50.57	
10	2,5,16,17,20,11,8,6,15,14	36	07:11.09	
10	1 through 10	29	03:51.13	
10	11 through 20	32	04:31.41	
	Average	30.1	05:33.23	00:33.32

Table A.8: Packing Time Study Data (Batch Size = 5 Orders).

Batch Size	Orders Packed	No. Items	Sort Time	ST/Order
5	1,2,3,4,5	14	02:13.25	
5	6,7,8,9,10	18	04:04.44	
5	1 through 5	14	02:46.44	
5	5 through 9	18	03:39.41	
5	6 through 10	18	03:46.38	
5	11 through 15	15	01:59.56	
5	16 through 20	14	01:32.32	
5	2,4,6,8,10	17	03:04.00	
5	12,14,16,18,20	13	01:57.72	
5	15 through 19	13	01:26.58	
	Average	15.4	02:39.01	00:31.80

Table A.9: Packing Time Study Data (Batch Size = 4 Orders).

Batch Size	Orders Packed	No. Items	Sort Time	ST/Order
4	1 through 4	12	02:10.13	
4	11 through 14	12	01:23.18	
4	16 through 19	10	01:06.41	
4	2,6,10,14	13	01:59.97	
4	8,12,16,20	13	01:44.13	
4	5,7,9,11	13	01:56.47	
4	13,15,17,19	11	01:29.21	
4	17,3,19,4	11	01:30.07	
4	8,2,12,16	12	01:30.81	
4	3,9,14,20	15	01:49.94	
4	18,6,13,9	16	02:21.10	
	Average	12.5	01:43.77	00:25.94

Table A.10: Packing Time Study Data (Batch Size = 2 Orders).

Batch Size	Orders Packed	No. Items	Sort Time	ST/Order
2	1,3	7	00:45.32	
2	5,7	4	00:23.71	
2	9,11	9	00:50.03	
2	13,15	7	00:39.34	
2	17,19	4	00:26.22	
2	2,4	5	00:32.72	
2	6,8	10	01:34.12	
2	10,12	3	00:18.78	
2	14,16	6	00:34.75	
2	18,20	6	00:24.57	
Average		6.1	00:38.96	00:19.48

Table A.11: Packing Time Study Summary.

Sort Time per Order	Number of Boxes	Total Sort Time (min)	Sort Time (min)	Total Pack Time (min)	Pack Time per Order	Hour per Order	Packing Rate (o/h)	Picking Rate (o/h)
00:47.76	20	15:55.24	15.92	32.59	1.63	0.0272	36.82	146.28
00:33.32	10	05:33.23	5.55	13.89	1.39	0.0231	43.21	120.08
00:31.80	5	02:39.01	2.65	6.82	1.36	0.0227	44.01	101.49
00:25.94	4	01:43.77	1.73	5.06	1.27	0.0211	47.40	93.63
00:19.48	2	00:38.96	0.65	2.32	1.16	0.0193	51.81	76.13

Appendix B

Verification Simulation Results

Simulation data for picking and packing simulations are presented in this appendix. These simulations served to verify the relationships between order-batching and picking and packing times.

Picking simulations were completed for batch sizes ranging from one order to 750 orders. 100 replications were run for each batch size and wave length. The tables in this appendix represent the resulting average time to complete each batch size, and the corresponding picking rate in orders per hour. This was completed for high, medium, and low picking rates. In the model, this was represented as the time it takes to travel down an aisle. For the high level, 0.25 minutes was used for this time. The medium and low levels were 0.50 and 0.75 minutes, respectively. The picking area consisted of 50 aisles with 40 locations in each aisle, or 2000 total locations.

Packing simulation results are also presented in this appendix. The packing simulations were completed for the automated system only, but systems with wave overlap and no wave overlap were examined. Again, high, medium, and low levels of packing rates were considered. These values were represented as uniform distributions with the following upper and lower bounds in minutes per order: (0.4, 0.6) for high rates, (0.8, 0.9) for medium rates, and (1.0, 1.5) for low rates. The corresponding packing rates are (100, 150), (66.7, 75), and (40,60) orders per hour, respectively.

Manual packing results are also presented in this appendix. Table B.7 presents order-batching estimates based on extrapolated data from time studies presented in Tables A.6 through A.11. Although this table does not present simulation data, this data is used in the development of the efficiency curves in Appendix F.

Again, 100 replications were run, and a batch size and wave length were provided as input data. The resulting time to pack all orders assigned to a packer was recorded for both overlapping and non-overlapping waves.

Using the data collected in the simulation runs, the actual efficiency curves were developed for the following combinations of picking and packing rates: high picking and low packing, low picking and high packing, low levels of both, medium levels of both, and high levels of both. The resulting efficiency curves are used in the spreadsheet models which are presented in Appendix F.

Table B.1: Simulation Data for Picking Times (Medium Rate).

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
1	1.74	1.50	1.35	1.25	1.17	1.11	34.47	40.10	44.33	47.93	51.14	54.10
2	2.97	2.55	2.31	2.13	2.00	1.89	40.47	47.08	52.05	56.26	60.03	63.51
3	4.23	3.64	3.29	3.05	2.85	2.70	42.51	49.45	54.67	59.10	63.06	66.72
4	4.98	4.28	3.87	3.58	3.36	3.17	48.20	56.07	61.99	67.01	71.51	75.65
5	6.02	5.18	4.68	4.33	4.06	3.84	49.80	57.93	64.05	69.24	73.88	78.16
6	7.01	6.03	5.45	5.04	4.73	4.47	51.34	59.72	66.02	71.37	76.15	80.57
7	7.53	6.47	5.86	5.42	5.08	4.80	55.77	64.88	71.73	77.54	82.74	87.53
8	8.35	7.18	6.49	6.01	5.63	5.32	57.47	66.85	73.91	79.89	85.25	90.19
9	9.44	8.12	7.34	6.79	6.37	6.02	57.17	66.51	73.53	79.49	84.82	89.73
10	10.07	8.65	7.83	7.24	6.79	6.41	59.60	69.33	76.65	82.85	88.41	93.53
11	10.81	9.29	8.41	7.78	7.29	6.89	61.05	71.02	78.52	84.88	90.56	95.81
12	11.80	10.14	9.18	8.49	7.95	7.52	61.01	70.98	78.47	84.83	90.51	95.76
13	12.08	10.39	9.39	8.69	8.14	7.70	64.56	75.10	83.03	89.75	95.77	101.32
14	12.79	10.99	9.94	9.20	8.62	8.15	65.69	76.42	84.49	91.33	97.45	103.10
15	13.45	11.56	10.46	9.67	9.07	8.57	66.92	77.85	86.07	93.04	99.28	105.03
16	14.37	12.35	11.17	10.33	9.68	9.15	66.82	77.73	85.94	92.90	99.13	104.88
17	14.85	12.77	11.55	10.68	10.01	9.46	68.67	79.88	88.32	95.47	101.87	107.77
18	15.54	13.36	12.08	11.17	10.47	9.90	69.51	80.87	89.40	96.65	103.12	109.10
19	16.18	13.91	12.58	11.64	10.91	10.31	70.44	81.95	90.60	97.94	104.50	110.56
20	16.69	14.35	12.98	12.01	11.25	10.64	71.88	83.62	92.45	99.94	106.64	112.81
21	17.45	15.00	13.57	12.55	11.76	11.12	72.20	83.99	92.86	100.38	107.11	113.32
22	17.82	15.32	13.85	12.82	12.01	11.35	74.09	86.19	95.29	103.00	109.91	116.28

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
23	18.38	15.80	14.29	13.22	12.39	11.71	75.07	87.33	96.55	104.37	111.36	117.82
24	19.03	16.36	14.80	13.69	12.83	12.13	75.66	88.02	97.31	105.19	112.25	118.75
25	19.62	16.86	15.25	14.11	13.22	12.50	76.47	88.95	98.35	106.31	113.44	120.01
26	19.94	17.14	15.50	14.34	13.44	12.71	78.23	91.00	100.61	108.76	116.05	122.78
27	20.71	17.81	16.11	14.90	13.96	13.20	78.21	90.98	100.59	108.73	116.02	122.75
28	21.33	18.34	16.58	15.34	14.38	13.59	78.76	91.62	101.30	109.50	116.84	123.61
29	21.74	18.69	16.90	15.64	14.65	13.85	80.04	93.11	102.95	111.28	118.74	125.62
30	22.25	19.13	17.30	16.00	15.00	14.18	80.90	94.10	104.04	112.47	120.01	126.96
31	22.89	19.67	17.79	16.46	15.43	14.58	81.28	94.55	104.53	113.00	120.57	127.56
32	23.41	20.12	18.20	16.83	15.78	14.91	82.03	95.43	105.51	114.05	121.70	128.75
33	23.90	20.55	18.58	17.19	16.11	15.23	82.84	96.37	106.54	115.17	122.89	130.01
34	24.45	21.02	19.01	17.59	16.48	15.58	83.43	97.06	107.31	116.00	123.77	130.95
35	24.87	21.38	19.34	17.89	16.76	15.85	84.44	98.23	108.60	117.40	125.26	132.52
36	25.20	21.67	19.60	18.13	16.99	16.06	85.70	99.70	110.22	119.15	127.14	134.51
37	25.83	22.20	20.08	18.58	17.41	16.46	85.95	99.98	110.54	119.49	127.50	134.89
38	26.42	22.71	20.54	19.00	17.81	16.83	86.31	100.40	111.00	119.99	128.04	135.46
39	26.75	23.00	20.80	19.24	18.03	17.05	87.47	101.75	112.50	121.61	129.76	137.28
40	27.40	23.55	21.30	19.71	18.47	17.46	87.59	101.89	112.65	121.78	129.94	137.47
41	27.89	23.98	21.69	20.06	18.80	17.77	88.19	102.59	113.43	122.62	130.83	138.42
42	28.46	24.46	22.13	20.47	19.18	18.13	88.55	103.01	113.88	123.11	131.36	138.97
43	28.76	24.72	22.36	20.68	19.39	18.32	89.72	104.36	115.39	124.73	133.09	140.80
44	28.91	24.85	22.48	20.80	19.49	18.42	91.31	106.22	117.44	126.95	135.46	143.31
45	29.71	25.54	23.10	21.37	20.03	18.93	90.87	105.71	116.87	126.33	134.80	142.61
46	29.95	25.75	23.29	21.54	20.19	19.08	92.15	107.20	118.52	128.12	136.70	144.63
47	30.61	26.32	23.80	22.02	20.64	19.51	92.11	107.15	118.47	128.06	136.65	144.57
48	30.88	26.55	24.01	22.21	20.82	19.68	93.27	108.49	119.95	129.67	138.36	146.38
49	31.22	26.84	24.27	22.45	21.04	19.89	94.17	109.55	121.12	130.93	139.71	147.80
50	31.87	27.40	24.78	22.92	21.48	20.31	94.13	109.50	121.07	130.87	139.65	147.74
51	32.47	27.92	25.25	23.36	21.89	20.69	94.23	109.62	121.19	131.01	139.79	147.89
52	32.83	28.22	25.53	23.62	22.13	20.92	95.03	110.55	122.22	132.12	140.97	149.14
53	33.41	28.72	25.97	24.03	22.52	21.29	95.19	110.73	122.43	132.34	141.21	149.39
54	33.79	29.04	26.27	24.30	22.77	21.53	95.90	111.56	123.34	133.33	142.26	150.51
55	34.50	29.66	26.83	24.82	23.26	21.98	95.65	111.27	123.02	132.98	141.90	150.12
56	34.81	29.93	27.07	25.04	23.47	22.18	96.52	112.28	124.13	134.19	143.18	151.48
57	35.24	30.29	27.40	25.35	23.75	22.45	97.05	112.90	124.82	134.93	143.98	152.32
58	35.61	30.61	27.69	25.61	24.00	22.69	97.72	113.68	125.69	135.87	144.97	153.37
59	35.57	30.58	27.66	25.58	23.98	22.66	99.52	115.77	128.00	138.36	147.64	156.19
60	36.41	31.30	28.31	26.19	24.55	23.20	98.86	115.00	127.15	137.45	146.66	155.16
61	36.70	31.55	28.54	26.40	24.74	23.39	99.72	116.00	128.25	138.64	147.93	156.50
62	37.39	32.14	29.07	26.90	25.21	23.83	99.48	115.73	127.95	138.31	147.58	156.13
63	37.74	32.44	29.34	27.14	25.44	24.05	100.16	116.52	128.82	139.26	148.59	157.20
64	38.09	32.74	29.61	27.39	25.67	24.27	100.83	117.29	129.67	140.18	149.57	158.24

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
65	38.33	32.95	29.80	27.57	25.84	24.42	101.75	118.37	130.87	141.47	150.95	159.69
66	38.95	33.48	30.29	28.02	26.26	24.82	101.66	118.26	130.75	141.34	150.82	159.56
67	39.14	33.65	30.44	28.15	26.39	24.94	102.70	119.47	132.08	142.78	152.35	161.18
68	39.84	34.25	30.98	28.66	26.86	25.39	102.41	119.13	131.71	142.38	151.92	160.72
69	40.03	34.41	31.12	28.79	26.98	25.50	103.43	120.32	133.02	143.80	153.44	162.33
70	40.81	35.08	31.73	29.35	27.51	26.00	102.92	119.73	132.37	143.09	152.69	161.53
71	40.72	35.01	31.66	29.29	27.45	25.95	104.61	121.69	134.54	145.44	155.19	164.18
72	41.15	35.38	32.00	29.60	27.74	26.22	104.98	122.12	135.01	145.95	155.73	164.76
73	41.63	35.79	32.37	29.94	28.06	26.53	105.21	122.39	135.32	146.27	156.08	165.12
74	42.07	36.16	32.71	30.26	28.36	26.81	105.54	122.77	135.74	146.73	156.57	165.64
75	42.65	36.66	33.16	30.68	28.75	27.18	105.51	122.73	135.69	146.68	156.52	165.59
76	42.89	36.87	33.35	30.85	28.91	27.33	106.32	123.69	136.75	147.82	157.73	166.87
77	42.92	36.89	33.37	30.87	28.93	27.34	107.65	125.23	138.46	149.67	159.70	168.96
78	43.84	37.69	34.09	31.53	29.55	27.93	106.75	124.18	137.29	148.41	158.36	167.53
79	44.29	38.07	34.44	31.86	29.86	28.22	107.02	124.49	137.64	148.79	158.76	167.96
80	44.49	38.25	34.59	32.00	29.99	28.35	107.89	125.50	138.75	149.99	160.05	169.32
81	44.75	38.47	34.79	32.19	30.16	28.51	108.61	126.34	139.68	151.00	161.12	170.46
82	45.37	39.00	35.28	32.63	30.58	28.91	108.44	126.14	139.46	150.76	160.87	170.19
83	45.79	39.37	35.61	32.94	30.87	29.18	108.75	126.50	139.86	151.19	161.33	170.67
84	46.17	39.69	35.90	33.21	31.12	29.42	109.16	126.98	140.39	151.76	161.93	171.31
85	46.47	39.95	36.13	33.42	31.32	29.61	109.75	127.67	141.16	152.59	162.82	172.25
86	46.72	40.17	36.33	33.61	31.50	29.77	110.43	128.47	142.03	153.53	163.83	173.32
87	47.24	40.61	36.73	33.98	31.84	30.10	110.50	128.55	142.12	153.63	163.93	173.43
88	47.46	40.80	36.90	34.14	31.99	30.24	111.25	129.42	143.09	154.68	165.04	174.61
89	48.07	41.32	37.37	34.57	32.40	30.63	111.09	129.23	142.88	154.45	164.80	174.35
90	48.36	41.57	37.60	34.79	32.60	30.82	111.66	129.89	143.60	155.23	165.64	175.24
91	48.63	41.80	37.81	34.98	32.78	30.98	112.28	130.62	144.41	156.11	166.57	176.22
92	49.16	42.26	38.23	35.36	33.14	31.33	112.28	130.61	144.40	156.10	166.56	176.21
93	49.60	42.63	38.56	35.67	33.43	31.60	112.51	130.88	144.70	156.42	166.91	176.58
94	49.86	42.86	38.77	35.86	33.61	31.77	113.12	131.58	145.48	157.26	167.80	177.53
95	50.38	43.30	39.17	36.23	33.96	32.10	113.15	131.62	145.52	157.31	167.86	177.58
96	50.53	43.44	39.29	36.34	34.06	32.19	114.00	132.61	146.61	158.49	169.11	178.91
97	50.98	43.82	39.64	36.67	34.36	32.48	114.17	132.81	146.84	158.73	169.37	179.18
98	51.38	44.17	39.95	36.96	34.64	32.74	114.43	133.12	147.17	159.09	169.76	179.60
99	51.83	44.56	40.30	37.28	34.94	33.02	114.60	133.32	147.40	159.33	170.01	179.87
100	52.15	44.83	40.55	37.51	35.16	33.23	115.05	133.83	147.96	159.95	170.67	180.56
101	52.55	45.17	40.86	37.80	35.42	33.48	115.33	134.16	148.32	160.34	171.09	181.00
102	52.78	45.37	41.04	37.96	35.58	33.63	115.96	134.89	149.13	161.21	172.02	181.99
103	53.16	45.69	41.33	38.23	35.83	33.87	116.26	135.25	149.53	161.64	172.47	182.47
104	53.51	46.00	41.60	38.49	36.07	34.09	116.62	135.66	149.99	162.13	173.00	183.03
105	53.95	46.37	41.94	38.80	36.36	34.37	116.78	135.85	150.20	162.36	173.25	183.29
106	54.10	46.51	42.07	38.92	36.47	34.47	117.55	136.74	151.18	163.43	174.38	184.49

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
107	54.46	46.82	42.34	39.17	36.71	34.70	117.89	137.14	151.62	163.90	174.88	185.02
108	54.98	47.26	42.75	39.55	37.06	35.03	117.86	137.10	151.58	163.85	174.84	184.97
109	55.27	47.52	42.98	39.76	37.26	35.22	118.32	137.64	152.17	164.50	175.53	185.70
110	55.88	48.04	43.45	40.19	37.67	35.61	118.11	137.39	151.90	164.20	175.21	185.36
111	56.04	48.18	43.57	40.31	37.78	35.71	118.84	138.25	152.84	165.22	176.30	186.51
112	56.29	48.39	43.77	40.49	37.94	35.87	119.38	138.87	153.54	165.98	177.10	187.36
113	56.80	48.83	44.17	40.86	38.29	36.19	119.36	138.85	153.51	165.95	177.07	187.33
114	57.14	49.12	44.42	41.10	38.51	36.40	119.72	139.26	153.97	166.44	177.60	187.89
115	57.20	49.17	44.48	41.14	38.56	36.45	120.62	140.32	155.14	167.70	178.95	189.31
116	58.14	49.98	45.20	41.82	39.19	37.04	119.72	139.27	153.97	166.44	177.60	187.89
117	58.29	50.11	45.32	41.93	39.29	37.14	120.43	140.09	154.88	167.43	178.65	189.00
118	58.69	50.45	45.63	42.21	39.56	37.39	120.64	140.33	155.15	167.72	178.96	189.33
119	58.73	50.49	45.67	42.24	39.59	37.42	121.57	141.42	156.35	169.01	180.34	190.79
120	59.32	51.00	46.13	42.67	39.99	37.80	121.37	141.18	156.09	168.73	180.04	190.48
121	59.72	51.33	46.43	42.95	40.25	38.05	121.58	141.43	156.36	169.03	180.36	190.81
122	59.71	51.33	46.43	42.95	40.25	38.05	122.59	142.61	157.67	170.43	181.86	192.40
123	60.42	51.94	46.98	43.46	40.73	38.50	122.14	142.08	157.08	169.81	181.19	191.69
124	60.63	52.12	47.14	43.61	40.87	38.63	122.71	142.74	157.82	170.60	182.04	192.58
125	60.67	52.16	47.18	43.64	40.90	38.66	123.61	143.79	158.98	171.85	183.37	194.00
126	61.29	52.68	47.65	44.08	41.31	39.05	123.36	143.50	158.65	171.50	183.00	193.60
127	61.51	52.88	47.83	44.24	41.46	39.19	123.88	144.11	159.33	172.24	183.78	194.43
128	62.12	53.40	48.30	44.68	41.87	39.58	123.64	143.83	159.02	171.89	183.42	194.05
129	62.61	53.82	48.68	45.04	42.21	39.89	123.62	143.80	158.99	171.87	183.39	194.01
130	62.77	53.96	48.80	45.15	42.31	39.99	124.27	144.56	159.83	172.77	184.35	195.03
131	63.10	54.24	49.06	45.38	42.53	40.20	124.57	144.91	160.21	173.19	184.79	195.50
132	63.42	54.52	49.31	45.62	42.75	40.41	124.88	145.26	160.60	173.61	185.25	195.98
133	63.88	54.91	49.67	45.95	43.06	40.70	124.92	145.32	160.66	173.68	185.32	196.06
134	64.16	55.16	49.89	46.15	43.25	40.88	125.31	145.77	161.16	174.21	185.89	196.66
135	64.32	55.29	50.01	46.26	43.36	40.98	125.94	146.50	161.97	175.09	186.83	197.65
136	64.82	55.72	50.40	46.62	43.69	41.30	125.89	146.45	161.91	175.02	186.76	197.58
137	65.08	55.95	50.60	46.81	43.87	41.47	126.30	146.93	162.44	175.60	187.37	198.23
138	65.30	56.14	50.78	46.97	44.02	41.61	126.79	147.49	163.07	176.28	188.09	198.99
139	65.88	56.63	51.22	47.38	44.41	41.97	126.60	147.27	162.82	176.01	187.81	198.69
140	66.23	56.93	51.49	47.64	44.64	42.20	126.84	147.55	163.13	176.34	188.16	199.06
141	66.51	57.17	51.71	47.84	44.83	42.38	127.21	147.98	163.60	176.85	188.71	199.64
142	66.91	57.52	52.02	48.12	45.10	42.63	127.34	148.13	163.78	177.04	188.91	199.86
143	67.07	57.66	52.15	48.24	45.21	42.74	127.92	148.81	164.52	177.84	189.77	200.76
144	67.69	58.18	52.63	48.68	45.63	43.13	127.65	148.49	164.17	177.47	189.37	200.34
145	68.02	58.47	52.89	48.92	45.85	43.34	127.91	148.79	164.50	177.83	189.75	200.74
146	68.17	58.60	53.01	49.03	45.95	43.44	128.50	149.48	165.26	178.65	190.62	201.67
147	68.44	58.83	53.21	49.23	46.13	43.61	128.87	149.92	165.75	179.17	191.18	202.26
148	68.85	59.18	53.53	49.52	46.41	43.87	128.99	150.05	165.89	179.33	191.35	202.43

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
149	69.11	59.41	53.74	49.71	46.59	44.04	129.35	150.47	166.36	179.84	191.89	203.01
150	69.42	59.67	53.97	49.93	46.79	44.23	129.65	150.82	166.75	180.26	192.34	203.48
151	69.92	60.11	54.37	50.29	47.14	44.55	129.57	150.72	166.64	180.14	192.21	203.35
152	70.28	60.42	54.65	50.55	47.38	44.78	129.77	150.95	166.90	180.41	192.51	203.66
153	70.41	60.53	54.75	50.64	47.46	44.86	130.38	151.67	167.68	181.26	193.41	204.62
154	70.77	60.83	55.02	50.90	47.70	45.09	130.57	151.89	167.93	181.53	193.70	204.92
155	71.24	61.24	55.39	51.24	48.02	45.39	130.55	151.87	167.91	181.51	193.67	204.90
156	71.51	61.47	55.60	51.43	48.20	45.56	130.90	152.27	168.35	181.99	194.19	205.44
157	71.83	61.74	55.85	51.66	48.42	45.77	131.15	152.57	168.68	182.34	194.56	205.83
158	72.11	61.99	56.07	51.87	48.61	45.95	131.47	152.93	169.08	182.78	195.03	206.33
159	72.55	62.37	56.41	52.19	48.91	46.23	131.49	152.96	169.11	182.81	195.06	206.36
160	72.84	62.61	56.63	52.39	49.10	46.41	131.80	153.33	169.52	183.25	195.53	206.86
161	73.18	62.91	56.90	52.64	49.33	46.63	132.00	153.56	169.77	183.52	195.83	207.17
162	73.39	63.09	57.07	52.79	49.47	46.76	132.43	154.06	170.33	184.12	196.46	207.85
163	73.83	63.46	57.40	53.10	49.76	47.04	132.47	154.11	170.38	184.18	196.52	207.91
164	74.16	63.75	57.67	53.34	49.99	47.26	132.68	154.34	170.64	184.46	196.83	208.23
165	74.38	63.94	57.84	53.50	50.14	47.40	133.09	154.82	171.17	185.04	197.44	208.88
166	74.92	64.40	58.25	53.89	50.50	47.74	132.95	154.65	170.98	184.83	197.22	208.65
167	74.99	64.47	58.31	53.94	50.55	47.78	133.62	155.43	171.85	185.76	198.22	209.70
168	75.46	64.86	58.67	54.27	50.86	48.08	133.59	155.40	171.81	185.73	198.18	209.66
169	75.77	65.13	58.91	54.50	51.07	48.28	133.83	155.68	172.12	186.06	198.54	210.04
170	76.24	65.54	59.28	54.84	51.39	48.58	133.79	155.64	172.07	186.01	198.48	209.98
171	76.40	65.68	59.40	54.95	51.50	48.68	134.29	156.22	172.72	186.70	199.22	210.76
172	76.79	66.01	59.70	55.23	51.76	48.93	134.40	156.34	172.85	186.85	199.38	210.93
173	77.10	66.28	59.95	55.45	51.97	49.12	134.63	156.62	173.16	187.18	199.73	211.30
174	77.36	66.50	60.15	55.64	52.14	49.29	134.96	157.00	173.58	187.63	200.21	211.81
175	77.63	66.73	60.36	55.84	52.33	49.46	135.26	157.34	173.96	188.05	200.66	212.28
176	78.10	67.13	60.72	56.17	52.64	49.76	135.22	157.30	173.91	187.99	200.59	212.22
177	78.39	67.38	60.95	56.38	52.84	49.94	135.48	157.61	174.25	188.36	200.99	212.63
178	78.94	67.86	61.38	56.78	53.21	50.30	135.30	157.39	174.01	188.11	200.71	212.34
179	79.13	68.02	61.52	56.92	53.34	50.42	135.73	157.89	174.56	188.70	201.35	213.02
180	79.34	68.20	61.69	57.06	53.48	50.55	136.13	158.36	175.08	189.26	201.94	213.65
181	79.71	68.52	61.98	57.33	53.73	50.79	136.24	158.49	175.22	189.41	202.11	213.82
182	80.12	68.87	62.29	57.63	54.01	51.05	136.30	158.56	175.30	189.50	202.20	213.92
183	80.28	69.01	62.42	57.75	54.12	51.15	136.77	159.10	175.90	190.14	202.89	214.65
184	80.65	69.33	62.71	58.01	54.37	51.39	136.89	159.24	176.05	190.31	203.07	214.84
185	80.91	69.55	62.91	58.20	54.54	51.55	137.19	159.59	176.44	190.73	203.52	215.31
186	81.34	69.92	63.24	58.51	54.83	51.83	137.20	159.61	176.46	190.75	203.54	215.33
187	81.72	70.25	63.54	58.78	55.09	52.07	137.30	159.72	176.58	190.89	203.68	215.48
188	81.99	70.48	63.75	58.97	55.27	52.24	137.58	160.04	176.94	191.27	204.09	215.92
189	82.38	70.82	64.05	59.26	55.53	52.49	137.65	160.13	177.04	191.38	204.20	216.04
190	82.57	70.98	64.20	59.39	55.66	52.61	138.06	160.60	177.56	191.94	204.81	216.68

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
191	83.03	71.38	64.56	59.72	55.97	52.91	138.02	160.56	177.51	191.89	204.75	216.61
192	83.25	71.56	64.73	59.88	56.12	53.04	138.38	160.98	177.98	192.39	205.29	217.18
193	83.61	71.87	65.01	60.14	56.36	53.27	138.51	161.12	178.14	192.56	205.47	217.38
194	83.80	72.04	65.16	60.28	56.49	53.40	138.90	161.58	178.64	193.11	206.06	218.00
195	84.31	72.48	65.56	60.64	56.83	53.72	138.77	161.43	178.47	192.93	205.86	217.79
196	84.50	72.64	65.70	60.78	56.96	53.84	139.18	161.90	179.00	193.50	206.47	218.43
197	84.67	72.79	65.84	60.90	57.08	53.95	139.59	162.39	179.54	194.08	207.09	219.09
198	85.10	73.16	66.17	61.21	57.36	54.22	139.60	162.39	179.54	194.08	207.10	219.09
199	85.56	73.55	66.52	61.54	57.67	54.51	139.56	162.34	179.48	194.02	207.03	219.02
200	85.88	73.83	66.77	61.77	57.89	54.72	139.73	162.54	179.71	194.26	207.29	219.30
201	86.00	73.93	66.87	61.86	57.97	54.80	140.23	163.12	180.35	194.96	208.03	220.08
202	86.36	74.24	67.15	62.12	58.21	55.02	140.35	163.26	180.50	195.12	208.20	220.26
203	86.64	74.48	67.36	62.32	58.40	55.20	140.59	163.54	180.81	195.46	208.56	220.64
204	87.07	74.85	67.70	62.63	58.69	55.48	140.57	163.53	180.80	195.44	208.54	220.62
205	87.26	75.01	67.84	62.76	58.82	55.60	140.96	163.98	181.30	195.98	209.12	221.24
206	87.73	75.41	68.21	63.10	59.13	55.90	140.89	163.90	181.21	195.88	209.01	221.13
207	88.14	75.77	68.53	63.40	59.41	56.16	140.91	163.92	181.23	195.91	209.04	221.16
208	88.28	75.89	68.64	63.50	59.51	56.25	141.36	164.44	181.81	196.53	209.71	221.86
209	88.53	76.11	68.84	63.68	59.68	56.41	141.64	164.77	182.17	196.92	210.12	222.30
210	88.88	76.40	69.11	63.93	59.91	56.63	141.77	164.91	182.33	197.09	210.31	222.49
211	89.22	76.70	69.37	64.18	60.15	56.85	141.89	165.06	182.49	197.27	210.49	222.69
212	89.57	77.00	69.64	64.42	60.38	57.07	142.02	165.20	182.65	197.44	210.68	222.89
213	89.80	77.20	69.82	64.59	60.53	57.22	142.31	165.55	183.03	197.86	211.12	223.35
214	90.15	77.49	70.09	64.84	60.77	57.44	142.43	165.69	183.19	198.02	211.30	223.54
215	90.63	77.91	70.47	65.19	61.09	57.74	142.34	165.58	183.07	197.90	211.16	223.40
216	90.90	78.14	70.68	65.38	61.28	57.92	142.57	165.85	183.36	198.21	211.50	223.75
217	91.04	78.26	70.79	65.49	61.37	58.01	143.01	166.36	183.93	198.82	212.15	224.44
218	91.52	78.67	71.16	65.83	61.69	58.31	142.92	166.26	183.81	198.70	212.02	224.30
219	91.95	79.04	71.49	66.14	61.98	58.59	142.90	166.24	183.79	198.68	211.99	224.28
220	92.15	79.32	71.74	66.32	62.16	58.73	143.12	166.42	183.99	199.02	212.34	224.75
221	92.49	79.51	71.92	66.53	62.35	58.93	143.36	166.77	184.38	199.31	212.68	225.00
222	92.74	79.80	72.09	66.73	62.59	59.12	143.62	166.92	184.78	199.62	212.83	225.29
223	92.99	80.09	72.32	66.95	62.80	59.36	143.89	167.06	185.01	199.85	213.07	225.42
224	93.34	80.31	72.58	67.15	62.94	59.48	143.99	167.35	185.17	200.15	213.52	225.97
225	93.70	80.55	72.86	67.40	63.16	59.70	144.08	167.60	185.30	200.31	213.73	226.12
226	94.00	80.81	73.09	67.61	63.37	59.90	144.25	167.80	185.52	200.55	213.99	226.39
227	94.22	80.99	73.26	67.77	63.51	60.03	144.56	168.16	185.92	200.98	214.45	226.88
228	94.51	81.25	73.49	67.98	63.71	60.22	144.74	168.37	186.15	201.23	214.72	227.16
229	95.06	81.71	73.91	68.37	64.08	60.57	144.55	168.15	185.90	200.96	214.43	226.86
230	95.18	81.82	74.01	68.46	64.16	60.65	144.99	168.66	186.47	201.57	215.09	227.55
231	95.51	82.11	74.26	68.70	64.38	60.86	145.11	168.80	186.63	201.74	215.27	227.74
232	96.01	82.54	74.65	69.06	64.72	61.18	144.98	168.65	186.46	201.56	215.07	227.54

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
233	96.14	82.64	74.75	69.15	64.80	61.25	145.42	169.16	187.03	202.18	215.73	228.23
234	96.53	82.98	75.05	69.43	65.07	61.50	145.45	169.20	187.07	202.22	215.78	228.28
235	96.82	83.23	75.28	69.64	65.26	61.69	145.63	169.41	187.30	202.47	216.05	228.57
236	97.19	83.55	75.57	69.91	65.51	61.93	145.70	169.48	187.38	202.56	216.14	228.66
237	97.49	83.81	75.80	70.12	65.72	62.12	145.86	169.67	187.59	202.78	216.37	228.91
238	97.68	83.97	75.95	70.26	65.85	62.24	146.19	170.06	188.02	203.24	216.87	229.43
239	98.02	84.26	76.22	70.51	66.08	62.46	146.29	170.18	188.15	203.39	217.02	229.60
240	98.33	84.53	76.45	70.73	66.28	62.65	146.45	170.36	188.35	203.60	217.25	229.84
241	98.70	84.85	76.74	70.99	66.53	62.89	146.50	170.42	188.42	203.68	217.33	229.92
242	99.07	85.17	77.03	71.26	66.78	63.13	146.56	170.49	188.49	203.76	217.42	230.02
243	99.24	85.31	77.16	71.38	66.90	63.23	146.91	170.90	188.95	204.25	217.94	230.57
244	99.58	85.60	77.43	71.63	67.13	63.45	147.01	171.02	189.08	204.39	218.09	230.73
245	99.78	85.78	77.59	71.77	67.26	63.58	147.32	171.37	189.47	204.81	218.54	231.21
246	100.35	86.27	78.03	72.18	67.65	63.94	147.08	171.10	189.17	204.49	218.19	230.84
247	100.61	86.49	78.23	72.37	67.82	64.11	147.30	171.35	189.44	204.79	218.51	231.17
248	101.01	86.83	78.54	72.65	68.09	64.36	147.32	171.37	189.47	204.81	218.54	231.21
249	101.19	86.98	78.68	72.78	68.21	64.47	147.65	171.76	189.89	205.27	219.03	231.73
250	101.55	87.29	78.96	73.04	68.45	64.70	147.71	171.83	189.98	205.37	219.13	231.83
251	101.81	87.52	79.16	73.23	68.63	64.87	147.93	172.08	190.25	205.66	219.45	232.16
252	102.07	87.74	79.36	73.42	68.80	65.04	148.13	172.32	190.52	205.95	219.75	232.49
253	102.40	88.03	79.62	73.65	69.03	65.24	148.25	172.45	190.66	206.10	219.92	232.66
254	102.74	88.32	79.88	73.90	69.25	65.46	148.34	172.56	190.78	206.24	220.06	232.81
255	103.06	88.60	80.13	74.13	69.47	65.67	148.45	172.69	190.93	206.40	220.23	232.99
256	103.37	88.86	80.37	74.35	69.68	65.86	148.60	172.86	191.12	206.60	220.44	233.22
257	103.59	89.05	80.54	74.51	69.83	66.00	148.86	173.17	191.46	206.96	220.83	233.63
258	103.89	89.31	80.78	74.73	70.03	66.20	149.00	173.33	191.63	207.15	221.04	233.85
259	104.33	89.69	81.12	75.04	70.33	66.48	148.95	173.27	191.57	207.08	220.96	233.77
260	104.58	89.90	81.31	75.22	70.49	66.63	149.17	173.53	191.86	207.39	221.30	234.12
261	104.89	90.17	81.56	75.45	70.71	66.83	149.29	173.67	192.01	207.56	221.48	234.31
262	105.16	90.40	81.77	75.64	70.89	67.01	149.49	173.89	192.26	207.83	221.76	234.61
263	105.61	90.79	82.12	75.96	71.19	67.29	149.41	173.81	192.17	207.73	221.65	234.50
264	105.88	91.02	82.33	76.16	71.37	67.46	149.60	174.03	192.41	207.99	221.93	234.79
265	106.05	91.17	82.46	76.28	71.49	67.57	149.93	174.40	192.82	208.44	222.41	235.30
266	106.43	91.49	82.75	76.55	71.74	67.81	149.96	174.44	192.87	208.49	222.46	235.35
267	106.64	91.67	82.92	76.71	71.89	67.95	150.22	174.75	193.20	208.85	222.85	235.76
268	107.10	92.06	83.27	77.03	72.19	68.24	150.15	174.66	193.11	208.75	222.74	235.65
269	107.37	92.30	83.48	77.23	72.37	68.41	150.33	174.87	193.34	209.00	223.01	235.93
270	107.69	92.58	83.73	77.46	72.59	68.62	150.43	174.99	193.47	209.14	223.16	236.09
271	107.92	92.77	83.91	77.63	72.75	68.76	150.66	175.27	193.77	209.47	223.51	236.46
272	108.29	93.09	84.20	77.89	73.00	69.00	150.71	175.31	193.83	209.53	223.57	236.53
273	108.68	93.42	84.50	78.17	73.26	69.24	150.72	175.33	193.85	209.55	223.60	236.55
274	109.01	93.71	84.76	78.41	73.48	69.46	150.81	175.44	193.96	209.67	223.73	236.69

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
275	109.18	93.85	84.89	78.53	73.60	69.56	151.13	175.81	194.37	210.11	224.20	237.19
276	109.51	94.14	85.15	78.77	73.82	69.78	151.22	175.91	194.48	210.24	224.33	237.33
277	109.78	94.37	85.36	78.96	74.00	69.95	151.39	176.11	194.71	210.48	224.59	237.60
278	110.08	94.63	85.59	79.18	74.21	70.14	151.52	176.26	194.87	210.66	224.78	237.80
279	110.32	94.84	85.78	79.35	74.37	70.29	151.74	176.51	195.15	210.96	225.10	238.14
280	110.73	95.19	86.10	79.65	74.65	70.56	151.71	176.49	195.12	210.93	225.07	238.11
281	110.99	95.41	86.30	79.83	74.82	70.72	151.90	176.71	195.37	211.19	225.35	238.41
282	111.30	95.68	86.54	80.06	75.03	70.92	152.02	176.84	195.51	211.35	225.52	238.58
283	111.85	96.15	86.97	80.45	75.40	71.27	151.81	176.60	195.25	211.06	225.21	238.26
284	112.09	96.36	87.15	80.62	75.56	71.42	152.02	176.84	195.52	211.35	225.52	238.59
285	112.32	96.55	87.33	80.79	75.71	71.56	152.25	177.11	195.81	211.67	225.86	238.94
286	112.69	96.87	87.62	81.05	75.96	71.80	152.28	177.14	195.85	211.71	225.90	238.99
287	112.93	97.08	87.81	81.23	76.12	71.95	152.49	177.38	196.11	212.00	226.21	239.32
288	113.17	97.28	87.99	81.40	76.29	72.11	152.69	177.62	196.38	212.28	226.51	239.64
289	113.39	97.47	88.16	81.56	76.43	72.25	152.93	177.90	196.68	212.61	226.86	240.01
290	113.85	97.87	88.52	81.89	76.74	72.54	152.84	177.79	196.57	212.49	226.73	239.87
291	114.16	98.14	88.77	82.11	76.96	72.74	152.94	177.91	196.70	212.63	226.88	240.03
292	114.55	98.47	89.07	82.39	77.22	72.99	152.95	177.92	196.71	212.64	226.89	240.04
293	114.83	98.71	89.28	82.59	77.40	73.16	153.10	178.10	196.91	212.85	227.12	240.28
294	115.14	98.97	89.52	82.81	77.61	73.36	153.21	178.23	197.05	213.01	227.29	240.46
295	115.37	99.18	89.71	82.99	77.77	73.51	153.42	178.46	197.31	213.29	227.59	240.78
296	115.72	99.48	89.98	83.24	78.01	73.74	153.47	178.53	197.38	213.36	227.67	240.86
297	116.04	99.75	90.22	83.46	78.22	73.94	153.57	178.64	197.51	213.50	227.82	241.02
298	116.20	99.89	90.35	83.58	78.33	74.04	153.87	178.99	197.89	213.92	228.26	241.49
299	116.64	100.27	90.69	83.90	78.63	74.32	153.81	178.92	197.82	213.84	228.17	241.39
300	116.94	100.52	90.92	84.11	78.83	74.51	153.93	179.06	197.97	214.01	228.35	241.59
301	117.24	100.78	91.16	84.33	79.03	74.70	154.04	179.20	198.12	214.17	228.52	241.76
302	117.51	101.01	91.37	84.52	79.21	74.87	154.20	179.38	198.32	214.39	228.76	242.01
303	117.76	101.23	91.56	84.70	79.38	75.03	154.38	179.59	198.55	214.63	229.02	242.29
304	118.13	101.55	91.85	84.97	79.63	75.27	154.40	179.62	198.58	214.67	229.06	242.33
305	118.47	101.84	92.11	85.21	79.86	75.48	154.47	179.70	198.67	214.76	229.16	242.44
306	118.70	102.04	92.29	85.38	80.02	75.63	154.67	179.93	198.93	215.04	229.46	242.75
307	118.98	102.28	92.51	85.58	80.20	75.81	154.81	180.09	199.11	215.24	229.66	242.97
308	119.24	102.51	92.72	85.77	80.38	75.98	154.98	180.28	199.32	215.46	229.90	243.23
309	119.59	102.81	92.99	86.02	80.62	76.20	155.03	180.34	199.38	215.53	229.98	243.31
310	119.87	103.05	93.21	86.22	80.81	76.38	155.16	180.50	199.56	215.72	230.18	243.52
311	120.36	103.46	93.58	86.57	81.13	76.69	155.04	180.36	199.40	215.55	230.00	243.33
312	120.57	103.64	93.74	86.72	81.27	76.82	155.27	180.62	199.69	215.87	230.34	243.68
313	120.90	103.93	94.01	86.96	81.50	77.04	155.33	180.69	199.77	215.95	230.43	243.78
314	121.22	104.21	94.26	87.19	81.72	77.24	155.41	180.79	199.88	216.07	230.55	243.91
315	121.50	104.44	94.47	87.39	81.90	77.42	155.56	180.96	200.07	216.27	230.77	244.14
316	121.71	104.63	94.64	87.54	82.04	77.55	155.78	181.21	200.35	216.58	231.09	244.48

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
317	122.17	105.02	94.99	87.87	82.35	77.84	155.69	181.11	200.23	216.45	230.96	244.34
318	122.38	105.20	95.15	88.02	82.49	77.97	155.91	181.37	200.52	216.76	231.30	244.70
319	122.65	105.44	95.37	88.22	82.68	78.15	156.05	181.53	200.70	216.96	231.50	244.91
320	123.06	105.78	95.68	88.51	82.95	78.41	156.03	181.50	200.67	216.92	231.46	244.87
321	123.17	105.88	95.76	88.59	83.02	78.48	156.38	181.91	201.12	217.41	231.98	245.42
322	123.66	106.31	96.15	88.95	83.36	78.79	156.23	181.74	200.93	217.21	231.77	245.20
323	123.86	106.47	96.30	89.09	83.49	78.92	156.47	182.02	201.24	217.54	232.12	245.57
324	124.21	106.77	96.58	89.34	83.73	79.14	156.51	182.07	201.29	217.60	232.18	245.64
325	124.47	107.00	96.78	89.53	83.90	79.31	156.66	182.24	201.49	217.81	232.41	245.87
326	124.72	107.22	96.98	89.71	84.07	79.47	156.83	182.43	201.70	218.04	232.65	246.13
327	125.14	107.58	97.30	90.01	84.36	79.74	156.78	182.38	201.64	217.98	232.59	246.06
328	125.40	107.80	97.50	90.20	84.53	79.90	156.94	182.56	201.84	218.19	232.81	246.30
329	125.81	108.15	97.82	90.49	84.81	80.16	156.90	182.52	201.80	218.14	232.77	246.25
330	126.11	108.40	98.05	90.70	85.01	80.35	157.01	182.65	201.94	218.29	232.92	246.42
331	126.27	108.55	98.18	90.83	85.12	80.46	157.28	182.96	202.28	218.66	233.32	246.84
332	126.65	108.87	98.47	91.09	85.37	80.70	157.29	182.97	202.29	218.68	233.33	246.85
333	126.85	109.05	98.63	91.24	85.51	80.82	157.51	183.23	202.58	218.98	233.66	247.20
334	127.38	109.50	99.04	91.62	85.87	81.16	157.32	183.01	202.34	218.72	233.39	246.91
335	127.64	109.73	99.25	91.81	86.04	81.33	157.47	183.18	202.53	218.93	233.60	247.14
336	127.89	109.94	99.44	91.99	86.21	81.49	157.63	183.37	202.74	219.15	233.85	247.40
337	128.18	110.19	99.66	92.20	86.40	81.67	157.75	183.51	202.88	219.32	234.02	247.58
338	128.65	110.59	100.03	92.54	86.72	81.97	157.63	183.37	202.74	219.16	233.85	247.40
339	128.73	110.66	100.09	92.59	86.77	82.02	158.01	183.81	203.22	219.68	234.40	247.99
340	129.11	110.99	100.39	92.86	87.03	82.26	158.01	183.81	203.22	219.68	234.40	247.98
341	129.32	111.17	100.55	93.02	87.17	82.40	158.21	184.05	203.48	219.96	234.71	248.31
342	129.67	111.47	100.82	93.27	87.41	82.62	158.25	184.09	203.52	220.01	234.76	248.36
343	130.10	111.84	101.16	93.58	87.70	82.90	158.18	184.01	203.44	219.92	234.66	248.26
344	130.38	112.08	101.37	93.78	87.89	83.07	158.31	184.16	203.61	220.10	234.85	248.46
345	130.68	112.34	101.61	94.00	88.09	83.27	158.40	184.26	203.72	220.22	234.98	248.60
346	130.92	112.55	101.80	94.17	88.25	83.42	158.57	184.46	203.94	220.45	235.23	248.86
347	131.24	112.82	102.04	94.40	88.47	83.62	158.64	184.54	204.03	220.55	235.34	248.98
348	131.53	113.07	102.27	94.61	88.66	83.81	158.75	184.67	204.17	220.71	235.50	249.15
349	131.83	113.32	102.50	94.82	88.86	84.00	158.84	184.78	204.29	220.84	235.64	249.30
350	132.12	113.57	102.73	95.03	89.06	84.18	158.95	184.90	204.43	220.98	235.80	249.46
351	132.43	113.84	102.97	95.25	89.27	84.38	159.03	185.00	204.53	221.10	235.92	249.59
352	132.66	114.04	103.15	95.42	89.43	84.53	159.20	185.20	204.75	221.34	236.18	249.86
353	133.02	114.35	103.43	95.68	89.67	84.76	159.23	185.22	204.78	221.37	236.21	249.90
354	133.31	114.60	103.65	95.89	89.86	84.94	159.33	185.34	204.91	221.51	236.36	250.05
355	133.65	114.89	103.92	96.13	90.09	85.16	159.37	185.39	204.97	221.57	236.42	250.12
356	133.91	115.12	104.12	96.32	90.27	85.33	159.51	185.55	205.14	221.76	236.62	250.33
357	134.28	115.43	104.41	96.59	90.52	85.56	159.51	185.56	205.15	221.77	236.64	250.35
358	134.57	115.68	104.63	96.79	90.71	85.74	159.62	185.69	205.29	221.92	236.80	250.52

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
359	134.87	115.94	104.87	97.01	90.91	85.94	159.71	185.79	205.40	222.04	236.92	250.65
360	135.14	116.17	105.08	97.21	91.10	86.11	159.83	185.93	205.56	222.21	237.11	250.85
361	135.48	116.46	105.34	97.45	91.32	86.32	159.88	185.98	205.62	222.28	237.18	250.92
362	135.80	116.74	105.59	97.68	91.54	86.53	159.94	186.06	205.71	222.37	237.28	251.02
363	136.00	116.91	105.74	97.82	91.67	86.65	160.15	186.30	205.97	222.66	237.58	251.35
364	136.36	117.22	106.03	98.08	91.92	86.89	160.16	186.31	205.99	222.67	237.60	251.36
365	136.70	117.51	106.29	98.32	92.14	87.10	160.21	186.37	206.05	222.74	237.67	251.44
366	136.95	117.73	106.48	98.50	92.32	87.26	160.35	186.53	206.23	222.93	237.88	251.66
367	137.25	117.98	106.72	98.72	92.52	87.45	160.44	186.64	206.34	223.06	238.01	251.80
368	137.65	118.33	107.03	99.01	92.79	87.71	160.41	186.60	206.30	223.01	237.96	251.75
369	137.85	118.50	107.19	99.15	92.93	87.84	160.61	186.83	206.56	223.29	238.26	252.06
370	138.16	118.77	107.42	99.37	93.13	88.03	160.68	186.92	206.66	223.40	238.37	252.19
371	138.50	119.06	107.69	99.62	93.36	88.25	160.72	186.96	206.70	223.44	238.42	252.24
372	138.84	119.35	107.95	99.86	93.59	88.46	160.77	187.02	206.76	223.51	238.49	252.31
373	139.05	119.53	108.12	100.02	93.73	88.60	160.95	187.23	207.00	223.77	238.77	252.60
374	139.38	119.82	108.37	100.25	93.95	88.81	161.00	187.29	207.07	223.84	238.84	252.68
375	139.76	120.15	108.67	100.53	94.21	89.05	160.99	187.27	207.05	223.82	238.82	252.66
376	140.12	120.46	108.95	100.79	94.46	89.28	161.00	187.29	207.06	223.84	238.84	252.68
377	140.39	120.69	109.16	100.98	94.64	89.45	161.12	187.43	207.22	224.01	239.02	252.87
378	140.71	120.96	109.40	101.21	94.85	89.65	161.19	187.51	207.31	224.10	239.12	252.97
379	141.00	121.21	109.63	101.42	95.04	89.84	161.28	187.61	207.43	224.23	239.26	253.12
380	141.22	121.40	109.80	101.58	95.19	89.98	161.45	187.81	207.65	224.46	239.51	253.39
381	141.48	121.62	110.00	101.76	95.37	90.15	161.58	187.96	207.81	224.64	239.70	253.59
382	141.83	121.92	110.27	102.01	95.60	90.37	161.61	187.99	207.84	224.68	239.74	253.63
383	142.14	122.19	110.52	102.24	95.82	90.57	161.67	188.07	207.93	224.77	239.83	253.73
384	142.38	122.39	110.70	102.41	95.98	90.72	161.82	188.24	208.12	224.98	240.06	253.97
385	142.74	122.70	110.98	102.67	96.22	90.95	161.84	188.26	208.14	225.00	240.08	253.99
386	143.04	122.96	111.22	102.88	96.42	91.14	161.92	188.35	208.24	225.11	240.20	254.12
387	143.40	123.27	111.49	103.14	96.66	91.37	161.93	188.37	208.26	225.13	240.22	254.14
388	143.71	123.54	111.74	103.37	96.87	91.57	161.99	188.44	208.34	225.21	240.31	254.24
389	143.96	123.76	111.94	103.55	97.04	91.73	162.13	188.60	208.51	225.40	240.51	254.45
390	144.29	124.03	112.19	103.78	97.26	91.94	162.18	188.66	208.58	225.47	240.59	254.53
391	144.51	124.23	112.36	103.94	97.41	92.08	162.34	188.84	208.79	225.70	240.83	254.78
392	144.75	124.44	112.55	104.12	97.58	92.23	162.48	189.01	208.97	225.90	241.04	255.01
393	145.23	124.84	112.92	104.46	97.90	92.53	162.37	188.88	208.82	225.74	240.87	254.82
394	145.36	124.95	113.02	104.55	97.98	92.62	162.64	189.19	209.17	226.11	241.27	255.25
395	145.80	125.34	113.37	104.87	98.28	92.90	162.55	189.09	209.06	225.99	241.14	255.11
396	146.12	125.61	113.61	105.10	98.50	93.10	162.60	189.15	209.13	226.07	241.22	255.20
397	146.27	125.74	113.73	105.21	98.60	93.20	162.85	189.44	209.45	226.41	241.59	255.59
398	146.74	126.14	114.09	105.54	98.91	93.50	162.74	189.31	209.30	226.26	241.42	255.41
399	147.04	126.40	114.33	105.76	99.12	93.69	162.82	189.40	209.40	226.36	241.53	255.53
400	147.29	126.62	114.52	105.94	99.29	93.85	162.94	189.55	209.57	226.54	241.73	255.73

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
401	147.58	126.86	114.75	106.15	99.48	94.03	163.03	189.65	209.68	226.66	241.85	255.87
402	147.89	127.13	114.99	106.38	99.69	94.23	163.09	189.72	209.76	226.74	241.94	255.96
403	148.13	127.34	115.17	106.54	99.85	94.38	163.24	189.89	209.94	226.95	242.16	256.19
404	148.48	127.64	115.44	106.79	100.09	94.60	163.26	189.92	209.97	226.98	242.19	256.23
405	148.77	127.89	115.68	107.01	100.29	94.79	163.34	190.01	210.07	227.09	242.31	256.35
406	149.10	128.17	115.93	107.24	100.50	95.00	163.38	190.06	210.13	227.15	242.38	256.42
407	149.37	128.40	116.14	107.44	100.69	95.17	163.49	190.18	210.26	227.29	242.53	256.58
408	149.66	128.65	116.36	107.64	100.88	95.36	163.58	190.28	210.38	227.42	242.66	256.72
409	149.90	128.86	116.55	107.82	101.04	95.51	163.71	190.44	210.55	227.61	242.87	256.94
410	150.34	129.24	116.89	108.14	101.34	95.79	163.63	190.35	210.45	227.49	242.74	256.81
411	150.51	129.38	117.02	108.25	101.45	95.90	163.85	190.60	210.73	227.80	243.07	257.15
412	150.79	129.62	117.24	108.46	101.65	96.08	163.94	190.71	210.84	227.92	243.20	257.29
413	151.25	130.02	117.60	108.79	101.95	96.37	163.84	190.59	210.71	227.78	243.05	257.13
414	151.50	130.23	117.79	108.97	102.12	96.53	163.96	190.74	210.88	227.96	243.24	257.33
415	151.82	130.51	118.04	109.20	102.34	96.73	164.01	190.79	210.94	228.03	243.31	257.41
416	152.17	130.81	118.32	109.45	102.57	96.96	164.03	190.81	210.96	228.05	243.33	257.43
417	152.43	131.04	118.52	109.64	102.75	97.13	164.14	190.94	211.10	228.20	243.49	257.60
418	152.65	131.23	118.69	109.80	102.90	97.27	164.29	191.12	211.30	228.41	243.72	257.85
419	153.00	131.53	118.97	110.05	103.14	97.49	164.31	191.14	211.32	228.44	243.75	257.87
420	153.30	131.78	119.20	110.27	103.34	97.68	164.38	191.22	211.42	228.54	243.86	257.99
421	153.58	132.02	119.41	110.46	103.52	97.85	164.48	191.33	211.54	228.67	244.00	258.14
422	153.91	132.30	119.67	110.70	103.75	98.06	164.52	191.38	211.59	228.72	244.06	258.20
423	154.20	132.56	119.90	110.91	103.95	98.25	164.59	191.46	211.68	228.83	244.16	258.31
424	154.52	132.83	120.14	111.14	104.16	98.46	164.64	191.52	211.75	228.90	244.24	258.39
425	154.78	133.05	120.35	111.33	104.34	98.62	164.75	191.65	211.89	229.05	244.40	258.57
426	155.15	133.37	120.63	111.60	104.59	98.86	164.74	191.64	211.88	229.04	244.39	258.55
427	155.38	133.57	120.81	111.76	104.74	99.00	164.89	191.81	212.07	229.24	244.61	258.79
428	155.75	133.88	121.10	112.02	104.99	99.24	164.88	191.81	212.06	229.24	244.60	258.78
429	156.10	134.19	121.37	112.28	105.23	99.46	164.89	191.82	212.07	229.25	244.62	258.79
430	156.35	134.40	121.56	112.46	105.39	99.62	165.02	191.96	212.23	229.42	244.80	258.99
431	156.53	134.56	121.71	112.59	105.52	99.74	165.21	192.18	212.48	229.68	245.08	259.28
432	156.94	134.91	122.03	112.88	105.79	100.00	165.16	192.13	212.41	229.62	245.01	259.21
433	157.25	135.18	122.27	113.11	106.00	100.20	165.21	192.19	212.48	229.69	245.09	259.29
434	157.64	135.51	122.57	113.39	106.26	100.44	165.19	192.16	212.45	229.66	245.05	259.25
435	157.85	135.69	122.73	113.54	106.41	100.58	165.35	192.34	212.65	229.88	245.29	259.50
436	158.11	135.92	122.94	113.72	106.58	100.74	165.45	192.47	212.79	230.03	245.45	259.67
437	158.39	136.16	123.16	113.93	106.77	100.92	165.54	192.57	212.90	230.14	245.57	259.80
438	158.73	136.45	123.42	114.17	107.00	101.14	165.56	192.60	212.93	230.18	245.61	259.84
439	159.09	136.76	123.70	114.43	107.24	101.37	165.57	192.60	212.94	230.18	245.61	259.85
440	159.42	137.04	123.95	114.67	107.46	101.58	165.60	192.64	212.98	230.23	245.67	259.90
441	159.69	137.27	124.16	114.86	107.64	101.75	165.70	192.75	213.11	230.37	245.81	260.05
442	159.98	137.52	124.39	115.07	107.84	101.93	165.77	192.84	213.20	230.47	245.92	260.17

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
443	160.27	137.77	124.61	115.28	108.03	102.12	165.85	192.93	213.30	230.58	246.04	260.29
444	160.59	138.05	124.87	115.51	108.25	102.33	165.88	192.97	213.35	230.63	246.09	260.35
445	160.79	138.22	125.02	115.65	108.39	102.45	166.05	193.17	213.57	230.86	246.34	260.61
446	161.12	138.51	125.28	115.89	108.61	102.66	166.09	193.20	213.61	230.91	246.39	260.66
447	161.51	138.84	125.58	116.17	108.87	102.91	166.06	193.17	213.57	230.87	246.35	260.62
448	161.79	139.08	125.79	116.37	109.06	103.09	166.14	193.27	213.68	230.99	246.47	260.75
449	162.10	139.35	126.04	116.60	109.27	103.29	166.19	193.33	213.74	231.05	246.54	260.83
450	162.43	139.63	126.30	116.83	109.50	103.50	166.22	193.36	213.78	231.10	246.59	260.87
451	162.80	139.95	126.58	117.10	109.74	103.73	166.22	193.35	213.77	231.09	246.58	260.87
452	162.92	140.05	126.67	117.18	109.82	103.81	166.47	193.65	214.09	231.43	246.95	261.26
453	163.32	140.40	126.99	117.47	110.09	104.06	166.42	193.59	214.03	231.37	246.88	261.18
454	163.61	140.65	127.21	117.68	110.29	104.25	166.49	193.68	214.13	231.47	246.99	261.30
455	163.85	140.85	127.40	117.85	110.45	104.40	166.62	193.82	214.29	231.65	247.18	261.50
456	164.21	141.16	127.68	118.11	110.69	104.63	166.62	193.82	214.29	231.64	247.17	261.49
457	164.46	141.37	127.87	118.29	110.86	104.79	166.73	193.95	214.44	231.80	247.34	261.67
458	164.72	141.60	128.08	118.48	111.04	104.96	166.83	194.06	214.56	231.94	247.48	261.82
459	165.06	141.89	128.34	118.72	111.26	105.17	166.85	194.09	214.59	231.97	247.52	261.86
460	165.36	142.15	128.57	118.94	111.47	105.36	166.91	194.16	214.66	232.05	247.60	261.95
461	165.72	142.46	128.85	119.20	111.71	105.59	166.91	194.16	214.67	232.05	247.61	261.95
462	166.00	142.70	129.07	119.40	111.90	105.77	166.99	194.26	214.77	232.17	247.73	262.08
463	166.23	142.90	129.25	119.57	112.06	105.92	167.11	194.40	214.93	232.34	247.91	262.27
464	166.51	143.14	129.46	119.76	112.24	106.09	167.20	194.50	215.04	232.46	248.04	262.41
465	166.88	143.45	129.75	120.03	112.49	106.33	167.19	194.49	215.02	232.44	248.02	262.39
466	167.16	143.70	129.97	120.23	112.68	106.51	167.27	194.58	215.12	232.55	248.14	262.51
467	167.44	143.94	130.19	120.44	112.87	106.69	167.34	194.66	215.22	232.65	248.25	262.63
468	167.82	144.26	130.48	120.71	113.12	106.93	167.33	194.65	215.20	232.63	248.23	262.61
469	168.13	144.53	130.72	120.93	113.33	107.13	167.37	194.70	215.26	232.70	248.30	262.68
470	168.33	144.70	130.88	121.07	113.47	107.25	167.53	194.89	215.47	232.92	248.53	262.93
471	168.73	145.05	131.20	121.37	113.74	107.51	167.48	194.83	215.40	232.85	248.46	262.85
472	168.92	145.21	131.34	121.50	113.87	107.63	167.65	195.02	215.62	233.08	248.70	263.11
473	169.29	145.53	131.63	121.77	114.12	107.87	167.64	195.01	215.61	233.07	248.69	263.10
474	169.54	145.75	131.82	121.95	114.29	108.03	167.75	195.14	215.74	233.21	248.85	263.27
475	169.87	146.03	132.08	122.18	114.51	108.24	167.78	195.17	215.78	233.26	248.89	263.32
476	170.17	146.29	132.31	122.40	114.71	108.43	167.83	195.24	215.85	233.33	248.98	263.40
477	170.46	146.53	132.54	122.61	114.90	108.61	167.90	195.32	215.94	233.43	249.08	263.51
478	170.80	146.82	132.80	122.85	115.13	108.83	167.92	195.34	215.96	233.46	249.10	263.54
479	171.11	147.09	133.04	123.08	115.34	109.03	167.96	195.38	216.02	233.51	249.17	263.60
480	171.39	147.33	133.26	123.27	115.53	109.20	168.04	195.48	216.12	233.63	249.29	263.73
481	171.80	147.69	133.58	123.57	115.81	109.47	167.99	195.42	216.05	233.55	249.21	263.65
482	171.93	147.80	133.68	123.67	115.90	109.55	168.20	195.67	216.33	233.85	249.53	263.99
483	172.32	148.13	133.98	123.94	116.16	109.79	168.18	195.64	216.30	233.82	249.49	263.95
484	172.63	148.40	134.23	124.17	116.37	109.99	168.22	195.69	216.35	233.87	249.55	264.01

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
485	172.94	148.67	134.47	124.39	116.58	110.19	168.27	195.74	216.41	233.94	249.62	264.08
486	173.28	148.96	134.73	124.64	116.81	110.41	168.28	195.75	216.43	233.96	249.64	264.10
487	173.49	149.14	134.90	124.79	116.95	110.55	168.42	195.92	216.61	234.15	249.85	264.33
488	173.79	149.40	135.13	125.00	117.15	110.73	168.48	195.99	216.68	234.23	249.93	264.42
489	174.14	149.70	135.40	125.25	117.38	110.96	168.49	196.00	216.69	234.24	249.95	264.43
490	174.40	149.92	135.60	125.44	117.56	111.12	168.58	196.10	216.81	234.37	250.08	264.57
491	174.69	150.17	135.82	125.65	117.75	111.30	168.65	196.18	216.90	234.47	250.18	264.68
492	175.03	150.46	136.09	125.89	117.98	111.52	168.66	196.20	216.92	234.49	250.21	264.70
493	175.29	150.69	136.30	126.09	118.16	111.69	168.74	196.30	217.03	234.60	250.33	264.83
494	175.63	150.98	136.55	126.32	118.39	111.90	168.77	196.32	217.06	234.64	250.36	264.87
495	175.87	151.19	136.75	126.50	118.56	112.06	168.87	196.44	217.19	234.78	250.52	265.03
496	176.23	151.49	137.02	126.76	118.79	112.29	168.87	196.44	217.19	234.78	250.52	265.03
497	176.45	151.68	137.19	126.92	118.94	112.43	169.00	196.60	217.36	234.96	250.71	265.24
498	176.72	151.92	137.41	127.11	119.13	112.60	169.08	196.69	217.46	235.07	250.83	265.36
499	177.22	152.34	137.79	127.47	119.46	112.92	168.95	196.53	217.29	234.88	250.63	265.15
500	177.41	152.51	137.94	127.61	119.59	113.04	169.10	196.71	217.48	235.09	250.85	265.39
501	177.65	152.72	138.13	127.78	119.75	113.19	169.21	196.84	217.62	235.25	251.02	265.56
502	178.06	153.07	138.45	128.08	120.03	113.46	169.16	196.78	217.55	235.17	250.94	265.48
503	178.31	153.28	138.64	128.26	120.20	113.61	169.25	196.89	217.68	235.31	251.09	265.63
504	178.64	153.57	138.90	128.49	120.42	113.83	169.28	196.92	217.71	235.34	251.12	265.67
505	178.88	153.77	139.08	128.66	120.58	113.98	169.39	197.05	217.86	235.50	251.29	265.85
506	179.19	154.04	139.33	128.89	120.79	114.18	169.43	197.09	217.90	235.55	251.34	265.90
507	179.53	154.33	139.59	129.13	121.02	114.39	169.44	197.11	217.92	235.57	251.36	265.93
508	179.73	154.50	139.75	129.28	121.15	114.52	169.59	197.28	218.11	235.78	251.58	266.16
509	180.06	154.79	140.00	129.51	121.38	114.73	169.61	197.30	218.14	235.80	251.61	266.19
510	180.52	155.18	140.36	129.84	121.69	115.02	169.51	197.19	218.01	235.67	251.46	266.04
511	180.69	155.33	140.50	129.97	121.80	115.13	169.68	197.38	218.23	235.90	251.72	266.30
512	180.95	155.55	140.69	130.15	121.98	115.30	169.77	197.49	218.35	236.03	251.85	266.45
513	181.30	155.85	140.96	130.40	122.21	115.52	169.78	197.50	218.35	236.04	251.86	266.45
514	181.61	156.12	141.21	130.63	122.42	115.72	169.81	197.54	218.40	236.09	251.91	266.51
515	181.90	156.37	141.43	130.84	122.62	115.90	169.87	197.61	218.48	236.17	252.01	266.61
516	182.24	156.66	141.70	131.08	122.85	116.12	169.88	197.62	218.49	236.18	252.02	266.62
517	182.52	156.90	141.92	131.29	123.04	116.30	169.95	197.70	218.58	236.28	252.12	266.73
518	182.85	157.18	142.17	131.52	123.26	116.51	169.98	197.73	218.61	236.32	252.16	266.77
519	183.10	157.40	142.37	131.70	123.43	116.67	170.07	197.84	218.73	236.45	252.30	266.91
520	183.36	157.62	142.57	131.88	123.60	116.83	170.16	197.94	218.85	236.57	252.43	267.06
521	183.77	157.98	142.89	132.18	123.88	117.09	170.10	197.88	218.77	236.49	252.35	266.97
522	184.02	158.19	143.09	132.36	124.05	117.25	170.19	197.98	218.89	236.62	252.48	267.11
523	184.26	158.40	143.27	132.54	124.21	117.41	170.30	198.10	219.02	236.76	252.64	267.27
524	184.59	158.68	143.53	132.77	124.43	117.62	170.32	198.13	219.05	236.80	252.67	267.31
525	184.86	158.91	143.73	132.96	124.61	117.78	170.40	198.23	219.16	236.91	252.79	267.44
526	185.18	159.18	143.98	133.19	124.83	117.99	170.43	198.26	219.20	236.95	252.83	267.48

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
527	185.64	159.58	144.34	133.53	125.14	118.28	170.33	198.14	219.06	236.81	252.68	267.32
528	185.74	159.67	144.42	133.60	125.21	118.35	170.56	198.41	219.36	237.13	253.02	267.68
529	186.18	160.04	144.76	133.91	125.50	118.63	170.48	198.32	219.26	237.02	252.91	267.56
530	186.40	160.23	144.93	134.07	125.65	118.77	170.61	198.46	219.42	237.19	253.09	267.76
531	186.73	160.52	145.19	134.31	125.87	118.98	170.62	198.48	219.44	237.22	253.12	267.78
532	187.01	160.76	145.41	134.51	126.06	119.16	170.68	198.55	219.52	237.30	253.20	267.88
533	187.32	161.02	145.64	134.73	126.27	119.35	170.73	198.60	219.58	237.36	253.27	267.95
534	187.64	161.30	145.89	134.96	126.48	119.56	170.75	198.64	219.61	237.40	253.31	267.99
535	187.92	161.55	146.12	135.17	126.68	119.74	170.81	198.70	219.69	237.48	253.40	268.08
536	188.29	161.86	146.40	135.43	126.92	119.97	170.80	198.69	219.67	237.46	253.38	268.06
537	188.52	162.06	146.58	135.60	127.08	120.12	170.91	198.81	219.81	237.61	253.54	268.23
538	188.88	162.36	146.86	135.85	127.32	120.35	170.91	198.81	219.81	237.61	253.54	268.23
539	189.17	162.62	147.09	136.07	127.52	120.53	170.96	198.87	219.87	237.68	253.61	268.31
540	189.53	162.93	147.37	136.33	127.76	120.76	170.95	198.86	219.86	237.67	253.60	268.29
541	189.62	163.01	147.44	136.39	127.82	120.82	171.18	199.13	220.16	237.99	253.95	268.66
542	190.04	163.37	147.76	136.69	128.10	121.09	171.12	199.06	220.08	237.91	253.86	268.57
543	190.38	163.66	148.03	136.94	128.33	121.31	171.13	199.07	220.09	237.92	253.87	268.58
544	190.71	163.94	148.28	137.17	128.56	121.52	171.15	199.09	220.12	237.95	253.90	268.61
545	190.98	164.17	148.49	137.37	128.74	121.69	171.22	199.18	220.21	238.05	254.00	268.72
546	191.26	164.41	148.71	137.57	128.93	121.86	171.29	199.25	220.29	238.14	254.10	268.82
547	191.52	164.63	148.91	137.75	129.10	122.03	171.37	199.35	220.40	238.25	254.23	268.96
548	191.93	164.99	149.23	138.05	129.38	122.29	171.31	199.28	220.33	238.17	254.14	268.86
549	192.23	165.24	149.46	138.26	129.58	122.48	171.36	199.34	220.39	238.24	254.21	268.94
550	192.44	165.43	149.63	138.42	129.72	122.62	171.48	199.48	220.55	238.41	254.39	269.13
551	192.83	165.76	149.93	138.69	129.98	122.86	171.45	199.44	220.51	238.36	254.34	269.08
552	193.02	165.92	150.08	138.83	130.11	122.98	171.59	199.61	220.69	238.56	254.55	269.30
553	193.28	166.15	150.28	139.02	130.29	123.15	171.67	199.70	220.79	238.67	254.67	269.43
554	193.66	166.47	150.57	139.29	130.54	123.39	171.64	199.67	220.75	238.63	254.63	269.38
555	193.96	166.73	150.81	139.51	130.75	123.58	171.69	199.72	220.81	238.69	254.69	269.45
556	194.22	166.96	151.01	139.70	130.92	123.75	171.76	199.81	220.91	238.80	254.80	269.57
557	194.53	167.22	151.25	139.92	131.13	123.95	171.80	199.85	220.96	238.85	254.86	269.63
558	194.80	167.46	151.47	140.12	131.31	124.12	171.87	199.93	221.04	238.94	254.96	269.73
559	195.18	167.78	151.76	140.39	131.57	124.36	171.84	199.90	221.01	238.91	254.93	269.70
560	195.40	167.97	151.93	140.55	131.72	124.50	171.96	200.03	221.16	239.07	255.09	269.87
561	195.76	168.28	152.21	140.80	131.96	124.73	171.95	200.02	221.15	239.06	255.08	269.86
562	196.03	168.52	152.42	141.00	132.14	124.91	172.01	200.10	221.23	239.15	255.18	269.96
563	196.36	168.80	152.68	141.24	132.37	125.12	172.03	200.12	221.25	239.17	255.20	269.99
564	196.60	169.00	152.86	141.41	132.52	125.26	172.13	200.24	221.38	239.31	255.35	270.15
565	197.00	169.35	153.18	141.70	132.80	125.52	172.08	200.18	221.31	239.24	255.28	270.07
566	197.23	169.54	153.35	141.86	132.95	125.67	172.19	200.30	221.46	239.39	255.44	270.24
567	197.55	169.82	153.60	142.09	133.17	125.87	172.21	200.33	221.48	239.42	255.47	270.27
568	197.87	170.10	153.85	142.33	133.38	126.08	172.23	200.35	221.51	239.45	255.50	270.31

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
569	198.12	170.31	154.04	142.50	133.55	126.24	172.32	200.46	221.63	239.58	255.63	270.45
570	198.47	170.61	154.32	142.76	133.79	126.46	172.32	200.45	221.62	239.57	255.63	270.44
571	198.70	170.81	154.49	142.92	133.94	126.60	172.42	200.58	221.76	239.72	255.79	270.61
572	199.03	171.09	154.75	143.16	134.16	126.82	172.44	200.59	221.77	239.74	255.81	270.63
573	199.41	171.42	155.05	143.43	134.42	127.06	172.41	200.56	221.74	239.70	255.77	270.59
574	199.64	171.62	155.23	143.60	134.58	127.21	172.51	200.67	221.87	239.84	255.91	270.74
575	199.96	171.90	155.48	143.83	134.79	127.41	172.53	200.70	221.90	239.87	255.95	270.78
576	200.27	172.16	155.72	144.05	135.00	127.61	172.56	200.74	221.94	239.91	256.00	270.83
577	200.63	172.47	156.00	144.31	135.25	127.84	172.55	200.73	221.92	239.90	255.98	270.81
578	200.98	172.77	156.27	144.56	135.48	128.06	172.56	200.73	221.93	239.91	255.99	270.82
579	201.15	172.92	156.40	144.68	135.59	128.17	172.71	200.90	222.12	240.11	256.21	271.05
580	201.36	173.10	156.57	144.84	135.74	128.30	172.82	201.04	222.27	240.27	256.38	271.23
581	201.73	173.42	156.85	145.10	135.99	128.54	172.80	201.02	222.25	240.25	256.35	271.20
582	202.07	173.71	157.11	145.34	136.21	128.75	172.81	201.03	222.26	240.26	256.36	271.22
583	202.39	173.98	157.37	145.58	136.43	128.96	172.83	201.05	222.28	240.29	256.39	271.25
584	202.63	174.19	157.55	145.75	136.59	129.11	172.92	201.16	222.40	240.41	256.53	271.40
585	202.90	174.42	157.76	145.94	136.77	129.28	172.99	201.24	222.49	240.51	256.63	271.50
586	203.26	174.73	158.04	146.20	137.01	129.51	172.98	201.23	222.48	240.50	256.62	271.49
587	203.61	175.03	158.31	146.45	137.25	129.73	172.98	201.23	222.48	240.49	256.61	271.48
588	203.79	175.19	158.46	146.58	137.38	129.85	173.12	201.38	222.65	240.68	256.81	271.69
589	204.13	175.48	158.72	146.83	137.60	130.07	173.12	201.39	222.66	240.69	256.82	271.70
590	204.52	175.82	159.02	147.11	137.87	130.32	173.08	201.35	222.61	240.64	256.77	271.65
591	204.68	175.95	159.15	147.22	137.97	130.42	173.24	201.53	222.81	240.86	257.01	271.90
592	205.13	176.34	159.50	147.55	138.28	130.70	173.16	201.43	222.70	240.74	256.88	271.76
593	205.42	176.59	159.72	147.75	138.47	130.89	173.21	201.49	222.76	240.81	256.95	271.84
594	205.61	176.75	159.87	147.89	138.60	131.01	173.34	201.64	222.93	240.99	257.14	272.04
595	205.95	177.04	160.13	148.13	138.83	131.22	173.35	201.65	222.94	241.00	257.16	272.06
596	206.20	177.26	160.33	148.32	139.00	131.39	173.42	201.74	223.04	241.11	257.27	272.18
597	206.50	177.51	160.56	148.53	139.20	131.57	173.46	201.79	223.10	241.17	257.33	272.24
598	206.89	177.85	160.86	148.81	139.46	131.82	173.42	201.74	223.05	241.11	257.27	272.18
599	207.18	178.10	161.09	149.02	139.66	132.01	173.47	201.80	223.11	241.18	257.35	272.26
600	207.59	178.46	161.41	149.32	139.94	132.27	173.42	201.73	223.03	241.10	257.26	272.17
601	207.77	178.60	161.54	149.44	140.05	132.38	173.56	201.90	223.22	241.30	257.47	272.39
602	208.12	178.91	161.82	149.70	140.29	132.61	173.55	201.89	223.21	241.28	257.46	272.38
603	208.28	179.04	161.94	149.81	140.40	132.71	173.71	202.08	223.41	241.51	257.70	272.63
604	208.73	179.43	162.29	150.13	140.70	132.99	173.63	201.97	223.30	241.39	257.57	272.50
605	209.00	179.66	162.50	150.33	140.88	133.17	173.69	202.05	223.38	241.47	257.66	272.59
606	209.34	179.96	162.77	150.57	141.11	133.39	173.69	202.05	223.38	241.48	257.66	272.59
607	209.59	180.17	162.96	150.75	141.28	133.54	173.77	202.14	223.49	241.59	257.78	272.72
608	209.82	180.37	163.14	150.92	141.44	133.69	173.86	202.25	223.61	241.72	257.93	272.87
609	210.12	180.62	163.37	151.13	141.64	133.88	173.90	202.30	223.66	241.78	257.98	272.93
610	210.52	180.97	163.69	151.42	141.91	134.14	173.85	202.24	223.60	241.71	257.91	272.85

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
611	210.73	181.15	163.85	151.57	142.05	134.27	173.97	202.38	223.75	241.87	258.08	273.03
612	210.97	181.36	164.04	151.75	142.21	134.42	174.05	202.47	223.85	241.98	258.20	273.16
613	211.34	181.67	164.32	152.01	142.46	134.66	174.03	202.45	223.83	241.96	258.18	273.14
614	211.64	181.93	164.56	152.23	142.66	134.85	174.07	202.49	223.87	242.01	258.23	273.19
615	212.08	182.32	164.90	152.55	142.96	135.13	173.99	202.40	223.77	241.89	258.11	273.06
616	212.32	182.52	165.09	152.72	143.12	135.29	174.07	202.50	223.88	242.01	258.24	273.20
617	212.53	182.70	165.25	152.87	143.26	135.42	174.19	202.63	224.03	242.17	258.41	273.38
618	212.86	182.98	165.50	153.10	143.49	135.63	174.20	202.64	224.04	242.19	258.42	273.40
619	213.00	183.10	165.61	153.21	143.58	135.72	174.37	202.84	224.26	242.42	258.67	273.66
620	213.44	183.48	165.95	153.52	143.88	135.99	174.29	202.75	224.16	242.31	258.56	273.54
621	213.75	183.75	166.20	153.75	144.09	136.20	174.31	202.78	224.19	242.35	258.59	273.58
622	214.11	184.06	166.48	154.00	144.33	136.42	174.30	202.76	224.18	242.33	258.58	273.56
623	214.32	184.24	166.64	154.16	144.47	136.56	174.41	202.89	224.31	242.48	258.73	273.73
624	214.60	184.48	166.86	154.36	144.66	136.74	174.46	202.95	224.38	242.56	258.82	273.81
625	215.01	184.83	167.17	154.65	144.93	136.99	174.41	202.89	224.32	242.49	258.74	273.73
626	215.20	185.00	167.33	154.79	145.07	137.12	174.53	203.03	224.47	242.65	258.92	273.92
627	215.58	185.32	167.62	155.06	145.32	137.36	174.51	203.00	224.44	242.61	258.88	273.88
628	215.89	185.58	167.86	155.28	145.53	137.56	174.54	203.03	224.47	242.66	258.92	273.92
629	216.30	185.94	168.18	155.58	145.81	137.82	174.48	202.97	224.40	242.57	258.83	273.83
630	216.45	186.07	168.29	155.68	145.90	137.91	174.64	203.15	224.61	242.80	259.07	274.09
631	216.73	186.31	168.52	155.89	146.10	138.09	174.69	203.21	224.67	242.86	259.14	274.16
632	216.99	186.53	168.71	156.07	146.27	138.26	174.76	203.29	224.76	242.96	259.25	274.27
633	217.33	186.83	168.23	156.32	146.51	138.48	174.76	203.29	225.76	242.96	259.24	274.26
634	217.67	187.12	169.25	156.56	146.73	138.69	174.76	203.29	224.76	242.97	259.25	274.28
635	218.02	187.41	169.51	156.81	146.96	138.91	174.76	203.29	224.76	242.96	259.25	274.27
636	218.21	187.59	169.67	156.96	147.10	139.04	174.87	203.43	224.91	243.12	259.42	274.45
637	218.48	187.81	169.87	157.14	147.27	139.21	174.94	203.50	224.99	243.22	259.52	274.56
638	218.84	188.12	170.16	157.41	147.52	139.44	174.92	203.48	224.97	243.19	259.49	274.53
639	219.15	188.39	170.39	157.63	147.72	139.63	174.95	203.52	225.01	243.23	259.54	274.58
640	219.48	188.68	170.65	157.87	147.95	139.85	174.96	203.52	225.02	243.24	259.55	274.58
641	219.73	188.89	170.84	158.04	148.12	140.00	175.04	203.62	225.12	243.35	259.66	274.71
642	220.00	189.12	171.06	158.24	148.30	140.18	175.09	203.68	225.19	243.43	259.75	274.80
643	220.36	189.43	171.34	158.50	148.54	140.41	175.08	203.66	225.17	243.41	259.72	274.77
644	220.70	189.73	171.60	158.75	148.77	140.63	175.08	203.66	225.17	243.41	259.72	274.77
645	220.98	189.96	171.82	158.94	148.96	140.80	175.13	203.73	225.24	243.48	259.80	274.86
646	221.16	190.12	171.96	159.08	149.08	140.92	175.26	203.87	225.40	243.66	259.99	275.05
647	221.54	190.44	172.25	159.35	149.34	141.16	175.23	203.84	225.37	243.62	259.95	275.01
648	221.97	190.81	172.59	159.66	149.63	141.43	175.16	203.76	225.28	243.52	259.85	274.91
649	222.13	190.95	172.71	159.77	149.74	141.53	175.30	203.93	225.46	243.72	260.06	275.13
650	222.55	191.31	173.04	160.08	150.02	141.80	175.24	203.85	225.38	243.64	259.97	275.03
651	222.70	191.44	173.16	160.18	150.12	141.90	175.39	204.03	225.58	243.85	260.19	275.27
652	223.14	191.82	173.50	160.50	150.42	142.18	175.31	203.94	225.48	243.74	260.08	275.15

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
653	223.42	192.06	173.72	160.70	150.61	142.36	175.36	204.00	225.54	243.81	260.15	275.22
654	223.78	192.37	174.00	160.96	150.85	142.59	175.35	203.98	225.52	243.78	260.13	275.20
655	224.07	192.62	174.23	161.17	151.05	142.77	175.39	204.03	225.57	243.84	260.18	275.26
656	224.34	192.85	174.43	161.36	151.22	142.94	175.45	204.10	225.65	243.92	260.27	275.36
657	224.53	193.01	174.58	161.50	151.35	143.06	175.57	204.23	225.80	244.09	260.45	275.54
658	224.82	193.26	174.80	161.71	151.55	143.25	175.61	204.28	225.85	244.15	260.51	275.61
659	225.12	193.52	175.04	161.92	151.75	143.44	175.64	204.32	225.89	244.19	260.56	275.65
660	225.58	193.92	175.39	162.25	152.06	143.73	175.55	204.21	225.78	244.06	260.42	275.51
661	225.77	194.08	175.54	162.39	152.19	143.85	175.67	204.35	225.93	244.23	260.60	275.70
662	226.08	194.35	175.79	162.62	152.40	144.05	175.69	204.38	225.96	244.26	260.63	275.73
663	226.49	194.70	176.10	162.91	152.68	144.31	175.64	204.31	225.89	244.18	260.55	275.65
664	226.72	194.90	176.29	163.08	152.83	144.46	175.72	204.41	226.00	244.30	260.68	275.78
665	226.92	195.07	176.44	163.22	152.96	144.58	175.84	204.55	226.15	244.46	260.85	275.96
666	227.15	195.27	176.62	163.38	153.12	144.73	175.92	204.64	226.25	244.58	260.97	276.09
667	227.48	195.54	176.84	163.61	153.35	144.94	175.93	204.66	226.30	244.60	260.98	276.11
668	227.78	195.82	177.10	163.85	153.57	145.13	175.96	204.68	226.31	244.62	260.99	276.16
669	228.13	196.09	177.38	164.08	153.81	145.36	175.95	204.70	226.29	244.63	260.97	276.15
670	228.51	196.40	177.60	164.32	154.01	145.58	175.92	204.68	226.35	244.65	261.02	276.13
671	228.79	196.68	177.89	164.57	154.23	145.78	175.97	204.70	226.31	244.64	261.04	276.17
672	229.19	197.02	178.21	164.85	154.50	146.04	175.92	204.65	226.26	244.58	260.98	276.10
673	229.30	197.11	178.29	164.93	154.57	146.10	176.10	204.86	226.49	244.83	261.25	276.38
674	229.64	197.40	178.55	165.17	154.80	146.32	176.10	204.86	226.49	244.84	261.25	276.39
675	230.00	197.71	178.83	165.43	155.04	146.55	176.09	204.84	226.47	244.82	261.23	276.36
676	230.33	198.00	179.09	165.67	155.26	146.76	176.10	204.85	226.48	244.82	261.24	276.37
677	230.63	198.25	179.32	165.88	155.46	146.95	176.13	204.89	226.52	244.87	261.29	276.43
678	230.85	198.45	179.49	166.04	155.61	147.09	176.22	204.99	226.64	245.00	261.42	276.57
679	231.21	198.76	179.77	166.30	155.86	147.32	176.20	204.97	226.62	244.97	261.39	276.54
680	231.52	199.02	180.01	166.52	156.06	147.52	176.23	205.00	226.65	245.01	261.43	276.58
681	231.75	199.22	180.19	166.69	156.22	147.66	176.31	205.10	226.76	245.12	261.55	276.71
682	232.09	199.52	180.46	166.94	156.45	147.88	176.31	205.10	226.75	245.12	261.55	276.71
683	232.27	199.67	180.60	167.07	156.57	148.00	176.43	205.24	226.91	245.29	261.73	276.90
684	232.81	200.13	181.02	167.45	156.93	148.34	176.28	205.07	226.72	245.08	261.51	276.67
685	232.97	200.27	181.14	167.57	157.04	148.44	176.42	205.22	226.89	245.27	261.71	276.87
686	233.28	200.54	181.38	167.79	157.25	148.64	176.44	205.25	226.92	245.30	261.75	276.91
687	233.61	200.82	181.64	168.03	157.47	148.85	176.45	205.26	226.94	245.32	261.76	276.93
688	233.84	201.02	181.82	168.20	157.63	149.00	176.53	205.35	227.04	245.42	261.88	277.05
689	234.22	201.34	182.11	168.47	157.88	149.24	176.50	205.32	227.00	245.39	261.84	277.01
690	234.48	201.57	182.32	168.66	158.06	149.41	176.56	205.39	227.08	245.47	261.92	277.10
691	234.86	201.90	182.61	168.93	158.32	149.65	176.53	205.35	227.04	245.43	261.88	277.05
692	235.07	202.08	182.78	169.08	158.46	149.78	176.63	205.46	227.16	245.56	262.02	277.20
693	235.33	202.30	182.98	169.27	158.64	149.95	176.69	205.53	227.24	245.64	262.11	277.30
694	235.68	202.60	183.25	169.52	158.87	150.17	176.68	205.53	227.23	245.63	262.10	277.29

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
695	236.04	202.91	183.53	169.78	159.11	150.40	176.67	205.51	227.22	245.62	262.08	277.27
696	236.29	203.12	183.72	169.95	159.28	150.55	176.74	205.59	227.30	245.71	262.18	277.38
697	236.64	203.42	183.99	170.21	159.51	150.78	176.73	205.58	227.29	245.70	262.17	277.36
698	236.83	203.59	184.15	170.35	159.65	150.90	176.83	205.71	227.43	245.85	262.33	277.53
699	237.12	203.83	184.37	170.55	159.84	151.08	176.87	205.76	227.48	245.91	262.39	277.60
700	237.46	204.13	184.63	170.80	160.07	151.30	176.87	205.75	227.48	245.90	262.38	277.59
701	237.87	204.48	184.95	171.09	160.34	151.56	176.82	205.69	227.41	245.83	262.31	277.51
702	238.19	204.76	185.20	171.33	160.56	151.77	176.83	205.71	227.43	245.85	262.33	277.53
703	238.42	204.96	185.38	171.49	160.72	151.92	176.91	205.80	227.53	245.96	262.45	277.65
704	238.60	205.11	185.52	171.62	160.83	152.03	177.04	205.94	227.69	246.13	262.63	277.85
705	238.89	205.36	185.75	171.83	161.03	152.21	177.07	205.98	227.73	246.18	262.68	277.90
706	239.42	205.82	186.16	172.21	161.39	152.55	176.92	205.81	227.55	245.98	262.46	277.67
707	239.48	205.87	186.21	172.25	161.43	152.59	177.13	206.05	227.81	246.26	262.77	278.00
708	239.93	206.25	186.55	172.57	161.73	152.87	177.05	205.96	227.71	246.16	262.66	277.88
709	240.10	206.40	186.69	172.70	161.85	152.98	177.18	206.11	227.87	246.33	262.84	278.07
710	240.54	206.78	187.03	173.01	162.14	153.26	177.10	206.02	227.78	246.22	262.73	277.95
711	240.71	206.92	187.16	173.13	162.26	153.37	177.23	206.17	227.94	246.40	262.92	278.15
712	241.20	207.34	187.54	173.49	162.59	153.69	177.11	206.03	227.79	246.24	262.75	277.97
713	241.38	207.50	187.68	173.62	162.71	153.80	177.23	206.17	227.94	246.41	262.92	278.16
714	241.67	207.74	187.90	173.82	162.90	153.98	177.27	206.21	227.99	246.46	262.98	278.21
715	241.87	207.92	188.06	173.97	163.04	154.11	177.37	206.33	228.11	246.59	263.12	278.36
716	242.25	208.25	188.36	174.25	163.30	154.36	177.33	206.29	228.07	246.55	263.07	278.32
717	242.72	208.65	188.72	174.58	163.62	154.65	177.24	206.18	227.95	246.42	262.93	278.17
718	242.93	208.84	188.89	174.74	163.76	154.79	177.33	206.29	228.07	246.54	263.07	278.31
719	243.16	209.03	189.06	174.90	163.91	154.93	177.41	206.38	228.18	246.66	263.19	278.44
720	243.56	209.37	189.37	175.19	164.18	155.19	177.37	206.33	228.12	246.60	263.13	278.37
721	243.89	209.66	189.63	175.43	164.40	155.40	177.37	206.34	228.12	246.60	263.13	278.38
722	244.22	209.94	189.89	175.66	164.63	155.61	177.38	206.34	228.13	246.61	263.14	278.39
723	244.49	210.17	190.10	175.85	164.81	155.78	177.43	206.40	228.20	246.68	263.22	278.47
724	244.66	210.32	190.23	175.98	164.92	155.89	177.55	206.54	228.36	246.85	263.40	278.66
725	245.04	210.65	190.53	176.25	165.18	156.13	177.52	206.51	228.31	246.81	263.35	278.61
726	245.20	210.78	190.65	176.37	165.29	156.23	177.65	206.66	228.48	246.98	263.54	278.81
727	245.62	211.15	190.98	176.67	165.57	156.50	177.59	206.59	228.40	246.90	263.45	278.72
728	245.88	211.37	191.18	176.85	165.74	156.67	177.65	206.66	228.48	246.98	263.54	278.81
729	246.24	211.67	191.46	177.11	165.99	156.89	177.63	206.64	228.46	246.96	263.52	278.79
730	246.46	211.86	191.63	177.27	166.13	157.03	177.72	206.74	228.57	247.08	263.64	278.92
731	246.76	212.13	191.87	177.49	166.34	157.23	177.74	206.76	228.60	247.11	263.68	278.96
732	247.13	212.45	192.15	177.76	166.59	157.47	177.72	206.74	228.57	247.08	263.64	278.92
733	247.50	212.76	192.44	178.02	166.84	157.70	177.69	206.71	228.54	247.05	263.61	278.88
734	247.69	212.93	192.59	178.16	166.97	157.82	177.80	206.83	228.67	247.19	263.77	279.05
735	248.07	213.25	192.88	178.43	167.22	158.06	177.77	206.80	228.63	247.15	263.72	279.00
736	248.33	213.48	193.09	178.62	167.40	158.23	177.83	206.86	228.71	247.23	263.80	279.09

Table B.1: Simulation Data for Picking Times (Medium Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
737	248.59	213.70	193.29	178.80	167.57	158.39	177.88	206.93	228.78	247.31	263.89	279.18
738	248.84	213.91	193.48	178.99	167.74	158.55	177.94	207.00	228.86	247.39	263.98	279.27
739	249.27	214.28	193.81	179.29	168.03	158.83	177.88	206.93	228.78	247.31	263.88	279.17
740	249.45	214.44	193.96	179.43	168.15	158.94	177.99	207.05	228.92	247.46	264.04	279.34
741	249.81	214.74	194.23	179.68	168.39	159.17	177.98	207.04	228.90	247.44	264.03	279.32
742	249.96	214.87	194.35	179.79	168.49	159.27	178.11	207.19	229.07	247.62	264.22	279.53
743	250.36	215.22	194.66	180.08	168.77	159.52	178.06	207.14	229.01	247.56	264.15	279.46
744	250.65	215.47	194.89	180.28	168.96	159.70	178.10	207.18	229.06	247.61	264.21	279.52
745	251.00	215.77	195.16	180.54	169.20	159.93	178.09	207.17	229.04	247.59	264.19	279.50
746	251.28	216.01	195.38	180.74	169.38	160.11	178.13	207.22	229.10	247.65	264.25	279.56
747	251.50	216.20	195.55	180.90	169.54	160.25	178.21	207.31	229.20	247.76	264.37	279.69
748	251.92	216.56	195.87	181.20	169.82	160.51	178.15	207.24	229.13	247.68	264.29	279.60
749	252.16	216.76	196.06	181.37	169.98	160.67	178.22	207.32	229.22	247.78	264.39	279.71
750	252.48	217.04	196.31	181.60	170.20	160.87	178.23	207.33	229.23	247.79	264.40	279.72

Table B.2: Simulation Data for Picking Times (High Rate).

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
1	1.29	1.11	1.01	0.93	0.87	0.82	46.35	53.92	59.61	64.44	68.76	72.74
2	2.27	1.95	1.77	1.63	1.53	1.45	52.81	61.43	67.92	73.42	78.34	82.88
3	2.92	2.51	2.27	2.10	1.97	1.86	61.65	71.71	79.29	85.71	91.45	96.75
4	3.79	3.26	2.95	2.73	2.55	2.41	63.33	73.67	81.45	88.05	93.95	99.39
5	4.37	3.75	3.40	3.14	2.94	2.78	68.69	79.91	88.34	95.50	101.90	107.81
6	5.11	4.39	3.97	3.68	3.44	3.26	70.45	81.96	90.61	97.95	104.52	110.57
7	5.57	4.79	4.33	4.01	3.75	3.55	75.40	87.71	96.97	104.83	111.86	118.34
8	6.30	5.41	4.89	4.53	4.24	4.01	76.25	88.70	98.07	106.01	113.12	119.67
9	6.94	5.97	5.40	4.99	4.68	4.42	77.82	90.52	100.08	108.19	115.44	122.13
10	7.38	6.35	5.74	5.31	4.98	4.70	81.27	94.54	104.52	112.99	120.56	127.55
11	7.86	6.76	6.11	5.66	5.30	5.01	83.94	97.65	107.96	116.70	124.52	131.74
12	8.25	7.09	6.41	5.93	5.56	5.25	87.32	101.57	112.30	121.40	129.53	137.04
13	9.02	7.75	7.01	6.49	6.08	5.75	86.51	100.63	111.26	120.27	128.33	135.77
14	9.40	8.08	7.31	6.76	6.34	5.99	89.36	103.95	114.93	124.23	132.56	140.24
15	9.96	8.57	7.75	7.17	6.72	6.35	90.32	105.07	116.16	125.57	133.99	141.75
16	10.50	9.02	8.16	7.55	7.08	6.69	91.45	106.38	117.62	127.14	135.66	143.52
17	10.95	9.41	8.51	7.87	7.38	6.98	93.17	108.39	119.83	129.54	138.22	146.23
18	11.52	9.90	8.95	8.28	7.76	7.34	93.78	109.09	120.61	130.38	139.12	147.18
19	11.94	10.27	9.29	8.59	8.05	7.61	95.46	111.04	122.77	132.71	141.61	149.81
20	12.51	10.75	9.73	9.00	8.43	7.97	95.94	111.61	123.39	133.38	142.33	150.57
21	12.85	11.04	9.99	9.24	8.66	8.18	98.09	114.11	126.16	136.37	145.52	153.95
22	13.28	11.42	10.33	9.55	8.95	8.46	99.40	115.63	127.84	138.19	147.46	156.00

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
23	13.57	11.67	10.55	9.76	9.15	8.65	101.68	118.28	130.77	141.36	150.84	159.58
24	14.22	12.22	11.05	10.22	9.58	9.06	101.30	117.84	130.28	140.83	150.27	158.98
25	14.65	12.59	11.39	10.54	9.88	9.33	102.39	119.11	131.69	142.35	151.90	160.70
26	15.03	12.92	11.69	10.81	10.13	9.58	103.76	120.70	133.45	144.25	153.92	162.84
27	15.46	13.29	12.02	11.12	10.42	9.85	104.78	121.89	134.76	145.68	155.44	164.45
28	15.82	13.60	12.30	11.38	10.66	10.08	106.23	123.57	136.62	147.69	157.59	166.72
29	16.45	14.14	12.79	11.83	11.09	10.48	105.77	123.04	136.03	147.05	156.91	166.00
30	16.89	14.52	13.14	12.15	11.39	10.76	106.54	123.94	137.03	148.13	158.05	167.21
31	17.13	14.72	13.32	12.32	11.55	10.91	108.60	126.33	139.67	150.99	161.11	170.44
32	17.51	15.05	13.62	12.60	11.81	11.16	109.63	127.53	141.00	152.42	162.64	172.06
33	17.95	15.43	13.96	12.91	12.10	11.44	110.31	128.32	141.87	153.36	163.64	173.12
34	18.34	15.77	14.26	13.19	12.37	11.69	111.21	129.36	143.02	154.61	164.97	174.53
35	18.80	16.16	14.61	13.52	12.67	11.98	111.72	129.96	143.69	155.33	165.74	175.34
36	19.24	16.54	14.96	13.84	12.97	12.26	112.27	130.61	144.40	156.09	166.56	176.21
37	19.57	16.82	15.21	14.07	13.19	12.47	113.45	131.98	145.92	157.73	168.31	178.06
38	20.16	17.33	15.67	14.50	13.59	12.84	113.12	131.59	145.49	157.27	167.81	177.53
39	20.38	17.52	15.85	14.66	13.74	12.99	114.79	133.54	147.64	159.59	170.29	180.16
40	20.73	17.82	16.12	14.91	13.98	13.21	115.75	134.65	148.87	160.92	171.71	181.66
41	21.18	18.20	16.47	15.23	14.27	13.49	116.17	135.14	149.41	161.51	172.33	182.32
42	21.57	18.54	16.77	15.52	14.54	13.75	116.82	135.89	150.24	162.41	173.30	183.34
43	21.91	18.83	17.03	15.76	14.77	13.96	117.77	137.00	151.46	163.73	174.71	184.83
44	22.20	19.08	17.26	15.97	14.96	14.14	118.93	138.34	152.95	165.34	176.43	186.65
45	22.79	19.59	17.72	16.39	15.36	14.52	118.46	137.80	152.35	164.69	175.73	185.91
46	23.18	19.92	18.02	16.67	15.62	14.77	119.09	138.54	153.17	165.57	176.67	186.91
47	23.47	20.17	18.25	16.88	15.82	14.95	120.17	139.80	154.56	167.08	178.28	188.61
48	23.91	20.55	18.59	17.20	16.12	15.24	120.45	140.12	154.91	167.46	178.68	189.04
49	24.34	20.93	18.93	17.51	16.41	15.51	120.77	140.49	155.32	167.91	179.16	189.54
50	24.62	21.16	19.14	17.70	16.59	15.68	121.88	141.78	156.75	169.44	180.80	191.28
51	25.07	21.55	19.49	18.03	16.90	15.97	122.06	141.99	156.98	169.70	181.07	191.57
52	25.39	21.83	19.74	18.26	17.12	16.18	122.88	142.94	158.04	170.84	182.29	192.85
53	25.86	22.23	20.11	18.60	17.43	16.48	122.96	143.04	158.14	170.95	182.41	192.98
54	26.19	22.51	20.36	18.84	17.65	16.69	123.73	143.93	159.13	172.02	183.55	194.18
55	26.49	22.77	20.59	19.05	17.85	16.88	124.59	144.93	160.23	173.21	184.82	195.53
56	26.97	23.18	20.97	19.40	18.18	17.18	124.58	144.92	160.23	173.20	184.81	195.52
57	27.27	23.44	21.20	19.62	18.38	17.38	125.40	145.88	161.29	174.35	186.04	196.82
58	27.49	23.63	21.38	19.77	18.53	17.52	126.59	147.25	162.80	175.99	187.79	198.67
59	27.78	23.88	21.60	19.98	18.73	17.70	127.42	148.22	163.87	177.15	189.02	199.97
60	28.36	24.38	22.05	20.40	19.12	18.07	126.95	147.68	163.28	176.50	188.33	199.25
61	28.80	24.76	22.40	20.72	19.42	18.35	127.06	147.81	163.42	176.66	188.50	199.42
62	29.13	25.04	22.65	20.95	19.64	18.56	127.69	148.54	164.23	177.53	189.43	200.41
63	29.49	25.35	22.93	21.21	19.88	18.79	128.20	149.13	164.88	178.23	190.18	201.20
64	29.82	25.64	23.19	21.45	20.10	19.00	128.76	149.78	165.60	179.01	191.01	202.08

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
65	30.13	25.90	23.43	21.67	20.31	19.20	129.43	150.56	166.46	179.94	192.00	203.13
66	30.52	26.23	23.73	21.95	20.57	19.45	129.76	150.94	166.88	180.40	192.49	203.65
67	30.90	26.56	24.03	22.23	20.83	19.69	130.10	151.34	167.32	180.87	193.00	204.18
68	31.25	26.87	24.30	22.48	21.07	19.91	130.55	151.87	167.91	181.50	193.67	204.89
69	31.61	27.17	24.58	22.74	21.31	20.14	130.97	152.35	168.44	182.08	194.29	205.54
70	32.12	27.61	24.97	23.10	21.65	20.47	130.76	152.11	168.18	181.80	193.99	205.23
71	32.34	27.80	25.14	23.26	21.80	20.60	131.74	153.25	169.43	183.15	195.43	206.75
72	32.60	28.03	25.35	23.45	21.98	20.77	132.50	154.14	170.41	184.21	196.56	207.95
73	32.98	28.35	25.64	23.72	22.23	21.01	132.82	154.51	170.83	184.66	197.04	208.46
74	33.31	28.63	25.90	23.96	22.45	21.22	133.30	155.06	171.44	185.32	197.75	209.21
75	33.55	28.84	26.09	24.13	22.62	21.38	134.11	156.01	172.49	186.46	198.95	210.48
76	34.02	29.24	26.45	24.47	22.93	21.67	134.05	155.94	172.41	186.37	198.87	210.39
77	34.29	29.48	26.67	24.67	23.12	21.85	134.71	156.71	173.26	187.29	199.85	211.43
78	34.74	29.87	27.01	24.99	23.42	22.14	134.70	156.70	173.24	187.27	199.83	211.41
79	35.11	30.18	27.30	25.25	23.67	22.37	135.01	157.06	173.65	187.71	200.29	211.90
80	35.55	30.56	27.64	25.57	23.97	22.65	135.01	157.06	173.64	187.71	200.29	211.90
81	35.74	30.72	27.79	25.71	24.09	22.77	135.98	158.19	174.89	189.06	201.73	213.42
82	36.08	31.02	28.06	25.95	24.32	22.99	136.35	158.62	175.37	189.57	202.28	214.00
83	36.46	31.34	28.35	26.22	24.57	23.23	136.60	158.91	175.69	189.92	202.65	214.39
84	36.85	31.68	28.65	26.50	24.84	23.48	136.78	159.11	175.91	190.16	202.90	214.66
85	37.28	32.04	28.98	26.81	25.13	23.75	136.81	159.15	175.96	190.21	202.96	214.72
86	37.51	32.24	29.16	26.98	25.28	23.90	137.57	160.03	176.93	191.26	204.08	215.91
87	37.93	32.61	29.49	27.28	25.57	24.17	137.63	160.10	177.00	191.34	204.17	216.00
88	38.21	32.85	29.71	27.48	25.76	24.35	138.18	160.74	177.71	192.11	204.99	216.86
89	38.55	33.14	29.97	27.73	25.99	24.56	138.52	161.14	178.15	192.58	205.49	217.40
90	38.84	33.39	30.20	27.94	26.18	24.75	139.03	161.73	178.81	193.29	206.25	218.20
91	39.19	33.69	30.47	28.19	26.42	24.97	139.33	162.08	179.19	193.71	206.69	218.67
92	39.52	33.98	30.73	28.43	26.64	25.18	139.66	162.47	179.62	194.17	207.19	219.19
93	39.90	34.30	31.02	28.70	26.89	25.42	139.86	162.69	179.87	194.44	207.47	219.50
94	40.17	34.53	31.23	28.89	27.08	25.59	140.42	163.34	180.59	195.22	208.31	220.38
95	40.67	34.96	31.62	29.25	27.42	25.91	140.15	163.03	180.25	194.85	207.91	219.96
96	40.88	35.14	31.78	29.40	27.56	26.05	140.91	163.91	181.22	195.90	209.03	221.14
97	41.34	35.54	32.14	29.73	27.87	26.34	140.79	163.78	181.07	195.74	208.86	220.96
98	41.50	35.68	32.27	29.85	27.97	26.44	141.69	164.82	182.23	196.98	210.19	222.37
99	41.93	36.05	32.60	30.16	28.27	26.72	141.66	164.79	182.19	196.95	210.15	222.33
100	42.34	36.40	32.92	30.46	28.54	26.98	141.70	164.84	182.24	197.01	210.21	222.39
101	42.46	36.50	33.01	30.54	28.62	27.05	142.74	166.05	183.58	198.45	211.75	224.02
102	43.04	37.00	33.47	30.96	29.01	27.43	142.19	165.40	182.87	197.68	210.93	223.15
103	43.20	37.14	33.59	31.08	29.12	27.53	143.04	166.40	183.97	198.87	212.20	224.50
104	43.48	37.38	33.81	31.28	29.31	27.71	143.51	166.94	184.57	199.52	212.89	225.23
105	43.92	37.76	34.15	31.59	29.61	27.99	143.44	166.86	184.48	199.42	212.79	225.12
106	44.14	37.94	34.32	31.75	29.75	28.12	144.10	167.63	185.33	200.34	213.77	226.16

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
107	44.56	38.30	34.64	32.05	30.04	28.39	144.08	167.61	185.31	200.32	213.74	226.13
108	44.85	38.55	34.87	32.26	30.23	28.57	144.50	168.09	185.84	200.89	214.36	226.78
109	45.21	38.86	35.15	32.52	30.47	28.81	144.66	168.28	186.06	201.12	214.61	227.04
110	45.64	39.24	35.49	32.83	30.77	29.08	144.60	168.21	185.98	201.04	214.52	226.95
111	45.92	39.47	35.70	33.03	30.95	29.26	145.04	168.72	186.54	201.65	215.16	227.63
112	46.12	39.65	35.86	33.18	31.09	29.39	145.69	169.48	187.38	202.56	216.13	228.66
113	46.65	40.11	36.28	33.56	31.45	29.73	145.32	169.05	186.91	202.04	215.59	228.08
114	46.92	40.34	36.48	33.75	31.63	29.90	145.77	169.57	187.48	202.66	216.25	228.78
115	47.16	40.54	36.67	33.92	31.79	30.05	146.32	170.21	188.19	203.43	217.07	229.64
116	47.60	40.92	37.01	34.24	32.09	30.33	146.23	170.10	188.06	203.30	216.92	229.49
117	47.95	41.22	37.29	34.49	32.33	30.55	146.39	170.29	188.28	203.52	217.17	229.75
118	48.20	41.43	37.48	34.67	32.49	30.71	146.89	170.88	188.92	204.23	217.92	230.54
119	48.53	41.72	37.73	34.91	32.71	30.92	147.12	171.15	189.22	204.54	218.26	230.90
120	48.71	41.88	37.88	35.04	32.84	31.04	147.80	171.93	190.09	205.48	219.26	231.96
121	49.18	42.28	38.24	35.38	33.15	31.34	147.61	171.71	189.84	205.22	218.98	231.67
122	49.56	42.60	38.53	35.65	33.41	31.58	147.71	171.82	189.97	205.35	219.12	231.82
123	49.88	42.88	38.78	35.88	33.62	31.78	147.95	172.11	190.29	205.70	219.49	232.20
124	50.04	43.02	38.91	35.99	33.73	31.89	148.67	172.95	191.21	206.70	220.56	233.34
125	50.47	43.39	39.24	36.30	34.02	32.16	148.59	172.85	191.11	206.59	220.43	233.21
126	50.81	43.68	39.51	36.55	34.25	32.38	148.78	173.07	191.34	206.84	220.71	233.49
127	51.07	43.90	39.71	36.74	34.43	32.54	149.20	173.56	191.89	207.43	221.33	234.16
128	51.36	44.15	39.94	36.94	34.62	32.73	149.52	173.94	192.31	207.88	221.82	234.67
129	51.78	44.51	40.26	37.24	34.90	32.99	149.48	173.89	192.26	207.83	221.76	234.61
130	52.03	44.73	40.45	37.42	35.07	33.15	149.92	174.40	192.81	208.43	222.40	235.29
131	52.51	45.14	40.83	37.77	35.39	33.46	149.70	174.14	192.53	208.12	222.07	234.94
132	52.68	45.28	40.96	37.89	35.51	33.57	150.35	174.89	193.36	209.02	223.03	235.96
133	53.14	45.68	41.31	38.22	35.82	33.86	150.18	174.70	193.15	208.80	222.79	235.70
134	53.29	45.81	41.44	38.33	35.92	33.96	150.87	175.50	194.03	209.75	223.81	236.78
135	53.69	46.16	41.75	38.62	36.20	34.21	150.85	175.48	194.02	209.73	223.79	236.75
136	54.03	46.44	42.01	38.86	36.42	34.42	151.04	175.70	194.25	209.98	224.06	237.04
137	54.29	46.67	42.21	39.05	36.59	34.59	151.42	176.14	194.74	210.52	224.63	237.64
138	54.72	47.04	42.55	39.36	36.89	34.87	151.30	176.01	194.59	210.36	224.46	237.46
139	54.93	47.22	42.71	39.51	37.03	35.00	151.83	176.62	195.27	211.08	225.23	238.28
140	55.32	47.55	43.01	39.79	37.29	35.25	151.85	176.64	195.30	211.11	225.27	238.32
141	55.47	47.68	43.13	39.90	37.39	35.34	152.52	177.43	196.16	212.05	226.27	239.38
142	55.85	48.01	43.42	40.17	37.65	35.59	152.55	177.46	196.20	212.09	226.31	239.43
143	56.25	48.35	43.73	40.46	37.92	35.84	152.54	177.45	196.19	212.08	226.29	239.41
144	56.53	48.60	43.95	40.66	38.11	36.02	152.84	177.79	196.57	212.49	226.73	239.87
145	56.92	48.93	44.26	40.94	38.37	36.27	152.85	177.81	196.59	212.51	226.75	239.89
146	57.22	49.19	44.49	41.16	38.57	36.46	153.08	178.08	196.88	212.83	227.10	240.25
147	57.51	49.44	44.72	41.37	38.77	36.64	153.36	178.40	197.24	213.22	227.51	240.69
148	57.81	49.70	44.95	41.58	38.97	36.83	153.61	178.69	197.56	213.56	227.88	241.08

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
149	58.16	50.00	45.22	41.83	39.21	37.06	153.71	178.81	197.69	213.71	228.03	241.24
150	58.36	50.17	45.38	41.98	39.34	37.18	154.22	179.40	198.35	214.41	228.78	242.04
151	58.79	50.53	45.71	42.28	39.63	37.46	154.12	179.28	198.21	214.27	228.63	241.88
152	59.16	50.86	46.00	42.56	39.88	37.70	154.15	179.32	198.25	214.31	228.67	241.92
153	59.52	51.16	46.28	42.81	40.12	37.92	154.24	179.43	198.38	214.44	228.82	242.08
154	59.80	51.41	46.50	43.02	40.31	38.11	154.50	179.73	198.71	214.81	229.20	242.49
155	59.95	51.53	46.61	43.12	40.41	38.20	155.14	180.47	199.53	215.69	230.14	243.48
156	60.35	51.88	46.92	43.41	40.68	38.45	155.10	180.43	199.48	215.64	230.09	243.42
157	60.61	52.10	47.12	43.59	40.85	38.62	155.43	180.81	199.90	216.09	230.58	243.94
158	61.03	52.46	47.45	43.90	41.14	38.88	155.34	180.71	199.79	215.97	230.45	243.80
159	61.26	52.66	47.63	44.06	41.29	39.03	155.73	181.16	200.29	216.51	231.02	244.41
160	61.71	53.05	47.98	44.39	41.60	39.32	155.56	180.96	200.07	216.27	230.77	244.14
161	61.95	53.25	48.17	44.56	41.76	39.47	155.93	181.39	200.55	216.79	231.33	244.73
162	62.26	53.52	48.41	44.78	41.97	39.67	156.13	181.62	200.80	217.06	231.61	245.03
163	62.61	53.82	48.68	45.03	42.20	39.89	156.21	181.71	200.90	217.17	231.73	245.16
164	63.01	54.17	48.99	45.32	42.48	40.15	156.16	181.65	200.84	217.10	231.66	245.08
165	63.25	54.37	49.18	45.50	42.64	40.30	156.52	182.07	201.30	217.60	232.19	245.65
166	63.61	54.68	49.46	45.75	42.88	40.53	156.59	182.15	201.39	217.70	232.29	245.75
167	63.79	54.84	49.60	45.88	43.00	40.65	157.08	182.72	202.02	218.38	233.02	246.52
168	64.16	55.16	49.89	46.15	43.25	40.88	157.10	182.76	202.06	218.42	233.06	246.57
169	64.40	55.36	50.07	46.32	43.41	41.04	157.45	183.16	202.50	218.90	233.57	247.11
170	64.85	55.75	50.43	46.65	43.72	41.32	157.28	182.96	202.28	218.66	233.32	246.84
171	65.09	55.95	50.61	46.82	43.87	41.47	157.63	183.37	202.74	219.16	233.85	247.40
172	65.41	56.23	50.86	47.05	44.10	41.68	157.76	183.52	202.90	219.33	234.04	247.60
173	65.71	56.49	51.09	47.27	44.30	41.87	157.96	183.75	203.16	219.61	234.33	247.91
174	66.05	56.78	51.36	47.51	44.53	42.09	158.05	183.86	203.27	219.74	234.47	248.05
175	66.35	57.04	51.59	47.72	44.73	42.28	158.25	184.09	203.53	220.01	234.76	248.36
176	66.64	57.29	51.82	47.94	44.92	42.46	158.45	184.33	203.79	220.30	235.06	248.68
177	66.99	57.59	52.09	48.18	45.16	42.68	158.53	184.42	203.89	220.40	235.18	248.81
178	67.32	57.87	52.34	48.42	45.38	42.89	158.65	184.55	204.04	220.57	235.35	248.99
179	67.60	58.11	52.56	48.62	45.57	43.07	158.88	184.82	204.34	220.89	235.70	249.35
180	67.90	58.37	52.79	48.84	45.77	43.26	159.06	185.03	204.57	221.13	235.96	249.63
181	68.23	58.65	53.05	49.08	45.99	43.47	159.17	185.15	204.71	221.29	236.12	249.80
182	68.62	58.99	53.35	49.36	46.26	43.72	159.14	185.12	204.67	221.25	236.08	249.76
183	68.83	59.17	53.52	49.51	46.40	43.85	159.53	185.58	205.17	221.79	236.66	250.37
184	69.27	59.55	53.86	49.82	46.69	44.14	159.38	185.40	204.98	221.58	236.43	250.13
185	69.42	59.68	53.98	49.93	46.80	44.23	159.89	186.00	205.64	222.29	237.19	250.94
186	69.78	59.98	54.25	50.19	47.04	44.46	159.94	186.05	205.70	222.36	237.26	251.01
187	70.12	60.28	54.52	50.44	47.27	44.68	160.01	186.14	205.80	222.46	237.38	251.13
188	70.45	60.56	54.78	50.67	47.49	44.89	160.12	186.26	205.93	222.61	237.53	251.29
189	70.69	60.76	54.96	50.84	47.65	45.04	160.43	186.62	206.33	223.04	237.99	251.78
190	70.98	61.02	55.19	51.06	47.85	45.23	160.60	186.82	206.55	223.28	238.24	252.05

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
191	71.35	61.33	55.48	51.32	48.10	45.46	160.62	186.84	206.57	223.30	238.27	252.08
192	71.63	61.57	55.69	51.52	48.28	45.64	160.83	187.09	206.85	223.60	238.59	252.42
193	71.92	61.83	55.92	51.73	48.48	45.83	161.01	187.29	207.07	223.84	238.85	252.69
194	72.25	62.11	56.18	51.97	48.70	46.03	161.11	187.42	207.21	223.99	239.00	252.85
195	72.48	62.30	56.35	52.13	48.86	46.18	161.43	187.79	207.62	224.44	239.48	253.36
196	72.90	62.66	56.68	52.43	49.14	46.45	161.33	187.67	207.48	224.29	239.32	253.19
197	73.18	62.91	56.90	52.64	49.33	46.63	161.51	187.88	207.72	224.54	239.60	253.48
198	73.57	63.24	57.20	52.92	49.59	46.88	161.48	187.85	207.68	224.50	239.55	253.43
199	73.78	63.42	57.37	53.07	49.73	47.01	161.83	188.26	208.13	224.99	240.07	253.98
200	74.21	63.79	57.70	53.38	50.02	47.28	161.70	188.10	207.97	224.81	239.88	253.78
201	74.41	63.97	57.86	53.52	50.16	47.41	162.07	188.53	208.44	225.32	240.43	254.36
202	74.68	64.20	58.07	53.72	50.34	47.58	162.29	188.79	208.73	225.63	240.76	254.71
203	75.10	64.56	58.39	54.02	50.62	47.85	162.19	188.67	208.60	225.49	240.61	254.55
204	75.45	64.86	58.66	54.27	50.86	48.07	162.23	188.71	208.64	225.54	240.66	254.60
205	75.65	65.03	58.82	54.42	51.00	48.20	162.58	189.13	209.10	226.04	241.19	255.17
206	75.99	65.33	59.09	54.66	51.23	48.42	162.64	189.20	209.18	226.12	241.28	255.26
207	76.26	65.56	59.29	54.85	51.41	48.59	162.86	189.46	209.46	226.43	241.61	255.61
208	76.62	65.87	59.58	55.11	51.65	48.82	162.87	189.47	209.47	226.44	241.62	255.62
209	76.88	66.09	59.78	55.30	51.82	48.99	163.11	189.74	209.78	226.77	241.97	255.99
210	77.24	66.39	60.05	55.55	52.06	49.21	163.14	189.77	209.81	226.81	242.01	256.04
211	77.54	66.66	60.29	55.77	52.27	49.41	163.27	189.93	209.99	226.99	242.21	256.24
212	77.84	66.92	60.52	55.99	52.47	49.60	163.41	190.09	210.16	227.18	242.41	256.46
213	78.10	67.14	60.73	56.18	52.65	49.76	163.63	190.35	210.45	227.49	242.74	256.81
214	78.53	67.51	61.06	56.49	52.94	50.04	163.50	190.20	210.29	227.32	242.55	256.61
215	78.78	67.72	61.25	56.67	53.11	50.20	163.74	190.48	210.60	227.65	242.91	256.99
216	79.02	67.93	61.44	56.84	53.27	50.35	164.01	190.79	210.94	228.02	243.31	257.40
217	79.31	68.18	61.67	57.05	53.46	50.53	164.17	190.97	211.14	228.24	243.54	257.65
218	79.71	68.52	61.98	57.34	53.73	50.79	164.09	190.88	211.04	228.13	243.42	257.53
219	80.05	68.81	62.24	57.58	53.96	51.00	164.15	190.96	211.12	228.22	243.52	257.63
220	80.24	68.97	62.39	57.71	54.09	51.12	164.52	191.38	211.59	228.72	244.06	258.20
221	80.64	69.32	62.70	58.00	54.36	51.38	164.44	191.29	211.49	228.62	243.94	258.08
222	80.88	69.53	62.89	58.17	54.52	51.53	164.69	191.58	211.81	228.97	244.32	258.47
223	81.22	69.82	63.15	58.42	54.75	51.75	164.73	191.63	211.87	229.03	244.38	258.54
224	81.57	70.12	63.42	58.67	54.98	51.97	164.77	191.67	211.91	229.08	244.43	258.59
225	81.85	70.36	63.64	58.87	55.18	52.15	164.93	191.86	212.12	229.30	244.68	258.85
226	82.12	70.59	63.85	59.07	55.36	52.33	165.12	192.08	212.37	229.57	244.95	259.15
227	82.43	70.86	64.09	59.29	55.57	52.52	165.23	192.21	212.51	229.72	245.11	259.32
228	82.74	71.13	64.33	59.51	55.77	52.72	165.33	192.33	212.64	229.86	245.27	259.48
229	83.05	71.39	64.57	59.74	55.98	52.92	165.44	192.46	212.78	230.01	245.43	259.65
230	83.30	71.61	64.77	59.92	56.15	53.08	165.66	192.71	213.06	230.32	245.76	260.00
231	83.70	71.96	65.08	60.21	56.42	53.33	165.58	192.62	212.96	230.21	245.64	259.87
232	84.06	72.26	65.36	60.46	56.66	53.56	165.60	192.64	212.98	230.23	245.67	259.90

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
233	84.28	72.45	65.53	60.62	56.81	53.70	165.88	192.96	213.34	230.62	246.08	260.34
234	84.57	72.70	65.76	60.83	57.01	53.89	166.01	193.12	213.51	230.81	246.28	260.55
235	84.94	73.02	66.04	61.10	57.26	54.12	166.00	193.10	213.50	230.79	246.26	260.53
236	85.27	73.31	66.30	61.34	57.48	54.33	166.05	193.16	213.56	230.86	246.34	260.61
237	85.61	73.59	66.56	61.58	57.71	54.55	166.11	193.23	213.63	230.93	246.41	260.69
238	85.70	73.67	66.64	61.64	57.77	54.61	166.62	193.83	214.29	231.65	247.18	261.50
239	86.11	74.02	66.95	61.93	58.04	54.86	166.54	193.73	214.19	231.53	247.05	261.37
240	86.45	74.31	67.21	62.18	58.27	55.08	166.58	193.78	214.24	231.59	247.12	261.44
241	86.74	74.57	67.45	62.39	58.47	55.27	166.70	193.92	214.40	231.76	247.30	261.63
242	87.09	74.86	67.71	62.64	58.70	55.49	166.73	193.96	214.44	231.81	247.35	261.68
243	87.37	75.11	67.93	62.85	58.90	55.67	166.87	194.12	214.62	232.00	247.55	261.90
244	87.65	75.35	68.15	63.05	59.09	55.85	167.02	194.29	214.81	232.21	247.77	262.13
245	87.89	75.55	68.34	63.22	59.24	56.00	167.26	194.57	215.12	232.54	248.13	262.50
246	88.33	75.94	68.68	63.54	59.54	56.28	167.09	194.38	214.90	232.31	247.88	262.24
247	88.58	76.15	68.87	63.71	59.71	56.44	167.31	194.63	215.18	232.61	248.20	262.58
248	88.85	76.38	69.08	63.91	59.89	56.61	167.48	194.82	215.40	232.84	248.45	262.85
249	89.15	76.64	69.32	64.12	60.10	56.80	167.58	194.95	215.53	232.99	248.61	263.01
250	89.40	76.85	69.51	64.31	60.27	56.96	167.78	195.18	215.79	233.26	248.90	263.32
251	89.71	77.12	69.75	64.52	60.47	57.16	167.88	195.29	215.91	233.40	249.04	263.47
252	90.09	77.44	70.05	64.80	60.73	57.40	167.83	195.24	215.86	233.34	248.98	263.41
253	90.45	77.75	70.33	65.06	60.97	57.63	167.83	195.23	215.85	233.33	248.97	263.40
254	90.66	77.94	70.49	65.21	61.11	57.77	168.10	195.54	216.19	233.70	249.37	263.82
255	91.00	78.23	70.76	65.45	61.34	57.98	168.13	195.58	216.24	233.75	249.42	263.87
256	91.40	78.57	71.06	65.74	61.61	58.23	168.06	195.50	216.15	233.65	249.32	263.76
257	91.53	78.68	71.17	65.84	61.70	58.32	168.47	195.97	216.67	234.22	249.92	264.40
258	91.85	78.95	71.41	66.06	61.91	58.52	168.54	196.06	216.77	234.32	250.03	264.52
259	92.28	79.33	71.75	66.37	62.20	58.80	168.40	195.90	216.59	234.13	249.82	264.30
260	92.53	79.54	71.94	66.55	62.37	58.95	168.60	196.13	216.84	234.41	250.12	264.61
261	92.80	79.78	72.16	66.75	62.56	59.13	168.74	196.30	217.02	234.60	250.33	264.83
262	93.10	80.03	72.39	66.96	62.76	59.32	168.85	196.42	217.17	234.76	250.49	265.01
263	93.52	80.39	72.72	67.27	63.04	59.59	168.73	196.28	217.01	234.59	250.31	264.82
264	93.77	80.61	72.91	67.44	63.21	59.75	168.93	196.51	217.26	234.86	250.60	265.12
265	94.02	80.83	73.11	67.63	63.38	59.91	169.11	196.72	217.49	235.11	250.87	265.40
266	94.32	81.08	73.34	67.84	63.58	60.10	169.21	196.84	217.63	235.25	251.02	265.57
267	94.67	81.38	73.61	68.09	63.82	60.32	169.22	196.85	217.63	235.26	251.03	265.58
268	95.06	81.72	73.92	68.38	64.08	60.57	169.15	196.77	217.54	235.16	250.93	265.47
269	95.31	81.93	74.10	68.55	64.25	60.73	169.35	197.00	217.80	235.44	251.23	265.78
270	95.59	82.17	74.33	68.76	64.44	60.91	169.47	197.14	217.96	235.61	251.41	265.98
271	95.83	82.38	74.51	68.92	64.59	61.06	169.68	197.39	218.23	235.91	251.72	266.31
272	96.16	82.66	74.77	69.16	64.82	61.27	169.72	197.43	218.28	235.96	251.78	266.37
273	96.46	82.92	75.00	69.38	65.02	61.46	169.82	197.55	218.41	236.10	251.92	266.52
274	96.83	83.24	75.29	69.65	65.27	61.70	169.78	197.50	218.35	236.04	251.86	266.46

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
275	97.10	83.47	75.50	69.84	65.45	61.87	169.93	197.68	218.56	236.26	252.09	266.70
276	97.44	83.76	75.76	70.09	65.68	62.09	169.95	197.70	218.58	236.28	252.12	266.73
277	97.68	83.97	75.95	70.26	65.84	62.24	170.15	197.93	218.84	236.56	252.42	267.04
278	97.98	84.23	76.18	70.47	66.05	62.43	170.24	198.04	218.95	236.68	252.55	267.18
279	98.33	84.53	76.45	70.73	66.28	62.65	170.24	198.04	218.96	236.69	252.56	267.19
280	98.69	84.84	76.73	70.98	66.53	62.88	170.23	198.03	218.94	236.67	252.54	267.17
281	98.92	85.04	76.91	71.15	66.68	63.03	170.44	198.27	219.21	236.96	252.85	267.50
282	99.23	85.30	77.15	71.37	66.89	63.23	170.52	198.36	219.30	237.07	252.96	267.61
283	99.51	85.54	77.37	71.58	67.08	63.41	170.63	198.49	219.45	237.23	253.13	267.80
284	99.75	85.75	77.56	71.74	67.24	63.55	170.83	198.73	219.71	237.51	253.43	268.11
285	100.18	86.12	77.90	72.06	67.53	63.83	170.69	198.56	219.53	237.31	253.21	267.89
286	100.46	86.36	78.11	72.26	67.72	64.01	170.82	198.71	219.70	237.49	253.41	268.09
287	100.77	86.63	78.35	72.48	67.93	64.21	170.88	198.78	219.78	237.58	253.50	268.19
288	101.09	86.90	78.60	72.71	68.14	64.41	170.94	198.85	219.85	237.66	253.59	268.28
289	101.31	87.09	78.77	72.87	68.29	64.55	171.15	199.10	220.12	237.95	253.90	268.61
290	101.68	87.41	79.06	73.14	68.54	64.79	171.12	199.06	220.09	237.91	253.86	268.57
291	101.96	87.65	79.28	73.34	68.73	64.97	171.24	199.20	220.23	238.07	254.03	268.75
292	102.24	87.89	79.50	73.54	68.92	65.14	171.36	199.34	220.39	238.24	254.21	268.94
293	102.54	88.15	79.73	73.75	69.12	65.34	171.45	199.44	220.50	238.36	254.34	269.07
294	102.85	88.41	79.97	73.98	69.33	65.53	171.52	199.52	220.59	238.46	254.44	269.19
295	103.16	88.68	80.21	74.20	69.54	65.73	171.58	199.60	220.67	238.55	254.54	269.29
296	103.40	88.88	80.39	74.37	69.70	65.88	171.76	199.81	220.91	238.80	254.81	269.57
297	103.76	89.20	80.68	74.63	69.94	66.11	171.74	199.78	220.88	238.77	254.78	269.54
298	104.10	89.48	80.94	74.87	70.17	66.33	171.76	199.81	220.91	238.80	254.81	269.57
299	104.35	89.70	81.13	75.05	70.34	66.49	171.93	200.00	221.12	239.03	255.05	269.83
300	104.73	90.03	81.43	75.33	70.60	66.73	171.87	199.93	221.05	238.95	254.97	269.74
301	105.00	90.26	81.64	75.52	70.78	66.90	172.00	200.08	221.21	239.13	255.16	269.94
302	105.31	90.52	81.88	75.74	70.99	67.10	172.07	200.17	221.30	239.23	255.26	270.05
303	105.55	90.74	82.07	75.92	71.15	67.25	172.24	200.36	221.52	239.46	255.51	270.32
304	105.99	91.12	82.41	76.24	71.45	67.54	172.09	200.19	221.32	239.25	255.29	270.08
305	106.17	91.27	82.55	76.37	71.57	67.65	172.36	200.51	221.68	239.63	255.70	270.51
306	106.44	91.50	82.76	76.56	71.75	67.82	172.49	200.65	221.84	239.81	255.88	270.71
307	106.82	91.83	83.06	76.83	72.01	68.06	172.44	200.59	221.78	239.74	255.81	270.63
308	107.09	92.05	83.26	77.02	72.19	68.23	172.57	200.75	221.95	239.93	256.01	270.84
309	107.46	92.38	83.55	77.29	72.44	68.47	172.53	200.70	221.89	239.86	255.94	270.77
310	107.71	92.59	83.75	77.48	72.61	68.63	172.68	200.88	222.09	240.08	256.17	271.01
311	108.00	92.84	83.98	77.68	72.80	68.82	172.77	200.98	222.21	240.20	256.30	271.16
312	108.35	93.14	84.24	77.93	73.04	69.04	172.78	200.99	222.21	240.21	256.31	271.17
313	108.59	93.35	84.43	78.11	73.20	69.19	172.94	201.18	222.42	240.44	256.56	271.42
314	108.94	93.65	84.71	78.36	73.44	69.42	172.93	201.17	222.41	240.43	256.55	271.41
315	109.29	93.95	84.98	78.61	73.67	69.64	172.93	201.17	222.42	240.43	256.55	271.41
316	109.50	94.13	85.14	78.76	73.81	69.77	173.15	201.42	222.69	240.73	256.86	271.75

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
317	109.82	94.40	85.39	78.99	74.03	69.97	173.19	201.47	222.75	240.79	256.93	271.82
318	110.14	94.68	85.64	79.22	74.24	70.18	173.24	201.52	222.80	240.85	256.99	271.88
319	110.40	94.91	85.84	79.41	74.42	70.34	173.37	201.67	222.97	241.03	257.19	272.09
320	110.76	95.22	86.12	79.67	74.66	70.57	173.34	201.65	222.94	241.00	257.15	272.05
321	110.99	95.41	86.30	79.84	74.82	70.72	173.52	201.86	223.17	241.25	257.42	272.34
322	111.40	95.76	86.62	80.13	75.09	70.98	173.43	201.74	223.05	241.11	257.28	272.18
323	111.63	95.96	86.80	80.29	75.25	71.13	173.61	201.96	223.28	241.37	257.55	272.47
324	111.91	96.20	87.01	80.49	75.44	71.30	173.71	202.08	223.42	241.51	257.70	272.64
325	112.28	96.52	87.30	80.76	75.69	71.54	173.67	202.02	223.36	241.45	257.63	272.56
326	112.56	96.76	87.52	80.96	75.88	71.72	173.77	202.15	223.49	241.59	257.79	272.73
327	112.84	97.00	87.73	81.16	76.06	71.90	173.88	202.27	223.63	241.74	257.95	272.89
328	113.11	97.23	87.95	81.36	76.25	72.07	173.99	202.40	223.77	241.90	258.11	273.07
329	113.47	97.54	88.23	81.62	76.49	72.30	173.96	202.37	223.74	241.86	258.07	273.03
330	113.83	97.85	88.51	81.88	76.73	72.53	173.94	202.34	223.71	241.83	258.04	272.99
331	114.11	98.09	88.72	82.08	76.92	72.71	174.04	202.46	223.84	241.97	258.19	273.15
332	114.42	98.36	88.96	82.30	77.13	72.90	174.10	202.53	223.92	242.05	258.28	273.24
333	114.69	98.59	89.18	82.49	77.31	73.08	174.21	202.65	224.05	242.20	258.43	273.41
334	115.07	98.92	89.47	82.76	77.56	73.32	174.16	202.60	223.99	242.13	258.36	273.34
335	115.22	99.04	89.58	82.87	77.67	73.41	174.45	202.94	224.37	242.54	258.80	273.79
336	115.58	99.36	89.87	83.14	77.91	73.65	174.42	202.90	224.33	242.50	258.75	273.74
337	115.86	99.60	90.08	83.33	78.10	73.82	174.52	203.02	224.46	242.64	258.90	273.90
338	116.18	99.87	90.33	83.57	78.32	74.03	174.55	203.06	224.50	242.68	258.95	273.95
339	116.49	100.14	90.57	83.79	78.52	74.22	174.61	203.12	224.57	242.76	259.03	274.04
340	116.83	100.43	90.84	84.03	78.75	74.44	174.61	203.13	224.58	242.76	259.04	274.05
341	117.11	100.67	91.06	84.23	78.94	74.62	174.71	203.23	224.70	242.89	259.18	274.19
342	117.37	100.89	91.26	84.42	79.12	74.78	174.84	203.38	224.86	243.07	259.37	274.40
343	117.67	101.16	91.49	84.64	79.32	74.98	174.89	203.45	224.93	243.15	259.45	274.48
344	118.01	101.45	91.76	84.88	79.55	75.19	174.90	203.46	224.94	243.16	259.46	274.49
345	118.27	101.67	91.96	85.07	79.72	75.36	175.03	203.60	225.10	243.34	259.65	274.69
346	118.65	102.00	92.26	85.34	79.98	75.60	174.96	203.53	225.03	243.25	259.56	274.60
347	118.98	102.28	92.51	85.58	80.21	75.81	174.98	203.55	225.05	243.27	259.58	274.62
348	119.26	102.52	92.73	85.78	80.39	75.99	175.08	203.66	225.17	243.41	259.72	274.77
349	119.48	102.71	92.90	85.94	80.54	76.13	175.26	203.88	225.41	243.67	260.00	275.07
350	119.77	102.96	93.13	86.15	80.74	76.31	175.33	203.96	225.50	243.76	260.10	275.18
351	120.14	103.28	93.42	86.42	80.99	76.55	175.29	203.91	225.44	243.70	260.04	275.11
352	120.40	103.50	93.62	86.60	81.16	76.72	175.41	204.06	225.60	243.88	260.22	275.30
353	120.71	103.77	93.86	86.82	81.37	76.91	175.46	204.11	225.67	243.94	260.30	275.38
354	120.97	103.99	94.06	87.01	81.54	77.08	175.58	204.25	225.82	244.11	260.48	275.57
355	121.31	104.28	94.32	87.26	81.77	77.30	175.58	204.25	225.82	244.11	260.47	275.56
356	121.60	104.53	94.55	87.47	81.97	77.48	175.66	204.34	225.91	244.21	260.58	275.68
357	121.97	104.85	94.83	87.73	82.22	77.71	175.62	204.30	225.87	244.16	260.53	275.63
358	122.13	104.99	94.96	87.84	82.33	77.82	175.88	204.60	226.20	244.52	260.92	276.03

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
359	122.53	105.33	95.27	88.13	82.60	78.07	175.79	204.50	226.09	244.40	260.79	275.90
360	122.84	105.59	95.51	88.35	82.80	78.27	175.84	204.56	226.16	244.47	260.86	275.98
361	123.17	105.88	95.77	88.59	83.03	78.48	175.86	204.57	226.17	244.49	260.88	276.00
362	123.39	106.07	95.94	88.75	83.17	78.62	176.03	204.77	226.40	244.73	261.14	276.27
363	123.74	106.37	96.21	89.00	83.41	78.84	176.02	204.75	226.38	244.71	261.12	276.25
364	124.03	106.62	96.44	89.21	83.61	79.03	176.09	204.84	226.47	244.81	261.22	276.36
365	124.32	106.87	96.66	89.42	83.80	79.21	176.16	204.92	226.56	244.91	261.33	276.47
366	124.63	107.13	96.90	89.64	84.01	79.41	176.21	204.98	226.63	244.98	261.40	276.55
367	124.98	107.44	97.18	89.90	84.25	79.63	176.19	204.96	226.60	244.95	261.37	276.52
368	125.30	107.71	97.42	90.12	84.46	79.83	176.22	205.00	226.65	245.00	261.43	276.57
369	125.51	107.90	97.59	90.28	84.61	79.97	176.40	205.20	226.87	245.24	261.68	276.84
370	125.82	108.16	97.83	90.50	84.81	80.17	176.44	205.25	226.93	245.31	261.75	276.92
371	126.16	108.45	98.09	90.75	85.04	80.39	176.44	205.25	226.92	245.30	261.75	276.91
372	126.48	108.72	98.34	90.97	85.26	80.59	176.48	205.29	226.97	245.35	261.80	276.97
373	126.74	108.95	98.55	91.16	85.44	80.76	176.58	205.41	227.10	245.49	261.95	277.13
374	127.01	109.18	98.75	91.36	85.62	80.93	176.68	205.53	227.23	245.63	262.10	277.29
375	127.34	109.46	99.01	91.59	85.84	81.14	176.70	205.55	227.25	245.66	262.13	277.31
376	127.63	109.72	99.24	91.80	86.03	81.32	176.76	205.62	227.33	245.75	262.22	277.41
377	127.93	109.97	99.47	92.01	86.23	81.51	176.82	205.69	227.41	245.83	262.31	277.51
378	128.24	110.24	99.71	92.24	86.44	81.71	176.86	205.74	227.46	245.89	262.37	277.57
379	128.60	110.55	99.99	92.50	86.69	81.94	176.83	205.70	227.43	245.84	262.32	277.52
380	128.87	110.78	100.20	92.69	86.87	82.11	176.92	205.81	227.54	245.97	262.46	277.67
381	129.17	111.04	100.44	92.91	87.08	82.31	176.97	205.87	227.60	246.04	262.53	277.74
382	129.45	111.28	100.65	93.11	87.26	82.48	177.05	205.96	227.71	246.15	262.65	277.87
383	129.77	111.55	100.90	93.34	87.48	82.68	177.09	206.00	227.75	246.20	262.70	277.92
384	130.07	111.81	101.13	93.55	87.68	82.87	177.14	206.07	227.83	246.28	262.79	278.01
385	130.26	111.98	101.28	93.69	87.81	83.00	177.34	206.29	228.08	246.55	263.08	278.32
386	130.74	112.39	101.66	94.04	88.13	83.31	177.14	206.07	227.83	246.28	262.79	278.01
387	130.92	112.54	101.79	94.17	88.25	83.42	177.36	206.32	228.11	246.58	263.11	278.36
388	131.24	112.82	102.04	94.40	88.47	83.62	177.39	206.35	228.14	246.62	263.15	278.40
389	131.62	113.14	102.34	94.67	88.72	83.86	177.33	206.29	228.07	246.54	263.07	278.31
390	131.89	113.38	102.55	94.87	88.91	84.04	177.42	206.39	228.18	246.66	263.19	278.45
391	132.22	113.66	102.81	95.11	89.13	84.25	177.43	206.40	228.19	246.67	263.21	278.46
392	132.49	113.90	103.02	95.30	89.31	84.42	177.52	206.51	228.31	246.80	263.35	278.61
393	132.80	114.16	103.26	95.52	89.52	84.62	177.56	206.55	228.36	246.86	263.40	278.67
394	133.08	114.40	103.47	95.72	89.71	84.79	177.64	206.64	228.46	246.97	263.52	278.79
395	133.38	114.66	103.71	95.94	89.91	84.99	177.69	206.70	228.53	247.04	263.60	278.87
396	133.77	114.99	104.01	96.22	90.17	85.23	177.62	206.62	228.44	246.94	263.50	278.76
397	133.98	115.17	104.17	96.37	90.31	85.37	177.79	206.82	228.66	247.18	263.74	279.03
398	134.36	115.50	104.47	96.64	90.57	85.61	177.73	206.75	228.58	247.09	263.65	278.93
399	134.52	115.63	104.59	96.75	90.68	85.71	177.97	207.03	228.89	247.43	264.02	279.32
400	134.89	115.96	104.88	97.02	90.93	85.95	177.92	206.97	228.83	247.36	263.94	279.24

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
401	135.12	116.16	105.06	97.19	91.08	86.10	178.06	207.14	229.01	247.56	264.15	279.46
402	135.50	116.48	105.35	97.46	91.34	86.33	178.01	207.08	228.95	247.49	264.08	279.38
403	135.86	116.79	105.63	97.72	91.58	86.56	177.98	207.04	228.91	247.45	264.03	279.33
404	136.08	116.98	105.81	97.88	91.73	86.71	178.13	207.21	229.09	247.65	264.25	279.56
405	136.37	117.23	106.03	98.09	91.92	86.89	178.20	207.29	229.18	247.74	264.35	279.67
406	136.72	117.53	106.30	98.34	92.16	87.11	178.18	207.27	229.16	247.72	264.32	279.64
407	137.09	117.85	106.59	98.61	92.41	87.35	178.13	207.21	229.09	247.65	264.25	279.56
408	137.26	117.99	106.72	98.73	92.53	87.46	178.35	207.47	229.38	247.95	264.57	279.90
409	137.57	118.26	106.97	98.95	92.74	87.66	178.38	207.50	229.42	248.00	264.62	279.95
410	137.86	118.51	107.19	99.16	92.93	87.84	178.44	207.57	229.49	248.08	264.71	280.05
411	138.13	118.74	107.40	99.35	93.11	88.01	178.53	207.68	229.62	248.21	264.85	280.20
412	138.51	119.07	107.70	99.63	93.37	88.25	178.47	207.61	229.54	248.13	264.76	280.10
413	138.77	119.30	107.90	99.82	93.55	88.42	178.56	207.72	229.66	248.26	264.90	280.25
414	139.08	119.56	108.14	100.04	93.75	88.62	178.60	207.76	229.70	248.31	264.95	280.31
415	139.35	119.79	108.35	100.23	93.93	88.79	178.69	207.87	229.82	248.43	265.09	280.45
416	139.74	120.13	108.65	100.51	94.20	89.04	178.62	207.78	229.72	248.33	264.98	280.33
417	139.95	120.30	108.81	100.66	94.34	89.17	178.78	207.98	229.94	248.56	265.22	280.59
418	140.32	120.63	109.11	100.93	94.59	89.41	178.73	207.91	229.87	248.48	265.14	280.50
419	140.51	120.79	109.25	101.07	94.72	89.53	178.91	208.13	230.10	248.74	265.42	280.79
420	140.90	121.12	109.55	101.35	94.98	89.78	178.85	208.05	230.02	248.65	265.32	280.69
421	141.30	121.46	109.86	101.63	95.25	90.03	178.77	207.96	229.92	248.54	265.20	280.57
422	141.56	121.69	110.07	101.82	95.43	90.20	178.86	208.07	230.04	248.67	265.34	280.71
423	141.80	121.90	110.25	101.99	95.58	90.35	178.99	208.21	230.20	248.84	265.52	280.91
424	142.04	122.10	110.44	102.17	95.75	90.50	179.10	208.35	230.35	249.00	265.70	281.09
425	142.42	122.43	110.74	102.44	96.01	90.75	179.04	208.28	230.27	248.92	265.61	281.00
426	142.65	122.63	110.91	102.60	96.16	90.89	179.18	208.44	230.45	249.12	265.81	281.22
427	143.05	122.97	111.22	102.89	96.43	91.14	179.10	208.35	230.35	249.01	265.70	281.09
428	143.34	123.22	111.45	103.10	96.62	91.33	179.16	208.41	230.42	249.08	265.78	281.18
429	143.62	123.46	111.67	103.30	96.81	91.51	179.22	208.49	230.50	249.17	265.88	281.28
430	143.97	123.76	111.94	103.55	97.05	91.73	179.20	208.47	230.48	249.15	265.85	281.25
431	144.18	123.94	112.11	103.71	97.19	91.87	179.36	208.64	230.68	249.36	266.07	281.49
432	144.49	124.21	112.35	103.93	97.40	92.06	179.39	208.68	230.72	249.40	266.12	281.54
433	144.83	124.50	112.61	104.17	97.63	92.28	179.39	208.68	230.71	249.40	266.12	281.54
434	145.13	124.76	112.84	104.39	97.83	92.47	179.42	208.72	230.76	249.45	266.17	281.60
435	145.43	125.01	113.07	104.60	98.03	92.66	179.47	208.78	230.82	249.52	266.24	281.67
436	145.72	125.27	113.30	104.81	98.23	92.85	179.52	208.84	230.89	249.59	266.32	281.75
437	145.96	125.47	113.49	104.99	98.39	93.00	179.64	208.97	231.03	249.75	266.49	281.93
438	146.32	125.78	113.77	105.24	98.63	93.23	179.61	208.93	231.00	249.70	266.44	281.88
439	146.61	126.03	113.99	105.45	98.83	93.41	179.67	209.00	231.07	249.79	266.53	281.97
440	146.94	126.32	114.25	105.69	99.05	93.63	179.66	209.00	231.06	249.78	266.52	281.97
441	147.28	126.60	114.51	105.93	99.28	93.84	179.66	209.00	231.07	249.78	266.53	281.97
442	147.51	126.80	114.69	106.10	99.43	93.99	179.78	209.14	231.23	249.95	266.71	282.16

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
443	147.81	127.06	114.92	106.31	99.64	94.18	179.83	209.19	231.28	250.01	266.77	282.23
444	148.15	127.36	115.19	106.56	99.87	94.40	179.81	209.17	231.26	249.99	266.75	282.21
445	148.43	127.60	115.41	106.76	100.06	94.58	179.88	209.25	231.35	250.08	266.85	282.31
446	148.73	127.85	115.64	106.98	100.26	94.77	179.92	209.30	231.40	250.15	266.91	282.38
447	149.04	128.12	115.88	107.20	100.47	94.96	179.95	209.33	231.44	250.18	266.95	282.42
448	149.29	128.34	116.08	107.38	100.64	95.12	180.05	209.45	231.57	250.32	267.10	282.58
449	149.59	128.59	116.31	107.60	100.84	95.31	180.09	209.50	231.62	250.38	267.17	282.65
450	149.91	128.87	116.56	107.83	101.06	95.52	180.10	209.51	231.64	250.40	267.18	282.66
451	150.25	129.16	116.83	108.07	101.29	95.74	180.09	209.50	231.62	250.38	267.17	282.65
452	150.50	129.38	117.02	108.25	101.45	95.89	180.20	209.62	231.76	250.53	267.32	282.81
453	150.86	129.69	117.30	108.51	101.70	96.13	180.16	209.58	231.71	250.48	267.27	282.76
454	151.11	129.90	117.50	108.69	101.86	96.29	180.26	209.69	231.84	250.61	267.41	282.91
455	151.47	130.21	117.77	108.95	102.10	96.51	180.23	209.66	231.80	250.58	267.37	282.87
456	151.67	130.38	117.93	109.09	102.24	96.64	180.40	209.85	232.01	250.80	267.61	283.12
457	152.01	130.68	118.19	109.34	102.47	96.86	180.38	209.83	231.99	250.78	267.59	283.10
458	152.34	130.96	118.45	109.58	102.69	97.07	180.38	209.84	232.00	250.79	267.60	283.10
459	152.67	131.24	118.71	109.81	102.91	97.28	180.39	209.84	232.00	250.79	267.60	283.11
460	152.92	131.46	118.90	109.99	103.08	97.44	180.48	209.95	232.12	250.92	267.74	283.26
461	153.19	131.69	119.11	110.19	103.27	97.61	180.56	210.04	232.22	251.03	267.85	283.37
462	153.52	131.97	119.36	110.42	103.48	97.82	180.57	210.05	232.23	251.04	267.87	283.39
463	153.87	132.27	119.64	110.67	103.72	98.04	180.54	210.02	232.20	251.01	267.83	283.35
464	154.15	132.51	119.85	110.87	103.91	98.22	180.61	210.10	232.28	251.09	267.93	283.45
465	154.47	132.79	120.10	111.11	104.13	98.42	180.62	210.11	232.30	251.11	267.95	283.47
466	154.80	133.07	120.36	111.34	104.35	98.63	180.62	210.11	232.30	251.11	267.95	283.47
467	155.09	133.32	120.59	111.55	104.55	98.82	180.67	210.16	232.36	251.18	268.01	283.54
468	155.35	133.55	120.79	111.74	104.72	98.99	180.75	210.26	232.46	251.29	268.14	283.67
469	155.58	133.74	120.97	111.90	104.87	99.13	180.87	210.40	232.62	251.46	268.32	283.87
470	155.94	134.05	121.25	112.17	105.12	99.36	180.84	210.36	232.58	251.41	268.27	283.81
471	156.26	134.33	121.50	112.39	105.33	99.56	180.85	210.38	232.60	251.44	268.29	283.84
472	156.55	134.57	121.72	112.60	105.53	99.75	180.90	210.44	232.66	251.51	268.37	283.92
473	156.79	134.78	121.91	112.77	105.69	99.90	181.01	210.57	232.80	251.66	268.53	284.09
474	157.15	135.09	122.19	113.04	105.94	100.13	180.97	210.52	232.75	251.60	268.47	284.02
475	157.45	135.35	122.42	113.25	106.13	100.32	181.01	210.57	232.81	251.66	268.53	284.09
476	157.67	135.54	122.59	113.41	106.28	100.46	181.14	210.72	232.97	251.84	268.72	284.29
477	158.04	135.86	122.88	113.67	106.53	100.70	181.09	210.66	232.91	251.77	268.65	284.22
478	158.31	136.09	123.09	113.87	106.71	100.87	181.17	210.75	233.00	251.87	268.76	284.33
479	158.71	136.43	123.40	114.16	106.99	101.13	181.08	210.65	232.90	251.76	268.63	284.20
480	158.97	136.66	123.60	114.34	107.16	101.29	181.17	210.75	233.00	251.88	268.76	284.33
481	159.26	136.90	123.83	114.55	107.35	101.47	181.22	210.81	233.07	251.94	268.83	284.41
482	159.51	137.12	124.02	114.73	107.52	101.63	181.31	210.91	233.19	252.07	268.97	284.56
483	159.80	137.37	124.25	114.94	107.72	101.82	181.35	210.96	233.24	252.13	269.03	284.62
484	160.17	137.68	124.53	115.20	107.97	102.05	181.31	210.92	233.19	252.08	268.97	284.56

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
485	160.45	137.93	124.75	115.41	108.16	102.23	181.37	210.98	233.26	252.15	269.06	284.65
486	160.74	138.18	124.98	115.62	108.35	102.42	181.41	211.03	233.31	252.21	269.12	284.71
487	161.04	138.44	125.21	115.83	108.56	102.61	181.45	211.07	233.36	252.26	269.17	284.77
488	161.31	138.67	125.42	116.03	108.74	102.78	181.51	211.15	233.45	252.36	269.27	284.88
489	161.68	138.99	125.71	116.29	108.99	103.02	181.47	211.10	233.39	252.29	269.21	284.80
490	161.93	139.21	125.91	116.48	109.16	103.18	181.55	211.20	233.50	252.41	269.33	284.94
491	162.24	139.47	126.15	116.70	109.36	103.37	181.58	211.23	233.54	252.45	269.38	284.98
492	162.57	139.76	126.41	116.94	109.59	103.59	181.58	211.23	233.53	252.45	269.37	284.98
493	162.81	139.96	126.59	117.11	109.75	103.74	181.68	211.35	233.67	252.59	269.52	285.14
494	163.16	140.26	126.86	117.35	109.98	103.96	181.67	211.33	233.64	252.57	269.50	285.11
495	163.46	140.52	127.10	117.57	110.19	104.15	181.69	211.36	233.68	252.61	269.54	285.16
496	163.73	140.75	127.31	117.77	110.37	104.33	181.76	211.44	233.77	252.70	269.64	285.26
497	164.07	141.04	127.57	118.01	110.60	104.54	181.75	211.42	233.75	252.68	269.62	285.24
498	164.29	141.23	127.74	118.17	110.75	104.68	181.87	211.56	233.91	252.85	269.80	285.43
499	164.65	141.54	128.02	118.43	110.99	104.91	181.84	211.53	233.87	252.81	269.76	285.39
500	164.97	141.81	128.27	118.66	111.20	105.11	181.85	211.55	233.89	252.83	269.78	285.41
501	165.32	142.12	128.54	118.91	111.44	105.34	181.83	211.52	233.85	252.79	269.74	285.37
502	165.52	142.29	128.70	119.05	111.57	105.46	181.97	211.69	234.04	252.99	269.95	285.60
503	165.91	142.63	129.00	119.34	111.84	105.72	181.90	211.60	233.95	252.89	269.85	285.48
504	166.19	142.86	129.22	119.54	112.03	105.89	181.96	211.67	234.03	252.98	269.94	285.58
505	166.44	143.07	129.41	119.71	112.19	106.05	182.05	211.78	234.14	253.10	270.07	285.72
506	166.80	143.39	129.69	119.98	112.44	106.28	182.01	211.73	234.09	253.05	270.02	285.66
507	166.97	143.54	129.83	120.10	112.55	106.39	182.19	211.93	234.31	253.29	270.27	285.93
508	167.33	143.85	130.11	120.36	112.80	106.62	182.15	211.89	234.27	253.24	270.22	285.88
509	167.60	144.07	130.31	120.55	112.98	106.79	182.22	211.97	234.36	253.34	270.32	285.99
510	167.95	144.38	130.59	120.81	113.22	107.02	182.19	211.94	234.32	253.30	270.28	285.94
511	168.25	144.64	130.82	121.02	113.42	107.21	182.23	211.98	234.37	253.35	270.33	285.99
512	168.52	144.86	131.03	121.21	113.59	107.37	182.30	212.06	234.46	253.45	270.44	286.11
513	168.83	145.14	131.27	121.44	113.81	107.58	182.31	212.08	234.47	253.46	270.45	286.12
514	169.22	145.47	131.57	121.71	114.07	107.82	182.25	212.01	234.40	253.38	270.37	286.03
515	169.44	145.66	131.75	121.88	114.22	107.96	182.36	212.14	234.54	253.54	270.53	286.21
516	169.77	145.94	132.00	122.11	114.44	108.17	182.36	212.14	234.54	253.54	270.53	286.21
517	170.02	146.15	132.19	122.29	114.61	108.33	182.45	212.24	234.66	253.66	270.67	286.35
518	170.34	146.43	132.44	122.52	114.82	108.53	182.46	212.25	234.67	253.67	270.68	286.36
519	170.73	146.76	132.75	122.80	115.08	108.78	182.40	212.18	234.58	253.58	270.58	286.26
520	171.00	147.00	132.96	123.00	115.27	108.95	182.46	212.25	234.66	253.67	270.67	286.36
521	171.26	147.22	133.16	123.19	115.45	109.12	182.53	212.33	234.75	253.76	270.77	286.46
522	171.46	147.39	133.32	123.33	115.58	109.25	182.67	212.49	234.93	253.96	270.98	286.69
523	171.85	147.73	133.62	123.61	115.84	109.50	182.60	212.41	234.84	253.86	270.88	286.58
524	172.14	147.97	133.84	123.81	116.03	109.68	182.65	212.47	234.91	253.93	270.95	286.65
525	172.43	148.23	134.07	124.03	116.24	109.87	182.68	212.51	234.95	253.98	271.00	286.70
526	172.83	148.57	134.38	124.31	116.50	110.12	182.61	212.43	234.86	253.88	270.90	286.60

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
527	173.02	148.73	134.52	124.45	116.63	110.24	182.76	212.60	235.05	254.09	271.12	286.83
528	173.48	149.13	134.88	124.78	116.94	110.53	182.62	212.44	234.87	253.89	270.91	286.61
529	173.69	149.31	135.05	124.93	117.08	110.67	182.74	212.58	235.03	254.07	271.10	286.80
530	173.99	149.57	135.28	125.15	117.28	110.86	182.77	212.61	235.06	254.10	271.14	286.85
531	174.22	149.76	135.46	125.31	117.44	111.01	182.88	212.74	235.20	254.25	271.29	287.01
532	174.57	150.07	135.73	125.56	117.68	111.23	182.85	212.70	235.16	254.21	271.25	286.97
533	174.86	150.31	135.96	125.77	117.87	111.41	182.89	212.75	235.22	254.27	271.32	287.04
534	175.14	150.56	136.18	125.97	118.06	111.59	182.94	212.81	235.28	254.34	271.39	287.11
535	175.48	150.85	136.44	126.22	118.29	111.81	182.93	212.80	235.27	254.32	271.37	287.09
536	175.80	151.12	136.69	126.45	118.50	112.01	182.94	212.81	235.28	254.33	271.38	287.11
537	176.07	151.36	136.90	126.65	118.69	112.19	182.99	212.87	235.35	254.41	271.46	287.19
538	176.45	151.68	137.19	126.91	118.94	112.43	182.94	212.82	235.29	254.35	271.39	287.12
539	176.64	151.85	137.34	127.05	119.07	112.55	183.08	212.98	235.47	254.54	271.60	287.34
540	176.92	152.09	137.56	127.25	119.26	112.73	183.14	213.04	235.53	254.61	271.68	287.42
541	177.32	152.43	137.87	127.54	119.53	112.98	183.06	212.95	235.44	254.51	271.57	287.30
542	177.62	152.69	138.10	127.76	119.73	113.17	183.09	212.98	235.47	254.55	271.61	287.35
543	177.88	152.91	138.31	127.94	119.91	113.34	183.16	213.06	235.56	254.64	271.71	287.46
544	178.26	153.24	138.60	128.22	120.16	113.58	183.11	213.00	235.50	254.57	271.64	287.38
545	178.40	153.36	138.71	128.32	120.25	113.67	183.30	213.23	235.75	254.84	271.92	287.68
546	178.75	153.66	138.98	128.57	120.49	113.89	183.27	213.20	235.71	254.80	271.88	287.64
547	179.07	153.94	139.24	128.80	120.71	114.10	183.28	213.20	235.72	254.81	271.89	287.64
548	179.34	154.17	139.44	128.99	120.89	114.27	183.34	213.28	235.80	254.89	271.98	287.74
549	179.66	154.45	139.69	129.23	121.11	114.48	183.34	213.28	235.80	254.90	271.99	287.75
550	180.01	154.75	139.97	129.48	121.35	114.70	183.32	213.25	235.77	254.87	271.95	287.71
551	180.29	154.98	140.18	129.68	121.53	114.87	183.37	213.32	235.84	254.94	272.03	287.79
552	180.59	155.25	140.42	129.90	121.74	115.07	183.39	213.34	235.87	254.97	272.06	287.83
553	180.84	155.46	140.61	130.07	121.90	115.23	183.48	213.43	235.97	255.09	272.18	287.96
554	181.20	155.77	140.89	130.33	122.15	115.46	183.44	213.40	235.93	255.04	272.14	287.90
555	181.51	156.03	141.13	130.56	122.35	115.65	183.46	213.42	235.95	255.06	272.16	287.93
556	181.74	156.23	141.31	130.72	122.51	115.80	183.55	213.52	236.07	255.19	272.30	288.08
557	182.11	156.54	141.59	130.98	122.76	116.03	183.52	213.49	236.03	255.15	272.25	288.02
558	182.37	156.78	141.80	131.18	122.94	116.20	183.58	213.55	236.10	255.23	272.34	288.12
559	182.64	157.01	142.01	131.37	123.12	116.37	183.64	213.62	236.18	255.31	272.42	288.21
560	183.02	157.33	142.30	131.64	123.37	116.61	183.59	213.57	236.12	255.24	272.35	288.14
561	183.22	157.50	142.46	131.79	123.51	116.74	183.71	213.71	236.28	255.41	272.54	288.33
562	183.52	157.76	142.69	132.00	123.71	116.93	183.74	213.74	236.31	255.45	272.58	288.37
563	183.82	158.02	142.93	132.22	123.91	117.13	183.76	213.77	236.34	255.48	272.61	288.40
564	184.18	158.33	143.21	132.48	124.16	117.36	183.73	213.73	236.30	255.44	272.56	288.35
565	184.53	158.63	143.48	132.73	124.39	117.58	183.71	213.71	236.28	255.41	272.53	288.33
566	184.82	158.88	143.70	132.93	124.58	117.76	183.75	213.75	236.32	255.46	272.59	288.38
567	185.06	159.08	143.89	133.11	124.75	117.91	183.83	213.85	236.43	255.58	272.71	288.51
568	185.30	159.29	144.08	133.28	124.91	118.07	183.92	213.95	236.54	255.70	272.84	288.65

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
569	185.73	159.66	144.41	133.59	125.20	118.34	183.82	213.83	236.41	255.56	272.69	288.49
570	186.00	159.89	144.62	133.78	125.38	118.51	183.87	213.90	236.48	255.64	272.77	288.58
571	186.31	160.15	144.86	134.00	125.59	118.71	183.89	213.92	236.51	255.66	272.80	288.61
572	186.53	160.35	145.03	134.17	125.74	118.85	183.99	214.03	236.63	255.80	272.95	288.76
573	186.78	160.56	145.23	134.35	125.91	119.01	184.07	214.12	236.73	255.91	273.06	288.88
574	187.24	160.96	145.58	134.67	126.21	119.30	183.94	213.97	236.57	255.73	272.87	288.68
575	187.47	161.16	145.77	134.84	126.37	119.45	184.03	214.08	236.68	255.85	273.00	288.82
576	187.76	161.41	145.99	135.05	126.57	119.64	184.06	214.12	236.73	255.90	273.05	288.88
577	188.09	161.69	146.25	135.29	126.79	119.85	184.06	214.11	236.72	255.90	273.05	288.87
578	188.37	161.93	146.47	135.49	126.98	120.03	184.10	214.16	236.78	255.96	273.11	288.94
579	188.65	162.17	146.68	135.69	127.17	120.20	184.15	214.22	236.84	256.02	273.19	289.02
580	188.97	162.44	146.93	135.92	127.38	120.40	184.16	214.23	236.85	256.04	273.20	289.03
581	189.29	162.72	147.18	136.15	127.60	120.61	184.16	214.23	236.85	256.03	273.20	289.03
582	189.51	162.91	147.35	136.31	127.75	120.75	184.26	214.35	236.98	256.18	273.35	289.19
583	189.86	163.21	147.63	136.56	127.99	120.98	184.24	214.32	236.95	256.14	273.31	289.15
584	190.13	163.44	147.83	136.76	128.17	121.15	184.29	214.38	237.02	256.22	273.40	289.24
585	190.52	163.78	148.13	137.04	128.43	121.39	184.23	214.31	236.95	256.14	273.31	289.14
586	190.83	164.04	148.38	137.26	128.64	121.59	184.25	214.33	236.97	256.16	273.33	289.17
587	191.03	164.22	148.53	137.40	128.77	121.72	184.37	214.47	237.12	256.33	273.51	289.36
588	191.39	164.52	148.81	137.66	129.01	121.95	184.34	214.44	237.08	256.28	273.46	289.31
589	191.64	164.74	149.00	137.84	129.18	122.11	184.41	214.52	237.18	256.38	273.57	289.42
590	191.90	164.96	149.21	138.03	129.36	122.27	184.47	214.59	237.25	256.47	273.66	289.52
591	192.31	165.32	149.53	138.33	129.64	122.54	184.39	214.49	237.14	256.35	273.53	289.38
592	192.55	165.52	149.71	138.50	129.79	122.69	184.47	214.59	237.25	256.47	273.66	289.52
593	192.90	165.82	149.98	138.75	130.03	122.91	184.45	214.57	237.23	256.44	273.63	289.48
594	193.13	166.03	150.17	138.92	130.19	123.06	184.53	214.67	237.33	256.56	273.75	289.62
595	193.41	166.27	150.38	139.12	130.38	123.24	184.58	214.72	237.39	256.62	273.82	289.69
596	193.72	166.53	150.62	139.33	130.58	123.43	184.60	214.74	237.42	256.65	273.85	289.72
597	194.07	166.83	150.90	139.59	130.82	123.66	184.57	214.71	237.38	256.61	273.81	289.67
598	194.40	167.12	151.15	139.83	131.04	123.87	184.57	214.70	237.37	256.60	273.80	289.66
599	194.70	167.37	151.38	140.04	131.24	124.05	184.59	214.74	237.41	256.64	273.84	289.71
600	194.93	167.57	151.57	140.21	131.40	124.21	184.68	214.83	237.52	256.75	273.97	289.84
601	195.28	167.87	151.84	140.46	131.64	124.43	184.66	214.81	237.49	256.72	273.93	289.81
602	195.52	168.07	152.02	140.63	131.80	124.58	184.74	214.90	237.60	256.84	274.06	289.94
603	195.77	168.29	152.21	140.81	131.96	124.74	184.81	214.99	237.69	256.94	274.17	290.05
604	196.18	168.64	152.54	141.11	132.24	125.00	184.73	214.89	237.58	256.82	274.04	289.92
605	196.54	168.95	152.82	141.37	132.49	125.23	184.69	214.85	237.54	256.78	273.99	289.87
606	196.84	169.21	153.05	141.58	132.68	125.42	184.72	214.88	237.58	256.82	274.03	289.91
607	197.14	169.47	153.28	141.80	132.89	125.61	184.74	214.91	237.60	256.84	274.06	289.94
608	197.40	169.69	153.48	141.98	133.06	125.78	184.80	214.98	237.68	256.93	274.15	290.04
609	197.80	170.04	153.80	142.27	133.34	126.03	184.73	214.89	237.58	256.83	274.04	289.92
610	197.99	170.20	153.95	142.41	133.47	126.16	184.85	215.04	237.74	257.00	274.23	290.12

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
611	198.28	170.45	154.17	142.62	133.66	126.34	184.89	215.08	237.79	257.05	274.28	290.17
612	198.64	170.75	154.45	142.87	133.90	126.56	184.86	215.04	237.75	257.01	274.24	290.13
613	198.90	170.98	154.65	143.06	134.07	126.73	184.92	215.11	237.83	257.09	274.33	290.22
614	199.30	171.32	154.96	143.35	134.34	126.99	184.85	215.03	237.74	257.00	274.22	290.11
615	199.46	171.47	155.09	143.47	134.46	127.09	185.00	215.20	237.93	257.20	274.44	290.34
616	199.75	171.71	155.31	143.68	134.65	127.27	185.03	215.24	237.97	257.25	274.49	290.40
617	200.06	171.98	155.55	143.90	134.86	127.47	185.04	215.26	237.99	257.26	274.51	290.42
618	200.45	172.32	155.86	144.18	135.12	127.72	184.98	215.19	237.91	257.18	274.42	290.32
619	200.72	172.54	156.06	144.37	135.30	127.89	185.04	215.25	237.98	257.26	274.50	290.41
620	200.98	172.77	156.27	144.56	135.48	128.06	185.09	215.31	238.05	257.33	274.58	290.49
621	201.31	173.05	156.52	144.79	135.70	128.27	185.09	215.31	238.05	257.33	274.58	290.49
622	201.64	173.34	156.78	145.04	135.92	128.48	185.08	215.30	238.04	257.32	274.56	290.47
623	201.81	173.48	156.91	145.16	136.04	128.59	185.22	215.47	238.22	257.51	274.78	290.70
624	202.26	173.87	157.27	145.48	136.34	128.88	185.11	215.33	238.07	257.35	274.60	290.51
625	202.43	174.01	157.39	145.60	136.45	128.98	185.25	215.50	238.26	257.56	274.82	290.74
626	202.82	174.35	157.70	145.88	136.72	129.23	185.19	215.43	238.18	257.47	274.72	290.64
627	203.10	174.60	157.92	146.09	136.91	129.41	185.23	215.47	238.22	257.52	274.78	290.70
628	203.35	174.81	158.11	146.27	137.08	129.57	185.29	215.55	238.31	257.61	274.88	290.81
629	203.70	175.11	158.38	146.52	137.31	129.79	185.27	215.52	238.28	257.58	274.85	290.77
630	204.04	175.40	158.64	146.76	137.54	130.01	185.26	215.51	238.27	257.57	274.83	290.76
631	204.19	175.53	158.76	146.87	137.64	130.10	185.42	215.70	238.47	257.79	275.07	291.01
632	204.57	175.86	159.06	147.14	137.90	130.34	185.37	215.63	238.40	257.71	274.99	290.92
633	204.97	176.20	159.37	147.43	138.16	130.60	185.30	215.56	238.32	257.62	274.89	290.82
634	205.20	176.40	159.55	147.59	138.32	130.75	185.38	215.65	238.42	257.74	275.01	290.95
635	205.55	176.70	159.82	147.85	138.56	130.97	185.35	215.62	238.39	257.70	274.97	290.90
636	205.83	176.94	160.04	148.05	138.75	131.15	185.39	215.67	238.44	257.75	275.03	290.97
637	206.14	177.21	160.28	148.27	138.96	131.35	185.41	215.68	238.45	257.77	275.05	290.98
638	206.41	177.44	160.49	148.47	139.14	131.52	185.45	215.73	238.52	257.83	275.12	291.06
639	206.80	177.77	160.79	148.75	139.40	131.77	185.40	215.67	238.44	257.76	275.03	290.97
640	206.99	177.93	160.94	148.88	139.53	131.88	185.52	215.81	238.60	257.93	275.22	291.16
641	207.41	178.30	161.27	149.18	139.81	132.15	185.43	215.71	238.49	257.80	275.08	291.02
642	207.46	178.34	161.31	149.22	139.85	132.19	185.67	215.99	238.80	258.14	275.44	291.40
643	207.91	178.73	161.66	149.55	140.15	132.48	185.56	215.86	238.65	257.98	275.27	291.22
644	208.13	178.92	161.83	149.70	140.30	132.62	185.65	215.96	238.77	258.11	275.41	291.37
645	208.54	179.27	162.15	150.00	140.57	132.87	185.58	215.88	238.67	258.00	275.30	291.25
646	208.77	179.47	162.33	150.16	140.73	133.02	185.66	215.97	238.78	258.12	275.42	291.38
647	209.03	179.69	162.52	150.35	140.90	133.19	185.72	216.04	238.86	258.20	275.51	291.47
648	209.43	180.03	162.84	150.64	141.17	133.44	185.65	215.96	238.77	258.11	275.41	291.37
649	209.66	180.23	163.01	150.80	141.33	133.59	185.73	216.06	238.88	258.22	275.53	291.50
650	210.07	180.59	163.34	151.10	141.61	133.85	185.65	215.96	238.77	258.11	275.41	291.37
651	210.16	180.67	163.41	151.17	141.67	133.91	185.85	216.20	239.03	258.39	275.71	291.69
652	210.60	181.04	163.75	151.48	141.97	134.19	185.75	216.08	238.90	258.25	275.56	291.53

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
653	210.89	181.29	163.98	151.69	142.16	134.37	185.78	216.12	238.94	258.29	275.60	291.57
654	211.18	181.54	164.20	151.90	142.35	134.56	185.81	216.15	238.98	258.33	275.65	291.62
655	211.54	181.85	164.48	152.15	142.59	134.78	185.78	216.12	238.94	258.29	275.61	291.58
656	211.76	182.04	164.65	152.31	142.74	134.93	185.87	216.22	239.05	258.41	275.74	291.71
657	212.06	182.30	164.89	152.53	142.95	135.12	185.89	216.24	239.08	258.44	275.76	291.74
658	212.42	182.60	165.16	152.79	143.19	135.35	185.86	216.21	239.04	258.40	275.72	291.70
659	212.62	182.77	165.32	152.93	143.32	135.47	185.97	216.33	239.18	258.55	275.88	291.87
660	212.97	183.08	166.27	153.17	143.54	135.69	185.94	216.30	238.16	258.53	275.89	291.85
661	213.31	183.37	165.86	153.43	143.79	135.91	185.93	216.28	239.12	258.49	275.82	291.80
662	213.55	183.57	166.04	153.60	143.95	136.06	186.00	216.37	239.22	258.60	275.93	291.92
663	213.85	183.85	166.29	153.83	144.17	136.27	186.02	216.37	239.22	258.60	275.93	291.92
664	214.15	184.09	166.51	154.03	144.36	136.45	186.04	216.41	239.27	258.64	275.98	291.97
665	214.49	184.38	166.77	154.28	144.59	136.67	186.02	216.40	239.25	258.63	275.96	291.95
666	214.71	184.57	166.94	154.43	144.73	136.80	186.11	216.50	239.37	258.75	276.10	292.10
667	215.03	184.85	167.20	154.66	144.94	137.00	186.12	216.50	239.36	258.77	276.11	292.11
668	215.31	185.10	167.42	154.86	145.13	137.18	186.15	216.53	239.39	258.81	276.16	292.16
669	215.14	185.36	167.65	155.07	145.32	137.37	186.58	216.55	239.42	258.86	276.21	292.21
670	215.95	185.61	167.88	155.27	145.52	137.55	186.15	216.58	239.45	258.90	276.26	292.26
671	216.31	185.94	168.18	155.58	145.81	137.82	186.13	216.52	239.38	258.77	276.11	292.11
672	216.75	186.33	168.53	155.90	146.11	138.11	186.02	216.40	239.25	258.62	275.96	291.95
673	216.95	186.50	168.69	156.05	146.24	138.23	186.13	216.52	239.38	258.77	276.12	292.11
674	217.23	186.74	168.90	156.25	146.43	138.41	186.16	216.56	239.43	258.82	276.17	292.17
675	217.48	186.96	169.10	156.43	146.60	138.57	186.22	216.63	239.50	258.90	276.26	292.26
676	217.79	187.22	169.34	156.65	146.81	138.77	186.23	216.64	239.52	258.92	276.27	292.28
677	218.01	187.41	169.51	156.81	146.96	138.91	186.32	216.74	239.63	259.04	276.40	292.42
678	218.43	187.77	169.83	157.11	147.24	139.18	186.24	216.65	239.53	258.93	276.28	292.29
679	218.68	187.99	170.03	157.29	147.41	139.34	186.30	216.71	239.60	259.00	276.37	292.38
680	218.92	188.19	170.22	157.46	147.57	139.49	186.37	216.80	239.70	259.11	276.48	292.50
681	219.31	188.52	170.52	157.74	147.83	139.73	186.32	216.74	239.62	259.03	276.40	292.41
682	219.58	188.76	170.73	157.94	148.02	139.91	186.35	216.78	239.68	259.09	276.45	292.47
683	219.91	189.04	170.99	158.18	148.24	140.12	186.35	216.78	239.67	259.08	276.45	292.46
684	220.19	189.28	171.20	158.38	148.43	140.30	186.38	216.82	239.71	259.13	276.50	292.52
685	220.52	189.56	171.46	158.61	148.65	140.51	186.38	216.81	239.71	259.12	276.49	292.51
686	220.77	189.78	171.65	158.79	148.82	140.67	186.44	216.88	239.79	259.21	276.58	292.61
687	221.04	190.01	171.86	158.99	149.00	140.84	186.48	216.93	239.84	259.27	276.65	292.68
688	221.44	190.36	172.18	159.28	149.27	141.09	186.42	216.85	239.75	259.17	276.55	292.57
689	221.71	190.59	172.38	159.47	149.45	141.26	186.46	216.91	239.81	259.24	276.61	292.64
690	221.80	190.67	172.46	159.54	149.51	141.33	186.65	217.13	240.06	259.50	276.90	292.94
691	222.32	191.12	172.86	159.91	149.87	141.66	186.48	216.93	239.84	259.27	276.65	292.68
692	222.56	191.32	173.05	160.08	150.02	141.81	186.56	217.02	239.94	259.37	276.76	292.79
693	222.85	191.57	173.27	160.29	150.22	141.99	186.58	217.05	239.97	259.40	276.79	292.83
694	223.24	191.90	173.57	160.57	150.48	142.24	186.53	216.98	239.90	259.33	276.71	292.74

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
695	223.43	192.07	173.73	160.71	150.61	142.37	186.63	217.11	240.03	259.47	276.87	292.91
696	223.74	192.34	173.97	160.93	150.82	142.56	186.64	217.12	240.05	259.49	276.88	292.93
697	224.12	192.66	174.26	161.20	151.08	142.80	186.60	217.07	239.99	259.42	276.81	292.85
698	224.37	192.88	174.46	161.39	151.25	142.96	186.65	217.13	240.06	259.50	276.90	292.94
699	224.66	193.13	174.68	161.59	151.44	143.15	186.68	217.16	240.09	259.54	276.94	292.99
700	225.01	193.43	174.95	161.85	151.68	143.37	186.66	217.13	240.06	259.50	276.90	292.95
701	225.33	193.70	175.20	162.07	151.89	143.57	186.66	217.14	240.07	259.52	276.91	292.96
702	225.63	193.96	175.44	162.29	152.10	143.77	186.67	217.15	240.09	259.53	276.93	292.97
703	225.96	194.25	175.69	162.53	152.32	143.98	186.67	217.15	240.08	259.52	276.92	292.97
704	226.28	194.52	175.94	162.75	152.53	144.18	186.67	217.15	240.09	259.53	276.93	292.97
705	226.44	194.66	176.06	162.87	152.64	144.28	186.80	217.31	240.25	259.71	277.12	293.18
706	226.83	194.99	176.37	163.15	152.90	144.53	186.75	217.24	240.18	259.63	277.04	293.09
707	227.14	195.26	176.61	163.38	153.11	144.73	186.76	217.25	240.19	259.65	277.05	293.11
708	227.50	195.57	176.89	163.63	153.35	144.95	186.73	217.22	240.15	259.60	277.01	293.06
709	227.73	195.76	177.07	163.80	153.51	145.10	186.80	217.30	240.25	259.71	277.12	293.17
710	227.98	195.98	177.26	163.98	153.68	145.26	186.86	217.37	240.32	259.79	277.20	293.26
711	228.15	196.13	177.40	164.10	153.80	145.37	186.98	217.51	240.48	259.96	277.38	293.45
712	228.65	196.56	177.78	164.46	154.13	145.69	186.83	217.34	240.29	259.75	277.17	293.23
713	228.98	196.84	178.04	164.70	154.35	145.90	186.83	217.34	240.29	259.75	277.16	293.22
714	229.29	197.11	178.28	164.92	154.56	146.10	186.84	217.34	240.29	259.76	277.17	293.23
715	229.49	197.28	178.43	165.06	154.70	146.22	186.94	217.46	240.43	259.90	277.32	293.39
716	229.75	197.50	178.63	165.25	154.87	146.39	186.99	217.52	240.49	259.97	277.40	293.47
717	230.17	197.86	178.96	165.55	155.15	146.66	186.91	217.43	240.39	259.86	277.27	293.34
718	230.36	198.03	179.11	165.69	155.28	146.78	187.01	217.55	240.52	260.00	277.43	293.50
719	230.74	198.36	179.41	165.97	155.54	147.02	186.96	217.49	240.45	259.93	277.35	293.42
720	230.94	198.53	179.57	166.11	155.68	147.15	187.06	217.60	240.58	260.06	277.50	293.58
721	231.24	198.78	179.80	166.33	155.88	147.34	187.08	217.62	240.60	260.09	277.53	293.61
722	231.55	199.05	180.03	166.55	156.08	147.53	187.09	217.64	240.62	260.11	277.55	293.63
723	231.82	199.28	180.25	166.75	156.27	147.71	187.12	217.68	240.66	260.16	277.60	293.68
724	232.14	199.56	180.50	166.97	156.48	147.91	187.13	217.68	240.67	260.16	277.60	293.68
725	232.58	199.93	180.84	167.29	156.78	148.19	187.03	217.57	240.55	260.03	277.46	293.54
726	232.81	200.13	181.02	167.45	156.93	148.34	187.11	217.66	240.64	260.13	277.57	293.65
727	233.20	200.47	181.32	167.73	157.20	148.59	187.05	217.59	240.57	260.05	277.49	293.57
728	233.36	200.60	181.44	167.85	157.30	148.69	187.18	217.74	240.74	260.23	277.68	293.77
729	233.76	200.94	181.75	168.13	157.57	148.94	187.12	217.67	240.66	260.15	277.59	293.67
730	233.96	201.12	181.91	168.28	157.71	149.07	187.21	217.78	240.78	260.28	277.72	293.82
731	234.28	201.39	182.16	168.51	157.92	149.27	187.22	217.78	240.78	260.28	277.73	293.82
732	234.60	201.67	182.41	168.74	158.14	149.48	187.21	217.78	240.77	260.28	277.72	293.82
733	234.83	201.87	182.58	168.90	158.29	149.62	187.29	217.87	240.87	260.38	277.84	293.94
734	235.15	202.14	182.84	169.14	158.51	149.83	187.28	217.86	240.87	260.38	277.83	293.93
735	235.41	202.36	183.04	169.32	158.69	149.99	187.34	217.92	240.94	260.45	277.91	294.01
736	235.81	202.71	183.35	169.61	158.96	150.25	187.27	217.84	240.85	260.36	277.81	293.91

Table B.2: Simulation Data for Picking Times (High Rate)—*continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
737	236.06	202.92	183.54	169.79	159.12	150.41	187.33	217.91	240.93	260.44	277.90	294.00
738	236.45	203.26	183.85	170.07	159.39	150.66	187.27	217.85	240.85	260.36	277.81	293.91
739	236.69	203.47	184.03	170.24	159.55	150.81	187.34	217.92	240.94	260.45	277.91	294.01
740	236.99	203.73	184.27	170.46	159.75	151.00	187.35	217.94	240.95	260.47	277.93	294.03
741	237.28	203.97	184.49	170.67	159.95	151.19	187.38	217.97	240.99	260.51	277.97	294.08
742	237.68	204.32	184.80	170.96	160.22	151.44	187.31	217.90	240.90	260.42	277.87	293.97
743	237.88	204.49	184.96	171.10	160.35	151.57	187.40	218.00	241.02	260.55	278.01	294.12
744	238.19	204.76	185.20	171.33	160.56	151.77	187.41	218.01	241.03	260.55	278.02	294.13
745	238.62	205.13	185.53	171.63	160.85	152.04	187.33	217.92	240.93	260.44	277.90	294.00
746	238.78	205.26	185.66	171.75	160.96	152.14	187.46	218.06	241.09	260.62	278.09	294.20
747	239.20	205.62	185.98	172.05	161.24	152.41	187.38	217.97	240.99	260.51	277.97	294.08
748	239.33	205.74	186.09	172.15	161.33	152.49	187.52	218.14	241.18	260.71	278.19	294.31
749	239.68	206.04	186.36	172.40	161.57	152.72	187.50	218.11	241.14	260.67	278.15	294.27
750	240.08	206.38	186.67	172.69	161.84	152.97	187.43	218.04	241.06	260.59	278.06	294.17

Table B.3: Simulation Data for Picking Times (Low Rate).

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
1	2.34	2.01	1.82	1.68	1.58	1.49	25.65	29.84	32.99	35.66	38.05	40.26
2	3.80	3.26	2.95	2.73	2.56	2.42	31.62	36.78	40.67	43.96	46.91	49.62
3	5.09	4.38	3.96	3.66	3.43	3.24	35.36	41.14	45.48	49.17	52.46	55.50
4	6.31	5.42	4.90	4.54	4.25	4.02	38.06	44.28	48.95	52.92	56.46	59.74
5	7.53	6.48	5.86	5.42	5.08	4.80	39.83	46.33	51.22	55.37	59.08	62.51
6	8.69	7.47	6.76	6.25	5.86	5.54	41.42	48.19	53.27	57.59	61.45	65.01
7	9.69	8.33	7.54	6.97	6.53	6.17	43.34	50.41	55.74	60.25	64.29	68.02
8	10.42	8.95	8.10	7.49	7.02	6.64	46.09	53.61	59.27	64.07	68.37	72.33
9	11.70	10.06	9.10	8.42	7.89	7.46	46.14	53.67	59.34	64.14	68.44	72.41
10	12.76	10.97	9.92	9.18	8.60	8.13	47.02	54.70	60.48	65.38	69.76	73.80
11	13.56	11.66	10.54	9.75	9.14	8.64	48.68	56.62	62.60	67.67	72.21	76.39
12	14.64	12.58	11.38	10.53	9.87	9.33	49.19	57.22	63.26	68.39	72.97	77.20
13	15.58	13.39	12.11	11.21	10.50	9.93	50.07	58.24	64.40	69.61	74.28	78.58
14	16.42	14.11	12.77	11.81	11.07	10.46	51.16	59.52	65.80	71.13	75.90	80.30
15	17.39	14.95	13.52	12.51	11.72	11.08	51.76	60.21	66.57	71.96	76.78	81.23
16	17.91	15.39	13.92	12.88	12.07	11.41	53.61	62.37	68.95	74.54	79.54	84.14
17	18.76	16.13	14.59	13.49	12.65	11.95	54.37	63.24	69.92	75.59	80.65	85.33
18	19.06	16.39	14.82	13.71	12.85	12.15	56.65	65.90	72.86	78.76	84.04	88.91
19	20.28	17.43	15.77	14.59	13.67	12.92	56.22	65.40	72.30	78.16	83.40	88.23
20	21.26	18.28	16.53	15.29	14.33	13.55	56.43	65.65	72.58	78.46	83.72	88.57
21	21.82	18.76	16.96	15.69	14.71	13.90	57.75	67.18	74.28	80.29	85.67	90.64
22	22.96	19.74	17.85	16.52	15.48	14.63	57.48	66.87	73.93	79.92	85.27	90.22

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
23	23.01	19.78	17.89	16.55	15.51	14.66	59.97	69.76	77.12	83.37	88.96	94.11
24	24.54	21.09	19.08	17.65	16.54	15.64	58.68	68.26	75.47	81.59	87.05	92.10
25	24.50	21.06	19.05	17.62	16.52	15.61	61.22	71.22	78.74	85.12	90.82	96.09
26	25.31	21.76	19.68	18.21	17.06	16.13	61.63	71.69	79.26	85.68	91.43	96.73
27	26.06	22.40	20.26	18.75	17.57	16.61	62.16	72.31	79.95	86.42	92.21	97.56
28	26.53	22.81	20.63	19.09	17.89	16.91	63.32	73.65	81.43	88.03	93.93	99.37
29	26.98	23.20	20.98	19.41	18.19	17.19	64.49	75.01	82.94	89.65	95.66	101.21
30	27.96	24.03	21.74	20.11	18.85	17.81	64.38	74.89	82.80	89.51	95.51	101.04
31	28.27	24.30	21.98	20.34	19.06	18.01	65.79	76.53	84.61	91.46	97.59	103.25
32	28.90	24.84	22.47	20.78	19.48	18.41	66.45	77.29	85.46	92.38	98.57	104.28
33	29.73	25.55	23.11	21.38	20.04	18.94	66.61	77.48	85.67	92.61	98.81	104.54
34	30.31	26.05	23.56	21.80	20.43	19.31	67.31	78.31	86.57	93.59	99.86	105.65
35	31.15	26.78	24.22	22.40	21.00	19.85	67.42	78.43	86.71	93.74	100.02	105.81
36	31.72	27.27	24.66	22.81	21.38	20.21	68.10	79.22	87.58	94.68	101.02	106.88
37	32.04	27.55	24.91	23.05	21.60	20.42	69.28	80.59	89.10	96.32	102.78	108.73
38	33.16	28.51	25.78	23.85	22.35	21.13	68.76	79.98	88.43	95.59	102.00	107.91
39	32.92	28.30	25.60	23.68	22.19	20.98	71.08	82.68	91.42	98.82	105.44	111.55
40	33.56	28.85	26.10	24.14	22.63	21.39	71.50	83.18	91.96	99.41	106.08	112.22
41	34.21	29.41	26.60	24.61	23.06	21.80	71.91	83.65	92.49	99.98	106.68	112.86
42	35.32	30.36	27.46	25.40	23.81	22.50	71.35	83.00	91.76	99.19	105.84	111.98
43	35.28	30.32	27.43	25.37	23.78	22.48	73.14	85.08	94.07	101.68	108.50	114.79
44	36.20	31.12	28.15	26.04	24.40	23.07	72.93	84.84	93.79	101.39	108.19	114.46
45	36.59	31.45	28.45	26.32	24.66	23.31	73.80	85.85	94.91	102.60	109.48	115.82
46	37.63	32.35	29.26	27.07	25.36	23.98	73.35	85.33	94.34	101.98	108.81	115.12
47	38.05	32.71	29.59	27.37	25.65	24.25	74.11	86.21	95.31	103.03	109.94	116.31
48	37.82	32.51	29.41	27.20	25.49	24.10	76.15	88.59	97.94	105.87	112.97	119.52
49	39.19	33.69	30.47	28.19	26.42	24.97	75.01	87.26	96.48	104.29	111.28	117.73
50	39.16	33.67	30.45	28.17	26.40	24.95	76.60	89.11	98.52	106.50	113.64	120.23
51	39.98	34.37	31.08	28.76	26.95	25.47	76.54	89.04	98.44	106.42	113.55	120.13
52	40.25	34.60	31.30	28.95	27.13	25.65	77.51	90.17	99.69	107.76	114.98	121.65
53	40.65	34.95	31.61	29.24	27.40	25.90	78.22	90.99	100.60	108.75	116.04	122.77
54	41.43	35.62	32.21	29.80	27.93	26.40	78.20	90.97	100.58	108.73	116.01	122.74
55	42.17	36.25	32.79	30.33	28.42	26.87	78.26	91.04	100.65	108.80	116.10	122.82
56	42.32	36.38	32.90	30.44	28.53	26.96	79.40	92.36	102.12	110.39	117.79	124.61
57	42.92	36.89	33.37	30.87	28.93	27.35	79.69	92.70	102.49	110.79	118.21	125.06
58	43.33	37.25	33.69	31.17	29.21	27.61	80.31	93.43	103.29	111.66	119.14	126.04
59	44.27	38.05	34.42	31.84	29.84	28.21	79.97	93.02	102.85	111.18	118.63	125.50
60	44.50	38.25	34.60	32.00	29.99	28.35	80.91	94.12	104.06	112.48	120.02	126.98
61	44.98	38.67	34.97	32.35	30.32	28.66	81.37	94.66	104.65	113.13	120.71	127.71
62	45.56	39.16	35.42	32.77	30.71	29.03	81.65	94.98	105.02	113.52	121.13	128.15
63	46.10	39.63	35.85	33.16	31.08	29.38	81.99	95.38	105.45	113.99	121.63	128.68
64	46.56	40.02	36.20	33.49	31.38	29.66	82.48	95.95	106.08	114.67	122.36	129.45

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
65	46.81	40.24	36.40	33.67	31.55	29.83	83.32	96.92	107.15	115.83	123.60	130.76
66	47.18	40.56	36.68	33.94	31.80	30.06	83.93	97.64	107.95	116.69	124.51	131.73
67	47.91	41.18	37.25	34.46	32.29	30.53	83.91	97.61	107.92	116.66	124.48	131.70
68	48.24	41.47	37.51	34.70	32.52	30.74	84.57	98.38	108.77	117.58	125.46	132.73
69	48.27	41.50	37.53	34.72	32.54	30.76	85.77	99.77	110.31	119.24	127.23	134.61
70	49.30	42.38	38.33	35.46	33.23	31.41	85.20	99.11	109.58	118.45	126.39	133.72
71	49.52	42.57	38.50	35.62	33.38	31.55	86.02	100.07	110.64	119.60	127.61	135.01
72	49.98	42.97	38.86	35.95	33.69	31.85	86.43	100.54	111.16	120.16	128.22	135.65
73	50.16	43.12	39.00	36.08	33.81	31.96	87.31	101.57	112.30	121.39	129.53	137.03
74	51.26	44.06	39.85	36.87	34.55	32.66	86.62	100.76	111.40	120.43	128.50	135.95
75	51.43	44.21	39.99	36.99	34.67	32.77	87.50	101.79	112.53	121.65	129.80	137.32
76	51.92	44.63	40.37	37.34	35.00	33.08	87.83	102.17	112.96	122.11	130.29	137.84
77	52.05	44.74	40.47	37.44	35.09	33.16	88.76	103.25	114.16	123.40	131.68	139.31
78	52.89	45.46	41.12	38.04	35.65	33.70	88.49	102.94	113.81	123.03	131.28	138.88
79	53.20	45.73	41.36	38.26	35.86	33.90	89.10	103.65	114.60	123.88	132.18	139.84
80	53.83	46.27	41.85	38.72	36.28	34.30	89.17	103.73	114.69	123.98	132.29	139.95
81	53.91	46.34	41.92	38.78	36.34	34.35	90.15	104.87	115.94	125.33	133.74	141.49
82	54.31	46.69	42.23	39.07	36.61	34.61	90.58	105.38	116.50	125.94	134.38	142.17
83	55.04	47.31	42.79	39.59	37.10	35.07	90.48	105.26	116.37	125.80	134.23	142.01
84	55.39	47.62	43.07	39.84	37.34	35.30	90.98	105.84	117.02	126.49	134.97	142.79
85	55.90	48.05	43.46	40.21	37.68	35.62	91.23	106.13	117.34	126.84	135.34	143.19
86	55.94	48.08	43.49	40.23	37.71	35.64	92.25	107.31	118.64	128.25	136.85	144.78
87	56.76	48.79	44.13	40.83	38.26	36.17	91.97	106.98	118.28	127.86	136.43	144.34
88	56.93	48.94	44.27	40.95	38.38	36.28	92.74	107.88	119.27	128.93	137.58	145.55
89	57.40	49.34	44.63	41.29	38.69	36.57	93.03	108.22	119.65	129.34	138.01	146.00
90	57.96	49.82	45.06	41.69	39.07	36.93	93.17	108.39	119.83	129.54	138.22	146.23
91	58.20	50.03	45.25	41.86	39.23	37.08	93.82	109.14	120.66	130.43	139.18	147.24
92	58.95	50.68	45.84	42.40	39.74	37.56	93.63	108.92	120.42	130.18	138.90	146.95
93	59.33	51.00	46.13	42.67	39.99	37.80	94.05	109.41	120.96	130.76	139.53	147.61
94	59.60	51.24	46.34	42.87	40.18	37.98	94.62	110.07	121.70	131.55	140.37	148.51
95	60.01	51.59	46.66	43.16	40.45	38.24	94.98	110.49	122.16	132.05	140.90	149.07
96	60.29	51.83	46.88	43.36	40.64	38.41	95.54	111.14	122.88	132.83	141.74	149.95
97	61.00	52.44	47.43	43.87	41.12	38.87	95.41	110.99	122.71	132.65	141.54	149.75
98	61.15	52.57	47.55	43.99	41.22	38.97	96.15	111.85	123.66	133.68	142.64	150.90
99	61.71	53.05	47.98	44.39	41.60	39.32	96.25	111.97	123.79	133.82	142.79	151.06
100	62.22	53.49	48.38	44.75	41.94	39.64	96.43	112.18	124.03	134.07	143.06	151.35
101	62.43	53.67	48.54	44.91	42.09	39.78	97.06	112.91	124.84	134.95	143.99	152.34
102	62.59	53.81	48.67	45.02	42.19	39.88	97.77	113.74	125.75	135.93	145.05	153.45
103	63.49	54.58	49.37	45.67	42.80	40.45	97.34	113.23	125.19	135.32	144.40	152.76
104	63.62	54.69	49.47	45.76	42.89	40.54	98.08	114.10	126.14	136.36	145.50	153.93
105	63.80	54.85	49.61	45.89	43.01	40.65	98.74	114.86	126.99	137.28	146.48	154.97
106	64.52	55.47	50.17	46.41	43.50	41.11	98.57	114.66	126.77	137.04	146.22	154.70

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
107	64.69	55.61	50.30	46.53	43.61	41.22	99.24	115.45	127.64	137.98	147.23	155.76
108	65.13	55.99	50.64	46.85	43.90	41.50	99.49	115.74	127.96	138.32	147.59	156.15
109	65.59	56.39	51.00	47.18	44.22	41.79	99.70	115.98	128.23	138.62	147.91	156.48
110	65.92	56.66	51.25	47.41	44.43	42.00	100.13	116.48	128.78	139.21	148.54	157.14
111	66.59	57.24	51.77	47.89	44.88	42.43	100.02	116.35	128.64	139.06	148.38	156.98
112	66.59	57.25	51.78	47.90	44.89	42.43	100.91	117.39	129.78	140.30	149.70	158.38
113	67.09	57.68	52.17	48.26	45.23	42.75	101.05	117.55	129.97	140.49	149.91	158.60
114	67.40	57.94	52.40	48.48	45.43	42.94	101.49	118.06	130.53	141.10	150.56	159.28
115	68.02	58.47	52.89	48.92	45.85	43.34	101.45	118.01	130.47	141.04	150.49	159.21
116	67.95	58.41	52.83	48.87	45.80	43.29	102.43	119.16	131.74	142.41	151.96	160.77
117	68.72	59.07	53.43	49.43	46.32	43.79	102.16	118.84	131.38	142.03	151.55	160.33
118	69.33	59.59	53.90	49.86	46.73	44.17	102.13	118.80	131.35	141.99	151.50	160.28
119	69.67	59.89	54.17	50.11	46.97	44.39	102.48	119.21	131.80	142.47	152.02	160.83
120	69.38	59.64	53.95	49.91	46.77	44.21	103.77	120.72	133.46	144.27	153.94	162.86
121	70.36	60.48	54.71	50.61	47.43	44.83	103.18	120.03	132.71	143.45	153.07	161.94
122	70.55	60.65	54.86	50.75	47.56	44.95	103.75	120.70	133.44	144.25	153.92	162.84
123	70.77	60.84	55.03	50.90	47.71	45.09	104.28	121.30	134.11	144.98	154.69	163.66
124	71.44	61.41	55.55	51.39	48.16	45.52	104.14	121.15	133.94	144.79	154.49	163.44
125	71.83	61.75	55.85	51.67	48.42	45.77	104.41	121.46	134.28	145.16	154.89	163.86
126	72.42	62.25	56.31	52.09	48.82	46.14	104.39	121.44	134.26	145.14	154.87	163.84
127	72.33	62.18	56.24	52.02	48.75	46.08	105.35	122.56	135.50	146.47	156.29	165.35
128	72.45	62.28	56.33	52.11	48.84	46.16	106.01	123.31	136.34	147.38	157.26	166.37
129	73.08	62.82	56.82	52.57	49.26	46.57	105.91	123.20	136.21	147.24	157.11	166.22
130	73.56	63.24	57.20	52.91	49.59	46.87	106.03	123.34	136.37	147.41	157.29	166.41
131	73.74	63.39	57.33	53.04	49.71	46.98	106.60	124.00	137.09	148.20	158.13	167.30
132	74.15	63.74	57.65	53.33	49.98	47.24	106.81	124.26	137.38	148.50	158.46	167.64
133	74.38	63.94	57.83	53.50	50.14	47.39	107.28	124.80	137.98	149.15	159.15	168.37
134	74.80	64.30	58.16	53.80	50.42	47.66	107.48	125.03	138.24	149.43	159.45	168.69
135	75.09	64.55	58.38	54.01	50.62	47.84	107.87	125.49	138.74	149.97	160.03	169.30
136	75.68	65.05	58.84	54.43	51.01	48.22	107.83	125.43	138.68	149.91	159.96	169.23
137	75.74	65.11	58.89	54.48	51.06	48.26	108.52	126.24	139.57	150.88	160.99	170.32
138	76.76	65.98	59.68	55.21	51.74	48.91	107.87	125.49	138.74	149.97	160.03	169.30
139	76.89	66.09	59.78	55.30	51.83	48.99	108.47	126.18	139.51	150.81	160.92	170.24
140	77.24	66.40	60.06	55.56	52.07	49.22	108.75	126.51	139.86	151.19	161.33	170.67
141	77.61	66.72	60.35	55.83	52.32	49.45	109.00	126.80	140.19	151.54	161.70	171.07
142	77.93	67.00	60.60	56.06	52.53	49.66	109.32	127.17	140.60	151.99	162.18	171.58
143	78.10	67.14	60.73	56.18	52.65	49.76	109.85	127.79	141.29	152.73	162.97	172.41
144	78.71	67.66	61.20	56.61	53.05	50.15	109.78	127.70	141.19	152.62	162.85	172.29
145	78.66	67.62	61.16	56.58	53.02	50.12	110.60	128.66	142.25	153.77	164.07	173.58
146	79.28	68.15	61.64	57.02	53.44	50.51	110.50	128.54	142.11	153.62	163.92	173.42
147	79.99	68.76	62.19	57.53	53.92	50.97	110.26	128.27	141.81	153.30	163.58	173.05
148	80.26	69.00	62.41	57.73	54.10	51.14	110.64	128.70	142.29	153.81	164.13	173.64

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
149	80.31	69.04	62.44	57.76	54.13	51.17	111.32	129.50	143.17	154.77	165.14	174.71
150	80.91	69.55	62.91	58.20	54.54	51.55	111.23	129.40	143.06	154.65	165.01	174.57
151	81.14	69.75	63.09	58.36	54.70	51.70	111.66	129.89	143.60	155.23	165.64	175.24
152	81.59	70.13	63.44	58.68	55.00	51.98	111.79	130.04	143.77	155.41	165.83	175.44
153	81.94	70.44	63.71	58.94	55.24	52.21	112.03	130.32	144.08	155.75	166.19	175.82
154	82.17	70.64	63.89	59.10	55.39	52.36	112.45	130.81	144.62	156.34	166.82	176.48
155	82.37	70.81	64.04	59.25	55.52	52.48	112.91	131.34	145.21	156.97	167.49	177.20
156	82.89	71.25	64.45	59.62	55.87	52.81	112.92	131.36	145.23	156.99	167.52	177.22
157	83.19	71.51	64.68	59.83	56.07	53.00	113.24	131.73	145.64	157.44	167.99	177.72
158	83.71	71.96	65.08	60.21	56.43	53.33	113.25	131.75	145.66	157.46	168.01	177.75
159	84.00	72.21	65.31	60.42	56.62	53.52	113.57	132.11	146.06	157.89	168.48	178.24
160	84.44	72.58	65.65	60.73	56.92	53.80	113.70	132.26	146.23	158.07	168.67	178.44
161	84.70	72.81	65.86	60.92	57.09	53.97	114.05	132.67	146.68	158.56	169.19	179.00
162	84.95	73.03	66.05	61.10	57.26	54.13	114.42	133.10	147.16	159.08	169.74	179.57
163	85.22	73.26	66.26	61.30	57.44	54.30	114.76	133.50	147.60	159.55	170.25	180.11
164	85.63	73.61	66.58	61.59	57.72	54.56	114.92	133.68	147.80	159.77	170.48	180.35
165	85.90	73.84	66.79	61.78	57.90	54.73	115.25	134.07	148.23	160.24	170.98	180.89
166	86.14	74.05	66.98	61.96	58.07	54.89	115.63	134.51	148.71	160.75	171.53	181.47
167	86.75	74.57	67.45	62.40	58.48	55.27	115.51	134.37	148.56	160.59	171.35	181.28
168	87.24	75.00	67.83	62.75	58.81	55.59	115.54	134.40	148.60	160.63	171.40	181.33
169	87.23	74.99	67.83	62.74	58.80	55.58	116.24	135.22	149.50	161.61	172.44	182.43
170	87.41	75.14	67.97	62.87	58.92	55.70	116.69	135.74	150.07	162.23	173.10	183.13
171	88.09	75.73	68.49	63.36	59.38	56.13	116.47	135.49	149.80	161.93	172.78	182.79
172	88.46	76.05	68.78	63.63	59.63	56.37	116.66	135.71	150.04	162.19	173.06	183.09
173	88.67	76.22	68.94	63.78	59.77	56.50	117.06	136.18	150.56	162.75	173.66	183.73
174	88.94	76.46	69.15	63.97	59.95	56.67	117.38	136.55	150.97	163.19	174.13	184.22
175	89.36	76.82	69.48	64.28	60.24	56.94	117.50	136.68	151.12	163.36	174.31	184.41
176	89.88	77.26	69.88	64.65	60.59	57.27	117.49	136.68	151.11	163.35	174.30	184.40
177	89.93	77.31	69.92	64.68	60.62	57.30	118.09	137.37	151.88	164.18	175.19	185.34
178	90.45	77.75	70.32	65.06	60.97	57.63	118.08	137.36	151.87	164.17	175.17	185.32
179	90.68	77.95	70.51	65.22	61.13	57.78	118.44	137.78	152.33	164.66	175.70	185.88
180	90.99	78.22	70.75	65.45	61.33	57.97	118.70	138.08	152.66	165.02	176.08	186.29
181	91.49	78.65	71.13	65.80	61.67	58.29	118.70	138.09	152.67	165.03	176.10	186.30
182	91.78	78.90	71.36	66.02	61.87	58.48	118.98	138.41	153.02	165.41	176.50	186.73
183	92.02	79.11	71.55	66.19	62.03	58.63	119.32	138.80	153.46	165.89	177.01	187.26
184	92.38	79.42	71.83	66.45	62.27	58.86	119.50	139.01	153.69	166.14	177.28	187.55
185	92.56	79.57	71.97	66.57	62.39	58.97	119.93	139.51	154.24	166.73	177.91	188.22
186	93.23	80.14	72.49	67.06	62.85	59.40	119.70	139.25	153.95	166.42	177.58	187.87
187	93.56	80.43	72.75	67.30	63.07	59.62	119.92	139.50	154.23	166.72	177.89	188.20
188	93.54	80.41	72.73	67.28	63.05	59.60	120.59	140.28	155.10	167.66	178.90	189.26
189	93.97	80.78	73.07	67.59	63.35	59.88	120.67	140.38	155.20	167.77	179.02	189.39
190	94.50	81.24	73.48	67.97	63.70	60.22	120.63	140.33	155.14	167.71	178.95	189.32

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
191	94.75	81.45	73.67	68.15	63.87	60.37	120.94	140.69	155.55	168.15	179.42	189.81
192	95.05	81.71	73.91	68.37	64.07	60.56	121.20	140.99	155.87	168.50	179.79	190.21
193	95.42	82.03	74.19	68.63	64.32	60.80	121.36	141.17	156.08	168.72	180.03	190.46
194	95.18	81.82	74.01	68.46	64.16	60.65	122.29	142.26	157.29	170.02	181.42	191.93
195	95.91	82.45	74.57	68.99	64.65	61.11	121.99	141.91	156.89	169.60	180.97	191.46
196	96.31	82.79	74.88	69.27	64.92	61.36	122.11	142.05	157.05	169.77	181.15	191.64
197	96.67	83.10	75.16	69.53	65.16	61.59	122.27	142.24	157.26	170.00	181.39	191.90
198	96.98	83.37	75.41	69.76	65.38	61.79	122.50	142.50	157.54	170.30	181.72	192.25
199	97.36	83.70	75.70	70.03	65.63	62.04	122.64	142.66	157.73	170.50	181.93	192.47
200	97.88	84.15	76.11	70.41	65.98	62.37	122.59	142.61	157.67	170.44	181.86	192.40
201	98.00	84.25	76.20	70.49	66.06	62.44	123.06	143.15	158.27	171.09	182.55	193.13
202	98.40	84.59	76.51	70.78	66.33	62.70	123.17	143.28	158.41	171.24	182.72	193.31
203	98.70	84.85	76.75	71.00	66.54	62.89	123.40	143.55	158.71	171.56	183.06	193.67
204	98.85	84.97	76.86	71.10	66.63	62.98	123.83	144.04	159.26	172.15	183.69	194.34
205	99.47	85.51	77.34	71.55	67.05	63.38	123.65	143.84	159.03	171.91	183.44	194.07
206	99.52	85.55	77.38	71.58	67.08	63.41	124.20	144.48	159.73	172.67	184.25	194.92
207	100.20	86.14	77.91	72.07	67.54	63.84	123.95	144.19	159.42	172.33	183.88	194.54
208	100.22	86.15	77.92	72.09	67.56	63.86	124.52	144.86	160.15	173.13	184.73	195.43
209	100.70	86.56	78.30	72.43	67.88	64.16	124.53	144.86	160.16	173.13	184.74	195.44
210	100.95	86.78	78.50	72.61	68.05	64.33	124.81	145.19	160.52	173.52	185.15	195.88
211	101.24	87.03	78.71	72.82	68.24	64.51	125.05	145.47	160.83	173.86	185.51	196.26
212	101.83	87.54	79.18	73.24	68.64	64.88	124.91	145.31	160.65	173.67	185.31	196.05
213	101.77	87.49	79.13	73.20	68.61	64.85	125.57	146.08	161.50	174.58	186.28	197.08
214	102.32	87.96	79.56	73.60	68.97	65.20	125.49	145.98	161.39	174.46	186.16	196.94
215	102.39	88.01	79.61	73.64	69.02	65.24	125.99	146.57	162.04	175.17	186.91	197.74
216	103.11	88.64	80.17	74.17	69.51	65.70	125.69	146.21	161.65	174.74	186.46	197.26
217	103.43	88.91	80.42	74.39	69.72	65.90	125.88	146.44	161.90	175.02	186.75	197.57
218	103.40	88.89	80.40	74.37	69.70	65.88	126.50	147.16	162.70	175.87	187.66	198.54
219	103.73	89.17	80.66	74.61	69.93	66.10	126.67	147.35	162.91	176.11	187.91	198.80
220	104.28	89.64	81.08	75.01	70.29	66.44	126.58	147.25	162.80	175.98	187.78	198.66
221	104.69	90.00	81.40	75.30	70.57	66.71	126.66	147.34	162.90	176.09	187.89	198.78
222	104.83	90.12	81.51	75.40	70.67	66.79	127.06	147.81	163.42	176.65	188.49	199.42
223	105.27	90.49	81.85	75.72	70.96	67.07	127.11	147.86	163.47	176.71	188.56	199.49
224	105.50	90.69	82.03	75.88	71.11	67.22	127.40	148.20	163.85	177.12	188.99	199.94
225	105.87	91.01	82.32	76.15	71.36	67.46	127.52	148.34	164.00	177.28	189.17	200.13
226	105.84	90.99	82.30	76.13	71.35	67.44	128.12	149.03	164.77	178.12	190.06	201.07
227	106.65	91.68	82.93	76.71	71.89	67.96	127.70	148.56	164.24	177.55	189.45	200.43
228	106.77	91.78	83.01	76.79	71.97	68.03	128.13	149.05	164.79	178.14	190.08	201.09
229	107.27	92.22	83.41	77.16	72.31	68.35	128.09	149.00	164.73	178.08	190.01	201.02
230	107.63	92.52	83.68	77.41	72.55	68.58	128.22	149.16	164.91	178.27	190.22	201.24
231	107.94	92.79	83.93	77.64	72.76	68.78	128.40	149.37	165.14	178.52	190.49	201.52
232	108.17	92.98	84.10	77.80	72.91	68.92	128.69	149.70	165.51	178.92	190.91	201.97

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
233	108.51	93.28	84.37	78.05	73.15	69.14	128.83	149.87	165.70	179.12	191.12	202.20
234	108.83	93.55	84.62	78.28	73.36	69.34	129.01	150.07	165.92	179.36	191.38	202.47
235	109.31	93.97	84.99	78.62	73.68	69.65	128.99	150.05	165.90	179.33	191.36	202.44
236	109.61	94.22	85.22	78.84	73.88	69.84	129.19	150.28	166.15	179.61	191.65	202.76
237	109.67	94.28	85.27	78.88	73.93	69.88	129.66	150.83	166.76	180.27	192.35	203.50
238	110.21	94.74	85.69	79.27	74.29	70.22	129.57	150.73	166.64	180.14	192.22	203.35
239	110.30	94.82	85.76	79.34	74.35	70.28	130.01	151.23	167.20	180.75	192.86	204.04
240	110.62	95.09	86.01	79.56	74.57	70.48	130.18	151.44	167.43	180.99	193.12	204.31
241	110.98	95.40	86.29	79.83	74.81	70.71	130.29	151.57	167.57	181.15	193.29	204.49
242	111.39	95.76	86.61	80.12	75.09	70.97	130.35	151.64	167.65	181.23	193.38	204.58
243	111.63	95.96	86.80	80.29	75.25	71.13	130.61	151.93	167.98	181.58	193.76	204.98
244	111.98	96.27	87.07	80.55	75.49	71.35	130.73	152.08	168.14	181.76	193.94	205.18
245	112.32	96.56	87.33	80.79	75.71	71.57	130.87	152.24	168.32	181.95	194.15	205.40
246	112.80	96.97	87.70	81.13	76.04	71.87	130.85	152.22	168.29	181.92	194.12	205.37
247	113.05	97.18	87.90	81.32	76.21	72.03	131.09	152.49	168.60	182.25	194.47	205.74
248	113.22	97.33	88.03	81.44	76.32	72.14	131.43	152.88	169.03	182.72	194.97	206.26
249	113.53	97.60	88.28	81.66	76.53	72.34	131.59	153.08	169.24	182.95	195.21	206.52
250	113.77	97.81	88.46	81.84	76.69	72.49	131.84	153.37	169.56	183.29	195.58	206.91
251	114.08	98.07	88.70	82.06	76.90	72.69	132.01	153.56	169.78	183.53	195.83	207.18
252	114.66	98.56	89.15	82.47	77.29	73.06	131.87	153.41	169.60	183.34	195.63	206.97
253	114.82	98.70	89.27	82.59	77.40	73.16	132.21	153.80	170.04	183.81	196.13	207.50
254	115.21	99.04	89.58	82.87	77.66	73.41	132.28	153.87	170.12	183.90	196.23	207.60
255	115.28	99.10	89.63	82.92	77.71	73.45	132.72	154.39	170.69	184.52	196.89	208.30
256	115.68	99.45	89.95	83.21	77.98	73.71	132.78	154.45	170.77	184.60	196.97	208.38
257	115.87	99.60	90.09	83.34	78.10	73.83	133.09	154.82	171.16	185.03	197.43	208.87
258	116.18	99.87	90.33	83.56	78.31	74.02	133.24	155.00	171.37	185.25	197.67	209.12
259	116.73	100.35	90.76	83.96	78.69	74.38	133.13	154.86	171.22	185.09	197.49	208.94
260	116.93	100.52	90.92	84.11	78.82	74.51	133.41	155.19	171.58	185.48	197.91	209.38
261	117.35	100.88	91.25	84.41	79.11	74.77	133.44	155.23	171.63	185.53	197.96	209.43
262	117.68	101.16	91.50	84.65	79.33	74.98	133.58	155.39	171.80	185.72	198.17	209.65
263	117.93	101.37	91.69	84.82	79.49	75.14	133.81	155.66	172.10	186.04	198.51	210.01
264	118.35	101.74	92.02	85.13	79.78	75.41	133.84	155.69	172.13	186.07	198.55	210.05
265	118.62	101.97	92.23	85.32	79.96	75.58	134.04	155.93	172.39	186.36	198.85	210.37
266	118.95	102.26	92.49	85.56	80.18	75.79	134.17	156.08	172.56	186.54	199.04	210.58
267	119.39	102.63	92.83	85.87	80.48	76.07	134.19	156.10	172.58	186.56	199.06	210.60
268	119.46	102.69	92.88	85.92	80.53	76.12	134.61	156.59	173.12	187.14	199.69	211.26
269	119.78	102.97	93.14	86.16	80.75	76.32	134.74	156.74	173.29	187.33	199.89	211.47
270	120.19	103.32	93.45	86.45	81.02	76.58	134.78	156.79	173.35	187.39	199.95	211.53
271	120.48	103.57	93.68	86.66	81.22	76.77	134.96	156.99	173.57	187.63	200.21	211.81
272	120.89	103.92	94.00	86.95	81.49	77.03	135.00	157.04	173.62	187.69	200.27	211.87
273	121.23	104.21	94.26	87.20	81.72	77.24	135.12	157.18	173.77	187.85	200.44	212.06
274	121.37	104.33	94.37	87.30	81.81	77.33	135.46	157.57	174.21	188.32	200.95	212.59

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
275	121.79	104.69	94.69	87.60	82.10	77.60	135.48	157.60	174.24	188.36	200.98	212.63
276	121.92	104.81	94.80	87.70	82.19	77.69	135.82	158.00	174.68	188.83	201.49	213.17
277	122.39	105.21	95.16	88.03	82.50	77.98	135.80	157.97	174.65	188.80	201.45	213.13
278	122.68	105.46	95.39	88.24	82.70	78.17	135.96	158.16	174.86	189.02	201.69	213.38
279	123.06	105.79	95.68	88.51	82.95	78.41	136.03	158.24	174.95	189.12	201.80	213.49
280	123.23	105.93	95.82	88.64	83.07	78.52	136.33	158.59	175.34	189.54	202.24	213.96
281	123.63	106.28	96.13	88.92	83.34	78.77	136.37	158.64	175.39	189.60	202.31	214.03
282	123.92	106.52	96.35	89.13	83.53	78.96	136.54	158.84	175.61	189.83	202.56	214.29
283	124.29	106.85	96.64	89.40	83.79	79.20	136.61	158.92	175.70	189.93	202.66	214.40
284	124.59	107.11	96.88	89.62	83.99	79.39	136.76	159.09	175.89	190.14	202.89	214.64
285	124.83	107.30	97.06	89.78	84.14	79.54	136.99	159.36	176.19	190.46	203.22	215.00
286	125.24	107.66	97.38	90.08	84.42	79.80	137.02	159.39	176.22	190.49	203.26	215.04
287	125.43	107.82	97.53	90.22	84.55	79.92	137.29	159.70	176.57	190.87	203.66	215.46
288	125.83	108.17	97.84	90.51	84.82	80.18	137.33	159.75	176.62	190.92	203.72	215.52
289	126.15	108.44	98.08	90.74	85.03	80.38	137.46	159.90	176.79	191.11	203.92	215.73
290	126.51	108.75	98.37	91.00	85.28	80.61	137.54	159.99	176.89	191.21	204.03	215.86
291	126.77	108.97	98.57	91.18	85.45	80.77	137.73	160.22	177.14	191.49	204.32	216.16
292	127.01	109.18	98.75	91.36	85.62	80.93	137.94	160.46	177.41	191.78	204.63	216.49
293	127.27	109.40	98.95	91.54	85.79	81.09	138.13	160.69	177.66	192.05	204.92	216.79
294	127.50	109.60	99.13	91.71	85.94	81.24	138.36	160.95	177.94	192.36	205.25	217.14
295	128.03	110.06	99.55	92.09	86.31	81.58	138.24	160.82	177.80	192.20	205.08	216.97
296	128.41	110.38	99.84	92.36	86.56	81.82	138.31	160.89	177.88	192.29	205.18	217.07
297	128.36	110.34	99.80	92.33	86.53	81.79	138.83	161.50	178.55	193.01	205.95	217.88
298	128.88	110.79	100.21	92.70	86.88	82.12	138.73	161.38	178.43	192.88	205.81	217.73
299	129.37	111.21	100.59	93.05	87.21	82.43	138.67	161.32	178.35	192.80	205.72	217.64
300	129.62	111.43	100.78	93.23	87.37	82.59	138.87	161.54	178.60	193.07	206.01	217.95
301	129.82	111.59	100.94	93.37	87.51	82.71	139.12	161.84	178.93	193.42	206.38	218.34
302	130.15	111.89	101.20	93.62	87.74	82.93	139.22	161.95	179.05	193.56	206.53	218.50
303	130.48	112.16	101.45	93.85	87.95	83.14	139.33	162.08	179.20	193.71	206.70	218.67
304	130.78	112.42	101.68	94.07	88.16	83.33	139.47	162.25	179.38	193.91	206.91	218.90
305	130.89	112.52	101.77	94.15	88.23	83.40	139.81	162.64	179.81	194.37	207.40	219.42
306	131.46	113.01	102.21	94.56	88.62	83.76	139.66	162.47	179.62	194.17	207.19	219.19
307	131.64	113.16	102.36	94.69	88.74	83.88	139.93	162.77	179.96	194.54	207.58	219.61
308	132.14	113.59	102.74	95.04	89.07	84.19	139.86	162.69	179.87	194.44	207.47	219.50
309	132.24	113.68	102.82	95.12	89.14	84.26	140.20	163.09	180.32	194.92	207.99	220.04
310	132.70	114.08	103.18	95.45	89.45	84.55	140.16	163.05	180.27	194.87	207.93	219.98
311	132.85	114.20	103.29	95.55	89.55	84.65	140.46	163.40	180.65	195.28	208.37	220.45
312	133.23	114.53	103.59	95.83	89.81	84.89	140.51	163.46	180.72	195.35	208.45	220.53
313	133.35	114.63	103.68	95.92	89.89	84.97	140.83	163.83	181.13	195.80	208.92	221.03
314	133.78	115.00	104.02	96.23	90.18	85.24	140.83	163.82	181.12	195.79	208.91	221.02
315	134.29	115.44	104.42	96.59	90.53	85.57	140.74	163.71	181.00	195.66	208.78	220.88
316	134.40	115.54	104.50	96.67	90.60	85.64	141.07	164.11	181.43	196.13	209.28	221.40

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
317	134.82	115.89	104.82	96.97	90.88	85.90	141.08	164.12	181.45	196.14	209.29	221.42
318	135.24	116.26	105.15	97.28	91.17	86.17	141.08	164.12	181.45	196.14	209.29	221.42
319	135.44	116.43	105.31	97.42	91.30	86.30	141.31	164.39	181.75	196.47	209.64	221.78
320	135.79	116.73	105.58	97.67	91.53	86.52	141.40	164.48	181.85	196.58	209.76	221.91
321	136.08	116.98	105.80	97.88	91.73	86.70	141.54	164.65	182.04	196.78	209.97	222.14
322	136.25	117.12	105.94	98.00	91.84	86.81	141.80	164.95	182.37	197.14	210.36	222.55
323	136.58	117.41	106.19	98.24	92.06	87.02	141.90	165.07	182.50	197.28	210.50	222.70
324	136.99	117.76	106.51	98.53	92.34	87.29	141.91	165.08	182.51	197.29	210.52	222.72
325	137.49	118.19	106.90	98.89	92.68	87.60	141.83	164.99	182.41	197.19	210.41	222.60
326	137.62	118.30	107.01	98.99	92.77	87.69	142.13	165.34	182.80	197.60	210.85	223.06
327	137.84	118.49	107.17	99.14	92.92	87.83	142.34	165.58	183.07	197.89	211.16	223.40
328	138.30	118.88	107.53	99.47	93.22	88.12	142.30	165.54	183.02	197.84	211.10	223.34
329	138.28	118.87	107.52	99.46	93.22	88.11	142.75	166.06	183.59	198.46	211.77	224.04
330	138.95	119.45	108.04	99.94	93.67	88.53	142.50	165.76	183.27	198.11	211.39	223.64
331	139.10	119.58	108.15	100.05	93.77	88.63	142.78	166.09	183.63	198.50	211.80	224.08
332	139.39	119.82	108.38	100.26	93.96	88.81	142.91	166.25	183.80	198.69	212.01	224.29
333	139.92	120.28	108.79	100.64	94.32	89.15	142.80	166.12	183.66	198.53	211.84	224.12
334	139.49	119.91	108.46	100.33	94.03	88.88	143.67	167.13	184.77	199.74	213.13	225.48
335	139.83	120.20	108.72	100.58	94.26	89.10	143.74	167.21	184.87	199.85	213.24	225.60
336	140.12	120.46	108.95	100.79	94.46	89.28	143.87	167.36	185.04	200.02	213.43	225.80
337	140.49	120.77	109.24	101.05	94.71	89.52	143.92	167.42	185.10	200.09	213.50	225.88
338	140.74	120.99	109.43	101.23	94.87	89.68	144.09	167.62	185.32	200.33	213.76	226.15
339	141.20	121.38	109.79	101.56	95.18	89.97	144.05	167.57	185.26	200.27	213.69	226.07
340	141.50	121.64	110.02	101.78	95.39	90.16	144.17	167.70	185.41	200.43	213.87	226.26
341	141.59	121.71	110.09	101.84	95.44	90.22	144.50	168.10	185.85	200.90	214.37	226.79
342	142.15	122.19	110.52	102.24	95.82	90.57	144.36	167.93	185.66	200.70	214.15	226.56
343	142.29	122.32	110.63	102.35	95.92	90.66	144.63	168.25	186.02	201.08	214.56	227.00
344	142.46	122.46	110.77	102.47	96.03	90.77	144.88	168.54	186.34	201.43	214.93	227.38
345	143.02	122.95	111.21	102.87	96.41	91.13	144.73	168.36	186.14	201.22	214.71	227.15
346	143.30	123.18	111.42	103.07	96.59	91.30	144.87	168.53	186.33	201.42	214.92	227.37
347	143.48	123.34	111.56	103.20	96.72	91.42	145.11	168.80	186.63	201.74	215.26	227.74
348	143.91	123.71	111.89	103.51	97.01	91.69	145.09	168.78	186.61	201.72	215.24	227.71
349	144.22	123.98	112.13	103.73	97.22	91.89	145.20	168.90	186.74	201.86	215.40	227.88
350	144.35	124.09	112.24	103.83	97.30	91.98	145.48	169.23	187.10	202.26	215.82	228.32
351	144.76	124.44	112.55	104.12	97.58	92.23	145.48	169.24	187.11	202.27	215.82	228.33
352	145.10	124.73	112.82	104.37	97.81	92.45	145.55	169.32	187.20	202.36	215.93	228.44
353	145.38	124.97	113.04	104.57	98.00	92.63	145.69	169.48	187.37	202.55	216.13	228.65
354	145.61	125.17	113.22	104.74	98.16	92.78	145.87	169.68	187.60	202.80	216.39	228.93
355	146.09	125.59	113.59	105.08	98.48	93.09	145.80	169.60	187.51	202.70	216.29	228.82
356	146.28	125.75	113.74	105.21	98.60	93.20	146.02	169.87	187.80	203.01	216.62	229.18
357	146.54	125.97	113.94	105.40	98.78	93.37	146.17	170.04	188.00	203.22	216.85	229.41
358	146.88	126.27	114.21	105.65	99.01	93.59	146.24	170.12	188.08	203.31	216.94	229.51

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
359	147.30	126.63	114.53	105.95	99.30	93.86	146.23	170.10	188.07	203.30	216.93	229.50
360	147.57	126.86	114.74	106.14	99.47	94.03	146.37	170.27	188.25	203.50	217.14	229.72
361	147.73	127.00	114.87	106.26	99.58	94.13	146.62	170.56	188.57	203.84	217.50	230.11
362	148.06	127.28	115.12	106.50	99.81	94.34	146.69	170.65	188.67	203.95	217.62	230.23
363	148.39	127.56	115.38	106.73	100.03	94.55	146.78	170.74	188.77	204.06	217.74	230.36
364	148.68	127.81	115.61	106.94	100.23	94.74	146.89	170.87	188.92	204.22	217.91	230.54
365	148.90	128.00	115.78	107.10	100.37	94.88	147.08	171.09	189.16	204.48	218.19	230.83
366	149.34	128.38	116.12	107.42	100.67	95.16	147.05	171.06	189.12	204.44	218.14	230.78
367	149.69	128.68	116.39	107.67	100.90	95.38	147.11	171.13	189.20	204.52	218.23	230.88
368	149.95	128.90	116.59	107.86	101.08	95.54	147.25	171.29	189.38	204.72	218.44	231.10
369	150.19	129.11	116.78	108.03	101.24	95.70	147.41	171.48	189.59	204.95	218.69	231.36
370	150.59	129.46	117.09	108.32	101.51	95.95	147.42	171.49	189.60	204.95	218.69	231.36
371	150.72	129.56	117.19	108.41	101.60	96.03	147.69	171.81	189.95	205.34	219.10	231.80
372	151.13	129.91	117.51	108.70	101.87	96.29	147.69	171.81	189.95	205.33	219.10	231.79
373	151.51	130.24	117.80	108.97	102.13	96.53	147.72	171.84	189.98	205.37	219.14	231.83
374	151.85	130.53	118.07	109.22	102.36	96.75	147.78	171.91	190.06	205.46	219.23	231.93
375	152.03	130.69	118.21	109.35	102.48	96.87	148.00	172.16	190.35	205.76	219.55	232.28
376	152.43	131.03	118.52	109.64	102.75	97.12	148.01	172.17	190.35	205.77	219.56	232.29
377	152.63	131.20	118.67	109.78	102.88	97.25	148.21	172.41	190.61	206.05	219.86	232.60
378	152.85	131.39	118.84	109.94	103.03	97.39	148.38	172.61	190.84	206.30	220.12	232.88
379	153.31	131.80	119.21	110.28	103.35	97.69	148.32	172.54	190.76	206.21	220.03	232.78
380	153.49	131.95	119.34	110.40	103.47	97.80	148.54	172.80	191.04	206.52	220.36	233.13
381	153.81	132.22	119.59	110.63	103.68	98.00	148.63	172.89	191.15	206.63	220.49	233.26
382	154.20	132.56	119.89	110.91	103.94	98.25	148.64	172.91	191.17	206.65	220.50	233.28
383	154.55	132.85	120.16	111.16	104.18	98.47	148.69	172.97	191.24	206.73	220.59	233.37
384	154.83	133.09	120.38	111.36	104.37	98.65	148.81	173.11	191.39	206.89	220.76	233.55
385	155.08	133.31	120.58	111.54	104.53	98.81	148.96	173.28	191.58	207.10	220.98	233.78
386	155.30	133.50	120.75	111.70	104.69	98.95	149.13	173.48	191.80	207.33	221.23	234.05
387	155.72	133.86	121.08	112.01	104.97	99.22	149.11	173.46	191.78	207.31	221.21	234.03
388	155.99	134.10	121.29	112.20	105.15	99.39	149.24	173.61	191.94	207.49	221.39	234.22
389	156.37	134.42	121.58	112.47	105.41	99.63	149.26	173.64	191.97	207.52	221.43	234.26
390	156.67	134.68	121.81	112.69	105.61	99.82	149.36	173.75	192.10	207.66	221.58	234.42
391	156.95	134.92	122.04	112.89	105.80	100.01	149.47	173.88	192.24	207.81	221.74	234.59
392	157.28	135.20	122.29	113.12	106.02	100.21	149.55	173.96	192.33	207.91	221.85	234.70
393	157.57	135.46	122.52	113.34	106.22	100.40	149.64	174.08	192.46	208.05	221.99	234.86
394	157.89	135.73	122.76	113.56	106.43	100.60	149.73	174.17	192.57	208.16	222.12	234.99
395	158.01	135.83	122.86	113.65	106.51	100.68	149.99	174.48	192.91	208.53	222.51	235.41
396	158.46	136.22	123.21	113.98	106.82	100.96	149.94	174.43	192.85	208.47	222.44	235.33
397	158.80	136.51	123.48	114.22	107.05	101.19	150.00	174.49	192.91	208.54	222.52	235.41
398	158.99	136.68	123.62	114.36	107.18	101.31	150.20	174.72	193.17	208.81	222.81	235.72
399	159.42	137.05	123.96	114.67	107.47	101.58	150.17	174.69	193.13	208.78	222.77	235.68
400	159.62	137.21	124.11	114.81	107.60	101.70	150.36	174.91	193.38	209.04	223.06	235.98

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
401	159.97	137.52	124.38	115.06	107.83	101.93	150.40	174.96	193.44	209.10	223.12	236.05
402	160.18	137.70	124.54	115.21	107.97	102.06	150.58	175.17	193.67	209.35	223.39	236.33
403	160.63	138.08	124.89	115.53	108.28	102.35	150.54	175.12	193.61	209.29	223.32	236.26
404	160.83	138.25	125.05	115.68	108.41	102.47	150.72	175.33	193.84	209.54	223.59	236.55
405	161.13	138.51	125.28	115.89	108.61	102.66	150.81	175.44	193.96	209.67	223.73	236.69
406	161.50	138.83	125.57	116.17	108.87	102.90	150.83	175.46	193.99	209.70	223.76	236.72
407	161.71	139.01	125.73	116.31	109.01	103.04	151.01	175.67	194.22	209.95	224.02	237.01
408	162.08	139.33	126.02	116.58	109.26	103.27	151.03	175.70	194.25	209.98	224.06	237.04
409	162.38	139.59	126.25	116.80	109.46	103.46	151.13	175.80	194.37	210.11	224.20	237.19
410	162.69	139.85	126.50	117.02	109.67	103.66	151.21	175.90	194.47	210.22	224.31	237.31
411	163.14	140.24	126.84	117.34	109.97	103.94	151.16	175.84	194.41	210.16	224.25	237.24
412	163.31	140.39	126.98	117.47	110.09	104.06	151.37	176.08	194.68	210.44	224.55	237.56
413	163.56	140.60	127.17	117.65	110.26	104.22	151.50	176.24	194.85	210.63	224.75	237.77
414	163.89	140.89	127.43	117.88	110.48	104.43	151.56	176.31	194.93	210.72	224.84	237.87
415	164.29	141.23	127.74	118.17	110.74	104.68	151.56	176.31	194.93	210.72	224.84	237.87
416	164.53	141.44	127.93	118.35	110.91	104.84	151.70	176.47	195.11	210.91	225.05	238.09
417	164.72	141.60	128.08	118.48	111.04	104.96	151.89	176.69	195.35	211.17	225.33	238.39
418	165.19	142.00	128.44	118.81	111.35	105.25	151.83	176.62	195.27	211.09	225.24	238.29
419	165.44	142.22	128.64	119.00	111.52	105.41	151.96	176.77	195.43	211.26	225.42	238.49
420	165.87	142.58	128.97	119.30	111.81	105.68	151.93	176.74	195.40	211.23	225.39	238.45
421	166.06	142.75	129.11	119.44	111.94	105.81	152.12	176.95	195.64	211.49	225.66	238.74
422	166.20	142.87	129.23	119.54	112.03	105.90	152.35	177.22	195.94	211.81	226.00	239.10
423	166.64	143.25	129.57	119.86	112.33	106.18	152.31	177.18	195.88	211.75	225.94	239.04
424	166.97	143.54	129.83	120.10	112.56	106.39	152.36	177.24	195.95	211.82	226.02	239.12
425	167.29	143.81	130.07	120.33	112.77	106.59	152.43	177.32	196.04	211.92	226.13	239.23
426	167.58	144.06	130.30	120.54	112.97	106.78	152.52	177.42	196.16	212.05	226.26	239.37
427	167.88	144.32	130.54	120.76	113.17	106.97	152.61	177.52	196.27	212.16	226.39	239.50
428	168.16	144.56	130.75	120.95	113.35	107.15	152.71	177.65	196.41	212.31	226.55	239.67
429	168.36	144.73	130.90	121.10	113.49	107.27	152.89	177.85	196.63	212.56	226.81	239.95
430	168.72	145.04	131.18	121.35	113.73	107.50	152.92	177.89	196.67	212.60	226.85	240.00
431	168.98	145.26	131.39	121.54	113.91	107.67	153.04	178.02	196.82	212.76	227.03	240.18
432	169.40	145.62	131.71	121.85	114.19	107.94	153.01	177.99	196.79	212.73	226.99	240.14
433	169.64	145.83	131.90	122.02	114.35	108.09	153.15	178.15	196.97	212.92	227.19	240.36
434	170.01	146.15	132.19	122.28	114.60	108.32	153.17	178.18	196.99	212.95	227.22	240.39
435	170.25	146.36	132.38	122.46	114.77	108.48	153.30	178.33	197.16	213.13	227.42	240.60
436	170.53	146.60	132.60	122.66	114.95	108.66	153.40	178.45	197.29	213.27	227.57	240.75
437	170.90	146.91	132.88	122.92	115.20	108.89	153.43	178.48	197.33	213.31	227.61	240.79
438	171.15	147.13	133.07	123.10	115.37	109.05	153.55	178.62	197.49	213.48	227.79	240.99
439	171.48	147.41	133.33	123.34	115.59	109.26	153.61	178.69	197.55	213.56	227.87	241.07
440	171.84	147.72	133.61	123.60	115.84	109.49	153.63	178.72	197.59	213.59	227.91	241.11
441	172.02	147.88	133.75	123.73	115.96	109.61	153.82	178.93	197.83	213.85	228.18	241.40
442	172.39	148.20	134.04	124.00	116.21	109.84	153.83	178.95	197.85	213.87	228.21	241.43

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
443	172.73	148.49	134.31	124.24	116.44	110.06	153.88	179.00	197.91	213.93	228.28	241.50
444	172.94	148.66	134.46	124.39	116.58	110.19	154.04	179.20	198.12	214.17	228.52	241.76
445	173.22	148.90	134.68	124.59	116.76	110.37	154.14	179.31	198.24	214.30	228.67	241.92
446	173.57	149.21	134.95	124.84	117.00	110.59	154.18	179.35	198.29	214.35	228.72	241.97
447	173.90	149.49	135.21	125.08	117.22	110.80	154.23	179.41	198.36	214.42	228.80	242.06
448	174.16	149.72	135.42	125.27	117.40	110.97	154.34	179.54	198.50	214.58	228.96	242.23
449	174.46	149.97	135.65	125.48	117.60	111.16	154.42	179.63	198.60	214.69	229.08	242.35
450	174.74	150.21	135.87	125.69	117.79	111.34	154.51	179.74	198.72	214.82	229.22	242.50
451	175.08	150.51	136.13	125.93	118.02	111.56	154.55	179.79	198.77	214.87	229.28	242.56
452	175.29	150.69	136.29	126.08	118.16	111.69	154.72	179.98	198.98	215.10	229.52	242.82
453	175.58	150.93	136.52	126.29	118.36	111.87	154.80	180.08	199.09	215.22	229.65	242.95
454	175.97	151.27	136.82	126.57	118.62	112.12	154.80	180.07	199.09	215.21	229.64	242.95
455	176.25	151.51	137.04	126.77	118.81	112.30	154.89	180.18	199.21	215.34	229.78	243.09
456	176.59	151.80	137.30	127.02	119.04	112.52	154.94	180.23	199.27	215.40	229.84	243.16
457	176.95	152.11	137.58	127.27	119.28	112.75	154.96	180.26	199.30	215.44	229.88	243.20
458	177.35	152.46	137.89	127.56	119.55	113.00	154.95	180.25	199.28	215.42	229.86	243.18
459	177.57	152.65	138.07	127.72	119.70	113.14	155.09	180.42	199.47	215.62	230.08	243.41
460	177.86	152.89	138.29	127.93	119.89	113.32	155.18	180.52	199.58	215.75	230.21	243.55
461	178.09	153.09	138.47	128.09	120.05	113.47	155.32	180.68	199.76	215.94	230.41	243.76
462	178.45	153.40	138.75	128.36	120.29	113.70	155.34	180.70	199.78	215.96	230.44	243.79
463	178.68	153.60	138.93	128.52	120.45	113.85	155.47	180.86	199.96	216.15	230.64	244.00
464	179.08	153.94	139.24	128.81	120.71	114.10	155.46	180.85	199.94	216.14	230.63	243.99
465	179.37	154.19	139.46	129.01	120.91	114.29	155.55	180.95	200.05	216.26	230.75	244.12
466	179.55	154.35	139.61	129.15	121.03	114.41	155.72	181.15	200.27	216.50	231.01	244.39
467	179.91	154.65	139.88	129.40	121.27	114.63	155.75	181.18	200.31	216.53	231.05	244.44
468	180.24	154.94	140.14	129.64	121.50	114.84	155.79	181.23	200.37	216.59	231.11	244.51
469	180.62	155.27	140.44	129.91	121.75	115.08	155.80	181.24	200.38	216.61	231.13	244.52
470	180.81	155.43	140.58	130.05	121.88	115.21	155.97	181.43	200.59	216.84	231.37	244.78
471	181.11	155.69	140.82	130.27	122.08	115.40	156.04	181.52	200.68	216.94	231.48	244.89
472	181.45	155.98	141.08	130.51	122.31	115.61	156.08	181.56	200.73	216.99	231.54	244.95
473	181.76	156.25	141.32	130.74	122.52	115.81	156.14	181.63	200.81	217.08	231.63	245.05
474	181.97	156.43	141.49	130.88	122.66	115.94	156.29	181.81	201.01	217.29	231.86	245.29
475	182.33	156.74	141.77	131.14	122.90	116.17	156.31	181.83	201.04	217.32	231.89	245.32
476	182.77	157.11	142.11	131.46	123.20	116.45	156.27	181.78	200.98	217.25	231.82	245.25
477	183.01	157.32	142.30	131.63	123.36	116.61	156.39	181.92	201.13	217.42	232.00	245.44
478	183.20	157.48	142.44	131.77	123.49	116.73	156.55	182.12	201.35	217.66	232.25	245.70
479	183.58	157.81	142.74	132.04	123.75	116.97	156.55	182.12	201.35	217.65	232.25	245.70
480	183.81	158.01	142.91	132.21	123.90	117.11	156.69	182.27	201.52	217.84	232.44	245.91
481	184.15	158.30	143.18	132.46	124.13	117.34	156.72	182.31	201.56	217.89	232.49	245.96
482	184.47	158.57	143.43	132.68	124.35	117.54	156.78	182.38	201.63	217.96	232.58	246.05
483	184.79	158.85	143.68	132.92	124.57	117.74	156.83	182.43	201.70	218.03	232.65	246.13
484	185.03	159.06	143.87	133.09	124.73	117.90	156.94	182.57	201.85	218.20	232.82	246.32

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
485	185.41	159.38	144.16	133.36	124.98	118.13	156.95	182.58	201.86	218.21	232.84	246.33
486	185.69	159.63	144.38	133.57	125.17	118.32	157.03	182.67	201.96	218.32	232.96	246.45
487	185.95	159.85	144.58	133.75	125.34	118.48	157.14	182.80	202.10	218.47	233.12	246.63
488	186.21	160.08	144.79	133.94	125.52	118.65	157.24	182.91	202.23	218.61	233.26	246.78
489	186.58	160.39	145.07	134.20	125.77	118.88	157.25	182.93	202.24	218.62	233.28	246.79
490	186.75	160.54	145.20	134.32	125.88	118.99	157.43	183.14	202.48	218.87	233.55	247.08
491	187.08	160.82	145.46	134.56	126.11	119.20	157.48	183.19	202.53	218.94	233.61	247.15
492	187.48	161.17	145.77	134.85	126.38	119.46	157.45	183.16	202.50	218.91	233.58	247.11
493	187.81	161.45	146.03	135.09	126.60	119.67	157.50	183.22	202.56	218.97	233.65	247.19
494	188.12	161.72	146.27	135.31	126.81	119.86	157.56	183.29	202.64	219.05	233.74	247.28
495	188.31	161.88	146.42	135.45	126.94	119.99	157.72	183.47	202.84	219.27	233.97	247.53
496	188.66	162.18	146.69	135.70	127.17	120.21	157.74	183.50	202.88	219.31	234.01	247.57
497	188.98	162.45	146.94	135.93	127.39	120.41	157.80	183.56	202.95	219.38	234.09	247.65
498	189.23	162.67	147.14	136.11	127.56	120.57	157.90	183.68	203.08	219.53	234.24	247.81
499	189.62	163.01	147.44	136.39	127.82	120.82	157.89	183.67	203.07	219.51	234.23	247.80
500	189.85	163.20	147.61	136.55	127.97	120.97	158.02	183.82	203.23	219.70	234.42	248.01
501	190.11	163.43	147.82	136.74	128.15	121.13	158.12	183.94	203.36	219.83	234.57	248.16
502	190.46	163.73	148.09	137.00	128.39	121.36	158.14	183.96	203.39	219.86	234.60	248.19
503	190.75	163.98	148.32	137.20	128.58	121.54	158.22	184.05	203.49	219.97	234.71	248.31
504	191.09	164.27	148.58	137.45	128.81	121.76	158.25	184.09	203.53	220.02	234.76	248.37
505	191.37	164.51	148.80	137.65	129.00	121.93	158.33	184.18	203.63	220.13	234.88	248.49
506	191.59	164.70	148.97	137.80	129.15	122.07	158.46	184.34	203.81	220.31	235.08	248.70
507	191.96	165.02	149.26	138.07	129.40	122.31	158.47	184.35	203.81	220.32	235.09	248.71
508	192.29	165.30	149.51	138.31	129.62	122.52	158.51	184.39	203.86	220.37	235.15	248.77
509	192.51	165.49	149.68	138.46	129.77	122.66	158.64	184.55	204.04	220.56	235.35	248.98
510	192.86	165.79	149.96	138.72	130.01	122.89	158.66	184.57	204.06	220.59	235.37	249.01
511	193.20	166.09	150.22	138.97	130.24	123.10	158.69	184.60	204.10	220.63	235.42	249.06
512	193.58	166.41	150.51	139.24	130.49	123.34	158.70	184.61	204.10	220.63	235.42	249.07
513	193.80	166.60	150.69	139.40	130.64	123.48	158.82	184.75	204.26	220.81	235.61	249.26
514	194.06	166.82	150.89	139.59	130.82	123.65	158.92	184.86	204.39	220.94	235.75	249.41
515	194.32	167.04	151.09	139.77	130.99	123.81	159.02	184.98	204.52	221.08	235.90	249.57
516	194.66	167.34	151.36	140.02	131.22	124.03	159.05	185.01	204.55	221.12	235.94	249.61
517	194.99	167.62	151.61	140.25	131.44	124.24	159.08	185.06	204.60	221.17	236.00	249.67
518	195.24	167.84	151.81	140.43	131.61	124.40	159.19	185.18	204.73	221.31	236.15	249.83
519	195.58	168.13	152.07	140.68	131.84	124.62	159.22	185.21	204.77	221.36	236.19	249.88
520	195.90	168.40	152.31	140.90	132.05	124.82	159.27	185.27	204.84	221.43	236.27	249.96
521	196.15	168.62	152.51	141.08	132.22	124.98	159.37	185.39	204.97	221.57	236.42	250.12
522	196.42	168.85	152.73	141.28	132.41	125.16	159.45	185.49	205.07	221.68	236.54	250.25
523	196.77	169.15	153.00	141.54	132.64	125.38	159.47	185.51	205.10	221.71	236.57	250.28
524	197.04	169.39	153.21	141.73	132.82	125.55	159.56	185.61	205.21	221.83	236.70	250.42
525	197.34	169.64	153.44	141.94	133.03	125.74	159.62	185.68	205.29	221.92	236.80	250.52
526	197.70	169.95	153.72	142.20	133.27	125.97	159.64	185.70	205.31	221.94	236.82	250.54

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
527	198.03	170.23	153.97	142.43	133.49	126.18	159.68	185.75	205.36	222.00	236.88	250.60
528	198.29	170.46	154.18	142.63	133.67	126.34	159.77	185.85	205.48	222.12	237.01	250.74
529	198.55	170.68	154.38	142.81	133.84	126.51	159.86	185.96	205.60	222.25	237.15	250.89
530	198.99	171.06	154.72	143.13	134.13	126.79	159.81	185.90	205.54	222.18	237.08	250.81
531	199.22	171.26	154.90	143.30	134.29	126.94	159.92	186.03	205.68	222.34	237.24	250.99
532	199.46	171.47	155.09	143.47	134.46	127.09	160.03	186.16	205.82	222.49	237.40	251.16
533	199.85	171.80	155.39	143.75	134.72	127.34	160.02	186.15	205.80	222.47	237.39	251.14
534	200.03	171.96	155.53	143.88	134.84	127.46	160.17	186.33	206.00	222.69	237.61	251.38
535	200.47	172.34	155.88	144.20	135.14	127.74	160.12	186.26	205.93	222.61	237.54	251.30
536	200.75	172.57	156.09	144.39	135.32	127.91	160.20	186.36	206.04	222.73	237.66	251.43
537	201.03	172.81	156.31	144.60	135.51	128.09	160.27	186.44	206.13	222.83	237.76	251.54
538	201.37	173.11	156.57	144.84	135.74	128.31	160.30	186.47	206.17	222.86	237.80	251.58
539	201.49	173.21	156.66	144.93	135.82	128.38	160.51	186.71	206.43	223.15	238.11	251.90
540	201.96	173.61	157.03	145.26	136.14	128.68	160.43	186.63	206.33	223.05	238.00	251.79
541	202.18	173.80	157.20	145.42	136.29	128.82	160.55	186.77	206.49	223.21	238.18	251.98
542	202.50	174.08	157.45	145.66	136.51	129.03	160.59	186.81	206.54	223.27	238.23	252.04
543	202.85	174.38	157.72	145.90	136.74	129.25	160.61	186.84	206.57	223.30	238.26	252.07
544	203.14	174.62	157.95	146.11	136.93	129.43	160.68	186.92	206.65	223.39	238.37	252.18
545	203.43	174.87	158.17	146.32	137.13	129.62	160.75	186.99	206.74	223.48	238.46	252.28
546	203.65	175.07	158.34	146.48	137.28	129.76	160.86	187.13	206.89	223.65	238.64	252.47
547	204.16	175.50	158.74	146.84	137.62	130.08	160.76	187.01	206.76	223.50	238.48	252.30
548	204.20	175.54	158.77	146.88	137.65	130.11	161.02	187.31	207.09	223.86	238.87	252.71
549	204.58	175.87	159.07	147.15	137.91	130.36	161.01	187.30	207.08	223.85	238.85	252.69
550	204.91	176.14	159.32	147.38	138.12	130.56	161.05	187.35	207.13	223.91	238.91	252.76
551	205.20	176.39	159.55	147.59	138.32	130.74	161.11	187.42	207.21	223.99	239.01	252.86
552	205.49	176.65	159.78	147.81	138.52	130.93	161.17	187.49	207.29	224.08	239.10	252.95
553	205.76	176.88	159.99	148.00	138.70	131.11	161.25	187.58	207.39	224.19	239.22	253.08
554	206.14	177.20	160.28	148.27	138.95	131.34	161.25	187.58	207.39	224.19	239.22	253.08
555	206.44	177.46	160.51	148.49	139.16	131.54	161.31	187.65	207.46	224.26	239.30	253.16
556	206.79	177.76	160.78	148.74	139.39	131.76	161.33	187.67	207.48	224.29	239.32	253.19
557	207.08	178.02	161.01	148.95	139.59	131.95	161.38	187.73	207.56	224.37	239.41	253.28
558	207.34	178.24	161.21	149.13	139.76	132.11	161.48	187.84	207.68	224.50	239.55	253.43
559	207.70	178.55	161.50	149.40	140.01	132.34	161.48	187.85	207.68	224.50	239.55	253.43
560	207.98	178.79	161.71	149.60	140.20	132.52	161.55	187.93	207.78	224.61	239.66	253.55
561	208.22	178.99	161.90	149.77	140.36	132.67	161.66	188.05	207.91	224.75	239.81	253.71
562	208.51	179.25	162.12	149.98	140.56	132.86	161.72	188.12	207.99	224.83	239.90	253.81
563	208.77	179.46	162.32	150.16	140.73	133.02	161.81	188.23	208.11	224.96	240.04	253.95
564	209.16	179.80	162.63	150.45	140.99	133.27	161.79	188.20	208.08	224.93	240.01	253.92
565	209.37	179.98	162.79	150.59	141.13	133.40	161.92	188.36	208.25	225.11	240.20	254.12
566	209.65	180.22	163.01	150.80	141.32	133.58	161.98	188.43	208.33	225.20	240.30	254.22
567	210.05	180.57	163.32	151.09	141.59	133.84	161.96	188.41	208.30	225.17	240.27	254.19
568	210.30	180.78	163.51	151.26	141.76	133.99	162.06	188.52	208.42	225.31	240.41	254.34

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
569	210.68	181.11	163.81	151.54	142.02	134.24	162.05	188.51	208.41	225.29	240.39	254.32
570	211.05	181.43	164.10	151.81	142.27	134.48	162.04	188.50	208.41	225.29	240.39	254.32
571	211.24	181.59	164.25	151.94	142.40	134.60	162.18	188.67	208.59	225.48	240.60	254.54
572	211.52	181.83	164.46	152.14	142.58	134.77	162.25	188.75	208.68	225.58	240.70	254.65
573	211.83	182.09	164.70	152.36	142.79	134.97	162.30	188.80	208.74	225.65	240.77	254.72
574	212.15	182.37	164.95	152.59	143.01	135.17	162.34	188.85	208.79	225.70	240.83	254.78
575	212.45	182.63	165.19	152.81	143.21	135.37	162.39	188.91	208.86	225.77	240.91	254.87
576	212.74	182.88	165.41	153.02	143.40	135.55	162.45	188.98	208.94	225.86	241.00	254.96
577	213.15	183.23	165.73	153.31	143.68	135.81	162.42	188.94	208.89	225.81	240.95	254.91
578	213.38	183.43	165.91	153.48	143.83	135.96	162.53	189.07	209.03	225.96	241.11	255.08
579	213.56	183.58	166.05	153.61	143.96	136.07	162.67	189.24	209.22	226.16	241.32	255.31
580	213.89	183.87	166.31	153.85	144.18	136.29	162.70	189.26	209.25	226.20	241.36	255.34
581	214.18	184.12	166.53	154.05	144.38	136.47	162.76	189.34	209.33	226.29	241.45	255.44
582	214.59	184.47	166.85	154.35	144.65	136.73	162.73	189.30	209.29	226.24	241.41	255.40
583	214.86	184.70	167.06	154.54	144.84	136.90	162.80	189.39	209.38	226.34	241.52	255.51
584	215.18	184.98	167.31	154.77	145.05	137.11	162.84	189.43	209.43	226.40	241.57	255.57
585	215.51	185.26	167.57	155.01	145.27	137.32	162.87	189.46	209.47	226.43	241.61	255.61
586	215.82	185.53	167.81	155.23	145.48	137.51	162.91	189.52	209.53	226.50	241.68	255.68
587	216.09	185.76	168.02	155.43	145.67	137.69	162.99	189.60	209.62	226.60	241.79	255.80
588	216.49	186.10	168.33	155.72	145.93	137.94	162.96	189.57	209.59	226.57	241.75	255.76
589	216.60	186.19	168.41	155.79	146.00	138.01	163.16	189.80	209.85	226.84	242.05	256.07
590	216.94	186.49	168.68	156.04	146.24	138.23	163.18	189.82	209.86	226.86	242.07	256.09
591	217.26	186.76	168.92	156.27	146.45	138.43	163.22	189.87	209.92	226.92	242.13	256.16
592	217.50	186.97	169.11	156.44	146.61	138.58	163.31	189.98	210.04	227.05	242.27	256.31
593	217.87	187.29	169.40	156.71	146.87	138.82	163.31	189.97	210.03	227.04	242.26	256.30
594	218.13	187.51	169.60	156.89	147.04	138.98	163.39	190.07	210.14	227.16	242.39	256.43
595	218.45	187.79	169.85	157.13	147.26	139.19	163.42	190.11	210.18	227.20	242.43	256.48
596	218.81	188.10	170.13	157.39	147.50	139.42	163.43	190.11	210.19	227.21	242.44	256.49
597	219.08	188.33	170.34	157.58	147.68	139.59	163.50	190.20	210.29	227.32	242.56	256.61
598	219.37	188.58	170.56	157.78	147.87	139.77	163.56	190.27	210.36	227.40	242.64	256.70
599	219.66	188.83	170.79	158.00	148.07	139.96	163.62	190.33	210.43	227.47	242.72	256.79
600	219.98	189.10	171.04	158.23	148.29	140.17	163.65	190.37	210.47	227.52	242.77	256.84
601	220.27	189.36	171.27	158.44	148.48	140.35	163.71	190.44	210.54	227.60	242.85	256.93
602	220.55	189.59	171.48	158.63	148.67	140.53	163.77	190.52	210.63	227.69	242.96	257.03
603	220.88	189.87	171.74	158.87	148.89	140.74	163.80	190.55	210.67	227.73	243.00	257.08
604	221.09	190.06	171.90	159.02	149.03	140.87	163.92	190.68	210.82	227.89	243.17	257.26
605	221.37	190.30	172.13	159.23	149.23	141.05	163.98	190.75	210.89	227.97	243.26	257.35
606	221.72	190.60	172.39	159.48	149.46	141.27	163.99	190.77	210.91	227.99	243.28	257.37
607	222.05	190.88	172.65	159.72	149.68	141.48	164.02	190.80	210.94	228.03	243.31	257.41
608	222.47	191.25	172.98	160.02	149.97	141.75	163.97	190.75	210.89	227.97	243.25	257.35
609	222.74	191.47	173.19	160.21	150.15	141.92	164.05	190.84	210.99	228.08	243.36	257.47
610	222.93	191.64	173.34	160.35	150.28	142.05	164.17	190.98	211.15	228.25	243.55	257.66

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
611	223.25	191.92	173.59	160.58	150.49	142.25	164.21	191.02	211.19	228.30	243.60	257.72
612	223.48	192.11	173.76	160.75	150.65	142.40	164.31	191.14	211.32	228.44	243.75	257.87
613	223.81	192.40	174.02	160.98	150.87	142.60	164.34	191.17	211.36	228.47	243.79	257.92
614	224.17	192.71	174.30	161.24	151.11	142.83	164.34	191.17	211.36	228.48	243.79	257.92
615	224.52	193.01	174.57	161.49	151.35	143.06	164.35	191.19	211.38	228.49	243.81	257.94
616	224.81	193.25	174.79	161.70	151.54	143.24	164.41	191.25	211.45	228.57	243.90	258.03
617	225.16	193.56	175.07	161.95	151.78	143.46	164.42	191.26	211.46	228.59	243.91	258.04
618	225.43	193.79	175.28	162.15	151.96	143.64	164.49	191.34	211.55	228.68	244.01	258.15
619	225.71	194.03	175.50	162.35	152.15	143.82	164.54	191.41	211.62	228.76	244.10	258.24
620	226.00	194.28	175.72	162.55	152.34	144.00	164.60	191.48	211.70	228.85	244.19	258.34
621	226.18	194.43	175.86	162.69	152.47	144.12	164.74	191.63	211.87	229.03	244.38	258.54
622	226.48	194.69	176.09	162.90	152.67	144.30	164.78	191.69	211.93	229.10	244.46	258.62
623	226.85	195.01	176.38	163.17	152.92	144.54	164.78	191.68	211.92	229.09	244.44	258.61
624	227.11	195.23	176.58	163.35	153.09	144.71	164.86	191.77	212.03	229.20	244.56	258.73
625	227.55	195.61	176.92	163.67	153.39	144.98	164.80	191.71	211.96	229.12	244.48	258.65
626	227.79	195.81	177.11	163.84	153.55	145.14	164.89	191.81	212.07	229.25	244.61	258.79
627	228.02	196.01	177.29	164.01	153.70	145.28	164.99	191.93	212.20	229.38	244.76	258.94
628	228.34	196.29	177.54	164.24	153.92	145.49	165.02	191.96	212.23	229.42	244.80	258.99
629	228.64	196.54	177.77	164.45	154.12	145.68	165.07	192.02	212.30	229.49	244.87	259.06
630	229.04	196.89	178.09	164.74	154.39	145.94	165.04	191.98	212.26	229.45	244.83	259.02
631	229.29	197.11	178.28	164.93	154.56	146.10	165.12	192.08	212.36	229.56	244.95	259.14
632	229.53	197.31	178.47	165.10	154.72	146.25	165.21	192.18	212.48	229.69	245.08	259.28
633	229.94	197.67	178.79	165.39	155.00	146.51	165.17	192.14	212.43	229.64	245.03	259.23
634	230.35	198.02	179.11	165.69	155.28	146.77	165.14	192.10	212.39	229.59	244.98	259.17
635	230.49	198.14	179.21	165.79	155.37	146.86	165.30	192.29	212.60	229.82	245.22	259.43
636	230.72	198.33	179.39	165.95	155.52	147.00	165.40	192.41	212.72	229.95	245.37	259.58
637	231.00	198.58	179.61	166.15	155.72	147.19	165.45	192.47	212.79	230.03	245.45	259.67
638	231.43	198.95	179.95	166.46	156.01	147.46	165.40	192.41	212.73	229.96	245.37	259.59
639	231.57	199.07	180.05	166.56	156.10	147.55	165.56	192.60	212.94	230.18	245.61	259.84
640	231.95	199.39	180.35	166.84	156.35	147.79	165.55	192.59	212.92	230.17	245.60	259.83
641	232.24	199.64	180.57	167.05	156.55	147.98	165.60	192.64	212.99	230.24	245.67	259.91
642	232.60	199.95	180.85	167.30	156.79	148.21	165.61	192.65	212.99	230.24	245.67	259.91
643	232.87	200.19	181.07	167.50	156.98	148.38	165.67	192.72	213.07	230.33	245.77	260.01
644	233.13	200.40	181.26	167.68	157.15	148.54	165.75	192.81	213.17	230.44	245.88	260.13
645	233.45	200.69	181.52	167.92	157.37	148.75	165.77	192.84	213.20	230.47	245.92	260.17
646	233.83	201.01	181.81	168.19	157.62	148.99	165.76	192.83	213.19	230.46	245.91	260.16
647	234.00	201.15	181.94	168.31	157.74	149.10	165.90	192.99	213.37	230.65	246.11	260.37
648	234.37	201.47	182.23	168.58	157.99	149.33	165.89	192.98	213.36	230.64	246.10	260.36
649	234.65	201.71	182.45	168.78	158.17	149.51	165.95	193.05	213.43	230.72	246.19	260.45
650	235.08	202.08	182.78	169.08	158.46	149.78	165.90	192.99	213.37	230.65	246.12	260.38
651	235.21	202.20	182.88	169.18	158.55	149.87	166.06	193.18	213.58	230.88	246.35	260.63
652	235.52	202.47	183.13	169.41	158.76	150.07	166.10	193.22	213.62	230.92	246.40	260.68

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
653	235.85	202.74	183.38	169.64	158.98	150.27	166.12	193.25	213.66	230.96	246.44	260.72
654	236.11	202.97	183.58	169.83	159.16	150.44	166.20	193.33	213.75	231.06	246.55	260.84
655	236.47	203.28	183.86	170.09	159.40	150.67	166.20	193.33	213.75	231.06	246.55	260.83
656	236.75	203.52	184.08	170.29	159.59	150.85	166.25	193.40	213.82	231.14	246.63	260.92
657	237.09	203.81	184.35	170.53	159.82	151.07	166.27	193.41	213.84	231.16	246.65	260.94
658	237.36	204.04	184.55	170.73	160.00	151.24	166.33	193.49	213.92	231.25	246.75	261.05
659	237.54	204.20	184.70	170.86	160.12	151.35	166.46	193.63	214.08	231.42	246.93	261.24
660	237.99	204.58	185.04	171.18	160.42	151.64	166.40	193.56	214.01	231.34	246.85	261.15
661	238.24	204.80	185.24	171.36	160.60	151.80	166.47	193.65	214.10	231.44	246.95	261.26
662	238.63	205.14	185.54	171.64	160.86	152.05	166.45	193.63	214.07	231.41	246.92	261.23
663	238.85	205.32	185.71	171.80	161.01	152.19	166.55	193.74	214.20	231.55	247.07	261.39
664	239.23	205.65	186.01	172.07	161.26	152.43	166.53	193.73	214.18	231.53	247.05	261.37
665	239.53	205.91	186.24	172.29	161.46	152.62	166.58	193.78	214.24	231.59	247.12	261.44
666	239.78	206.12	186.44	172.47	161.63	152.78	166.65	193.87	214.34	231.70	247.23	261.55
667	239.97	206.29	186.58	172.61	161.76	152.90	166.77	194.00	214.49	231.86	247.40	261.74
668	240.35	206.62	186.88	172.88	162.02	153.15	166.75	193.98	214.47	231.84	247.38	261.71
669	240.66	206.88	187.12	173.10	162.22	153.34	166.79	194.03	214.52	231.89	247.44	261.77
670	240.88	207.07	187.29	173.26	162.37	153.48	166.89	194.14	214.64	232.02	247.58	261.92
671	241.33	207.46	187.64	173.59	162.68	153.77	166.82	194.06	214.55	231.93	247.48	261.82
672	241.64	207.72	187.88	173.80	162.89	153.96	166.86	194.11	214.60	231.98	247.54	261.88
673	241.91	207.95	188.09	174.00	163.07	154.13	166.92	194.18	214.69	232.07	247.63	261.98
674	242.17	208.18	188.30	174.19	163.25	154.31	166.99	194.25	214.77	232.16	247.72	262.08
675	242.53	208.49	188.58	174.45	163.49	154.53	166.99	194.25	214.77	232.16	247.72	262.08
676	242.76	208.68	188.75	174.61	163.64	154.68	167.08	194.36	214.89	232.29	247.86	262.22
677	242.99	208.89	188.94	174.78	163.80	154.83	167.16	194.46	214.99	232.41	247.99	262.36
678	243.42	209.25	189.26	175.08	164.08	155.10	167.12	194.41	214.94	232.35	247.92	262.29
679	243.63	209.43	189.43	175.24	164.23	155.23	167.22	194.53	215.07	232.49	248.07	262.45
680	243.97	209.72	189.69	175.48	164.46	155.45	167.24	194.54	215.08	232.51	248.09	262.47
681	244.25	209.97	189.91	175.68	164.65	155.63	167.29	194.60	215.15	232.58	248.17	262.55
682	244.76	210.41	190.31	176.05	164.99	155.96	167.18	194.48	215.02	232.43	248.01	262.38
683	244.80	210.44	190.34	176.08	165.02	155.98	167.40	194.73	215.30	232.73	248.33	262.72
684	245.19	210.77	190.64	176.36	165.28	156.23	167.38	194.71	215.27	232.71	248.31	262.70
685	245.49	211.03	190.87	176.57	165.48	156.42	167.42	194.76	215.32	232.76	248.37	262.76
686	245.83	211.32	191.14	176.82	165.71	156.63	167.44	194.77	215.34	232.78	248.39	262.78
687	246.10	211.56	191.35	177.01	165.89	156.81	167.49	194.84	215.42	232.87	248.47	262.87
688	246.39	211.80	191.57	177.22	166.09	156.99	167.54	194.90	215.48	232.93	248.54	262.95
689	246.56	211.95	191.71	177.35	166.21	157.10	167.67	195.04	215.64	233.10	248.73	263.14
690	247.03	212.36	192.08	177.68	166.52	157.40	167.59	194.95	215.54	233.00	248.62	263.02
691	247.31	212.60	192.29	177.88	166.71	157.58	167.64	195.02	215.61	233.07	248.70	263.11
692	247.57	212.82	192.49	178.07	166.88	157.74	167.71	195.10	215.70	233.17	248.80	263.22
693	247.88	213.09	192.74	178.30	167.09	157.94	167.74	195.13	215.74	233.21	248.84	263.26
694	248.01	213.20	192.84	178.39	167.18	158.03	167.90	195.31	215.93	233.42	249.07	263.50

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
695	248.47	213.59	193.19	178.72	167.49	158.32	167.83	195.23	215.85	233.33	248.97	263.40
696	248.86	213.93	193.50	179.00	167.76	158.57	167.80	195.20	215.82	233.29	248.93	263.36
697	249.02	214.06	193.62	179.11	167.86	158.67	167.94	195.36	215.99	233.48	249.14	263.57
698	249.40	214.39	193.92	179.39	168.12	158.91	167.92	195.34	215.97	233.46	249.11	263.55
699	249.70	214.66	194.15	179.61	168.32	159.10	167.96	195.38	216.02	233.51	249.16	263.60
700	250.97	215.74	195.14	180.52	169.17	159.91	167.35	194.68	215.23	232.67	248.26	262.65
701	251.26	215.99	195.36	180.72	169.37	160.09	167.40	194.73	215.29	232.73	248.33	262.72
702	251.42	216.13	195.48	180.84	169.48	160.20	167.53	194.88	215.46	232.92	248.53	262.93
703	251.70	216.37	195.71	181.04	169.67	160.38	167.58	194.94	215.53	232.98	248.60	263.01
704	252.07	216.68	195.99	181.30	169.91	160.61	167.58	194.94	215.52	232.98	248.60	263.00
705	252.47	217.03	196.30	181.59	170.18	160.86	167.55	194.90	215.49	232.94	248.55	262.96
706	252.80	217.32	196.56	181.83	170.41	161.08	167.56	194.92	215.51	232.96	248.58	262.98
707	252.93	217.43	196.66	181.93	170.50	161.16	167.71	195.10	215.70	233.17	248.80	263.21
708	253.25	217.70	196.91	182.15	170.71	161.36	167.74	195.13	215.74	233.21	248.84	263.26
709	253.62	218.02	197.20	182.42	170.96	161.60	167.73	195.12	215.72	233.19	248.83	263.24
710	253.84	218.21	197.37	182.58	171.11	161.74	167.82	195.22	215.84	233.32	248.96	263.39
711	254.24	218.55	197.68	182.87	171.38	161.99	167.80	195.19	215.81	233.28	248.92	263.35
712	254.41	218.70	197.82	182.99	171.50	162.11	167.91	195.33	215.96	233.45	249.10	263.53
713	254.78	219.02	198.10	183.25	171.74	162.34	167.91	195.33	215.95	233.45	249.09	263.53
714	254.96	219.17	198.24	183.38	171.86	162.45	168.03	195.46	216.11	233.61	249.27	263.71
715	255.41	219.56	198.59	183.71	172.17	162.74	167.96	195.39	216.02	233.52	249.17	263.61
716	255.65	219.77	198.78	183.88	172.33	162.89	168.04	195.48	216.12	233.63	249.29	263.73
717	256.03	220.10	199.07	184.16	172.59	163.14	168.03	195.46	216.10	233.60	249.26	263.71
718	256.27	220.30	199.26	184.33	172.75	163.29	168.10	195.55	216.20	233.71	249.38	263.83
719	256.62	220.60	199.53	184.58	172.99	163.51	168.11	195.56	216.21	233.72	249.39	263.84
720	256.83	220.78	199.69	184.73	173.13	163.64	168.20	195.67	216.33	233.85	249.53	263.99
721	257.19	221.09	199.97	184.99	173.37	163.87	168.20	195.67	216.33	233.85	249.53	263.99
722	257.45	221.31	200.17	185.18	173.54	164.04	168.27	195.74	216.41	233.94	249.62	264.09
723	257.79	221.61	200.44	185.42	173.77	164.26	168.28	195.75	216.42	233.95	249.63	264.10
724	258.07	221.85	200.66	185.63	173.97	164.44	168.32	195.81	216.48	234.02	249.71	264.17
725	258.36	222.10	200.88	185.83	174.16	164.62	168.37	195.86	216.54	234.08	249.77	264.25
726	258.70	222.39	201.15	186.08	174.39	164.84	168.38	195.87	216.56	234.10	249.79	264.26
727	258.98	222.63	201.37	186.28	174.58	165.01	168.43	195.93	216.62	234.17	249.86	264.34
728	259.38	222.97	201.68	186.57	174.85	165.27	168.40	195.90	216.58	234.12	249.82	264.29
729	259.60	223.16	201.85	186.73	174.99	165.41	168.49	196.00	216.70	234.25	249.95	264.43
730	259.84	223.37	202.03	186.89	175.15	165.56	168.57	196.09	216.80	234.36	250.07	264.56
731	260.18	223.66	202.30	187.14	175.39	165.78	168.57	196.10	216.81	234.36	250.08	264.57
732	260.45	223.89	202.51	187.34	175.57	165.95	168.63	196.16	216.88	234.44	250.16	264.66
733	260.71	224.12	202.71	187.52	175.74	166.12	168.69	196.24	216.96	234.53	250.25	264.76
734	261.02	224.39	202.95	187.75	175.95	166.32	168.72	196.27	216.99	234.57	250.29	264.80
735	261.48	224.78	203.31	188.07	176.26	166.61	168.66	196.19	216.91	234.48	250.20	264.70
736	261.75	225.01	203.52	188.27	176.44	166.78	168.71	196.26	216.99	234.56	250.28	264.79

Table B.3: Simulation Data for Picking Times (Low Rate) — *continued*.

Batch Size	Picking Time (minutes)						Picking Rate (orders/hr)					
	20	40	60	80	100	120	20	40	60	80	100	120
737	261.92	225.15	203.65	188.39	176.55	166.88	168.83	196.40	217.14	234.73	250.46	264.97
738	261.31	224.63	203.18	187.96	176.15	166.50	169.45	197.12	217.94	235.59	251.38	265.95
739	261.68	224.95	203.46	188.22	176.39	166.73	169.45	197.11	217.93	235.58	251.37	265.93
740	261.90	225.14	203.64	188.38	176.55	166.88	169.53	197.21	218.03	235.69	251.49	266.07
741	262.29	225.47	203.94	188.66	176.81	167.12	169.51	197.18	218.01	235.66	251.46	266.03
742	262.52	225.67	204.12	188.82	176.96	167.27	169.59	197.28	218.11	235.77	251.58	266.16
743	262.84	225.94	204.36	189.05	177.18	167.47	169.61	197.30	218.14	235.81	251.61	266.19
744	263.16	226.22	204.61	189.28	177.39	167.67	169.63	197.33	218.17	235.84	251.65	266.23
745	263.52	226.54	204.90	189.55	177.64	167.91	169.62	197.32	218.16	235.83	251.63	266.22
746	263.91	226.87	205.20	189.82	177.90	168.15	169.60	197.30	218.13	235.80	251.60	266.18
747	264.01	226.95	205.27	189.89	177.96	168.22	169.77	197.49	218.34	236.03	251.85	266.44
748	264.41	227.29	205.58	190.18	178.23	168.47	169.74	197.45	218.30	235.99	251.80	266.39
749	264.67	227.52	205.79	190.37	178.41	168.64	169.79	197.52	218.38	236.06	251.89	266.48
750	264.96	227.77	206.01	190.58	178.60	168.82	169.84	197.57	218.43	236.13	251.95	266.55

Table B.4: Manual Packing Times and Rates.

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
1	1.31	0.91	0.56	38.85	56.95	78.79
2	2.61	1.83	1.12	38.08	52.67	71.86
3	4.37	2.98	1.70	36.36	50.65	67.14
4	5.82	3.98	2.27	35.74	48.35	63.76
5	7.66	5.18	2.86	34.47	46.65	61.98
6	9.19	6.21	3.43	33.51	46.46	59.63
7	11.08	7.44	4.04	34.18	45.59	57.64
8	12.66	8.50	4.62	34.01	44.73	56.64
9	14.61	9.75	5.25	32.46	42.73	55.37
10	16.23	10.84	5.83	32.74	42.14	54.55
11	18.21	12.11	6.48	32.03	42.18	53.30
12	19.86	13.21	7.07	31.18	41.49	52.34
13	21.88	14.49	7.73	31.73	41.33	51.71
14	23.56	15.61	8.32	31.08	40.80	50.73
15	25.60	16.91	9.00	30.08	39.84	49.57
16	27.31	18.04	9.60	30.52	39.10	49.43
17	29.37	19.35	10.30	29.86	39.36	48.32
18	31.10	20.49	10.91	29.24	38.87	47.52
19	33.19	21.82	11.62	30.45	38.72	47.61
20	34.94	22.97	12.23	29.66	37.96	46.71
21	37.05	24.30	12.97	29.87	37.22	46.62

Table B.4: Manual Packing Times and Rates — *continued*.

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
22	38.81	25.46	13.58	28.98	37.28	45.94
23	40.94	26.81	14.33	29.23	36.55	45.35
24	42.72	27.97	14.96	28.32	36.65	44.76
25	44.87	29.33	15.73	28.46	36.81	44.51
26	46.66	30.50	16.35	28.99	36.44	44.32
27	48.83	31.86	17.14	27.85	36.04	43.99
28	50.64	33.04	17.78	28.64	35.24	43.54
29	52.82	34.41	18.58	28.02	35.48	42.70
30	54.64	35.60	19.22	27.59	34.78	42.49
31	56.83	36.98	20.05	27.75	35.05	42.46
32	58.66	38.17	20.69	28.03	35.03	42.24
33	60.87	39.55	21.54	27.10	34.69	41.73
34	62.72	40.75	22.19	27.47	34.14	41.19
35	64.94	42.14	23.05	26.75	34.20	41.06
36	66.79	43.35	23.71	27.00	33.80	41.11
37	69.02	44.75	24.59	26.57	33.46	40.60
38	70.89	45.95	25.25	26.50	33.31	40.42
39	73.13	47.36	26.15	26.99	33.37	40.00
40	75.01	48.57	26.82	26.94	33.14	39.84
41	77.26	49.98	27.74	26.66	33.13	39.67
42	79.15	51.20	28.42	25.87	32.81	39.49
43	81.42	52.61	29.35	26.59	32.87	39.03
44	83.31	53.84	30.03	26.20	32.79	38.96
45	85.58	55.25	30.99	26.46	32.44	38.47
46	87.49	56.48	31.68	25.98	32.02	38.61
47	89.77	57.91	32.65	25.90	31.95	38.05
48	91.68	59.14	33.35	25.46	32.30	38.26
49	93.98	60.57	34.34	25.84	31.56	37.98
50	95.90	61.80	35.04	25.53	31.84	37.79
51	98.20	63.23	36.05	26.07	31.84	37.67
52	100.13	64.47	36.76	25.78	31.38	37.42
53	102.44	65.91	37.79	24.89	31.45	36.98
54	104.37	67.15	38.50	25.63	31.10	36.97
55	106.69	68.59	39.55	25.59	30.88	36.72
56	108.63	69.84	40.26	25.47	31.24	36.44
57	110.96	71.29	41.33	25.52	30.88	36.67
58	112.91	72.54	42.06	25.01	30.88	36.29
59	115.25	73.99	43.14	24.88	30.65	36.14
60	117.20	75.24	43.87	25.09	30.25	35.98
61	119.55	76.69	44.97	25.21	30.68	35.65
62	121.51	77.95	45.71	24.67	30.04	35.87

Table B.4: Manual Packing Times and Rates — *continued*.

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
63	123.86	79.40	46.83	24.93	29.99	35.49
64	125.83	80.67	47.57	24.65	30.23	35.56
65	128.19	82.12	48.71	24.77	30.14	35.26
66	130.16	83.39	49.46	24.85	30.13	35.13
67	132.53	84.85	50.61	24.01	29.98	35.11
68	134.50	86.12	51.37	24.09	29.64	34.98
69	136.88	87.58	52.54	24.17	29.65	34.76
70	138.86	88.85	53.30	24.54	29.61	34.62
71	141.24	90.32	54.49	24.26	29.19	34.53
72	143.23	91.60	55.25	23.86	29.51	34.43
73	145.62	93.07	56.46	24.17	29.24	34.17
74	147.62	94.34	57.23	24.01	29.03	34.21
75	150.01	95.82	58.45	23.44	29.19	33.88
76	152.01	97.10	59.23	23.94	29.19	33.84
77	154.41	98.58	60.47	23.27	28.74	33.57
78	156.42	99.86	61.25	23.52	29.00	33.56
79	158.82	101.34	62.50	23.39	28.91	33.60
80	160.83	102.62	63.29	24.00	28.43	33.50
81	163.24	104.11	64.56	23.11	28.37	33.27
82	165.26	105.39	65.35	23.81	28.70	33.24
83	167.68	106.88	66.63	23.33	28.26	32.91
84	169.70	108.17	67.43	23.70	28.19	33.00
85	172.12	109.66	68.73	22.90	28.20	33.01
86	174.15	110.95	69.53	23.57	28.38	32.76
87	176.58	112.44	70.84	22.84	27.84	32.75
88	178.61	113.73	71.65	23.47	28.10	32.41
89	181.04	115.23	72.97	23.39	27.74	32.53
90	183.08	116.52	73.79	22.78	27.98	32.46
91	185.52	118.02	75.12	23.14	27.81	32.18
92	187.55	119.32	75.95	22.84	27.77	32.03
93	190.00	120.82	77.29	23.03	27.41	32.00
94	192.04	122.12	78.12	22.60	27.44	31.84
95	194.49	123.62	79.47	22.55	27.33	31.99
96	196.54	124.92	80.30	22.67	27.20	31.66
97	199.00	126.43	81.66	22.79	27.36	31.75
98	201.05	127.73	82.51	22.93	27.48	31.58
99	203.51	129.24	83.88	22.98	27.44	31.47
100	205.56	130.54	84.72	22.44	27.06	31.38
101	208.03	132.06	86.10	22.27	26.93	31.38
102	210.09	133.36	86.95	22.83	26.95	31.23
103	212.56	134.88	88.34	22.86	27.06	31.37

Table B.4: Manual Packing Times and Rates — *continued*.

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
104	214.62	136.18	89.19	22.47	26.90	31.13
105	217.10	137.70	90.59	22.23	27.00	31.22
106	219.17	139.01	91.45	22.20	26.88	30.97
107	221.65	140.53	92.85	21.93	26.83	30.79
108	223.72	141.84	93.71	22.06	26.70	30.72
109	226.20	143.36	95.11	21.97	26.83	30.82
110	228.28	144.68	95.99	22.07	26.69	30.82
111	230.76	146.20	97.39	21.87	26.37	30.68
112	232.84	147.52	98.27	22.00	26.51	30.60
113	235.34	149.04	99.68	21.94	26.37	30.49
114	237.42	150.36	100.56	22.26	26.22	30.29
115	239.92	151.88	101.97	22.32	26.09	30.36
116	242.00	153.20	102.86	21.92	26.42	30.10
117	244.50	154.73	104.27	22.05	26.29	30.10
118	246.59	156.06	105.16	21.68	26.25	30.22
119	249.10	157.59	106.57	21.80	26.26	30.08
120	251.19	158.91	107.46	21.96	26.12	29.87
121	253.70	160.44	108.87	21.41	26.21	29.87
122	255.80	161.77	109.77	21.51	25.87	29.72
123	258.31	163.30	111.18	21.57	25.84	29.68
124	260.41	164.63	112.08	21.62	25.73	29.80
125	262.93	166.16	113.49	21.54	25.60	29.48
126	265.04	167.49	114.39	21.45	25.87	29.65
127	267.56	169.03	115.79	21.34	25.77	29.35
128	269.66	170.36	116.70	21.81	25.47	29.38
129	272.19	171.90	118.10	21.52	25.40	29.36
130	274.30	173.23	119.01	21.58	25.76	29.20
131	276.83	174.78	120.40	21.20	25.36	29.12

Table B.5: Simulation Data for Automated Packing with Overlapping Waves.

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
1	1.26	0.85	0.50	47.6929	70.2520	118.89
2	2.52	1.71	1.01	47.6928	70.1936	118.77
3	3.77	2.57	1.52	47.6928	70.1594	118.70
4	5.03	3.42	2.02	47.6927	70.1352	118.65
5	6.29	4.28	2.53	47.6926	70.1165	118.61
6	7.55	5.14	3.04	47.6925	70.1011	118.58

Table B.5: Simulation Data for Automated Packing with Overlapping Waves

— *continued.*

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
7	8.81	5.99	3.54	47.6924	70.0881	118.56
8	10.06	6.85	4.05	47.6924	70.0769	118.53
9	11.32	7.71	4.56	47.6923	70.0670	118.51
10	12.58	8.56	5.06	47.6922	70.0582	118.50
11	13.84	9.42	5.57	47.6921	70.0501	118.48
12	15.10	10.28	6.08	47.6920	70.0428	118.47
13	16.35	11.14	6.58	47.6920	70.0361	118.45
14	17.61	11.99	7.09	47.6919	70.0299	118.44
15	18.87	12.85	7.60	47.6918	70.0241	118.43
16	20.13	13.71	8.11	47.6917	70.0187	118.42
17	21.39	14.57	8.61	47.6916	70.0136	118.41
18	22.65	15.43	9.12	47.6916	70.0088	118.40
19	23.90	16.28	9.63	47.6915	70.0042	118.39
20	25.16	17.14	10.14	47.6914	69.9999	118.38
21	26.42	18.00	10.64	47.6913	69.9958	118.37
22	27.68	18.86	11.15	47.6912	69.9919	118.36
23	28.94	19.72	11.66	47.6912	69.9882	118.35
24	30.19	20.58	12.17	47.6911	69.9846	118.35
25	31.45	21.43	12.68	47.6910	69.9812	118.34
26	32.71	22.29	13.18	47.6909	69.9779	118.33
27	33.97	23.15	13.69	47.6908	69.9747	118.33
28	35.23	24.01	14.20	47.6908	69.9716	118.32
29	36.49	24.87	14.71	47.6907	69.9687	118.31
30	37.74	25.73	15.21	47.6906	69.9659	118.31
31	39.00	26.59	15.72	47.6905	69.9631	118.30
32	40.26	27.44	16.23	47.6904	69.9604	118.30
33	41.52	28.30	16.74	47.6904	69.9579	118.29
34	42.78	29.16	17.25	47.6903	69.9553	118.29
35	44.03	30.02	17.75	47.6902	69.9529	118.28
36	45.29	30.88	18.26	47.6901	69.9505	118.28
37	46.55	31.74	18.77	47.6900	69.9482	118.27
38	47.81	32.60	19.28	47.6900	69.9460	118.27
39	49.07	33.46	19.79	47.6899	69.9438	118.26
40	50.33	34.31	20.29	47.6898	69.9417	118.26
41	51.58	35.17	20.80	47.6897	69.9396	118.25
42	52.84	36.03	21.31	47.6896	69.9376	118.25
43	54.10	36.89	21.82	47.6896	69.9356	118.25
44	55.36	37.75	22.33	47.6895	69.9337	118.24
45	56.62	38.61	22.84	47.6894	69.9318	118.24
46	57.87	39.47	23.34	47.6893	69.9300	118.24

Table B.5: Simulation Data for Automated Packing with Overlapping Waves

— *continued.*

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
47	59.13	40.33	23.85	47.6892	69.9282	118.23
48	60.39	41.19	24.36	47.6892	69.9264	118.23
49	61.65	42.05	24.87	47.6891	69.9247	118.22
50	62.91	42.90	25.38	47.6890	69.9230	118.22
51	64.17	43.76	25.88	47.6889	69.9213	118.22
52	65.42	44.62	26.39	47.6888	69.9197	118.21
53	66.68	45.48	26.90	47.6888	69.9181	118.21
54	67.94	46.34	27.41	47.6887	69.9165	118.21
55	69.20	47.20	27.92	47.6886	69.9150	118.20
56	70.46	48.06	28.43	47.6885	69.9135	118.20
57	71.72	48.92	28.93	47.6884	69.9120	118.20
58	72.97	49.78	29.44	47.6884	69.9105	118.20
59	74.23	50.64	29.95	47.6883	69.9091	118.19
60	75.49	51.50	30.46	47.6882	69.9077	118.19
61	76.75	52.36	30.97	47.6881	69.9063	118.19
62	78.01	53.22	31.48	47.6880	69.9049	118.18
63	79.27	54.07	31.98	47.6880	69.9036	118.18
64	80.52	54.93	32.49	47.6879	69.9023	118.18
65	81.78	55.79	33.00	47.6878	69.9010	118.18
66	83.04	56.65	33.51	47.6877	69.8997	118.17
67	84.30	57.51	34.02	47.6876	69.8984	118.17
68	85.56	58.37	34.53	47.6876	69.8972	118.17
69	86.82	59.23	35.04	47.6875	69.8960	118.17
70	88.07	60.09	35.54	47.6874	69.8948	118.16
71	89.33	60.95	36.05	47.6873	69.8936	118.16
72	90.59	61.81	36.56	47.6872	69.8924	118.16
73	91.85	62.67	37.07	47.6872	69.8912	118.16
74	93.11	63.53	37.58	47.6871	69.8901	118.15
75	94.37	64.39	38.09	47.6870	69.8890	118.15
76	95.62	65.25	38.60	47.6869	69.8879	118.15
77	96.88	66.11	39.10	47.6868	69.8868	118.15
78	98.14	66.97	39.61	47.6868	69.8857	118.15
79	99.40	67.83	40.12	47.6867	69.8846	118.14
80	100.66	68.69	40.63	47.6866	69.8836	118.14
81	101.92	69.55	41.14	47.6865	69.8825	118.14
82	103.17	70.40	41.65	47.6864	69.8815	118.14
83	104.43	71.26	42.16	47.6864	69.8805	118.13
84	105.69	72.12	42.66	47.6863	69.8795	118.13
85	106.95	72.98	43.17	47.6862	69.8785	118.13
86	108.21	73.84	43.68	47.6861	69.8775	118.13

Table B.5: Simulation Data for Automated Packing with Overlapping Waves

— *continued.*

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
87	109.47	74.70	44.19	47.6860	69.8765	118.13
88	110.72	75.56	44.70	47.6860	69.8756	118.12
89	111.98	76.42	45.21	47.6859	69.8746	118.12
90	113.24	77.28	45.72	47.6858	69.8737	118.12
91	114.50	78.14	46.22	47.6857	69.8728	118.12
92	115.76	79.00	46.73	47.6856	69.8718	118.12
93	117.02	79.86	47.24	47.6856	69.8709	118.11
94	118.27	80.72	47.75	47.6855	69.8700	118.11
95	119.53	81.58	48.26	47.6854	69.8691	118.11
96	120.79	82.44	48.77	47.6853	69.8683	118.11
97	122.05	83.30	49.28	47.6852	69.8674	118.11
98	123.31	84.16	49.79	47.6852	69.8665	118.11
99	124.57	85.02	50.29	47.6851	69.8657	118.10
100	125.83	85.88	50.80	47.6850	69.8648	118.10
101	127.08	86.74	51.31	47.6849	69.8640	118.10
102	128.34	87.60	51.82	47.6848	69.8632	118.10
103	129.60	88.46	52.33	47.6848	69.8624	118.10
104	130.86	89.32	52.84	47.6847	69.8616	118.10
105	132.12	90.18	53.35	47.6846	69.8608	118.09
106	133.38	91.04	53.86	47.6845	69.8600	118.09
107	134.64	91.90	54.36	47.6844	69.8592	118.09
108	135.89	92.76	54.87	47.6844	69.8584	118.09
109	137.15	93.62	55.38	47.6843	69.8576	118.09
110	138.41	94.48	55.89	47.6842	69.8569	118.09
111	139.67	95.34	56.40	47.6841	69.8561	118.08
112	140.93	96.20	56.91	47.6840	69.8553	118.08
113	142.19	97.06	57.42	47.6840	69.8546	118.08
114	143.44	97.92	57.93	47.6839	69.8539	118.08
115	144.70	98.78	58.44	47.6838	69.8531	118.08
116	145.96	99.64	58.94	47.6837	69.8524	118.08
117	147.22	100.50	59.45	47.6836	69.8517	118.08
118	148.48	101.36	59.96	47.6836	69.8510	118.07
119	149.74	102.22	60.47	47.6835	69.8503	118.07
120	151.00	103.08	60.98	47.6834	69.8496	118.07
121	152.25	103.94	61.49	47.6833	69.8489	118.07
122	153.51	104.80	62.00	47.6832	69.8482	118.07
123	154.77	105.66	62.51	47.6832	69.8475	118.07
124	156.03	106.52	63.02	47.6831	69.8468	118.07
125	157.29	107.38	63.52	47.6830	69.8461	118.06
126	158.55	108.24	64.03	47.6829	69.8455	118.06

Table B.5: Simulation Data for Automated Packing with Overlapping Waves

— *continued.*

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
127	159.81	109.10	64.54	47.6828	69.8448	118.06
128	161.06	109.96	65.05	47.6828	69.8442	118.06
129	162.32	110.82	65.56	47.6827	69.8435	118.06
130	163.58	111.68	66.07	47.6826	69.8429	118.06
131	164.84	112.54	66.58	47.6825	69.8422	118.06
132	166.10	113.40	67.09	47.6824	69.8416	118.06
133	167.36	114.26	67.60	47.6824	69.8409	118.05
134	168.62	115.12	68.11	47.6823	69.8403	118.05
135	169.87	115.98	68.61	47.6822	69.8397	118.05
136	171.13	116.84	69.12	47.6821	69.8391	118.05
137	172.39	117.70	69.63	47.6820	69.8385	118.05
138	173.65	118.56	70.14	47.6820	69.8378	118.05
139	174.91	119.42	70.65	47.6819	69.8372	118.05
140	176.17	120.28	71.16	47.6818	69.8366	118.04
141	177.43	121.14	71.67	47.6817	69.8360	118.04
142	178.69	122.00	72.18	47.6816	69.8355	118.04
143	179.94	122.86	72.69	47.6816	69.8349	118.04
144	181.20	123.72	73.20	47.6815	69.8343	118.04
145	182.46	124.58	73.70	47.6814	69.8337	118.04
146	183.72	125.44	74.21	47.6813	69.8331	118.04
147	184.98	126.30	74.72	47.6812	69.8326	118.04
148	186.24	127.16	75.23	47.6812	69.8320	118.04
149	187.50	128.02	75.74	47.6811	69.8314	118.03
150	188.75	128.88	76.25	47.6810	69.8309	118.03
151	190.01	129.74	76.76	47.6809	69.8303	118.03
152	191.27	130.60	77.27	47.6808	69.8297	118.03
153	192.53	131.46	77.78	47.6808	69.8292	118.03
154	193.79	132.32	78.29	47.6807	69.8287	118.03
155	195.05	133.18	78.80	47.6806	69.8281	118.03
156	196.31	134.04	79.30	47.6805	69.8276	118.03
157	197.57	134.90	79.81	47.6804	69.8270	118.03
158	198.82	135.77	80.32	47.6804	69.8265	118.02
159	200.08	136.63	80.83	47.6803	69.8260	118.02
160	201.34	137.49	81.34	47.6802	69.8255	118.02
161	202.60	138.35	81.85	47.6801	69.8249	118.02
162	203.86	139.21	82.36	47.6800	69.8244	118.02
163	205.12	140.07	82.87	47.6800	69.8239	118.02
164	206.38	140.93	83.38	47.6799	69.8234	118.02
165	207.64	141.79	83.89	47.6798	69.8229	118.02
166	208.89	142.65	84.40	47.6797	69.8224	118.02

Table B.5: Simulation Data for Automated Packing with Overlapping Waves

— *continued.*

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
167	210.15	143.51	84.90	47.6796	69.8219	118.01
168	211.41	144.37	85.41	47.6796	69.8214	118.01
169	212.67	145.23	85.92	47.6795	69.8209	118.01
170	213.93	146.09	86.43	47.6794	69.8204	118.01
171	215.19	146.95	86.94	47.6793	69.8199	118.01
172	216.45	147.81	87.45	47.6792	69.8194	118.01
173	217.71	148.67	87.96	47.6792	69.8189	118.01
174	218.96	149.53	88.47	47.6791	69.8184	118.01
175	220.22	150.39	88.98	47.6790	69.8179	118.01
176	221.48	151.25	89.49	47.6789	69.8175	118.01
177	222.74	152.11	90.00	47.6788	69.8170	118.00
178	224.00	152.97	90.51	47.6788	69.8165	118.00
179	225.26	153.83	91.01	47.6787	69.8160	118.00
180	226.52	154.69	91.52	47.6786	69.8156	118.00
181	227.78	155.55	92.03	47.6785	69.8151	118.00
182	229.03	156.41	92.54	47.6784	69.8147	118.00
183	230.29	157.27	93.05	47.6784	69.8142	118.00
184	231.55	158.14	93.56	47.6783	69.8137	118.00
185	232.81	159.00	94.07	47.6782	69.8133	118.00
186	234.07	159.86	94.58	47.6781	69.8128	118.00
187	235.33	160.72	95.09	47.6780	69.8124	118.00
188	236.59	161.58	95.60	47.6780	69.8119	117.99
189	237.85	162.44	96.11	47.6779	69.8115	117.99
190	239.10	163.30	96.62	47.6778	69.8111	117.99
191	240.36	164.16	97.13	47.6777	69.8106	117.99
192	241.62	165.02	97.63	47.6776	69.8102	117.99
193	242.88	165.88	98.14	47.6776	69.8097	117.99
194	244.14	166.74	98.65	47.6775	69.8093	117.99
195	245.40	167.60	99.16	47.6774	69.8089	117.99
196	246.66	168.46	99.67	47.6773	69.8084	117.99
197	247.92	169.32	100.18	47.6772	69.8080	117.99
198	249.18	170.18	100.69	47.6772	69.8076	117.99
199	250.43	171.04	101.20	47.6771	69.8072	117.98
200	251.69	171.90	101.71	47.6770	69.8068	117.98
201	252.95	172.76	102.22	47.6769	69.8063	117.98
202	254.21	173.62	102.73	47.6768	69.8059	117.98
203	255.47	174.48	103.24	47.6768	69.8055	117.98
204	256.73	175.35	103.75	47.6767	69.8051	117.98
205	257.99	176.21	104.26	47.6766	69.8047	117.98
206	259.25	177.07	104.76	47.6765	69.8043	117.98

Table B.5: Simulation Data for Automated Packing with Overlapping Waves

— *continued.*

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
207	260.51	177.93	105.27	47.6764	69.8039	117.98
208	261.76	178.79	105.78	47.6764	69.8035	117.98
209	263.02	179.65	106.29	47.6763	69.8031	117.98
210	264.28	180.51	106.80	47.6762	69.8027	117.98
211	265.54	181.37	107.31	47.6761	69.8023	117.97
212	266.80	182.23	107.82	47.6760	69.8019	117.97
213	268.06	183.09	108.33	47.6760	69.8015	117.97
214	269.32	183.95	108.84	47.6759	69.8011	117.97
215	270.58	184.81	109.35	47.6758	69.8007	117.97
216	271.84	185.67	109.86	47.6757	69.8003	117.97
217	273.10	186.53	110.37	47.6756	69.7999	117.97
218	274.35	187.39	110.88	47.6756	69.7995	117.97
219	275.61	188.25	111.39	47.6755	69.7992	117.97
220	276.87	189.12	111.90	47.6754	69.7988	117.97
221	278.13	189.98	112.40	47.6753	69.7984	117.97
222	279.39	190.84	112.91	47.6752	69.7980	117.97
223	280.65	191.70	113.42	47.6752	69.7976	117.97
224	281.91	192.56	113.93	47.6751	69.7973	117.96
225	283.17	193.42	114.44	47.6750	69.7969	117.96
226	284.43	194.28	114.95	47.6749	69.7965	117.96
227	285.69	195.14	115.46	47.6748	69.7961	117.96
228	286.94	196.00	115.97	47.6748	69.7958	117.96
229	288.20	196.86	116.48	47.6747	69.7954	117.96
230	289.46	197.72	116.99	47.6746	69.7950	117.96
231	290.72	198.58	117.50	47.6745	69.7947	117.96
232	291.98	199.44	118.01	47.6744	69.7943	117.96
233	293.24	200.30	118.52	47.6744	69.7940	117.96
234	294.50	201.16	119.03	47.6743	69.7936	117.96
235	295.76	202.03	119.54	47.6742	69.7932	117.96
236	297.02	202.89	120.05	47.6741	69.7929	117.96
237	298.28	203.75	120.55	47.6740	69.7925	117.95
238	299.53	204.61	121.06	47.6740	69.7922	117.95
239	300.79	205.47	121.57	47.6739	69.7918	117.95
240	302.05	206.33	122.08	47.6738	69.7915	117.95

Table B.6: Simulation Data for Automated Packing with Non-Overlapping Waves.

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
1	1.31	0.91	0.56	45.92	65.68	106.88
2	2.80	1.93	1.13	42.88	62.24	106.37
3	4.37	2.98	1.70	41.20	60.31	105.86
4	5.99	4.07	2.28	40.05	58.98	105.35
5	7.66	5.18	2.86	39.18	57.96	104.85
6	9.36	6.30	3.45	38.48	57.15	104.35
7	11.08	7.44	4.04	37.90	56.47	103.85
8	12.83	8.59	4.64	37.40	55.88	103.35
9	14.61	9.75	5.25	36.97	55.37	102.86
10	16.40	10.92	5.86	36.59	54.92	102.37
11	18.21	12.11	6.48	36.25	54.52	101.88
12	20.03	13.30	7.10	35.94	54.15	101.40
13	21.88	14.49	7.73	35.66	53.81	100.92
14	23.73	15.70	8.36	35.40	53.51	100.44
15	25.60	16.91	9.00	35.16	53.22	99.97
16	27.48	18.13	9.65	34.93	52.95	99.50
17	29.37	19.35	10.30	34.73	52.70	99.03
18	31.28	20.58	10.96	34.53	52.47	98.56
19	33.19	21.82	11.62	34.35	52.25	98.10
20	35.11	23.06	12.29	34.17	52.04	97.64
21	37.05	24.30	12.97	34.01	51.85	97.18
22	38.99	25.55	13.65	33.85	51.66	96.73
23	40.94	26.81	14.33	33.71	51.48	96.28
24	42.90	28.06	15.03	33.56	51.31	95.83
25	44.87	29.33	15.73	33.43	51.15	95.39
26	46.85	30.59	16.43	33.30	50.99	94.95
27	48.83	31.86	17.14	33.18	50.84	94.51
28	50.82	33.14	17.86	33.06	50.70	94.07
29	52.82	34.41	18.58	32.94	50.56	93.64
30	54.82	35.69	19.31	32.83	50.43	93.21
31	56.83	36.98	20.05	32.73	50.30	92.78
32	58.85	38.26	20.79	32.63	50.18	92.36
33	60.87	39.55	21.54	32.53	50.06	91.94
34	62.90	40.85	22.29	32.43	49.94	91.52
35	64.94	42.14	23.05	32.34	49.83	91.11
36	66.98	43.44	23.82	32.25	49.72	90.70
37	69.02	44.75	24.59	32.16	49.61	90.29
38	71.08	46.05	25.37	32.08	49.51	89.88
39	73.13	47.36	26.15	32.00	49.41	89.48

Table B.6: Simulation Data for Automated Packing with Non-Overlapping Waves — *continued*.

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
40	75.20	48.67	26.94	31.92	49.31	89.08
41	77.26	49.98	27.74	31.84	49.22	88.68
42	79.34	51.29	28.54	31.76	49.13	88.29
43	81.42	52.61	29.35	31.69	49.04	87.90
44	83.50	53.93	30.17	31.62	48.95	87.51
45	85.58	55.25	30.99	31.55	48.87	87.13
46	87.68	56.58	31.82	31.48	48.78	86.75
47	89.77	57.91	32.65	31.41	48.70	86.37
48	91.87	59.23	33.49	31.35	48.62	85.99
49	93.98	60.57	34.34	31.28	48.54	85.62
50	96.09	61.90	35.19	31.22	48.47	85.25
51	98.20	63.23	36.05	31.16	48.39	84.88
52	100.32	64.57	36.91	31.10	48.32	84.52
53	102.44	65.91	37.79	31.04	48.25	84.16
54	104.56	67.25	38.66	30.99	48.18	83.80
55	106.69	68.59	39.55	30.93	48.11	83.45
56	108.83	69.94	40.44	30.87	48.04	83.10
57	110.96	71.29	41.33	30.82	47.98	82.75
58	113.10	72.63	42.23	30.77	47.91	82.40
59	115.25	73.99	43.14	30.72	47.85	82.06
60	117.40	75.34	44.05	30.67	47.78	81.72
61	119.55	76.69	44.97	30.62	47.72	81.38
62	121.70	78.05	45.90	30.57	47.66	81.05
63	123.86	79.40	46.83	30.52	47.60	80.72
64	126.02	80.76	47.77	30.47	47.55	80.39
65	128.19	82.12	48.71	30.42	47.49	80.07
66	130.36	83.49	49.66	30.38	47.43	79.75
67	132.53	84.85	50.61	30.33	47.38	79.43
68	134.70	86.22	51.57	30.29	47.32	79.11
69	136.88	87.58	52.54	30.25	47.27	78.80
70	139.06	88.95	53.51	30.20	47.22	78.49
71	141.24	90.32	54.49	30.16	47.16	78.18
72	143.43	91.69	55.47	30.12	47.11	77.88
73	145.62	93.07	56.46	30.08	47.06	77.58
74	147.81	94.44	57.45	30.04	47.01	77.28
75	150.01	95.82	58.45	30.00	46.96	76.99
76	152.21	97.20	59.46	29.96	46.92	76.70
77	154.41	98.58	60.47	29.92	46.87	76.41
78	156.61	99.96	61.48	29.88	46.82	76.12
79	158.82	101.34	62.50	29.84	46.77	75.84

Table B.6: Simulation Data for Automated Packing with Non-Overlapping Waves — *continued*.

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
80	161.03	102.72	63.53	29.81	46.73	75.56
81	163.24	104.11	64.56	29.77	46.68	75.28
82	165.46	105.49	65.59	29.74	46.64	75.01
83	167.68	106.88	66.63	29.70	46.60	74.74
84	169.90	108.27	67.68	29.66	46.55	74.47
85	172.12	109.66	68.73	29.63	46.51	74.21
86	174.35	111.05	69.78	29.60	46.47	73.95
87	176.58	112.44	70.84	29.56	46.43	73.69
88	178.81	113.83	71.90	29.53	46.38	73.43
89	181.04	115.23	72.97	29.50	46.34	73.18
90	183.28	116.62	74.04	29.46	46.30	72.93
91	185.52	118.02	75.12	29.43	46.26	72.68
92	187.76	119.42	76.20	29.40	46.22	72.44
93	190.00	120.82	77.29	29.37	46.19	72.20
94	192.25	122.22	78.37	29.34	46.15	71.96
95	194.49	123.62	79.47	29.31	46.11	71.73
96	196.74	125.02	80.56	29.28	46.07	71.50
97	199.00	126.43	81.66	29.25	46.03	71.27
98	201.25	127.83	82.77	29.22	46.00	71.04
99	203.51	129.24	83.88	29.19	45.96	70.82
100	205.77	130.65	84.99	29.16	45.93	70.60
101	208.03	132.06	86.10	29.13	45.89	70.38
102	210.29	133.46	87.22	29.10	45.85	70.17
103	212.56	134.88	88.34	29.07	45.82	69.96
104	214.83	136.29	89.46	29.05	45.79	69.75
105	217.10	137.70	90.59	29.02	45.75	69.55
106	219.37	139.11	91.71	28.99	45.72	69.35
107	221.65	140.53	92.85	28.97	45.68	69.15
108	223.92	141.94	93.98	28.94	45.65	68.95
109	226.20	143.36	95.11	28.91	45.62	68.76
110	228.48	144.78	96.25	28.89	45.59	68.57
111	230.76	146.20	97.39	28.86	45.55	68.38
112	233.05	147.62	98.53	28.84	45.52	68.20
113	235.34	149.04	99.68	28.81	45.49	68.02
114	237.63	150.46	100.82	28.78	45.46	67.84
115	239.92	151.88	101.97	28.76	45.43	67.67
116	242.21	153.31	103.12	28.74	45.40	67.50
117	244.50	154.73	104.27	28.71	45.37	67.33
118	246.80	156.16	105.42	28.69	45.34	67.16
119	249.10	157.59	106.57	28.66	45.31	67.00

Table B.6: Simulation Data for Automated Packing with Non-Overlapping Waves — *continued*.

Batch Size	Packing Times (minutes)			Packing Rates (orders/hr)		
	Low	Med.	High	Low	Med.	High
120	251.40	159.01	107.72	28.64	45.28	66.84
121	253.70	160.44	108.87	28.62	45.25	66.68
122	256.01	161.87	110.03	28.59	45.22	66.53
123	258.31	163.30	111.18	28.57	45.19	66.38
124	260.62	164.73	112.33	28.55	45.16	66.23
125	262.93	166.16	113.49	28.52	45.14	66.09
126	265.24	167.60	114.64	28.50	45.11	65.95
127	267.56	169.03	115.79	28.48	45.08	65.81
128	269.87	170.47	116.94	28.46	45.05	65.67
129	272.19	171.90	118.10	28.44	45.03	65.54
130	274.51	173.34	119.25	28.41	45.00	65.41
131	276.83	174.78	120.40	28.39	44.97	65.28
132	279.15	176.21	121.55	28.37	44.95	65.16
133	281.48	177.65	122.69	28.35	44.92	65.04
134	283.80	179.09	123.84	28.33	44.89	64.92
135	286.13	180.53	124.99	28.31	44.87	64.81
136	288.46	181.98	126.13	28.29	44.84	64.70
137	290.79	183.42	127.27	28.27	44.82	64.59
138	293.12	184.86	128.41	28.25	44.79	64.48
139	295.46	186.31	129.54	28.23	44.77	64.38
140	297.79	187.75	130.68	28.21	44.74	64.28
141	300.13	189.20	131.81	28.19	44.72	64.18
142	302.47	190.64	132.94	28.17	44.69	64.09
143	304.81	192.09	134.06	28.15	44.67	64.00
144	307.15	193.54	135.19	28.13	44.64	63.91
145	309.50	194.99	136.30	28.11	44.62	63.83
146	311.84	196.44	137.42	28.09	44.59	63.75
147	314.19	197.89	138.53	28.07	44.57	63.67
148	316.54	199.34	139.64	28.05	44.55	63.59
149	318.89	200.79	140.74	28.03	44.52	63.52
150	321.24	202.24	141.84	28.02	44.50	63.45

Table B.7: Manual Picking and Packing Rate Combinations.

Wave Length	H		L		L		L		M	
	Picking	Packing	Picking	Packing	Picking	Packing	Picking	Packing	Picking	Packing
20	63.33	63.76	63.33	35.74	31.62	71.86	31.62	38.08	42.51	50.65
20	68.69	61.98	68.69	34.47	35.36	67.14	35.36	36.36	48.20	48.35
20	70.45	59.63	70.45	33.51	38.06	63.76	35.36	36.36	49.80	46.65
20	77.82	55.37	77.82	32.46	39.83	61.98	39.83	34.47	51.34	46.46
20	90.32	49.57	90.32	30.08	43.34	57.64	43.34	34.18	59.60	42.14
20	113.12	40.42	113.12	26.50	56.22	47.61	56.22	30.45	78.21	36.04
40	97.65	53.30	97.65	32.03	48.19	59.63	48.19	33.51	66.85	44.73
40	103.95	50.73	103.95	31.08	50.41	57.64	50.41	34.18	66.51	42.73
40	111.04	47.61	111.04	30.45	53.67	55.37	53.67	32.46	70.98	41.49
40	121.89	43.99	121.89	27.85	58.24	51.71	58.24	31.73	80.87	38.87
40	138.54	38.61	138.54	25.98	68.26	44.76	68.26	28.32	95.43	35.03
40	169.05	30.49	169.05	21.94	95.95	35.56	95.95	24.65	128.47	28.38
60	126.16	46.62	126.16	29.87	62.60	53.30	62.60	32.03	86.07	39.84
60	134.76	43.99	134.76	27.85	64.40	51.71	64.40	31.73	89.40	38.87
60	144.40	41.11	144.40	27.00	72.30	47.61	72.30	30.45	98.35	36.81
60	158.14	36.98	158.14	24.89	79.95	43.99	79.95	27.85	110.54	33.46
60	178.15	32.53	178.15	23.39	96.48	37.98	96.48	25.84	130.75	30.13
60	209.81	25.61	209.81	19.68	139.86	28.80	139.86	21.00	173.58	23.70
80	155.33	41.06	155.33	26.75	75.59	48.32	75.59	29.86	105.19	36.65
80	164.69	38.47	164.69	26.46	79.92	45.94	79.92	28.98	112.47	34.78
80	177.15	36.14	177.15	24.88	89.51	42.49	89.51	27.59	122.62	33.13
80	190.21	33.01	190.21	22.90	101.98	38.61	101.98	25.98	138.31	30.04
80	212.09	28.49	212.09	21.13	126.84	33.01	126.84	22.90	164.20	26.69
80	241.11	22.61	241.11	17.44	181.23	24.55	181.23	18.75	211.35	20.97
100	181.07	37.67	181.07	26.07	91.43	44.32	91.43	28.99	125.26	34.20
100	191.01	35.56	191.01	24.65	98.81	41.73	98.81	27.10	134.80	32.44
100	202.96	33.01	202.96	22.90	108.81	38.61	108.81	25.98	147.58	30.04
100	219.12	29.72	219.12	21.51	127.61	34.53	127.61	24.26	166.91	27.41
100	239.88	25.98	239.88	19.34	158.46	29.14	158.46	21.24	196.83	24.23
100	266.85	20.47	266.85	16.35	217.74	21.73	217.74	17.33	242.19	19.08
120	205.54	34.76	205.54	24.17	106.88	41.11	106.88	27.00	147.74	31.84
120	216.00	32.75	216.00	22.84	116.31	38.05	116.31	25.90	157.20	29.99
120	229.64	30.36	229.64	22.32	131.73	35.13	131.73	24.85	173.43	27.84
120	245.08	27.57	245.08	20.25	152.76	31.37	152.76	22.86	195.03	25.76
120	265.57	23.98	265.57	18.29	189.32	26.39	189.32	20.05	118.96	22.45
120	288.94	18.96	288.94	15.49	247.57	19.81	247.57	15.89	268.23	17.63

Table B.8: Automated Picking and Packing Rate Combinations.

	WL	Picking		Packing (Overlap)		Packing (No Overlap)	
	(min)	Rate	Batch Size	Rate	Batch Size	Rate	Batch Size
HH	20	113.45	37	118.26	39	93.21	30
	40	169.48	112	118.15	78	83.45	55
	60	209.78	209	118.07	118	76.70	76
	80	241.25	321	118.03	157	71.73	95
	100	266.75	444	117.99	196	68.02	113
	120	288.87	577	117.96	235	65.41	130
HL	20	113.45	37	47.709	15	35.94	12
	40	169.48	92	47.704	31	33.85	22
	60	209.78	153	47.699	47	32.63	32
	80	241.25	218	47.694	63	31.76	42
	100	266.75	284	47.689	79	31.16	51
	120	288.87	350	47.685	95	30.62	61
LH	20	56.65	18	118.26	39	93.21	30
	40	95.38	63	118.15	78	83.45	55
	60	139.51	139	118.07	118	76.70	76
	80	181.15	241	118.03	157	71.73	95
	100	217.62	362	117.99	196	68.02	113
	120	247.53	495	117.96	235	65.41	130
LL	20	56.65	18	47.692	15	35.94	12
	40	95.38	63	47.691	31	33.85	22
	60	139.51	139	47.689	47	32.63	32
	80	181.15	241	47.688	63	31.76	42
	100	217.62	362	47.687	79	31.16	51
	120	247.53	495	47.685	95	30.62	61
MM	20	78.23	26	69.99	23	52.70	17
	40	127.67	85	69.93	46	50.06	33
	60	173.16	173	69.90	69	48.62	48
	80	211.19	281	69.87	93	47.60	63
	100	242.16	403	69.85	116	46.82	78
	120	268.06	536	69.84	139	46.22	92

Appendix C

Deterministic Spreadsheet Model

Results

The deterministic spreadsheet model calculates the total annual system cost for a set of given parameters for six wave lengths ranging from 20 minutes to 2 hours. Within each wave length, a range of picking and packing rate combinations are calculated. The lowest annual cost is determined and the system with this cost is recommended. Table C.1 presents the spreadsheet analyses for an automated system at a demand level of 1100 orders per hour. The first six rows represent the system with overlap, and the bottom six rows present the data for a system with no wave overlap. Table C.2 presents the spreadsheet analyses for a manual system at this demand level. In this analyses, an average of 3 items per order was used. Refer to Section 4.1 for all notation and units labeling each column.

The spreadsheets presented in this appendix are from the initial model discussed in Chapter 4. The picking and packing rate combinations are estimated from data gathered from several distribution centers. Appendix F presents the same model with combinations obtained from simulation data and are used in the throughput simulations. The italicized total annual costs represent the best annual solution within the wave length for the manual system, and the best solution for the overlap or no wave overlap system for the automated system. The boldface total annual cost represents the best overall solution.

Table C.1: Automated System Deterministic Model Calculations (Demand = 1100 orders/hr, Sorter Cost = \$250,000).

W	$p(n)$	$q(m)$	t	r_p	r_q	N_q	r_a	r_t	r_s	T_ℓ^a	$r_q c_q$	$r_s c_t$	C_t^s	$C_t^s * A$	T^a
20	75	75	20	15	15	25	15	3	1	990,000	150,000	50,000	450,000	150,480	1,140,480
40	90	75	20	13	15	25	30	3	1	930,000	300,000	50,000	600,000	200,640	1,130,640
60	105	75	20	11	15	25	44	3	1	870,000	440,000	50,000	740,000	247,456	1,117,456
80	120	75	20	10	15	25	59	3	1	840,000	590,000	50,000	890,000	297,616	1,137,616
100	135	75	20	9	15	25	74	3	1	810,000	740,000	50,000	1,040,000	347,776	1,157,776
120	150	75	20	8	15	25	88	3	1	780,000	880,000	50,000	1,180,000	394,592	1,174,592
20	75	75	20	15	15	25	15	3	1	990,000	150,000	50,000	450,000	150,480	1,140,480
40	90	73	20	13	16	25	30	3	1	960,000	300,000	50,000	600,000	200,640	1,160,640
60	105	71	20	11	16	25	44	3	1	900,000	440,000	50,000	740,000	247,456	1,147,456
80	120	69	20	10	16	25	59	3	1	870,000	590,000	50,000	890,000	297,616	1,167,616
100	135	67	20	9	17	25	74	3	1	870,000	740,000	50,000	1,040,000	347,776	1,217,776
120	150	65	20	8	17	25	88	3	1	840,000	880,000	50,000	1,180,000	394,592	1,234,592

Table C.2: Manual System Deterministic Model Calculations.

D	W	N_o	$p(n)$	$q(m)$	r_p	r_q	N_q	n_q	r_a	$r_a c_q$	T_ℓ^m	T^m
1100	20	3	50	45.1	22	25	25	15	25	5,852	1,410,000	1,415,852
1100	20	3	70	39.9	16	28	25	15	28	6,554	1,320,000	1,326,554
1100	20	3	90	35.5	13	31	25	15	31	7,256	1,320,000	1,327,256
1100	20	3	110	31.5	10	35	25	15	35	8,193	1,350,000	1,358,193
1100	20	3	130	28.0	9	40	25	15	40	9,363	1,470,000	1,479,363
1100	20	3	150	25.0	8	44	25	15	44	10,300	1,560,000	1,570,300
1100	40	3	60	45.0	19	25	25	30	30	7,022	1,320,000	1,327,022
1100	40	3	80	39.9	14	28	25	30	30	7,022	1,260,000	1,267,022
1100	40	3	100	35.5	11	31	25	30	31	7,256	1,260,000	1,267,256
1100	40	3	120	31.5	10	35	25	30	35	8,193	1,350,000	1,358,193
1100	40	3	140	28.0	8	40	25	30	40	9,363	1,440,000	1,449,363
1100	40	3	160	25.0	7	44	25	30	44	10,300	1,530,000	1,540,300
1100	60	3	70	45.0	16	25	25	44	44	10,300	1,230,000	1,240,300
1100	60	3	90	39.9	13	28	25	44	44	10,300	1,230,000	1,240,300
1100	60	3	110	35.5	10	31	25	44	44	10,300	1,230,000	1,240,300
1100	60	3	130	31.5	9	35	25	44	44	10,300	1,320,000	1,330,300
1100	60	3	150	28.0	8	40	25	44	44	10,300	1,440,000	1,450,300
1100	60	3	170	25.0	7	44	25	44	44	10,300	1,530,000	1,540,300
1100	80	3	80	45.0	14	25	25	59	59	13,811	1,170,000	1,183,811
1100	80	3	100	39.9	11	28	25	59	59	13,811	1,170,000	1,183,811
1100	80	3	120	35.5	10	31	25	59	59	13,811	1,230,000	1,243,811
1100	80	3	140	31.5	8	35	25	59	59	13,811	1,290,000	1,303,811
1100	80	3	160	28.0	7	40	25	59	59	13,811	1,410,000	1,423,811
1100	80	3	180	25.0	7	44	25	59	59	13,811	1,530,000	1,543,811
1100	100	3	90	45.0	13	25	25	74	74	17,322	1,140,000	1,157,322
1100	100	3	110	39.9	10	28	25	74	74	17,322	1,140,000	1,157,322
1100	100	3	130	35.5	9	31	25	74	74	17,322	1,200,000	1,217,322
1100	100	3	150	31.5	8	35	25	74	74	17,322	1,290,000	1,307,322
1100	100	3	170	28.0	7	40	25	74	74	17,322	1,410,000	1,427,322
1100	100	3	190	25.0	6	44	25	74	74	17,322	1,500,000	1,517,322
1100	120	3	100	45.0	11	25	25	88	88	20,599	1,080,000	1,100,599
1100	120	3	120	39.9	10	28	25	88	88	20,599	1,140,000	1,160,599
1100	120	3	140	35.5	8	31	25	88	88	20,599	1,170,000	1,190,599
1100	120	3	160	31.5	7	35	25	88	88	20,599	1,260,000	1,280,599
1100	120	3	180	28.0	7	40	25	88	88	20,599	1,410,000	1,430,599
1100	120	3	200	25.0	6	44	25	88	88	20,599	1,500,000	1,520,599

Appendix D

Sensitivity Analysis Data and Results

Sensitivity analysis results are presented in this appendix. For each demand level (550, 1100, 2200, and 3300 orders per hour), we present the resulting best manual and automated solution when other parameters are varied, as well as the corresponding wave length (WL) and difference between the two systems, manual (M) and automated (A). A value in parenthesis represents a negative number. In that case, the manual system is less expensive than the automated system, and thus, the difference is negative.

Table D.1: Sensitivity Analysis for Demand = 550 orders/hour.

Demand Level (orders/hr)	Labor Cost (\$)	PS Cost (Auto) (\$)	Induction Rate (items/min)	Manual Best (\$)	WL Manual (min)	Automated Best (\$)	WL Auto (min)	Difference (M-A) (\$)
250000	18000	2,500	20	350,661	100	389,104	120	(38,443)
250000	18000	2,500	60	350,661	100	371,104	120	(20,443)
250000	18000	10,000	20	350,661	100	451,072	20	(100,411)
250000	18000	10,000	60	350,661	100	433,072	20	(82,411)
250000	18000	20,000	20	350,661	100	477,824	20	(127,163)
250000	18000	20,000	60	350,661	100	459,824	20	(109,163)
250000	30000	2,500	20	578,661	100	557,104	120	21,557
250000	30000	2,500	60	578,661	100	527,104	120	51,557
250000	30000	10,000	20	578,661	100	650,640	80	(71,979)
250000	30000	10,000	60	578,661	100	620,640	80	(41,979)
250000	30000	20,000	20	578,661	100	693,824	20	(115,163)
250000	30000	20,000	60	578,661	100	663,824	20	(85,163)
500000	18000	2,500	20	350,661	100	472,704	120	(122,043)
500000	18000	2,500	60	350,661	100	454,704	120	(104,043)
500000	18000	10,000	20	350,661	100	534,672	20	(184,011)
500000	18000	10,000	60	350,661	100	516,672	20	(166,011)
500000	18000	20,000	20	350,661	100	561,424	20	(210,763)
500000	18000	20,000	60	350,661	100	543,424	20	(192,763)
500000	30000	2,500	20	578,661	100	640,704	120	(62,043)
500000	30000	2,500	60	578,661	100	610,704	120	(32,043)
500000	30000	10,000	20	578,661	100	734,240	80	(155,579)
500000	30000	10,000	60	578,661	100	704,240	80	(125,579)
500000	30000	20,000	20	578,661	100	777,424	20	(198,763)
500000	30000	20,000	60	578,661	100	747,424	20	(168,763)
1000000	18000	2,500	20	350,661	100	639,904	120	(289,243)
1000000	18000	2,500	60	350,661	100	621,904	120	(271,243)
1000000	18000	10,000	20	350,661	100	701,872	20	(351,211)
1000000	18000	10,000	60	350,661	100	683,872	20	(333,211)
1000000	18000	20,000	20	350,661	100	728,624	20	(377,963)
1000000	18000	20,000	60	350,661	100	710,624	20	(359,963)
1000000	30000	2,500	20	578,661	100	807,904	120	(229,243)
1000000	30000	2,500	60	578,661	100	777,904	120	(199,243)
1000000	30000	10,000	20	578,661	100	901,440	60	(322,779)
1000000	30000	10,000	60	578,661	100	871,440	60	(292,779)
1000000	30000	20,000	20	578,661	100	994,624	20	(415,963)
1000000	30000	20,000	60	578,661	100	914,624	20	(335,963)

Table D.2: Sensitivity Analysis for Demand = 1100 orders/hour.

Demand Level (orders/hr)	Labor Cost (\$)	PS Cost (Auto) (\$)	Induction Rate (items/min)	Manual Best (\$)	WL Manual (min)	Automated Best (\$)	WL Auto (min)	Difference (M-A) (\$)
250000	18000	2,500	20	668,599	120	641,888	120	26,711
250000	18000	2,500	60	668,599	120	605,888	120	62,711
250000	18000	10,000	20	668,599	120	744,480	20	(75,881)
250000	18000	10,000	60	668,599	120	708,480	20	(39,881)
250000	18000	20,000	20	668,599	120	794,640	20	(126,041)
250000	18000	20,000	60	668,599	120	758,640	20	(90,041)
250000	30000	2,500	20	1,100,599	120	953,888	120	146,711
250000	30000	2,500	60	1,100,599	120	893,888	120	206,711
250000	30000	10,000	20	1,100,599	120	1,117,456	60	(16,857)
250000	30000	10,000	60	1,100,599	120	1,057,456	60	43,143
250000	30000	20,000	20	1,100,599	120	1,190,640	20	(90,041)
250000	30000	20,000	60	1,100,599	120	1,130,640	20	(30,041)
500000	18000	2,500	20	668,599	120	725,488	120	(56,889)
500000	18000	2,500	60	668,599	120	689,488	120	(20,889)
500000	18000	10,000	20	668,599	120	828,080	20	(159,481)
500000	18000	10,000	60	668,599	120	792,080	20	(123,481)
500000	18000	20,000	20	668,599	120	878,240	20	(209,641)
500000	18000	20,000	60	668,599	120	842,240	20	(173,641)
500000	30000	2,500	20	1,100,599	120	1,037,488	120	63,111
500000	30000	2,500	60	1,100,599	120	977,488	120	123,111
500000	30000	10,000	20	1,100,599	120	1,201,056	60	(100,457)
500000	30000	10,000	60	1,100,599	120	1,141,056	60	(40,457)
500000	30000	20,000	20	1,100,599	120	1,274,240	20	(173,641)
500000	30000	20,000	60	1,100,599	120	1,214,240	20	(113,641)
1000000	18000	2,500	20	668,599	120	892,668	120	(224,069)
1000000	18000	2,500	60	668,599	120	856,688	120	(188,089)
1000000	18000	10,000	20	668,599	120	995,280	20	(326,681)
1000000	18000	10,000	60	668,599	120	959,280	20	(290,681)
1000000	18000	20,000	20	668,599	120	1,045,440	20	(376,841)
1000000	18000	20,000	60	668,599	120	1,009,440	20	(340,841)
1000000	30000	2,500	20	1,100,599	120	1,204,668	120	(104,069)
1000000	30000	2,500	60	1,100,599	120	1,144,688	120	(44,089)
1000000	30000	10,000	20	1,100,599	120	1,368,256	60	(267,657)
1000000	30000	10,000	60	1,100,599	120	1,308,256	60	(207,657)
1000000	30000	20,000	20	1,100,599	120	1,441,440	20	(340,841)
1000000	30000	20,000	60	1,100,599	120	1,381,440	20	(280,841)

Table D.3: Sensitivity Analysis for Demand = 2200 orders/hour.

Demand Level (orders/hr)	Labor Cost (\$)	PS Cost (Auto) (\$)	Induction Rate (items/min)	Manual Best (\$)	WL Manual (min)	Automated Best (\$)	WL Auto (min)	Difference (M-A) (\$)
250000	18000	2,500	20	1,319,198	120	1,254,176	120	65,022
250000	18000	2,500	60	1,319,198	120	1,146,176	120	173,022
250000	18000	10,000	20	1,319,198	120	1,477,360	20	(158,162)
250000	18000	10,000	60	1,319,198	120	1,369,360	20	(50,162)
250000	18000	20,000	20	1,319,198	120	1,577,680	20	(258,482)
250000	18000	20,000	60	1,319,198	120	1,469,680	20	(150,482)
250000	30000	2,500	20	2,171,198	120	1,914,176	120	257,022
250000	30000	2,500	60	2,171,198	120	1,734,176	120	437,022
250000	30000	10,000	20	2,171,198	120	2,241,312	60	(70,114)
250000	30000	10,000	60	2,171,198	120	2,061,312	60	109,886
250000	30000	20,000	20	2,171,198	120	2,417,680	20	(246,482)
250000	30000	20,000	60	2,171,198	120	2,237,680	20	(66,482)
500000	18000	2,500	20	1,319,198	120	1,337,776	120	(18,578)
500000	18000	2,500	60	1,319,198	120	1,229,776	120	89,422
500000	18000	10,000	20	1,319,198	120	1,560,960	20	(241,762)
500000	18000	10,000	60	1,319,198	120	1,452,960	20	(133,762)
500000	18000	20,000	20	1,319,198	120	1,661,280	20	(342,082)
500000	18000	20,000	60	1,319,198	120	1,553,280	20	(234,082)
500000	30000	2,500	20	2,171,198	120	1,997,776	120	173,422
500000	30000	2,500	60	2,171,198	120	1,817,776	120	353,422
500000	30000	10,000	20	2,171,198	120	2,324,912	60	(153,714)
500000	30000	10,000	60	2,171,198	120	2,144,912	60	26,286
500000	30000	20,000	20	2,171,198	120	2,501,280	20	(330,082)
500000	30000	20,000	60	2,171,198	120	2,321,280	20	(150,082)
1000000	18000	2,500	20	1,319,198	120	1,504,976	120	(185,778)
1000000	18000	2,500	60	1,319,198	120	1,396,976	20	(77,778)
1000000	18000	10,000	20	1,319,198	120	1,728,160	20	(408,962)
1000000	18000	10,000	60	1,319,198	120	1,620,160	20	(300,962)
1000000	18000	20,000	20	1,319,198	120	1,828,480	20	(509,282)
1000000	18000	20,000	60	1,319,198	120	1,720,480	20	(401,282)
1000000	30000	2,500	20	2,171,198	120	2,164,976	120	6,222
1000000	30000	2,500	60	2,171,198	120	1,984,976	120	186,222
1000000	30000	10,000	20	2,171,198	120	2,492,112	60	(320,914)
1000000	30000	10,000	60	2,171,198	120	2,312,112	60	(140,914)
1000000	30000	20,000	20	2,171,198	120	2,668,480	20	(497,282)
1000000	30000	20,000	60	2,171,198	120	2,488,480	20	(317,282)

Table D.4: Sensitivity Analysis for Demand = 3300 orders/hour.

Demand Level (orders/hr)	Labor Cost (\$)	PS Cost (Auto) (\$)	Induction Rate (items/min)	Manual Best (\$)	WL Manual (min)	Automated Best (\$)	WL Auto (min)	Difference (M-A) (\$)
250000	18000	2,500	20	1,987,797	120	2,025,904	120	(38,107)
250000	18000	2,500	60	1,987,797	120	1,755,904	120	231,893
250000	18000	10,000	20	1,987,797	120	2,348,336	20	(360,539)
250000	18000	10,000	60	1,987,797	120	2,078,336	20	(90,539)
250000	18000	20,000	20	1,987,797	120	2,495,472	20	(507,675)
250000	18000	20,000	60	1,987,797	120	2,225,472	20	(237,675)
250000	30000	2,500	20	3,271,797	120	3,117,904	120	153,893
250000	30000	2,500	60	3,271,797	120	2,667,904	120	603,893
250000	30000	10,000	20	3,271,797	120	3,638,608	60	(366,811)
250000	30000	10,000	60	3,271,797	120	3,188,608	60	83,189
250000	30000	20,000	20	3,271,797	120	3,851,472	20	(579,675)
250000	30000	20,000	60	3,271,797	120	3,401,472	20	(129,675)
500000	18000	2,500	20	1,987,797	120	2,109,504	120	(121,707)
500000	18000	2,500	60	1,987,797	120	1,839,504	120	148,293
500000	18000	10,000	20	1,987,797	120	2,431,936	20	(444,139)
500000	18000	10,000	60	1,987,797	120	2,309,072	20	(321,275)
500000	18000	20,000	20	1,987,797	120	2,579,072	20	(591,275)
500000	18000	20,000	60	1,987,797	120	2,309,072	20	(321,275)
500000	30000	2,500	20	3,271,797	120	3,201,504	120	70,293
500000	30000	2,500	60	3,271,797	120	2,751,504	120	520,293
500000	30000	10,000	20	3,271,797	120	3,722,208	60	(450,411)
500000	30000	10,000	60	3,271,797	120	3,272,208	60	(411)
500000	30000	20,000	20	3,271,797	120	3,935,072	20	(663,275)
500000	30000	20,000	60	3,271,797	120	3,485,072	20	(213,275)
1000000	18000	2,500	20	1,987,797	120	2,276,704	120	(288,907)
1000000	18000	2,500	60	1,987,797	120	2,006,704	120	(18,907)
1000000	18000	10,000	20	1,987,797	120	2,599,136	20	(611,339)
1000000	18000	10,000	60	1,987,797	120	2,329,136	20	(341,339)
1000000	18000	20,000	20	1,987,797	120	2,746,272	20	(758,475)
1000000	18000	20,000	60	1,987,797	120	2,476,272	20	(488,475)
1000000	30000	2,500	20	3,271,797	120	3,368,704	120	(96,907)
1000000	30000	2,500	60	3,271,797	120	2,918,704	120	353,093
1000000	30000	10,000	20	3,271,797	120	3,889,408	60	(617,611)
1000000	30000	10,000	60	3,271,797	120	3,439,408	60	(167,611)
1000000	30000	20,000	20	3,271,797	120	4,102,272	20	(830,475)
1000000	30000	20,000	60	3,271,797	120	3,652,272	20	(380,475)

Appendix E

Proof of Result 1.

Result 1 *The expression, (5.9), yields the optimal value for p_1^* when p_1 and p_2 are constrained to be greater than zero.*

Proof:

Taking the derivative of (5.6) and setting it equal to zero yields a quadratic equation in terms of p_1 . The two roots are expressed as:

$$p_1 = \frac{-2bm \pm \sqrt{4b^2m^2 - 4b^2m(m+1)}}{2m(m+1)}. \quad (\text{E.1})$$

We now refer to the first root as the positive root, and the second root as the negative root. Since p_1 must be positive, we know that:

$$\frac{-2bm \pm \sqrt{4b^2m^2 - 4b^2m(m+1)}}{2m(m+1)} > 0. \quad (\text{E.2})$$

Also, since $p_2 = b + mp_1 > 0$, we know that:

$$\frac{-2bm \pm \sqrt{4b^2m^2 - 4b^2m(m+1)}}{2m(m+1)} < \frac{-b}{m}. \quad (\text{E.3})$$

Consider the inequality given by (E.2). Simplification leads to the following expression:

$$\begin{aligned} \frac{-2bm \pm \sqrt{-4b^2m}}{2m(m+1)} &> 0; \\ \frac{-bm \pm b\sqrt{-m}}{m(m+1)} &> 0. \end{aligned} \tag{E.4}$$

The correct root is dependent on the sign of the denominator, $m(m+1)$.

Case 1: $-1 < m < 0$. This results in $m(m+1) < 0$. In order to satisfy (E.4), we need to determine the root that results in a negative numerator as well.

$$\begin{aligned} -bm \pm b\sqrt{-m} &< 0; \\ \pm b\sqrt{-m} &< bm; \\ \pm\sqrt{-m} &< m. \end{aligned}$$

Since $-1 < m < 0$, $-\sqrt{-m} < m$. Therefore, the second root is feasible for p_1 and the first root is not. Using the second root, we now show that $p_2 > 0$ by substituting (E.4) into $p_2 = b + mp_1$:

$$b + m \left(\frac{-bm - b\sqrt{-m}}{m(m+1)} \right) > 0.$$

This reduces to the following:

$$\frac{bm + b - bm - b\sqrt{-m}}{m+1} > 0.$$

The simplified inequality is

$$\frac{b - b\sqrt{-m}}{m+1} > 0.$$

Since $-1 < m < 0$, we know that $m+1 > 0$, and therefore $b - b\sqrt{-m}$ must be positive in order to satisfy the inequality. Since $b > 0$, $b > b\sqrt{-m}$, therefore the numerator is also positive, ensuring the second root is valid for p_2 as well.

Case 2: $m = -1$. This results in a denominator of 0. Therefore, we must prove Result 1

using the original equation for p_1 by substituting $m = -1$ into (5.6):

$$z' = \frac{-D}{p_1^2} + \frac{-Dm}{(mp_1 + b)^2} = 0;$$

$$\frac{-Dm}{(mp_1 + b)^2} = \frac{D}{p_1^2}.$$

Substituting $m = -1$ results in the following:

$$\frac{D}{(-p_1 + b)^2} = \frac{D}{p_1^2},$$

which is solved by:

$$p_1 = \frac{b}{2}.$$

This equation for p_1 is only valid for $m = -1$. Note that $p_2 = -\frac{b}{2} + b = \frac{b}{2}$, which is obviously greater than zero.

Case 3: $m < -1$. In this case, $m(m + 1) > 0$. Therefore, $-bm \pm b\sqrt{-m}$ must be greater than zero in order to ensure $p_1 > 0$. The correct root is determined by the following:

$$\pm b\sqrt{-m} > bm;$$

$$\pm\sqrt{-m} > m.$$

Since $m < -1$, both roots lead to the required result. Therefore, we must determine which root results in a positive value for p_2 , where $p_2 = b + mp_1$:

$$m \left(\frac{-2bm \pm \sqrt{-4b^2m}}{2m(m+1)} \right) + b > 0;$$

$$\frac{-bm \pm b\sqrt{-m}}{m+1} + \frac{bm+b}{m+1} > 0.$$

This reduces to the following:

$$\frac{b \pm b\sqrt{-m}}{m+1} > 0.$$

Since $m < -1$, $m + 1 < 0$, and therefore $b \pm b\sqrt{-m}$ must be negative. Since $b > 0$,

and $b\sqrt{-m} > 0$, the following inequality must hold:

$$\pm b\sqrt{-m} < -b$$

This inequality can only be satisfied by the second root for p_1 .

From Cases 1 and 3, we see that the second root for p_1 is the only valid root. Thus, p_1^* is equal to the second root when $m \neq 1$. Case 2 completes the proof by showing $p_1^* = \frac{b}{2}$ when $m = -1$. ■

Appendix F

Throughput Simulation Results

In this appendix we present the results from several throughput simulation models, as well as the spreadsheet models containing data for the efficiency curves developed using the simulation and time study data. The spreadsheet models represent different levels and combinations of picking and packing rates. Again, in Tables F.1 through F.10, the italicized total annual cost represents the best cost in the wavelength (or overlap/no overlap automated system) and the boldface total annual cost is the best overall cost in the manual or automated system. Fifteen scenarios were developed to test the system design recommended by the prescriptive model in order to see if the desired throughput could be met. Each level of picking and packing rate combinations were tested, as shown in the spreadsheet model calculations presented in Tables F.1 through F.10. Again, for the automated system results, the top six rows represent a system with wave overlap, and the bottom six rows represent a system with no wave overlap.

The models presented are for various levels of demand and sorter costs, as described in the table caption. Each of the fifteen scenarios run have a different set of input parameters, therefore we did not present every combination of this data. The main purpose of this presentation is to show the picking and packing rates from the efficiency curves developed from the data in Appendix B that are used in the model. Resulting picking, packing, and induction times were recorded for 100 replications. Picking and packing data are provided in

Tables F.11 through F.14. In order to see the effects of rounding the batch size, additional simulations were run. The results from these simulation runs are presented in Tables F.15 through F.18. Induction data are recorded in Tables F.19 through F.24.

Table F.1: Automated System Prescriptive Model Calculations (High Picking and High Packing Levels, Demand = 550 orders/hr, Sorter Cost = \$250,000).

W	$p(n)$	$q(m)$	t	r_p	r_q	N_q	r_a	r_t	r_s	T_f^a	$r_q c_q$	$r_s c_t$	C_t^s	$C_t^s * A$	T^a
20	113.45	118.26	120	5	5	25	8	1	1	330,000	20,000	50,000	320,000	84,415	414,415
40	169.48	118.15	120	4	5	25	15	1	1	300,000	37,500	50,000	337,500	89,032	389,032
60	209.78	118.07	120	3	5	25	22	1	1	270,000	55,000	50,000	355,000	93,648	363,648
80	241.25	118.03	120	3	5	25	30	1	1	270,000	75,000	50,000	375,000	98,924	368,924
100	266.75	117.99	120	3	5	25	37	1	1	270,000	92,500	50,000	392,500	103,541	373,541
120	288.87	117.96	120	2	5	25	44	1	1	240,000	110,000	50,000	410,000	108,157	348,157
20	113.45	93.21	120	5	6	25	8	1	1	360,000	20,000	50,000	320,000	84,415	<i>444,415</i>
40	169.48	83.45	120	4	7	25	15	1	1	360,000	37,500	50,000	337,500	89,032	449,032
60	209.78	76.70	120	3	8	25	22	1	1	360,000	55,000	50,000	355,000	93,648	453,648
80	241.25	71.73	120	3	8	25	30	1	1	360,000	75,000	50,000	375,000	98,924	458,924
100	266.75	68.02	120	3	9	25	37	1	1	390,000	92,500	50,000	392,500	103,541	493,541
120	288.87	65.41	120	2	9	25	44	1	1	360,000	110,000	50,000	410,000	108,157	468,157

Table F.2: Manual System Prescriptive Model Calculations (High Picking and High Packing Levels).

D	W	N_o	$p(n)$	$q(m)$	r_p	r_q	N_q	n_q	r_a	$r_a c_q$	T_f^m	T^m
550	20	3	61.65	67.14	9	9	25	8	9	2,107	540,000	<i>542,107</i>
550	20	3	63.33	63.76	9	9	25	8	9	2,107	540,000	<i>542,107</i>
550	20	3	68.69	61.98	9	9	25	8	9	2,107	540,000	<i>542,107</i>
550	20	3	76.25	56.64	8	10	25	8	10	2,341	540,000	<i>542,341</i>
550	20	3	89.36	50.73	7	11	25	8	11	2,575	540,000	<i>542,575</i>
550	20	3	113.45	40.60	5	14	25	8	14	3,277	570,000	<i>573,277</i>
550	40	3	94.54	54.55	6	11	25	15	15	3,511	510,000	513,511
550	40	3	100.63	51.71	6	11	25	15	15	3,511	510,000	513,511
550	40	3	109.09	47.52	6	12	25	15	15	3,511	540,000	<i>543,511</i>
550	40	3	120.70	44.32	5	13	25	15	15	3,511	540,000	<i>543,511</i>
550	40	3	137.80	38.47	4	15	25	15	15	3,511	570,000	<i>573,511</i>
550	40	3	169.48	30.60	4	18	25	15	18	4,213	660,000	<i>664,213</i>
550	60	3	123.39	46.71	5	12	25	22	22	5,150	510,000	<i>515,150</i>
550	60	3	133.45	44.32	5	13	25	22	22	5,150	540,000	<i>545,150</i>
550	60	3	143.69	41.06	4	14	25	22	22	5,150	540,000	<i>545,150</i>
550	60	3	158.04	37.42	4	15	25	22	22	5,150	570,000	<i>575,150</i>
550	60	3	177.71	32.41	4	17	25	22	22	5,150	630,000	<i>635,150</i>
550	60	3	209.78	25.55	3	22	25	22	22	5,150	750,000	<i>755,150</i>
550	80	3	154.61	41.19	4	14	25	30	30	7,022	540,000	<i>547,022</i>
550	80	3	165.34	38.96	4	15	25	30	30	7,022	570,000	<i>577,022</i>
550	80	3	175.99	36.29	4	16	25	30	30	7,022	600,000	<i>607,022</i>
550	80	3	190.16	33.00	3	17	25	30	30	7,022	600,000	<i>607,022</i>
550	80	3	212.05	28.60	3	20	25	30	30	7,022	690,000	<i>697,022</i>
550	80	3	241.25	22.62	3	25	25	30	30	7,022	840,000	<i>847,022</i>
550	100	3	180.80	37.79	4	15	25	37	37	8,661	570,000	<i>578,661</i>
550	100	3	190.18	35.49	3	16	25	37	37	8,661	570,000	<i>578,661</i>
550	100	3	202.90	33.00	3	17	25	37	37	8,661	600,000	<i>608,661</i>
550	100	3	218.98	29.87	3	19	25	37	37	8,661	660,000	<i>668,661</i>
550	100	3	240.07	25.91	3	22	25	37	37	8,661	750,000	<i>758,661</i>
550	100	3	266.75	20.56	3	27	25	37	37	8,661	900,000	<i>908,661</i>
550	120	3	204.89	34.98	3	16	25	44	44	10,300	570,000	<i>580,300</i>
550	120	3	215.91	32.76	3	17	25	44	44	10,300	600,000	<i>610,300</i>
550	120	3	228.78	30.29	3	19	25	44	44	10,300	660,000	<i>670,300</i>
550	120	3	245.16	27.53	3	20	25	44	44	10,300	690,000	<i>700,300</i>
550	120	3	265.40	23.88	3	24	25	44	44	10,300	810,000	<i>820,300</i>
550	120	3	288.87	18.91	2	30	25	44	44	10,300	960,000	<i>970,300</i>

Table F.3: Automated System Prescriptive Model Calculations (High Picking and Low Packing Levels, Demand = 550 orders/hr, Sorter Cost = \$1,000,000).

W	$p(n)$	$q(m)$	t	r_p	r_q	N_q	r_a	r_t	r_s	T_f^a	$r_q c_q$	$r_s c_t$	C_t^s	$C_t^s * A$	T^a
20	113.45	118.26	120	5	5	25	8	1	1	330,000	20,000	50,000	320,000	84,415	414,415
40	169.48	118.15	120	4	5	25	15	1	1	300,000	37,500	50,000	337,500	89,032	389,032
60	209.78	118.07	120	3	5	25	22	1	1	270,000	55,000	50,000	355,000	93,648	363,648
80	241.25	118.03	120	3	5	25	30	1	1	270,000	75,000	50,000	375,000	98,924	368,924
100	266.75	117.99	120	3	5	25	37	1	1	270,000	92,500	50,000	392,500	103,541	373,541
120	288.87	117.96	120	2	5	25	44	1	1	240,000	110,000	50,000	410,000	108,157	348,157
20	113.45	93.21	120	5	6	25	8	1	1	360,000	20,000	50,000	320,000	84,415	<i>444,415</i>
40	169.48	83.45	120	4	7	25	15	1	1	360,000	37,500	50,000	337,500	89,032	449,032
60	209.78	76.70	120	3	8	25	22	1	1	360,000	55,000	50,000	355,000	93,648	453,648
80	241.25	71.73	120	3	8	25	30	1	1	360,000	75,000	50,000	375,000	98,924	458,924
100	266.75	68.02	120	3	9	25	37	1	1	390,000	92,500	50,000	392,500	103,541	493,541
120	288.87	65.41	120	2	9	25	44	1	1	360,000	110,000	50,000	410,000	108,157	468,157

Table F.4: Manual System Prescriptive Model Calculations (High Picking and Low Packing Levels).

D	W	N_o	$p(n)$	$q(m)$	r_p	r_q	N_q	n_q	r_a	$r_a c_q$	T_f^m	T^m
1100	20	3	61.65	36.36	18	31	25	15	31	5,724	1,470,000	1,475,724
1100	20	3	63.33	35.74	18	31	25	15	31	5,724	1,470,000	1,475,724
1100	20	3	68.69	34.47	17	32	25	15	32	5,909	1,470,000	1,475,909
1100	20	3	76.25	34.01	15	33	25	15	33	6,094	1,440,000	<i>1,446,094</i>
1100	20	3	89.36	31.08	13	36	25	15	36	6,648	1,470,000	1,476,648
1100	20	3	113.45	26.57	10	42	25	15	42	7,756	1,560,000	1,567,756
1100	40	3	94.54	32.74	12	34	25	30	34	6,278	1,380,000	1,386,278
1100	40	3	100.63	31.73	11	35	25	30	35	6,463	1,380,000	1,386,463
1100	40	3	109.09	29.24	11	38	25	30	38	7,017	1,470,000	1,477,017
1100	40	3	120.70	28.99	10	38	25	30	38	7,017	1,440,000	1,447,017
1100	40	3	137.80	26.46	8	42	25	30	42	7,756	1,500,000	1,507,756
1100	40	3	169.48	22.00	7	50	25	30	50	9,233	1,710,000	1,719,233
1100	60	3	123.39	29.66	9	38	25	44	44	8,125	1,410,000	<i>1,418,125</i>
1100	60	3	133.45	28.99	9	38	25	44	44	8,125	1,410,000	<i>1,418,125</i>
1100	60	3	143.69	26.75	8	42	25	44	44	8,125	1,500,000	1,508,125
1100	60	3	158.04	25.78	7	43	25	44	44	8,125	1,500,000	1,508,125
1100	60	3	177.71	23.47	7	47	25	44	47	8,679	1,620,000	1,628,679
1100	60	3	209.78	19.40	6	57	25	44	57	10,526	1,890,000	1,900,526
1100	80	3	154.61	27.47	8	41	25	59	59	10,895	1,470,000	<i>1,480,895</i>
1100	80	3	165.34	26.20	7	42	25	59	59	10,895	1,470,000	<i>1,480,895</i>
1100	80	3	175.99	25.01	7	44	25	59	59	10,895	1,530,000	1,540,895
1100	80	3	190.16	23.70	6	47	25	59	59	10,895	1,590,000	1,600,895
1100	80	3	212.05	20.98	6	53	25	59	59	10,895	1,770,000	1,780,895
1100	80	3	241.25	17.86	5	62	25	59	62	11,449	2,010,000	2,021,449
1100	100	3	180.80	25.53	7	44	25	74	74	13,665	1,530,000	<i>1,543,665</i>
1100	100	3	190.18	24.93	6	45	25	74	74	13,665	1,530,000	<i>1,543,665</i>
1100	100	3	202.90	23.70	6	47	25	74	74	13,665	1,590,000	1,603,665
1100	100	3	218.98	21.41	6	52	25	74	74	13,665	1,740,000	1,753,665
1100	100	3	240.07	19.59	5	57	25	74	74	13,665	1,860,000	1,873,665
1100	100	3	266.75	16.19	5	68	25	74	74	13,665	2,190,000	2,203,665
1100	120	3	204.89	24.09	6	46	25	88	88	16,250	1,560,000	<i>1,576,250</i>
1100	120	3	215.91	23.57	6	47	25	88	88	16,250	1,590,000	1,606,250
1100	120	3	228.78	22.26	5	50	25	88	88	16,250	1,650,000	1,666,250
1100	120	3	245.16	20.42	5	54	25	88	88	16,250	1,770,000	1,786,250
1100	120	3	265.40	18.58	5	60	25	88	88	16,250	1,950,000	1,966,250
1100	120	3	288.87	15.52	4	71	25	88	88	16,250	2,250,000	2,266,250

Table F.5: Automated System Prescriptive Model Calculations (Medium Picking and Medium Packing Levels, Demand = 2200 orders/hr, Sorter Cost = \$250,000).

W	$p(n)$	$q(m)$	t	r_p	r_q	N_q	r_a	r_t	r_s	T_ℓ^a	$r_q c_q$	$r_s c_t$	C_t^s	$C_t^s * A$	T^a
20	78.23	69.99	20	29	32	25	30	8	4	2,070,000	600,000	200,000	1,050,000	351,099	2,421,099
40	127.67	69.93	20	18	32	25	59	8	4	1,740,000	1,180,000	200,000	1,630,000	545,039	2,285,039
60	173.16	69.90	20	13	32	25	88	8	4	1,590,000	1,760,000	200,000	2,210,000	738,979	2,328,979
80	211.19	69.87	20	11	32	25	118	8	4	1,530,000	2,360,000	200,000	2,810,000	939,607	2,469,607
100	242.16	69.85	20	10	32	25	147	8	4	1,500,000	2,940,000	200,000	3,390,000	1,133,547	2,633,547
120	268.06	69.84	20	9	32	25	176	8	4	1,470,000	3,520,000	200,000	3,970,000	1,327,487	2,797,487
20	78.23	52.70	20	29	42	25	30	8	4	2,370,000	600,000	200,000	1,050,000	351,099	2,721,099
40	127.67	50.06	20	18	44	25	59	8	4	2,100,000	1,180,000	200,000	1,630,000	545,039	2,645,039
60	173.16	48.62	20	13	46	25	88	8	4	2,010,000	1,760,000	200,000	2,210,000	738,979	2,748,979
80	211.19	47.60	20	11	47	25	118	8	4	1,980,000	2,360,000	200,000	2,810,000	939,607	2,919,607
100	242.16	46.82	20	10	47	25	147	8	4	1,950,000	2,940,000	200,000	3,390,000	1,133,547	3,083,547
120	268.06	46.22	20	9	48	25	176	8	4	1,950,000	3,520,000	200,000	3,970,000	1,327,487	3,277,487

Table F.6: Manual System Prescriptive Model Calculations (Medium Picking and Medium Packing Levels).

D	W	N_o	$p(n)$	$q(m)$	r_p	r_q	N_q	n_q	r_a	$r_a c_q$	T_ℓ^m	T^m
2200	20	3	40.47	52.67	55	42	25	30	42	9,831	2,910,000	2,919,831
2200	20	3	40.47	52.67	55	42	25	30	42	9,831	2,910,000	2,919,831
2200	20	3	48.20	48.35	46	46	25	30	46	10,768	2,760,000	2,770,768
2200	20	3	49.80	46.65	45	48	25	30	48	11,236	2,790,000	2,801,236
2200	20	3	57.17	42.73	39	52	25	30	52	12,172	2,730,000	2,742,172
2200	20	3	78.23	36.44	29	61	25	30	61	14,279	2,700,000	2,714,279
2200	40	3	64.88	45.59	34	49	25	59	59	13,811	2,490,000	2,503,811
2200	40	3	66.85	44.73	33	50	25	59	59	13,811	2,490,000	2,503,811
2200	40	3	71.02	42.18	31	53	25	59	59	13,811	2,520,000	2,533,811
2200	40	3	79.88	39.36	28	56	25	59	59	13,811	2,520,000	2,533,811
2200	40	3	94.55	35.05	24	63	25	59	63	14,747	2,610,000	2,624,747
2200	40	3	127.67	28.20	18	79	25	59	79	18,492	2,910,000	2,928,492
2200	60	3	84.49	40.80	27	54	25	88	88	20,599	2,430,000	2,450,599
2200	60	3	88.32	39.36	25	56	25	88	88	20,599	2,430,000	2,450,599
2200	60	3	97.31	36.65	23	61	25	88	88	20,599	2,520,000	2,450,599
2200	60	3	110.22	33.80	20	66	25	88	88	20,599	2,580,000	2,600,599
2200	60	3	130.87	30.14	17	73	25	88	88	20,599	2,700,000	2,720,599
2200	60	3	173.16	23.75	13	93	25	88	93	21,769	3,180,000	3,201,769
2200	80	3	104.37	36.55	22	61	25	118	118	27,621	2,490,000	2,517,621
2200	80	3	111.28	35.48	20	63	25	118	118	27,621	2,490,000	2,517,621
2200	80	3	121.78	33.14	19	67	25	118	118	27,621	2,580,000	2,607,621
2200	80	3	138.64	30.68	16	72	25	118	118	27,621	2,640,000	2,667,621
2200	80	3	164.50	26.83	14	82	25	118	118	27,621	2,880,000	2,907,621
2200	80	3	211.19	21.14	11	105	25	118	118	27,621	3,480,000	3,507,621
2200	100	3	123.77	34.14	18	65	25	147	147	34,410	2,490,000	2,524,410
2200	100	3	135.46	32.79	17	68	25	147	147	34,410	2,550,000	2,584,410
2200	100	3	147.93	30.68	15	72	25	147	147	34,410	2,610,000	2,644,410
2200	100	3	166.56	27.77	14	80	25	147	147	34,410	2,820,000	2,854,410
2200	100	3	196.52	24.06	12	92	25	147	147	34,410	3,120,000	3,154,410
2200	100	3	242.16	19.06	10	116	25	147	147	34,410	3,780,000	3,814,410
2200	120	3	147.80	31.56	15	70	25	176	176	41,198	2,550,000	2,591,198
2200	120	3	156.13	30.04	15	74	25	176	176	41,198	2,670,000	2,711,198
2200	120	3	173.32	28.38	13	78	25	176	176	41,198	2,730,000	2,771,198
2200	120	3	194.01	25.40	12	87	25	176	176	41,198	2,970,000	3,011,198
2200	120	3	225.00	22.36	10	99	25	176	176	41,198	3,270,000	3,311,198
2200	120	3	268.06	17.69	9	125	25	176	176	41,198	4,020,000	4,061,198

Table F.7: Automated System Prescriptive Model Calculations (Low Picking and High Packing Levels, Demand = 3300 orders/hr, Sorter Cost = \$250,000).

W	$p(n)$	$q(m)$	t	r_p	r_q	N_q	r_a	r_t	r_s	T_p^a	$r_q c_q$	$r_s c_t$	C_t^s	$C_t^s * A$	T^a
20	56.65	118.26	60	59	28	25	44	4	1	2,730,000	440,000	50,000	740,000	176,507	2,906,507
40	95.38	118.15	60	35	28	25	88	4	1	2,010,000	880,000	50,000	1,180,000	281,457	2,291,457
60	139.51	118.07	60	24	28	25	132	4	1	1,680,000	1,320,000	50,000	1,620,000	386,407	2,066,407
80	181.15	118.03	60	19	28	25	176	4	1	1,530,000	1,760,000	50,000	2,060,000	491,357	2,021,357
100	217.62	117.99	60	16	28	25	220	4	1	1,440,000	2,200,000	50,000	2,500,000	596,307	2,036,307
120	247.53	117.96	60	14	28	25	264	4	1	1,380,000	2,640,000	50,000	2,940,000	701,257	2,081,257
20	56.65	93.21	60	59	36	25	44	4	1	2,970,000	440,000	50,000	740,000	176,507	3,146,507
40	95.38	83.45	60	35	40	25	88	4	1	2,370,000	880,000	50,000	1,180,000	281,457	2,651,457
60	139.51	76.70	60	24	44	25	132	4	1	2,160,000	1,320,000	50,000	1,620,000	386,407	<i>2,546,407</i>
80	181.15	71.73	60	19	47	25	176	4	1	2,100,000	1,760,000	50,000	2,060,000	491,357	2,591,357
100	217.62	68.02	60	16	49	25	220	4	1	2,070,000	2,200,000	50,000	2,500,000	596,307	2,666,307
120	247.53	65.41	60	14	51	25	264	4	1	2,070,000	2,640,000	50,000	2,940,000	701,257	2,771,257

Table F.8: Manual System Prescriptive Model Calculations (Low Picking and High Packing Levels).

D	W	N_o	$p(n)$	$q(m)$	r_p	r_q	N_q	n_q	r_a	$r_a c_q$	T_ℓ^m	T^m
3300	20	3	25.65	78.79	129	42	25	44	44	7,346	5,130,000	5,137,346
3300	20	3	31.62	71.86	105	46	25	44	46	7,680	4,530,000	4,537,680
3300	20	3	31.62	71.86	105	46	25	44	46	7,680	4,530,000	4,537,680
3300	20	3	38.06	63.76	87	52	25	44	52	8,681	4,170,000	4,178,681
3300	20	3	41.42	59.63	80	56	25	44	56	9,349	4,080,000	4,089,349
3300	20	3	56.65	47.52	59	70	25	44	70	11,687	3,870,000	<i>3,881,687</i>
3300	40	3	46.33	61.98	72	54	25	88	88	14,692	3,780,000	3,794,692
3300	40	3	48.19	59.63	69	56	25	88	88	14,692	3,750,000	3,764,692
3300	40	3	53.61	56.64	62	59	25	88	88	14,692	3,630,000	<i>3,644,692</i>
3300	40	3	57.22	52.34	58	64	25	88	88	14,692	3,660,000	3,674,692
3300	40	3	69.76	45.35	48	73	25	88	88	14,692	3,630,000	<i>3,644,692</i>
3300	40	3	95.38	35.49	35	93	25	88	93	15,526	3,840,000	3,855,526
3300	60	3	60.48	54.55	55	61	25	132	132	22,037	3,480,000	<i>3,502,037</i>
3300	60	3	63.26	52.34	53	64	25	132	132	22,037	3,510,000	3,532,037
3300	60	3	72.86	47.52	46	70	25	132	132	22,037	3,480,000	<i>3,502,037</i>
3300	60	3	79.26	44.32	42	75	25	132	132	22,037	3,510,000	3,532,037
3300	60	3	97.94	38.26	34	87	25	132	132	22,037	3,630,000	3,652,037
3300	60	3	139.51	28.67	24	116	25	132	132	22,037	4,200,000	4,222,037
3300	80	3	74.54	49.43	45	67	25	176	176	29,383	3,360,000	3,389,383
3300	80	3	80.29	46.62	42	71	25	176	176	29,383	3,390,000	3,419,383
3300	80	3	89.65	42.70	37	78	25	176	176	29,383	3,450,000	3,479,383
3300	80	3	102.60	38.47	33	86	25	176	176	29,383	3,570,000	3,599,383
3300	80	3	126.49	33.00	27	101	25	176	176	29,383	3,840,000	3,869,383
3300	80	3	181.15	24.51	19	135	25	176	176	29,383	4,620,000	4,649,383
3300	100	3	90.82	44.51	37	75	25	220	220	36,729	3,360,000	3,396,729
3300	100	3	98.57	42.24	34	79	25	220	220	36,729	3,390,000	<i>3,426,729</i>
3300	100	3	109.48	38.47	31	86	25	220	220	36,729	3,510,000	3,546,729
3300	100	3	126.39	34.62	27	96	25	220	220	36,729	3,690,000	3,726,729
3300	100	3	158.13	29.12	21	114	25	220	220	36,729	4,050,000	4,086,729
3300	100	3	217.62	21.88	16	151	25	220	220	36,729	5,010,000	5,046,729
3300	120	3	105.81	41.06	32	81	25	264	264	44,075	3,390,000	<i>3,434,075</i>
3300	120	3	115.12	38.61	29	86	25	264	264	44,075	3,450,000	3,494,075
3300	120	3	130.76	35.26	26	94	25	264	264	44,075	3,600,000	3,644,075
3300	120	3	153.45	31.23	22	106	25	264	264	44,075	3,840,000	3,884,075
3300	120	3	189.39	26.32	18	126	25	264	264	44,075	4,320,000	4,364,075
3300	120	3	247.53	19.92	14	166	25	264	264	44,075	5,400,000	5,444,075

Table F.9: Automated System Prescriptive Model Calculations (Low Picking and Low Packing Levels, Demand = 2200 orders/hr, Sorter Cost = \$500,000).

W	$p(n)$	$q(m)$	t	r_p	r_q	N_q	r_a	r_t	r_s	T_ℓ^a	$r_q c_q$	$r_s c_t$	C_t^s	$C_t^s * A$	T^a
20	56.65	47.71	7200	39	47	25	30	2	2	2,640,000	75,000	100,000	675,000	178,063	2,818,063
40	95.38	47.70	7200	24	47	25	59	2	2	2,190,000	147,500	100,000	747,500	197,189	2,387,189
60	139.51	47.70	7200	16	47	25	88	2	2	1,950,000	220,000	100,000	820,000	216,314	2,166,314
80	181.15	47.69	7200	13	47	25	118	2	2	1,860,000	295,000	100,000	895,000	236,099	2,096,099
100	217.62	47.69	7200	11	47	25	147	2	2	1,800,000	367,500	100,000	967,500	255,224	2,055,224
120	247.53	47.68	7200	9	47	25	176	2	2	1,740,000	440,000	100,000	1,040,000	274,349	2,014,349
20	56.65	35.94	7200	39	62	25	30	2	2	3,090,000	75,000	100,000	675,000	178,063	3,268,063
40	95.38	33.85	7200	24	65	25	59	2	2	2,730,000	147,500	100,000	747,500	197,189	2,927,189
60	139.51	32.63	7200	16	68	25	88	2	2	2,580,000	220,000	100,000	820,000	216,314	2,796,314
80	181.15	31.76	7200	13	70	25	118	2	2	2,550,000	295,000	100,000	895,000	236,099	2,786,099
100	217.62	31.16	7200	11	71	25	147	2	2	2,520,000	367,500	100,000	967,500	255,224	2,775,224
120	247.53	30.62	7200	9	72	25	176	2	2	2,490,000	440,000	100,000	1,040,000	274,349	<i>2,764,349</i>

Table F.10: Manual System Prescriptive Model Calculations (Low Picking and Low Packing Levels).

D	W	N_o	$p(n)$	$q(m)$	r_p	r_q	N_q	n_q	r_a	$r_a c_q$	T_ℓ^m	T^m
2200	20	3	25.65	38.85	86	57	25	30	57	10,526	4,290,000	4,300,526
2200	20	3	31.62	38.08	70	58	25	30	58	10,710	3,840,000	3,850,710
2200	20	3	31.62	38.08	70	58	25	30	58	10,710	3,840,000	3,850,710
2200	20	3	38.06	35.74	58	62	25	30	62	11,449	3,600,000	3,611,449
2200	20	3	41.42	33.51	54	66	25	30	66	12,188	3,600,000	3,612,188
2200	20	3	56.65	29.24	39	76	25	30	76	14,034	3,450,000	<i>3,464,034</i>
2200	40	3	46.33	34.47	48	64	25	59	64	11,818	3,360,000	3,371,818
2200	40	3	48.19	33.51	46	66	25	59	66	12,188	3,360,000	3,372,188
2200	40	3	53.61	34.01	42	65	25	59	65	12,003	3,210,000	<i>3,222,003</i>
2200	40	3	57.22	31.18	39	71	25	59	71	13,111	3,300,000	3,313,111
2200	40	3	69.76	29.23	32	76	25	59	76	14,034	3,240,000	3,254,034
2200	40	3	95.38	24.93	24	89	25	59	89	16,435	3,390,000	3,406,435
2200	60	3	60.48	32.74	37	68	25	88	88	16,250	3,150,000	3,166,250
2200	60	3	63.26	31.18	35	71	25	88	88	16,250	3,180,000	3,196,250
2200	60	3	72.86	29.24	31	76	25	88	88	16,250	3,210,000	3,226,250
2200	60	3	79.26	28.99	28	76	25	88	88	16,250	3,120,000	<i>3,136,250</i>
2200	60	3	97.94	25.46	23	87	25	88	88	16,250	3,300,000	3,316,250
2200	60	3	139.51	21.49	16	103	25	88	103	19,020	3,570,000	3,589,020
2200	80	3	74.54	30.52	30	73	25	118	118	21,790	3,090,000	3,111,790
2200	80	3	80.29	29.87	28	74	25	118	118	21,790	3,060,000	3,081,790
2200	80	3	89.65	28.02	25	79	25	118	118	21,790	3,120,000	3,141,790
2200	80	3	102.60	26.46	22	84	25	118	118	21,790	3,180,000	3,201,790
2200	80	3	126.49	23.70	18	93	25	118	118	21,790	3,330,000	3,351,790
2200	80	3	181.15	18.87	13	117	25	118	118	21,790	3,900,000	3,921,790
2200	100	3	90.82	28.46	25	78	25	147	147	27,145	3,090,000	3,117,145
2200	100	3	98.57	28.03	23	79	25	147	147	27,145	3,060,000	<i>3,087,145</i>
2200	100	3	109.48	26.46	21	84	25	147	147	27,145	3,150,000	3,177,145
2200	100	3	126.39	24.54	18	90	25	147	147	27,145	3,240,000	3,267,145
2200	100	3	158.13	21.20	14	104	25	147	147	27,145	3,540,000	3,567,145
2200	100	3	217.62	17.03	11	130	25	147	147	27,145	4,230,000	4,257,145
2200	120	3	105.81	26.75	21	83	25	176	176	32,500	3,120,000	<i>3,152,500</i>
2200	120	3	115.12	25.98	20	85	25	176	176	32,500	3,150,000	3,182,500
2200	120	3	130.76	24.77	17	89	25	176	176	32,500	3,180,000	3,212,500
2200	120	3	153.45	22.83	15	97	25	176	176	32,500	3,360,000	3,392,500
2200	120	3	189.39	19.98	12	111	25	176	176	32,500	3,690,000	3,722,500
2200	120	3	247.53	16.11	9	137	25	176	176	32,500	4,380,000	4,412,500

Table F.11: Throughput Simulation Picking Times (Overlapping Waves) — *continued.*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
113.41	40.67	59.41	39.77	67.15	74.20	109.36	70.28	61.33	60.89	114.66	69.70	53.92	78.31	68.85
114.11	41.58	59.38	39.95	61.28	74.11	109.60	80.52	60.93	61.01	114.77	69.47	54.56	73.64	64.22
114.23	38.96	58.67	40.39	58.87	73.95	109.13	69.64	63.72	57.80	115.18	61.73	53.60	85.27	66.71
113.92	40.79	58.55	40.29	68.26	74.35	109.25	93.35	60.46	61.57	114.65	58.05	53.64	89.05	67.96
113.89	40.17	57.55	40.32	52.18	73.92	109.56	89.98	66.13	61.35	114.80	60.34	53.59	90.99	61.08
113.63	39.55	58.96	40.12	73.67	74.26	108.69	95.55	62.94	59.37	114.90	64.62	54.48	71.46	61.15
113.63	42.14	57.74	40.07	66.05	74.53	109.00	92.58	65.16	58.48	114.84	59.69	54.35	86.61	59.82
114.25	36.89	58.53	40.11	57.93	73.91	109.67	89.87	59.30	57.89	114.94	71.43	53.23	88.54	62.83
113.61	37.39	58.18	39.47	62.32	73.98	108.99	79.53	62.27	60.83	114.72	67.23	53.73	85.81	48.56
114.20	38.29	58.24	39.48	54.07	73.57	109.81	82.68	64.15	57.95	115.07	58.36	53.95	72.09	47.90
113.50	38.88	58.16	39.80	66.99	73.37	109.81	70.51	54.00	59.65	114.84	64.76	53.88	88.14	66.00
113.93	39.59	59.54	39.33	59.79	73.96	109.31	80.16	57.43	57.99	114.89	50.43	54.29	79.23	65.50
113.72	40.96	58.97	40.50	68.89	74.21	109.46	100.49	56.69	61.63	114.32	57.43	54.05	73.63	78.57
113.37	41.53	56.82	39.91	70.77	73.52	109.66	93.84	58.89	59.24	114.28	52.61	53.73	88.23	69.45
114.25	37.04	59.18	39.12	63.26	73.85	109.40	84.53	59.52	60.52	115.07	55.74	54.36	73.93	57.74
114.39	36.76	57.08	40.11	63.87	73.73	108.70	87.93	61.60	58.48	114.60	65.56	52.80	88.34	59.62
114.36	37.73	57.67	39.28	65.80	73.84	109.73	81.12	64.78	59.01	114.40	64.09	54.24	78.86	68.35
113.45	40.93	58.74	40.48	72.79	73.63	109.80	79.62	62.15	61.56	114.67	66.74	54.07	78.75	54.25
113.71	41.40	58.25	39.74	73.08	73.51	109.69	85.92	51.73	59.69	114.72	61.61	53.71	83.41	67.03
113.46	40.76	57.69	39.92	68.97	73.93	109.77	90.09	61.09	59.16	114.97	65.69	53.69	91.25	59.19
114.13	40.98	58.23	39.41	57.60	73.97	109.02	81.11	60.70	59.63	114.44	60.94	53.94	89.01	67.57
113.42	38.96	58.97	38.89	63.26	74.10	109.62	79.08	56.91	59.87	114.25	55.36	53.48	75.67	64.31
113.68	36.92	59.09	39.32	66.49	73.57	109.86	75.79	63.12	60.98	115.20	69.85	53.79	77.02	59.41
113.59	42.09	60.28	39.66	66.24	74.50	109.94	96.81	55.19	62.03	114.80	64.89	53.62	81.22	62.03
113.47	39.39	57.18	39.73	58.95	73.80	109.70	86.41	62.36	59.90	114.67	69.10	54.48	84.47	55.42
113.70	35.22	58.74	40.32	65.82	74.28	109.32	68.75	61.53	59.64	114.44	70.35	53.60	75.22	74.60
113.47	39.59	57.79	40.92	49.82	73.54	109.10	87.47	61.28	58.41	114.51	67.78	53.18	72.49	65.26
114.12	42.16	59.51	39.53	66.93	74.17	109.37	63.92	62.39	58.71	115.02	71.18	54.02	92.71	73.98
114.29	35.66	58.54	40.34	59.51	74.47	108.92	86.22	53.20	60.31	115.17	51.72	54.36	85.41	62.36
113.47	35.49	57.22	40.52	67.84	73.81	109.84	82.81	58.82	60.23	115.06	59.12	54.06	81.88	74.73
113.53	42.94	58.13	40.33	66.65	74.29	108.79	82.22	65.78	57.39	114.29	71.86	53.96	82.63	57.62
113.32	38.24	57.47	39.63	50.36	73.72	108.84	81.28	57.38	59.14	114.78	64.04	53.55	68.87	53.28
113.92	36.94	58.23	40.65	64.48	74.16	108.97	68.05	59.57	57.95	115.11	62.61	54.13	73.31	59.27
113.97	40.27	58.25	40.30	58.96	73.64	109.13	79.09	60.14	61.44	114.82	64.21	54.12	76.35	62.99
114.13	33.65	58.63	40.08	73.97	74.14	109.80	93.01	58.21	59.68	114.41	64.02	53.36	81.56	71.07
114.22	38.18	59.27	40.03	62.66	73.93	108.95	80.64	59.59	59.84	114.25	71.43	53.32	96.95	65.58
113.89	40.23	58.15	38.93	60.92	74.13	109.34	70.15	59.38	60.23	114.17	72.93	54.40	71.38	57.74
113.89	40.17	58.83	39.71	70.84	74.27	109.79	71.33	56.92	58.15	114.98	63.62	53.80	75.93	65.13
113.68	40.21	58.29	40.26	53.32	73.78	109.55	78.16	57.86	59.84	114.96	75.50	54.00	74.54	66.70
114.04	42.64	58.92	40.63	64.46	73.91	109.87	67.34	61.13	60.28	115.00	50.52	53.79	71.40	58.07
113.61	37.49	57.59	39.64	45.56	73.65	109.95	69.11	61.95	56.73	115.18	58.82	54.37	88.80	59.27
113.76	41.61	58.69	40.56	55.56	73.75	109.51	72.02	59.13	58.74	114.83	68.37	54.06	70.26	60.62

Table F.12: Throughput Simulation Packing Times (Overlapping Waves).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
118.15	42.79	59.81	38.82	Man.	78.60	115.55	Man.	Man.	57.29	112.76	Man.	56.12	Man.	Man.
118.10	39.83	60.44	38.69	Man.	79.14	114.83	Man.	Man.	58.25	110.78	Man.	56.92	Man.	Man.
116.88	40.45	60.27	39.41	Man.	77.76	115.08	Man.	Man.	57.80	110.78	Man.	56.17	Man.	Man.
119.03	40.87	60.00	38.97	Man.	76.25	116.41	Man.	Man.	58.15	112.03	Man.	55.57	Man.	Man.
117.76	39.86	59.97	39.87	Man.	78.85	115.69	Man.	Man.	57.75	111.40	Man.	56.73	Man.	Man.
118.81	40.04	59.81	38.97	Man.	76.57	117.73	Man.	Man.	58.09	112.23	Man.	56.03	Man.	Man.
117.62	41.47	60.14	38.53	Man.	77.18	117.39	Man.	Man.	58.24	110.43	Man.	55.92	Man.	Man.
116.49	39.31	60.50	39.34	Man.	80.28	116.28	Man.	Man.	56.78	111.82	Man.	56.26	Man.	Man.
117.27	39.94	60.85	39.28	Man.	79.58	117.56	Man.	Man.	57.07	111.09	Man.	56.08	Man.	Man.
117.96	39.94	59.71	39.73	Man.	78.23	115.96	Man.	Man.	58.85	111.93	Man.	56.34	Man.	Man.
117.32	39.87	59.93	39.12	Man.	79.24	117.03	Man.	Man.	57.77	112.22	Man.	56.53	Man.	Man.
119.11	40.73	59.76	39.50	Man.	77.42	114.79	Man.	Man.	57.85	112.86	Man.	57.56	Man.	Man.

Table F.12: Throughput Simulation Packing Times (Overlapping Waves) — *continued.*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
117.82	39.71	60.25	39.55	Man.	78.17	117.48	Man.	Man.	58.52	112.54	Man.	55.46	Man.	Man.
117.38	40.65	59.89	39.42	Man.	75.74	115.47	Man.	Man.	59.08	112.48	Man.	55.08	Man.	Man.
118.57	40.79	60.51	39.78	Man.	78.56	115.76	Man.	Man.	59.35	113.94	Man.	56.62	Man.	Man.
117.51	39.43	59.85	39.45	Man.	78.62	115.76	Man.	Man.	59.48	112.33	Man.	56.39	Man.	Man.
117.91	40.54	60.15	38.78	Man.	78.86	114.35	Man.	Man.	58.41	112.07	Man.	55.67	Man.	Man.
118.20	40.53	60.38	39.05	Man.	79.14	117.16	Man.	Man.	57.47	112.15	Man.	55.50	Man.	Man.
117.49	39.34	60.11	39.66	Man.	77.91	115.72	Man.	Man.	59.64	111.80	Man.	56.68	Man.	Man.
116.33	40.01	60.15	39.13	Man.	78.20	116.12	Man.	Man.	57.56	110.96	Man.	55.54	Man.	Man.
116.91	41.05	59.95	39.36	Man.	77.10	112.64	Man.	Man.	56.26	110.32	Man.	55.13	Man.	Man.
118.48	39.30	60.43	39.48	Man.	77.90	115.10	Man.	Man.	55.67	112.85	Man.	56.12	Man.	Man.
115.90	40.66	60.03	39.38	Man.	77.17	117.78	Man.	Man.	57.32	112.66	Man.	56.42	Man.	Man.
117.55	39.42	59.69	38.99	Man.	77.60	115.46	Man.	Man.	56.77	112.84	Man.	56.69	Man.	Man.
116.51	40.66	59.91	39.73	Man.	78.73	116.16	Man.	Man.	58.29	113.15	Man.	55.00	Man.	Man.
118.88	40.04	60.14	39.10	Man.	76.41	118.01	Man.	Man.	57.04	110.89	Man.	56.08	Man.	Man.
118.98	40.47	60.40	38.50	Man.	79.22	115.21	Man.	Man.	58.82	112.09	Man.	55.65	Man.	Man.
117.36	40.52	60.07	39.69	Man.	76.52	118.89	Man.	Man.	56.99	112.27	Man.	55.97	Man.	Man.
117.13	39.65	60.14	39.49	Man.	78.59	113.11	Man.	Man.	57.32	111.56	Man.	55.64	Man.	Man.
116.86	39.78	59.86	39.09	Man.	77.21	119.92	Man.	Man.	57.76	111.04	Man.	55.93	Man.	Man.
117.17	39.14	60.32	39.43	Man.	78.24	113.07	Man.	Man.	59.37	112.07	Man.	55.87	Man.	Man.
118.03	39.15	59.93	39.28	Man.	78.35	114.63	Man.	Man.	57.12	111.20	Man.	55.23	Man.	Man.
116.36	39.75	60.05	38.61	Man.	77.40	113.82	Man.	Man.	57.54	110.19	Man.	55.75	Man.	Man.
116.92	41.06	60.38	39.42	Man.	78.70	118.19	Man.	Man.	56.80	111.42	Man.	56.63	Man.	Man.
117.76	41.76	60.18	38.54	Man.	78.31	115.37	Man.	Man.	57.92	110.37	Man.	55.44	Man.	Man.
116.55	41.19	60.25	39.23	Man.	78.54	115.85	Man.	Man.	59.23	112.05	Man.	55.52	Man.	Man.
115.90	40.18	60.31	38.98	Man.	81.15	115.82	Man.	Man.	58.61	111.85	Man.	56.15	Man.	Man.
118.31	40.00	60.04	39.73	Man.	76.65	113.68	Man.	Man.	57.78	111.75	Man.	56.05	Man.	Man.
116.96	40.69	59.98	39.39	Man.	78.43	114.44	Man.	Man.	59.55	113.51	Man.	56.15	Man.	Man.
117.83	41.14	60.16	38.39	Man.	80.36	116.21	Man.	Man.	57.61	111.12	Man.	55.91	Man.	Man.
115.34	39.70	59.97	39.50	Man.	79.77	116.06	Man.	Man.	57.20	111.20	Man.	56.05	Man.	Man.
118.04	39.84	60.14	38.98	Man.	81.14	115.22	Man.	Man.	59.20	109.50	Man.	56.91	Man.	Man.
117.25	40.12	59.99	38.43	Man.	79.91	114.62	Man.	Man.	58.08	112.92	Man.	56.97	Man.	Man.
117.68	39.14	59.97	39.26	Man.	77.96	116.77	Man.	Man.	59.18	112.51	Man.	56.41	Man.	Man.
116.10	40.22	59.71	39.07	Man.	76.71	112.96	Man.	Man.	60.88	110.67	Man.	56.92	Man.	Man.
116.76	40.54	60.13	39.20	Man.	76.35	115.34	Man.	Man.	57.54	112.31	Man.	56.33	Man.	Man.
115.38	41.67	60.26	38.69	Man.	79.63	116.12	Man.	Man.	59.69	112.07	Man.	56.04	Man.	Man.
117.81	38.57	60.15	39.09	Man.	77.89	115.02	Man.	Man.	56.79	111.02	Man.	56.70	Man.	Man.
116.67	39.79	59.87	39.92	Man.	79.38	115.20	Man.	Man.	56.38	111.78	Man.	55.65	Man.	Man.
116.68	38.79	60.41	39.35	Man.	78.70	115.70	Man.	Man.	58.74	113.12	Man.	56.88	Man.	Man.
116.28	39.37	60.19	39.35	Man.	77.19	116.69	Man.	Man.	58.37	112.29	Man.	54.83	Man.	Man.
116.69	40.61	59.61	39.30	Man.	80.43	117.23	Man.	Man.	59.38	111.55	Man.	56.17	Man.	Man.
117.58	40.23	60.25	39.62	Man.	78.00	116.21	Man.	Man.	57.20	113.04	Man.	55.54	Man.	Man.
117.23	41.63	60.26	39.38	Man.	78.46	115.34	Man.	Man.	59.08	111.22	Man.	56.05	Man.	Man.
117.20	39.84	59.53	38.88	Man.	79.41	115.53	Man.	Man.	56.72	112.06	Man.	55.66	Man.	Man.
116.55	39.29	60.22	38.27	Man.	77.34	115.54	Man.	Man.	57.55	111.77	Man.	56.74	Man.	Man.
117.37	41.18	59.73	40.13	Man.	79.27	113.96	Man.	Man.	58.17	111.27	Man.	57.51	Man.	Man.
117.53	39.47	60.28	39.30	Man.	77.09	113.58	Man.	Man.	57.87	111.78	Man.	56.58	Man.	Man.
118.60	39.74	59.87	38.43	Man.	78.20	115.38	Man.	Man.	58.17	112.45	Man.	56.61	Man.	Man.
117.79	40.03	60.13	40.03	Man.	79.43	117.79	Man.	Man.	58.93	112.88	Man.	55.99	Man.	Man.
116.51	40.12	60.07	39.03	Man.	77.94	113.99	Man.	Man.	57.77	112.69	Man.	55.64	Man.	Man.
118.97	40.67	60.10	39.47	Man.	79.58	119.32	Man.	Man.	57.59	111.66	Man.	56.47	Man.	Man.
116.59	39.39	60.32	39.04	Man.	77.84	115.51	Man.	Man.	57.55	111.58	Man.	55.84	Man.	Man.
116.28	40.27	59.88	39.26	Man.	78.60	118.14	Man.	Man.	58.02	111.76	Man.	57.10	Man.	Man.
117.48	41.48	60.20	37.97	Man.	78.31	116.66	Man.	Man.	58.47	111.05	Man.	56.09	Man.	Man.
118.45	39.60	60.14	38.76	Man.	77.10	115.91	Man.	Man.	58.36	112.58	Man.	54.96	Man.	Man.
116.60	39.84	59.99	39.48	Man.	76.64	115.29	Man.	Man.	59.53	111.48	Man.	56.07	Man.	Man.
117.59	39.96	60.14	38.89	Man.	78.13	115.84	Man.	Man.	56.82	111.88	Man.	54.88	Man.	Man.
118.88	39.68	60.60	39.24	Man.	77.50	114.21	Man.	Man.	58.80	112.11	Man.	54.88	Man.	Man.
118.52	39.71	60.26	39.07	Man.	79.06	117.40	Man.	Man.	57.28	111.94	Man.	56.03	Man.	Man.
118.00	41.40	60.49	38.91	Man.	78.41	115.62	Man.	Man.	57.96	112.16	Man.	56.21	Man.	Man.

Table F.12: Throughput Simulation Packing Times (Overlapping Waves) — *continued*.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
117.18	39.67	59.76	39.87	Man.	76.45	115.87	Man.	Man.	58.92	112.44	Man.	55.55	Man.	Man.
119.08	40.18	59.78	39.00	Man.	78.15	116.00	Man.	Man.	57.41	111.39	Man.	56.34	Man.	Man.
114.97	41.06	60.01	39.37	Man.	77.01	118.04	Man.	Man.	58.18	112.34	Man.	54.76	Man.	Man.
118.66	41.22	60.05	38.78	Man.	77.35	117.07	Man.	Man.	58.06	112.04	Man.	55.29	Man.	Man.
116.82	40.14	59.88	39.65	Man.	79.74	118.26	Man.	Man.	57.35	112.30	Man.	57.18	Man.	Man.
116.03	39.59	60.45	38.51	Man.	77.56	117.04	Man.	Man.	57.91	110.85	Man.	56.63	Man.	Man.
119.51	39.94	60.13	39.04	Man.	73.43	115.41	Man.	Man.	57.71	111.24	Man.	54.05	Man.	Man.
116.95	40.35	60.10	39.11	Man.	78.35	114.31	Man.	Man.	56.98	110.86	Man.	55.21	Man.	Man.
117.92	39.80	60.04	39.08	Man.	78.92	115.16	Man.	Man.	57.45	111.36	Man.	57.28	Man.	Man.
117.70	40.69	60.15	39.26	Man.	75.54	115.30	Man.	Man.	58.19	113.41	Man.	56.43	Man.	Man.
115.88	41.37	60.29	38.93	Man.	78.44	115.45	Man.	Man.	55.85	112.49	Man.	55.91	Man.	Man.
116.45	40.81	59.82	38.67	Man.	76.58	117.70	Man.	Man.	57.79	110.28	Man.	56.40	Man.	Man.
117.07	41.43	60.20	39.20	Man.	75.96	114.21	Man.	Man.	58.47	112.62	Man.	54.96	Man.	Man.
117.40	40.48	60.18	38.59	Man.	75.82	115.65	Man.	Man.	56.49	109.85	Man.	56.59	Man.	Man.
116.53	39.72	59.88	39.82	Man.	78.26	118.64	Man.	Man.	59.22	109.93	Man.	56.10	Man.	Man.
116.90	42.15	60.05	39.28	Man.	78.55	113.73	Man.	Man.	57.75	113.01	Man.	54.83	Man.	Man.
116.39	41.12	59.84	39.49	Man.	78.18	115.59	Man.	Man.	56.66	111.55	Man.	55.67	Man.	Man.
118.80	39.30	59.93	39.29	Man.	77.70	117.75	Man.	Man.	56.98	111.93	Man.	56.71	Man.	Man.
118.09	40.23	59.94	38.49	Man.	78.24	116.95	Man.	Man.	56.85	110.96	Man.	55.86	Man.	Man.
118.25	39.98	60.04	39.69	Man.	78.95	115.19	Man.	Man.	59.07	112.98	Man.	56.57	Man.	Man.
117.92	40.39	60.12	40.30	Man.	77.78	115.89	Man.	Man.	55.16	111.45	Man.	57.16	Man.	Man.
119.00	39.35	60.09	39.30	Man.	78.16	117.45	Man.	Man.	57.58	110.92	Man.	55.10	Man.	Man.
116.71	40.58	60.24	38.82	Man.	80.53	115.59	Man.	Man.	59.26	111.79	Man.	56.13	Man.	Man.
119.00	40.58	59.51	39.27	Man.	76.44	115.99	Man.	Man.	59.91	112.89	Man.	55.33	Man.	Man.
116.80	41.74	60.01	39.28	Man.	76.89	116.16	Man.	Man.	58.81	112.55	Man.	56.21	Man.	Man.
116.31	41.25	59.96	39.09	Man.	78.75	115.66	Man.	Man.	58.27	112.43	Man.	56.07	Man.	Man.
118.98	39.98	60.16	39.76	Man.	75.86	114.43	Man.	Man.	56.47	111.52	Man.	57.32	Man.	Man.
118.12	39.46	59.86	38.78	Man.	78.27	115.88	Man.	Man.	58.90	110.19	Man.	56.71	Man.	Man.
117.41	40.21	60.33	39.55	Man.	76.38	114.78	Man.	Man.	57.32	111.94	Man.	56.09	Man.	Man.

Table F.13: Throughput Simulation Picking Times (Non-Overlapping Waves).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
39.34	113.02	71.11	19.83	80.21	37.44	108.52	55.84	63.54	102.35	18.31	61.78	21.43	72.38	61.15
39.63	95.28	51.41	19.74	67.08	37.90	109.19	89.71	59.08	96.07	19.44	57.51	19.22	83.52	56.97
40.20	104.01	60.27	20.20	66.89	37.42	109.81	95.75	58.78	107.54	18.81	58.28	19.63	70.57	47.31
39.77	91.59	68.30	21.13	60.18	36.64	109.93	64.71	61.20	89.49	18.88	63.84	20.74	83.09	63.14
39.23	111.03	55.54	20.20	80.23	37.36	109.40	70.34	56.84	88.65	19.50	60.22	19.55	83.35	60.97
39.32	101.56	55.07	20.42	47.12	38.40	109.26	90.52	56.18	110.97	18.99	54.76	19.28	93.99	63.75
39.62	107.43	72.15	19.13	66.96	37.50	109.38	64.94	60.01	107.58	19.53	48.06	19.03	74.19	61.75
39.09	114.16	63.14	20.21	61.52	37.93	109.37	80.34	58.41	115.81	19.18	59.34	19.85	83.73	62.46
39.49	107.19	65.11	20.49	70.45	37.94	109.66	69.42	68.98	102.05	19.85	52.74	18.94	81.11	52.56
39.88	101.69	59.47	18.44	62.02	37.27	109.88	78.29	59.50	116.42	20.80	67.05	19.15	70.00	65.71
40.10	106.53	65.74	20.24	69.06	38.35	109.71	60.86	59.64	106.54	18.83	56.67	20.05	81.19	59.15
39.57	92.47	49.88	19.03	62.20	37.33	109.24	84.38	65.67	92.97	20.33	56.26	19.17	77.57	76.41
39.76	93.79	62.78	20.14	67.41	37.26	109.82	76.21	60.06	103.48	17.29	68.56	20.05	63.50	60.10
39.44	92.20	59.94	20.73	58.54	37.74	109.70	82.51	60.12	108.52	20.39	70.81	19.49	74.67	54.95
40.44	90.29	64.48	19.46	63.28	37.36	109.80	76.32	56.33	99.08	18.75	65.96	18.42	70.47	58.57
39.44	109.66	63.75	20.22	65.07	38.19	109.43	90.55	52.12	97.66	20.34	62.65	21.00	88.02	56.29
39.85	98.53	67.40	19.72	52.72	37.09	109.58	82.55	60.93	103.95	18.76	63.85	19.75	86.41	51.19
39.07	109.52	66.86	20.02	71.24	36.93	109.26	79.77	59.03	110.90	19.45	70.37	19.92	80.75	68.41
40.27	91.53	75.81	18.24	59.62	37.67	109.10	80.42	62.43	103.16	20.75	79.60	18.52	88.37	51.85
39.38	113.73	59.75	19.10	74.72	37.81	109.20	70.48	60.10	87.06	19.05	64.32	21.10	87.12	67.67
38.48	95.81	67.14	18.56	61.14	38.56	109.29	83.54	59.82	109.76	19.69	61.31	18.93	63.06	65.64
39.39	100.39	57.10	21.26	49.17	39.18	109.72	79.50	58.51	107.74	19.41	64.18	19.06	87.75	48.26
40.44	99.45	70.93	20.22	63.93	36.29	109.50	66.41	59.75	90.48	20.78	61.02	21.04	80.88	64.23
39.21	95.30	66.63	19.93	58.85	38.16	109.18	92.74	58.29	104.22	18.01	67.98	20.45	77.77	70.59
40.34	94.16	67.83	19.62	68.82	38.15	108.81	54.63	52.88	99.21	19.46	60.16	19.51	74.36	51.51

Table F.13: Throughput Simulation Picking Times (Non-Overlapping Waves) — *continued.*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
39.80	93.33	70.49	20.19	58.51	37.39	108.96	90.46	60.25	101.23	19.82	70.59	18.80	80.67	58.18
39.89	104.93	58.51	20.38	62.69	37.00	109.71	82.78	61.77	101.17	18.59	59.33	18.05	68.11	55.74
39.08	121.92	57.63	19.36	76.93	37.88	109.20	86.46	60.46	104.90	21.88	61.02	19.76	79.88	55.76
39.48	94.15	59.16	18.30	59.35	37.57	109.96	75.30	63.14	97.53	18.92	59.49	19.99	86.00	69.14
40.07	98.92	69.41	20.82	59.95	37.46	109.46	82.37	60.22	104.74	19.85	61.64	19.65	79.22	62.33
38.73	99.74	65.92	20.87	47.39	38.16	109.65	83.56	55.94	100.40	19.34	65.13	19.50	76.22	58.36
40.55	97.55	66.85	19.61	58.50	37.45	108.90	86.33	60.09	98.43	19.71	62.81	20.15	81.94	51.56
39.44	100.01	70.91	20.42	70.69	38.66	109.46	78.08	58.64	96.18	22.20	66.88	19.48	90.92	54.88
39.91	98.21	58.35	21.19	68.48	37.55	108.47	80.42	59.59	89.16	20.34	56.21	19.00	86.25	62.95
39.84	96.45	71.17	21.10	73.19	38.51	109.09	63.94	55.33	102.02	18.77	55.85	21.22	74.39	65.78
39.21	107.65	73.10	20.16	70.25	39.24	109.80	78.69	57.09	104.42	18.40	66.54	19.79	72.37	59.49
40.24	101.89	62.47	19.21	52.88	37.73	109.30	80.74	50.41	82.16	20.33	55.79	20.04	85.86	64.86
40.66	110.27	54.54	18.01	60.70	37.51	109.70	75.94	58.65	97.77	18.98	67.75	19.60	77.14	59.71
39.54	93.34	62.28	20.80	63.21	36.35	109.44	73.76	55.91	113.69	20.04	72.14	20.69	83.66	63.45
39.28	90.62	66.65	20.17	63.73	37.63	109.58	83.56	57.21	110.25	19.49	56.45	19.27	73.09	58.74
39.52	88.68	60.40	19.95	62.35	38.07	109.61	88.99	60.55	99.14	18.64	61.21	19.17	86.49	56.62
39.19	112.75	57.18	20.36	66.52	38.34	109.93	78.14	63.01	89.18	20.14	61.42	22.04	76.15	73.30
40.14	104.66	65.88	19.67	64.66	37.85	109.83	84.94	57.97	103.35	20.59	51.59	21.02	82.52	76.46
39.89	107.50	56.97	20.33	60.45	36.43	110.00	80.83	63.57	111.38	18.82	66.11	18.24	82.25	58.83
40.16	103.42	76.44	20.41	64.80	36.81	108.75	90.39	59.84	103.86	18.68	55.65	18.34	94.39	74.49
39.75	98.74	69.37	19.46	65.11	37.53	109.62	87.20	64.19	100.85	19.30	55.38	19.20	69.71	56.83
38.46	91.82	49.37	20.84	56.06	37.33	109.39	71.15	56.39	97.57	19.98	56.38	21.08	83.90	59.95
39.97	116.95	63.89	19.99	73.89	37.73	109.07	82.75	61.14	109.08	19.24	63.85	18.21	78.72	65.77
39.89	107.53	58.50	21.08	66.92	36.78	109.84	68.00	70.55	110.33	18.23	70.48	19.45	74.99	65.93
38.74	104.89	58.83	20.66	66.56	38.38	109.21	83.46	62.92	62.26	20.15	56.12	18.96	79.14	57.14
39.99	98.58	60.52	19.70	58.62	37.74	109.27	75.75	63.53	104.82	20.57	52.21	20.73	82.27	53.74
40.10	98.43	67.48	18.50	54.15	37.71	109.27	73.78	54.23	90.11	19.54	59.40	18.47	91.26	51.07
39.77	107.84	57.48	19.10	57.25	37.30	109.28	72.41	52.34	89.71	18.51	60.12	20.06	75.32	61.89
39.71	113.54	52.20	19.17	53.01	36.61	109.16	72.92	59.46	117.01	19.90	67.17	19.55	66.98	64.82
39.50	111.00	62.12	19.33	54.77	37.51	110.01	79.76	58.10	100.66	20.14	74.85	19.91	73.19	48.33
38.45	100.00	71.00	19.62	56.98	37.06	108.72	74.15	60.70	97.24	19.30	60.97	19.91	83.36	67.20
39.55	103.95	71.31	21.40	68.12	37.40	109.86	85.85	54.77	101.98	20.54	60.26	19.34	79.47	63.75
39.80	103.18	62.04	20.65	72.04	38.31	109.38	75.64	50.51	96.81	18.38	58.59	18.90	94.30	57.92
39.75	114.34	67.57	20.51	67.36	37.53	109.36	86.20	56.01	107.11	19.37	78.15	18.05	88.02	73.91
39.88	104.66	60.75	19.88	61.76	38.47	109.60	79.77	54.75	113.57	19.79	58.15	19.25	86.29	64.82
39.58	119.82	56.72	19.92	60.42	37.52	109.13	90.50	61.17	98.55	18.90	67.89	19.42	82.77	63.16
38.98	108.77	62.89	19.35	54.42	38.06	109.25	89.02	61.32	91.79	19.12	66.40	19.20	76.36	66.01
39.41	101.42	63.71	21.10	63.95	37.57	109.56	81.72	52.15	109.91	20.18	73.92	18.64	62.49	55.84
39.70	110.93	60.65	19.36	67.88	37.27	108.69	82.20	63.57	104.66	19.89	58.14	18.89	75.77	69.05
39.81	117.11	71.77	20.78	65.74	37.97	109.00	59.10	61.90	97.66	18.97	50.86	19.43	93.57	67.63
39.84	100.85	58.13	19.95	56.24	38.64	109.67	85.85	63.12	111.12	18.54	73.49	20.04	86.16	64.41
40.08	106.83	65.60	18.52	62.92	37.45	108.99	89.64	52.75	98.39	18.50	59.75	20.35	69.83	75.74
40.22	104.54	59.99	20.21	70.07	37.33	109.81	81.65	55.31	93.91	19.97	52.78	19.05	93.06	73.47
39.55	80.27	58.51	17.95	76.77	38.25	109.81	83.26	55.82	97.06	19.53	61.43	19.82	91.81	64.85
40.13	95.35	61.09	19.29	65.56	37.14	109.31	88.80	63.69	114.24	18.07	69.81	19.74	90.52	60.46
39.56	110.79	58.76	19.90	54.36	38.42	109.46	73.08	55.30	97.32	19.81	66.78	19.82	80.50	71.89
39.25	95.16	62.46	20.29	56.42	37.41	109.66	92.58	56.17	106.88	19.82	66.11	21.01	73.83	66.19
39.73	88.63	56.60	16.82	56.85	37.91	109.40	67.76	58.76	99.83	18.95	76.69	18.50	71.91	84.98
39.91	95.39	71.70	19.53	64.17	38.33	108.70	80.17	56.42	118.85	18.49	56.67	19.30	81.70	57.70
39.94	90.20	59.42	19.97	59.00	37.17	109.73	79.99	59.80	107.99	20.33	55.53	19.70	66.10	60.51
39.93	113.92	65.83	20.21	52.47	38.64	109.80	70.99	64.26	107.89	20.75	60.22	19.86	77.28	69.13
39.16	100.65	72.14	20.25	54.82	37.06	109.69	96.46	59.61	107.59	19.46	69.97	18.77	82.98	52.34
39.73	111.88	60.94	20.99	72.34	36.97	109.77	86.95	66.81	117.03	19.83	59.67	20.32	90.17	75.64
39.76	99.78	59.53	18.73	55.60	37.84	109.02	85.60	66.19	106.33	18.85	56.02	19.33	77.26	54.34
40.73	115.97	61.37	20.68	78.38	38.47	109.62	63.29	58.67	107.28	20.25	63.24	19.44	79.46	67.81
39.65	100.46	61.44	20.01	67.12	38.58	109.86	82.56	55.21	91.76	19.43	64.53	20.10	88.39	69.56
39.21	110.45	64.19	20.05	71.47	38.33	109.94	83.28	56.07	117.60	19.75	58.93	20.11	73.44	54.68
39.49	94.94	63.23	20.13	72.02	38.25	109.70	90.16	64.27	100.25	19.51	65.09	17.88	85.73	61.41
40.24	91.73	59.21	21.00	61.07	37.13	109.32	69.27	59.33	110.14	19.74	48.44	19.06	85.94	63.84

Table F.13: Throughput Simulation Picking Times (Non-Overlapping Waves) — *continued*.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
39.48	107.90	62.36	19.67	66.58	36.85	109.10	79.73	60.36	116.70	19.10	64.54	19.54	81.17	58.56
39.18	92.98	63.84	19.32	58.16	38.34	109.37	81.25	62.45	113.14	19.65	58.98	19.44	84.95	70.24
38.94	113.77	60.86	19.43	67.60	37.74	108.92	69.15	59.17	111.62	19.25	57.42	19.73	77.64	65.95
39.49	113.45	68.12	20.15	55.22	37.06	109.84	76.25	59.31	97.79	19.20	57.25	17.93	78.26	61.67
38.97	112.72	61.32	20.49	60.74	38.05	108.79	65.69	55.67	109.56	20.18	56.96	19.55	87.36	66.96
40.17	75.10	65.03	19.31	58.54	38.81	108.84	83.07	69.47	101.63	19.27	61.11	18.61	71.51	56.18
40.18	95.55	74.32	21.58	62.73	38.49	108.97	85.83	61.86	113.38	20.07	55.28	20.19	88.25	62.12
39.83	110.84	66.40	21.65	71.78	36.96	109.13	77.57	60.46	95.13	20.05	65.87	19.62	85.27	54.72
40.30	107.30	67.36	18.91	62.03	38.43	109.80	82.91	61.93	105.08	18.01	60.63	19.44	87.95	61.54
40.81	105.05	71.47	20.68	66.85	37.66	108.95	88.13	59.85	102.07	18.94	67.03	19.18	70.56	59.93
39.17	101.43	64.23	18.14	66.08	37.86	109.34	93.89	57.10	116.21	19.71	72.15	19.21	70.36	50.47
39.56	104.61	69.48	19.66	64.61	37.80	109.79	90.10	58.59	95.51	17.88	69.24	19.45	82.15	60.39
39.79	105.98	60.32	19.06	64.38	38.11	109.55	73.97	67.14	113.58	21.46	60.12	19.37	86.06	58.32
39.38	107.93	66.40	20.22	66.34	37.45	109.87	70.14	56.09	120.64	20.74	73.45	20.45	85.72	68.19
38.64	108.00	52.75	19.63	62.25	36.55	109.95	70.96	58.27	110.89	21.52	67.47	20.23	79.85	50.23
39.86	94.75	62.66	19.13	56.52	38.13	109.51	82.62	57.20	116.06	19.89	62.10	20.02	83.31	62.77

Table F.14: Throughput Simulation Packing Times (Non-Overlapping Waves).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
41.00	Man.	Man.	20.33	Man.	40.32	123.47	Man.	Man.	Man.	20.99	Man.	22.56	Man.	Man.
43.70	Man.	Man.	20.72	Man.	41.77	120.77	Man.	Man.	Man.	20.34	Man.	19.66	Man.	Man.
38.10	Man.	Man.	19.83	Man.	40.43	120.98	Man.	Man.	Man.	19.92	Man.	20.94	Man.	Man.
41.84	Man.	Man.	18.80	Man.	35.46	123.36	Man.	Man.	Man.	21.98	Man.	18.76	Man.	Man.
40.62	Man.	Man.	20.67	Man.	38.17	120.54	Man.	Man.	Man.	20.55	Man.	21.58	Man.	Man.
42.21	Man.	Man.	20.56	Man.	42.83	120.58	Man.	Man.	Man.	23.32	Man.	19.51	Man.	Man.
42.28	Man.	Man.	20.46	Man.	42.57	118.72	Man.	Man.	Man.	20.17	Man.	20.19	Man.	Man.
40.49	Man.	Man.	20.35	Man.	42.64	116.33	Man.	Man.	Man.	20.54	Man.	19.94	Man.	Man.
41.27	Man.	Man.	22.04	Man.	42.09	118.99	Man.	Man.	Man.	20.51	Man.	20.05	Man.	Man.
41.29	Man.	Man.	20.15	Man.	41.35	120.56	Man.	Man.	Man.	19.79	Man.	19.74	Man.	Man.
43.14	Man.	Man.	20.12	Man.	40.83	122.03	Man.	Man.	Man.	20.89	Man.	20.75	Man.	Man.
41.41	Man.	Man.	20.70	Man.	38.62	121.12	Man.	Man.	Man.	23.46	Man.	20.45	Man.	Man.
39.42	Man.	Man.	19.61	Man.	41.87	123.93	Man.	Man.	Man.	18.80	Man.	20.97	Man.	Man.
40.07	Man.	Man.	20.03	Man.	40.76	123.15	Man.	Man.	Man.	20.88	Man.	21.12	Man.	Man.
39.89	Man.	Man.	20.04	Man.	43.09	123.16	Man.	Man.	Man.	20.02	Man.	21.44	Man.	Man.
41.41	Man.	Man.	21.05	Man.	40.95	123.84	Man.	Man.	Man.	21.14	Man.	20.08	Man.	Man.
39.21	Man.	Man.	20.29	Man.	41.71	120.82	Man.	Man.	Man.	20.36	Man.	21.09	Man.	Man.
38.11	Man.	Man.	21.17	Man.	39.28	122.55	Man.	Man.	Man.	20.27	Man.	21.06	Man.	Man.
39.43	Man.	Man.	21.42	Man.	40.99	119.65	Man.	Man.	Man.	20.43	Man.	21.03	Man.	Man.
41.34	Man.	Man.	21.30	Man.	41.47	122.84	Man.	Man.	Man.	20.92	Man.	20.57	Man.	Man.
38.46	Man.	Man.	21.21	Man.	42.20	123.47	Man.	Man.	Man.	19.84	Man.	20.53	Man.	Man.
41.03	Man.	Man.	20.25	Man.	41.14	120.02	Man.	Man.	Man.	21.76	Man.	21.88	Man.	Man.
39.86	Man.	Man.	21.46	Man.	43.03	120.72	Man.	Man.	Man.	21.22	Man.	21.96	Man.	Man.
39.98	Man.	Man.	20.57	Man.	39.81	124.96	Man.	Man.	Man.	20.04	Man.	19.98	Man.	Man.
41.72	Man.	Man.	20.38	Man.	39.75	125.49	Man.	Man.	Man.	20.43	Man.	18.89	Man.	Man.
40.33	Man.	Man.	20.55	Man.	42.00	121.62	Man.	Man.	Man.	20.44	Man.	20.43	Man.	Man.
41.48	Man.	Man.	20.47	Man.	41.36	122.75	Man.	Man.	Man.	19.85	Man.	22.66	Man.	Man.
40.45	Man.	Man.	20.30	Man.	45.16	120.97	Man.	Man.	Man.	20.80	Man.	20.22	Man.	Man.
41.07	Man.	Man.	20.54	Man.	41.64	119.64	Man.	Man.	Man.	19.68	Man.	20.54	Man.	Man.
40.88	Man.	Man.	21.70	Man.	42.90	119.16	Man.	Man.	Man.	20.87	Man.	19.33	Man.	Man.
41.50	Man.	Man.	20.50	Man.	38.41	122.17	Man.	Man.	Man.	21.70	Man.	21.07	Man.	Man.
40.58	Man.	Man.	19.05	Man.	39.35	115.89	Man.	Man.	Man.	20.86	Man.	22.81	Man.	Man.
40.79	Man.	Man.	21.17	Man.	40.94	119.26	Man.	Man.	Man.	19.98	Man.	21.95	Man.	Man.
41.22	Man.	Man.	20.56	Man.	38.84	122.00	Man.	Man.	Man.	20.39	Man.	18.03	Man.	Man.
41.73	Man.	Man.	20.39	Man.	39.03	117.46	Man.	Man.	Man.	21.11	Man.	21.23	Man.	Man.
40.55	Man.	Man.	19.74	Man.	44.10	116.52	Man.	Man.	Man.	22.11	Man.	21.09	Man.	Man.
40.01	Man.	Man.	21.40	Man.	40.18	119.41	Man.	Man.	Man.	20.58	Man.	21.10	Man.	Man.
40.29	Man.	Man.	21.65	Man.	41.33	121.80	Man.	Man.	Man.	20.65	Man.	20.25	Man.	Man.

Table F.14: Throughput Simulation Packing Times (Non-Overlapping Waves) — *continued*.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
39.97	Man.	Man.	20.45	Man.	37.77	120.52	Man.	Man.	Man.	19.23	Man.	21.50	Man.	Man.
41.11	Man.	Man.	20.79	Man.	41.18	115.38	Man.	Man.	Man.	22.11	Man.	20.71	Man.	Man.
39.02	Man.	Man.	21.14	Man.	39.61	121.80	Man.	Man.	Man.	21.51	Man.	21.16	Man.	Man.
40.70	Man.	Man.	21.45	Man.	41.25	121.54	Man.	Man.	Man.	20.15	Man.	20.87	Man.	Man.
41.04	Man.	Man.	20.69	Man.	43.56	120.58	Man.	Man.	Man.	20.21	Man.	19.70	Man.	Man.
39.84	Man.	Man.	20.26	Man.	42.23	122.07	Man.	Man.	Man.	20.90	Man.	19.81	Man.	Man.
40.72	Man.	Man.	20.91	Man.	40.73	126.17	Man.	Man.	Man.	19.86	Man.	18.31	Man.	Man.
41.91	Man.	Man.	21.14	Man.	39.84	118.50	Man.	Man.	Man.	18.83	Man.	19.89	Man.	Man.
40.75	Man.	Man.	20.03	Man.	43.28	123.20	Man.	Man.	Man.	20.52	Man.	22.30	Man.	Man.
41.95	Man.	Man.	18.54	Man.	40.86	120.49	Man.	Man.	Man.	21.81	Man.	20.95	Man.	Man.
40.03	Man.	Man.	20.58	Man.	43.15	109.78	Man.	Man.	Man.	20.54	Man.	20.84	Man.	Man.
40.54	Man.	Man.	20.81	Man.	43.63	118.76	Man.	Man.	Man.	22.30	Man.	19.26	Man.	Man.
41.05	Man.	Man.	21.25	Man.	36.86	117.60	Man.	Man.	Man.	21.23	Man.	20.67	Man.	Man.
41.41	Man.	Man.	20.20	Man.	39.46	119.29	Man.	Man.	Man.	19.21	Man.	21.80	Man.	Man.
41.01	Man.	Man.	20.46	Man.	40.41	121.07	Man.	Man.	Man.	21.60	Man.	20.60	Man.	Man.
41.04	Man.	Man.	20.76	Man.	39.93	120.74	Man.	Man.	Man.	21.15	Man.	22.00	Man.	Man.
42.60	Man.	Man.	20.53	Man.	42.00	121.12	Man.	Man.	Man.	20.71	Man.	21.08	Man.	Man.
41.36	Man.	Man.	21.03	Man.	40.52	120.94	Man.	Man.	Man.	19.70	Man.	20.09	Man.	Man.
40.06	Man.	Man.	20.65	Man.	40.33	115.56	Man.	Man.	Man.	22.85	Man.	20.86	Man.	Man.
39.95	Man.	Man.	21.75	Man.	43.84	113.04	Man.	Man.	Man.	22.36	Man.	20.68	Man.	Man.
40.35	Man.	Man.	20.83	Man.	41.01	121.21	Man.	Man.	Man.	22.27	Man.	21.62	Man.	Man.
42.05	Man.	Man.	20.52	Man.	41.19	122.82	Man.	Man.	Man.	20.66	Man.	21.64	Man.	Man.
40.93	Man.	Man.	21.42	Man.	39.39	119.56	Man.	Man.	Man.	22.12	Man.	20.82	Man.	Man.
40.65	Man.	Man.	20.28	Man.	41.66	122.82	Man.	Man.	Man.	21.49	Man.	21.52	Man.	Man.
41.40	Man.	Man.	20.54	Man.	42.50	116.32	Man.	Man.	Man.	20.81	Man.	20.64	Man.	Man.
42.41	Man.	Man.	20.31	Man.	36.87	121.10	Man.	Man.	Man.	21.31	Man.	21.45	Man.	Man.
41.57	Man.	Man.	21.89	Man.	42.09	123.55	Man.	Man.	Man.	23.39	Man.	20.24	Man.	Man.
41.12	Man.	Man.	20.25	Man.	41.03	120.90	Man.	Man.	Man.	19.67	Man.	20.71	Man.	Man.
40.40	Man.	Man.	20.09	Man.	41.72	116.29	Man.	Man.	Man.	21.20	Man.	18.72	Man.	Man.
42.04	Man.	Man.	20.82	Man.	39.44	121.16	Man.	Man.	Man.	21.74	Man.	21.28	Man.	Man.
40.08	Man.	Man.	21.48	Man.	40.90	123.12	Man.	Man.	Man.	23.38	Man.	22.33	Man.	Man.
42.13	Man.	Man.	20.60	Man.	39.08	118.86	Man.	Man.	Man.	19.82	Man.	21.08	Man.	Man.
40.95	Man.	Man.	20.76	Man.	38.78	120.40	Man.	Man.	Man.	19.98	Man.	21.97	Man.	Man.
41.08	Man.	Man.	21.10	Man.	40.86	120.99	Man.	Man.	Man.	21.26	Man.	20.32	Man.	Man.
40.66	Man.	Man.	20.75	Man.	38.77	120.82	Man.	Man.	Man.	20.83	Man.	20.14	Man.	Man.
40.33	Man.	Man.	20.83	Man.	41.28	122.99	Man.	Man.	Man.	19.40	Man.	20.13	Man.	Man.
40.33	Man.	Man.	20.77	Man.	42.33	121.72	Man.	Man.	Man.	19.49	Man.	19.97	Man.	Man.
41.36	Man.	Man.	20.18	Man.	44.45	120.48	Man.	Man.	Man.	20.99	Man.	20.16	Man.	Man.
40.39	Man.	Man.	21.10	Man.	40.80	120.51	Man.	Man.	Man.	21.18	Man.	21.05	Man.	Man.
42.11	Man.	Man.	20.81	Man.	40.27	120.11	Man.	Man.	Man.	19.45	Man.	20.69	Man.	Man.
40.03	Man.	Man.	21.74	Man.	39.86	120.41	Man.	Man.	Man.	22.30	Man.	21.15	Man.	Man.
41.41	Man.	Man.	21.52	Man.	40.30	119.69	Man.	Man.	Man.	20.24	Man.	21.29	Man.	Man.
40.72	Man.	Man.	21.41	Man.	38.88	119.27	Man.	Man.	Man.	20.74	Man.	19.85	Man.	Man.
40.80	Man.	Man.	20.79	Man.	39.93	122.58	Man.	Man.	Man.	22.51	Man.	20.56	Man.	Man.
41.61	Man.	Man.	20.90	Man.	39.36	120.23	Man.	Man.	Man.	20.38	Man.	20.75	Man.	Man.
40.11	Man.	Man.	21.59	Man.	40.88	120.86	Man.	Man.	Man.	22.19	Man.	20.95	Man.	Man.
41.07	Man.	Man.	19.08	Man.	37.53	119.17	Man.	Man.	Man.	20.75	Man.	21.56	Man.	Man.
40.48	Man.	Man.	20.20	Man.	41.46	118.50	Man.	Man.	Man.	20.48	Man.	19.32	Man.	Man.
40.30	Man.	Man.	20.00	Man.	39.55	117.98	Man.	Man.	Man.	20.18	Man.	22.25	Man.	Man.
40.67	Man.	Man.	20.03	Man.	40.28	120.06	Man.	Man.	Man.	20.30	Man.	21.84	Man.	Man.
41.09	Man.	Man.	20.40	Man.	44.87	120.37	Man.	Man.	Man.	20.46	Man.	21.89	Man.	Man.
41.70	Man.	Man.	20.47	Man.	36.66	121.17	Man.	Man.	Man.	19.19	Man.	20.17	Man.	Man.
41.33	Man.	Man.	20.38	Man.	44.42	120.38	Man.	Man.	Man.	22.01	Man.	20.23	Man.	Man.
41.73	Man.	Man.	21.13	Man.	40.13	120.22	Man.	Man.	Man.	21.81	Man.	21.99	Man.	Man.
40.37	Man.	Man.	20.84	Man.	40.49	121.01	Man.	Man.	Man.	21.43	Man.	21.02	Man.	Man.
40.42	Man.	Man.	20.02	Man.	39.29	121.07	Man.	Man.	Man.	20.18	Man.	20.43	Man.	Man.
40.52	Man.	Man.	19.76	Man.	41.24	118.56	Man.	Man.	Man.	21.15	Man.	19.57	Man.	Man.
40.01	Man.	Man.	20.36	Man.	40.63	127.49	Man.	Man.	Man.	20.05	Man.	22.42	Man.	Man.
42.95	Man.	Man.	21.10	Man.	42.81	121.22	Man.	Man.	Man.	20.54	Man.	20.93	Man.	Man.

Table F.14: Throughput Simulation Packing Times (Non-Overlapping Waves) — *continued*.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
41.66	Man.	Man.	20.81	Man.	41.80	125.30	Man.	Man.	Man.	20.27	Man.	21.65	Man.	Man.
40.18	Man.	Man.	22.48	Man.	41.21	124.01	Man.	Man.	Man.	21.20	Man.	20.04	Man.	Man.
41.87	Man.	Man.	20.39	Man.	41.00	119.76	Man.	Man.	Man.	21.56	Man.	20.80	Man.	Man.

Table F.15: Throughput Simulation Scaled Picking Times (Overlapping Waves).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
114.17	39.23	58.97	39.05	61.62	73.57	108.52	89.94	58.08	57.71	114.25	67.29	53.96	86.50	50.30
113.23	36.08	58.33	40.22	65.45	73.65	109.19	75.96	62.57	58.98	114.66	59.65	52.96	79.20	52.11
113.95	37.34	59.62	40.46	53.27	73.73	109.81	75.63	55.43	58.24	114.99	46.16	53.96	72.78	56.16
113.38	39.91	56.91	39.36	61.82	73.81	109.93	72.99	57.41	59.57	114.36	53.36	53.51	84.83	56.20
113.35	39.25	59.06	39.32	57.40	73.98	109.40	73.52	61.14	60.16	114.25	47.66	53.23	86.90	48.62
114.16	38.39	57.33	39.39	58.95	73.34	109.26	95.54	64.40	58.42	114.97	55.95	53.73	73.17	58.62
113.54	36.08	59.14	40.31	67.17	74.27	109.38	70.74	59.54	59.49	115.01	56.35	54.15	64.31	59.06
113.33	34.12	58.43	39.12	63.28	74.31	109.37	79.88	52.39	60.73	114.28	56.56	53.22	92.69	48.19
114.08	37.88	56.93	39.72	59.75	74.23	109.66	81.97	58.99	57.71	114.89	52.29	53.69	80.93	57.38
113.72	38.10	59.31	39.30	64.47	73.75	109.88	71.11	55.57	60.20	114.68	64.26	53.94	79.06	62.80
113.34	38.00	58.76	39.34	68.45	73.99	109.71	95.57	57.23	57.65	114.35	61.86	53.74	74.14	51.88
113.98	42.49	57.73	39.85	63.48	74.14	109.24	84.99	64.57	58.90	114.50	57.37	53.88	84.67	58.32
114.01	42.47	57.01	38.45	59.03	73.02	109.82	69.69	63.00	58.49	114.23	51.19	54.01	91.28	70.48
113.54	43.21	57.52	39.93	64.02	74.13	109.70	62.35	61.20	57.97	114.46	47.48	53.61	72.51	47.45
113.65	39.12	58.74	39.31	60.90	73.89	109.80	76.94	66.65	59.53	114.94	52.96	53.97	70.14	43.85
113.81	36.01	58.74	40.10	59.03	73.88	109.43	77.46	50.69	59.04	114.34	48.49	54.07	75.26	55.27
113.34	40.68	58.17	39.11	54.83	73.43	109.58	79.44	55.35	58.17	114.40	45.20	53.42	81.35	57.51
113.95	40.57	57.69	39.95	54.07	73.75	109.26	75.81	54.37	59.05	115.07	63.17	52.90	75.38	70.74
113.80	40.02	58.32	39.16	55.06	74.06	109.10	65.18	56.68	58.94	115.13	61.01	53.61	72.44	54.10
113.48	37.26	57.87	40.25	65.76	74.01	109.20	90.13	56.10	60.09	114.85	50.04	54.00	84.08	50.23
113.85	37.29	57.39	39.56	49.09	73.58	109.29	82.67	52.85	57.81	114.95	57.71	53.36	67.36	50.09
113.62	36.06	56.69	40.69	60.03	73.60	109.72	80.62	56.80	58.30	114.62	62.31	53.15	67.21	46.60
114.12	37.89	56.40	40.48	66.79	73.59	109.50	80.46	59.19	60.63	114.87	46.38	52.63	60.36	50.86
114.10	39.17	58.50	39.12	54.81	74.34	109.18	74.37	63.90	58.26	114.94	60.30	53.82	70.93	50.23
114.04	37.17	58.23	38.34	51.48	73.83	108.81	86.00	60.18	60.74	114.81	57.48	53.81	89.23	42.93
113.94	41.18	58.11	39.41	61.54	74.06	108.96	76.79	57.63	58.41	114.41	58.15	54.12	82.00	50.18
113.33	42.50	58.38	38.96	50.91	73.79	109.71	72.23	53.63	60.58	115.04	55.03	53.24	81.06	61.57
114.07	36.76	59.40	40.06	55.19	73.66	109.20	73.02	57.97	57.25	114.91	65.92	53.37	81.38	50.94
114.28	38.71	59.43	38.71	62.47	73.94	109.96	84.30	61.46	60.09	114.17	65.46	53.52	84.60	52.29
113.55	39.95	57.55	39.33	61.25	74.24	109.46	77.98	58.72	58.39	115.18	53.16	53.68	77.59	48.26
114.12	39.28	56.20	39.52	63.70	73.40	109.65	67.32	61.61	56.56	114.85	56.75	53.36	71.82	53.59
113.89	41.63	56.87	39.28	66.23	73.71	108.90	81.55	56.68	58.97	114.98	60.92	53.25	79.20	62.94
114.05	39.32	59.25	38.88	63.94	73.82	109.46	69.58	55.49	57.62	114.50	55.10	52.93	65.64	50.08
113.99	39.43	57.43	38.52	68.11	73.76	108.47	62.54	59.28	58.50	114.59	53.32	53.70	74.69	48.10
114.12	39.16	57.70	39.59	75.27	74.16	109.09	86.01	60.00	59.10	114.14	60.40	53.49	81.53	54.63
114.26	36.67	58.02	38.05	68.28	74.05	109.80	73.97	59.52	60.11	114.87	60.09	53.52	84.35	47.93
114.02	41.74	58.66	38.78	57.72	74.16	109.30	84.57	61.79	57.27	114.32	48.79	54.19	84.73	59.50
113.48	35.97	58.52	38.95	69.23	73.81	109.70	71.30	58.74	59.42	114.31	57.27	53.48	69.28	67.37
113.94	41.28	57.38	40.04	56.39	74.06	109.44	69.16	56.72	59.64	114.78	46.24	52.54	70.11	47.08
113.89	41.05	58.87	39.56	60.03	73.50	109.58	76.47	60.91	59.67	114.67	55.35	53.31	87.58	40.24
113.45	41.93	57.36	38.61	69.26	73.82	109.61	65.47	57.28	59.70	114.55	50.24	53.59	79.91	46.25
113.88	37.31	59.07	38.86	51.44	73.58	109.93	78.33	58.13	57.76	114.60	56.88	53.87	75.63	49.05
114.14	39.24	58.33	38.89	64.15	74.19	109.83	81.55	53.63	57.89	114.56	51.64	52.96	84.34	58.24
114.14	40.63	58.15	38.92	50.63	74.00	110.00	71.80	61.01	57.91	114.71	54.04	53.53	85.00	59.95
113.32	37.16	58.65	39.13	62.30	73.65	108.75	97.09	59.15	60.15	114.40	50.89	53.84	72.45	58.30
113.65	40.50	58.20	39.36	55.08	74.34	109.62	61.24	60.96	57.33	114.26	56.27	53.30	75.69	56.94
113.76	41.16	58.08	40.62	57.69	73.38	109.39	84.40	55.65	58.82	114.61	52.52	53.29	86.91	63.62
113.75	38.60	57.98	39.38	58.22	73.98	109.07	80.40	59.41	58.51	114.59	58.09	53.54	86.88	51.44
113.57	39.79	58.18	39.15	59.85	74.35	109.84	77.62	62.38	58.54	114.38	50.35	53.62	72.85	60.72
114.08	36.18	58.52	39.57	58.29	73.43	109.21	72.13	53.75	57.36	114.93	47.72	53.63	75.82	53.08
113.62	38.56	58.61	38.84	70.74	73.89	109.27	74.29	61.21	59.69	114.95	59.40	53.51	64.65	62.16

Table F.15: Throughput Simulation Scaled Picking Times (Overlapping Waves) — *continued*.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
113.50	36.76	57.97	39.18	57.76	73.79	109.27	72.29	63.38	60.25	114.34	46.01	53.66	77.08	54.61
114.17	41.22	59.09	39.63	51.19	73.87	109.28	85.92	60.75	57.17	114.36	60.92	53.86	64.91	52.62
113.49	38.42	57.65	39.80	55.70	73.83	109.16	79.98	57.89	59.67	115.07	59.27	53.92	80.19	55.62
114.06	39.99	58.10	39.84	52.73	74.08	110.01	79.73	61.30	56.08	114.29	58.48	53.29	68.10	60.26
113.98	38.46	57.82	38.51	57.24	73.67	108.72	59.47	64.01	58.29	114.78	59.26	53.63	82.42	54.45
113.42	40.67	58.76	39.58	49.38	73.65	109.86	82.55	55.71	61.39	114.48	48.31	53.41	78.20	59.03
113.77	37.97	58.62	38.76	62.58	73.28	109.38	75.53	60.65	57.37	114.48	51.73	53.89	84.87	51.36
113.30	40.35	59.29	39.46	63.95	74.04	109.36	67.37	59.49	60.67	114.66	60.85	53.72	74.58	60.11
114.00	41.25	59.26	39.63	58.36	73.94	109.60	77.18	59.10	60.79	114.77	60.65	54.36	70.13	56.07
114.12	38.65	58.55	40.07	56.06	73.78	109.13	66.76	61.81	57.59	115.18	53.89	53.40	81.21	58.24
113.81	40.47	58.43	39.97	65.01	74.18	109.25	89.48	58.65	61.35	114.65	50.68	53.45	84.81	59.33
113.78	39.85	57.44	40.00	49.70	73.75	109.56	86.26	64.15	61.12	114.80	52.68	53.39	86.66	53.33
113.51	39.24	58.84	39.81	70.16	74.09	108.69	91.60	61.05	59.15	114.90	56.42	54.28	68.06	53.38
113.51	41.81	57.62	39.76	62.91	74.36	109.00	88.75	63.21	58.27	114.84	52.11	54.15	82.48	52.22
114.13	36.59	58.41	39.79	55.17	73.75	109.67	86.15	57.53	57.68	114.94	62.36	53.03	84.33	54.85
113.49	37.10	58.06	39.16	59.35	73.81	108.99	76.24	60.41	60.61	114.72	58.69	53.53	81.72	42.40
114.09	37.99	58.13	39.16	51.49	73.40	109.81	79.25	62.22	57.74	115.07	50.95	53.75	68.65	41.82
113.39	38.57	58.04	39.49	63.80	73.20	109.81	67.59	52.38	59.43	114.84	56.54	53.69	83.95	57.62
113.82	39.27	59.42	39.02	56.95	73.79	109.31	76.85	55.71	57.78	114.89	44.03	54.09	75.46	57.19
113.61	40.63	58.85	40.18	65.61	74.05	109.46	96.33	54.99	61.41	114.32	50.14	53.86	70.12	68.59
113.26	41.20	56.71	39.60	67.40	73.35	109.66	89.96	57.12	59.03	114.28	45.93	53.53	84.03	60.63
114.13	36.75	59.06	38.81	60.25	73.69	109.40	81.04	57.73	60.30	115.07	48.66	54.16	70.41	50.41
114.28	36.47	56.97	39.79	60.83	73.57	108.70	84.29	59.75	58.26	114.60	57.23	52.61	84.13	52.05
114.25	37.43	57.56	38.96	62.66	73.67	109.73	77.76	62.83	58.80	114.40	55.95	54.04	75.11	59.67
113.34	40.60	58.62	40.16	69.32	73.46	109.80	76.32	60.29	61.33	114.67	58.27	53.88	75.00	47.36
113.59	41.07	58.13	39.43	69.60	73.34	109.69	82.36	50.18	59.47	114.72	53.78	53.52	79.44	58.52
113.34	40.43	57.58	39.60	65.69	73.76	109.77	86.36	59.25	58.95	114.97	57.35	53.50	86.91	51.67
114.02	40.66	58.12	39.09	54.86	73.80	109.02	77.76	58.88	59.42	114.44	53.21	53.75	84.77	58.99
113.30	38.65	58.85	38.58	60.25	73.93	109.62	75.81	55.20	59.65	114.25	48.33	53.29	72.07	56.14
113.56	36.63	58.97	39.00	63.32	73.40	109.86	72.65	61.23	60.76	115.20	60.98	53.60	73.35	51.87
113.47	41.76	60.16	39.34	63.08	74.33	109.94	92.80	53.53	61.81	114.80	56.65	53.43	77.35	54.15
113.36	39.08	57.07	39.41	56.14	73.63	109.70	82.84	60.49	59.68	114.67	60.33	54.29	80.44	48.39
113.58	34.94	58.62	40.00	62.68	74.11	109.32	65.90	59.69	59.42	114.44	61.42	53.40	71.64	65.13
113.36	39.27	57.68	40.59	47.45	73.37	109.10	83.85	59.44	58.20	114.51	59.17	52.99	69.04	56.97
114.00	41.82	59.39	39.22	63.74	74.00	109.37	61.27	60.52	58.50	115.02	62.14	53.82	88.29	64.59
114.17	35.38	58.42	40.02	56.68	74.30	108.92	82.65	51.60	60.09	115.17	45.15	54.17	81.34	54.44
113.36	35.20	57.11	40.19	64.61	73.64	109.84	79.39	57.06	60.01	115.06	51.61	53.86	77.98	65.24
113.42	42.60	58.01	40.01	63.47	74.12	108.79	78.82	63.81	57.19	114.29	62.74	53.76	78.70	50.31
113.21	37.94	57.35	39.31	47.96	73.56	108.84	77.92	55.66	58.93	114.78	55.91	53.36	65.59	46.51
113.81	36.65	58.12	40.33	61.41	73.99	108.97	65.23	57.78	57.74	115.11	54.66	53.93	69.82	51.74
113.86	39.95	58.13	39.98	56.15	73.47	109.13	75.82	58.34	61.22	114.82	56.06	53.92	72.71	55.00
114.02	33.38	58.51	39.77	70.45	73.97	109.80	89.16	56.46	59.46	114.41	55.89	53.17	77.67	62.05
114.11	37.88	59.15	39.71	59.68	73.76	108.95	77.30	57.80	59.62	114.25	62.36	53.13	92.33	57.25
113.78	39.91	58.03	38.63	58.02	73.97	109.34	67.25	57.60	60.01	114.17	63.67	54.20	67.98	50.41
113.77	39.85	58.71	39.40	67.47	74.10	109.79	68.38	55.21	57.94	114.98	55.54	53.60	72.32	56.86
113.57	39.89	58.18	39.94	50.78	73.62	109.55	74.93	56.12	59.62	114.96	65.92	53.80	70.99	58.23
113.92	42.30	58.81	40.31	61.39	73.75	109.87	64.55	59.30	60.06	115.00	44.11	53.60	68.00	50.70
113.49	37.19	57.48	39.33	43.39	73.48	109.95	66.25	60.09	56.53	115.18	51.35	54.18	84.57	51.75
113.64	41.28	58.58	40.24	52.92	73.58	109.51	69.04	57.36	58.52	114.83	59.68	53.87	66.92	52.92

Table F.16: Throughput Simulation Scaled Packing Times (Overlapping Waves).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
118.03	42.451	59.613	38.783	Man.	77.469	115.13	Man.	Man.	57.078	112.76	Man.	56.119	Man.	Man.
117.98	39.511	60.235	38.652	Man.	78.009	114.42	Man.	Man.	58.04	110.78	Man.	56.919	Man.	Man.
116.76	40.129	60.065	39.374	Man.	76.648	114.66	Man.	Man.	57.592	110.78	Man.	56.165	Man.	Man.
118.91	40.55	59.8	38.927	Man.	75.157	115.99	Man.	Man.	57.941	112.03	Man.	55.575	Man.	Man.

Table F.16: Throughput Simulation Scaled Packing Times (Overlapping Waves) — *continued*.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
117.64	39.544	59.769	39.828	Man.	77.719	115.27	Man.	Man.	57.537	111.4	Man.	56.733	Man.	Man.
118.69	39.723	59.613	38.931	Man.	75.47	117.3	Man.	Man.	57.882	112.23	Man.	56.03	Man.	Man.
117.5	41.141	59.943	38.49	Man.	76.077	116.97	Man.	Man.	58.025	110.43	Man.	55.916	Man.	Man.
116.37	38.997	60.299	39.298	Man.	79.126	115.85	Man.	Man.	56.575	111.82	Man.	56.26	Man.	Man.
117.15	39.619	60.649	39.246	Man.	78.441	117.13	Man.	Man.	56.863	111.09	Man.	56.084	Man.	Man.
117.84	39.624	59.515	39.695	Man.	77.109	115.54	Man.	Man.	58.638	111.93	Man.	56.336	Man.	Man.
117.2	39.55	59.73	39.081	Man.	78.101	116.6	Man.	Man.	57.559	112.22	Man.	56.528	Man.	Man.
118.99	40.403	59.563	39.461	Man.	76.313	114.37	Man.	Man.	57.638	112.86	Man.	57.559	Man.	Man.
117.7	39.391	60.051	39.514	Man.	77.047	117.05	Man.	Man.	58.305	112.54	Man.	55.465	Man.	Man.
117.26	40.323	59.69	39.376	Man.	74.658	115.05	Man.	Man.	58.87	112.48	Man.	55.083	Man.	Man.
118.45	40.464	60.308	39.738	Man.	77.435	115.34	Man.	Man.	59.134	113.94	Man.	56.624	Man.	Man.
117.39	39.116	59.655	39.413	Man.	77.494	115.34	Man.	Man.	59.266	112.33	Man.	56.386	Man.	Man.
117.79	40.217	59.955	38.743	Man.	77.726	113.94	Man.	Man.	58.195	112.07	Man.	55.668	Man.	Man.
118.08	40.211	60.18	39.009	Man.	78.001	116.73	Man.	Man.	57.263	112.15	Man.	55.497	Man.	Man.
117.37	39.028	59.907	39.616	Man.	76.794	115.3	Man.	Man.	59.421	111.8	Man.	56.676	Man.	Man.
116.21	39.694	59.955	39.095	Man.	77.076	115.7	Man.	Man.	57.355	110.96	Man.	55.539	Man.	Man.
116.8	40.723	59.749	39.322	Man.	75.991	112.23	Man.	Man.	56.051	110.32	Man.	55.126	Man.	Man.
118.36	38.991	60.226	39.441	Man.	76.781	114.69	Man.	Man.	55.467	112.85	Man.	56.118	Man.	Man.
115.78	40.339	59.832	39.344	Man.	76.06	117.35	Man.	Man.	57.115	112.66	Man.	56.424	Man.	Man.
117.43	39.107	59.496	38.955	Man.	76.491	115.04	Man.	Man.	56.565	112.84	Man.	56.695	Man.	Man.
116.39	40.333	59.707	39.693	Man.	77.606	115.74	Man.	Man.	58.077	113.15	Man.	55.004	Man.	Man.
118.76	39.724	59.939	39.062	Man.	75.312	117.58	Man.	Man.	56.834	110.89	Man.	56.077	Man.	Man.
118.86	40.15	60.195	38.465	Man.	78.085	114.79	Man.	Man.	58.611	112.09	Man.	55.645	Man.	Man.
117.24	40.197	59.869	39.646	Man.	75.425	118.46	Man.	Man.	56.785	112.27	Man.	55.971	Man.	Man.
117.02	39.336	59.942	39.451	Man.	77.463	112.7	Man.	Man.	57.116	111.56	Man.	55.643	Man.	Man.
116.74	39.464	59.659	39.055	Man.	76.105	119.49	Man.	Man.	57.553	111.04	Man.	55.929	Man.	Man.
117.05	38.832	60.115	39.392	Man.	77.12	112.66	Man.	Man.	59.151	112.07	Man.	55.868	Man.	Man.
117.91	38.838	59.731	39.244	Man.	77.225	114.22	Man.	Man.	56.915	111.2	Man.	55.227	Man.	Man.
116.24	39.439	59.85	38.567	Man.	76.289	113.41	Man.	Man.	57.331	110.19	Man.	55.751	Man.	Man.
116.8	40.736	60.174	39.384	Man.	77.573	117.76	Man.	Man.	56.597	111.42	Man.	56.626	Man.	Man.
117.64	41.431	59.977	38.506	Man.	77.187	114.95	Man.	Man.	57.714	110.37	Man.	55.439	Man.	Man.
116.43	40.867	60.049	39.188	Man.	77.414	115.43	Man.	Man.	59.019	112.05	Man.	55.52	Man.	Man.
115.78	39.863	60.11	38.938	Man.	79.986	115.4	Man.	Man.	58.393	111.85	Man.	56.146	Man.	Man.
118.19	39.681	59.841	39.693	Man.	75.552	113.26	Man.	Man.	57.574	111.75	Man.	56.055	Man.	Man.
116.84	40.367	59.786	39.351	Man.	77.302	114.03	Man.	Man.	59.337	113.51	Man.	56.145	Man.	Man.
117.71	40.814	59.961	38.349	Man.	79.205	115.79	Man.	Man.	57.403	111.12	Man.	55.909	Man.	Man.
115.23	39.39	59.772	39.461	Man.	78.625	115.64	Man.	Man.	56.99	111.2	Man.	56.046	Man.	Man.
117.92	39.526	59.937	38.942	Man.	79.978	114.8	Man.	Man.	58.986	109.5	Man.	56.912	Man.	Man.
117.13	39.806	59.786	38.39	Man.	78.76	114.2	Man.	Man.	57.871	112.92	Man.	56.975	Man.	Man.
117.56	38.829	59.772	39.223	Man.	76.842	116.35	Man.	Man.	58.965	112.51	Man.	56.41	Man.	Man.
115.98	39.896	59.513	39.035	Man.	75.608	112.56	Man.	Man.	60.662	110.67	Man.	56.915	Man.	Man.
116.64	40.216	59.932	39.157	Man.	75.251	114.92	Man.	Man.	57.327	112.31	Man.	56.333	Man.	Man.
115.26	41.335	60.058	38.648	Man.	78.489	115.7	Man.	Man.	59.477	112.07	Man.	56.038	Man.	Man.
117.69	38.268	59.954	39.051	Man.	76.774	114.6	Man.	Man.	56.582	111.02	Man.	56.699	Man.	Man.
116.55	39.47	59.67	39.877	Man.	78.245	114.79	Man.	Man.	56.176	111.78	Man.	55.653	Man.	Man.
116.57	38.484	60.207	39.313	Man.	77.575	115.28	Man.	Man.	58.525	113.12	Man.	56.876	Man.	Man.
116.16	39.062	59.992	39.313	Man.	76.088	116.27	Man.	Man.	58.159	112.29	Man.	54.833	Man.	Man.
116.58	40.292	59.414	39.26	Man.	79.281	116.8	Man.	Man.	59.167	111.55	Man.	56.17	Man.	Man.
117.46	39.914	60.053	39.583	Man.	76.884	115.79	Man.	Man.	56.998	113.04	Man.	55.536	Man.	Man.
117.12	41.301	60.06	39.344	Man.	77.337	114.92	Man.	Man.	58.862	111.22	Man.	56.046	Man.	Man.
117.09	39.524	59.328	38.841	Man.	78.272	115.11	Man.	Man.	56.513	112.06	Man.	55.665	Man.	Man.
116.44	38.974	60.019	38.23	Man.	76.231	115.12	Man.	Man.	57.341	111.77	Man.	56.738	Man.	Man.
117.26	40.854	59.53	40.091	Man.	78.131	113.55	Man.	Man.	57.957	111.27	Man.	57.512	Man.	Man.
117.42	39.158	60.08	39.263	Man.	75.984	113.17	Man.	Man.	57.658	111.78	Man.	56.58	Man.	Man.
118.48	39.421	59.674	38.394	Man.	77.076	114.97	Man.	Man.	57.957	112.45	Man.	56.611	Man.	Man.
117.67	39.714	59.931	39.986	Man.	78.296	117.37	Man.	Man.	58.717	112.88	Man.	55.992	Man.	Man.
116.39	39.803	59.871	38.99	Man.	76.826	113.57	Man.	Man.	57.562	112.69	Man.	55.643	Man.	Man.
118.85	40.349	59.903	39.428	Man.	78.436	118.89	Man.	Man.	57.383	111.66	Man.	56.471	Man.	Man.

Table F.16: Throughput Simulation Scaled Packing Times (Overlapping Waves) — *continued*.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
116.47	39.077	60.119	39	Man.	76.729	115.09	Man.	Man.	57.337	111.58	Man.	55.838	Man.	Man.
116.17	39.951	59.682	39.225	Man.	77.473	117.71	Man.	Man.	57.808	111.76	Man.	57.103	Man.	Man.
117.36	41.152	60.001	37.934	Man.	77.191	116.24	Man.	Man.	58.258	111.05	Man.	56.093	Man.	Man.
118.33	39.288	59.936	38.717	Man.	75.993	115.49	Man.	Man.	58.148	112.58	Man.	54.955	Man.	Man.
116.48	39.522	59.789	39.443	Man.	75.545	114.87	Man.	Man.	59.312	111.48	Man.	56.07	Man.	Man.
117.47	39.646	59.941	38.847	Man.	77.007	115.42	Man.	Man.	56.619	111.88	Man.	54.875	Man.	Man.
118.76	39.361	60.396	39.198	Man.	76.386	113.79	Man.	Man.	58.59	112.11	Man.	54.876	Man.	Man.
118.4	39.39	60.06	39.032	Man.	77.925	116.98	Man.	Man.	57.07	111.94	Man.	56.034	Man.	Man.
117.89	41.069	60.293	38.875	Man.	77.283	115.2	Man.	Man.	57.749	112.16	Man.	56.206	Man.	Man.
117.07	39.36	59.561	39.826	Man.	75.353	115.45	Man.	Man.	58.707	112.44	Man.	55.553	Man.	Man.
118.96	39.863	59.577	38.956	Man.	77.034	115.58	Man.	Man.	57.201	111.39	Man.	56.343	Man.	Man.
114.86	40.733	59.813	39.335	Man.	75.902	117.61	Man.	Man.	57.965	112.34	Man.	54.757	Man.	Man.
118.54	40.89	59.855	38.746	Man.	76.239	116.65	Man.	Man.	57.846	112.04	Man.	55.286	Man.	Man.
116.7	39.817	59.683	39.612	Man.	78.601	117.83	Man.	Man.	57.147	112.3	Man.	57.177	Man.	Man.
115.91	39.279	60.246	38.47	Man.	76.446	116.62	Man.	Man.	57.705	110.85	Man.	56.626	Man.	Man.
119.39	39.619	59.931	39	Man.	72.379	114.99	Man.	Man.	57.5	111.24	Man.	54.054	Man.	Man.
116.83	40.031	59.897	39.075	Man.	77.223	113.89	Man.	Man.	56.776	110.86	Man.	55.209	Man.	Man.
117.8	39.488	59.837	39.037	Man.	77.788	114.74	Man.	Man.	57.243	111.36	Man.	57.282	Man.	Man.
117.58	40.363	59.955	39.219	Man.	74.456	114.88	Man.	Man.	57.98	113.41	Man.	56.433	Man.	Man.
115.76	41.044	60.086	38.893	Man.	77.311	115.03	Man.	Man.	55.644	112.49	Man.	55.91	Man.	Man.
116.33	40.49	59.622	38.631	Man.	75.484	117.27	Man.	Man.	57.581	110.28	Man.	56.401	Man.	Man.
116.96	41.103	60.001	39.163	Man.	74.873	113.79	Man.	Man.	58.259	112.62	Man.	54.962	Man.	Man.
117.28	40.16	59.981	38.552	Man.	74.732	115.24	Man.	Man.	56.29	109.85	Man.	56.586	Man.	Man.
116.42	39.408	59.686	39.777	Man.	77.143	118.21	Man.	Man.	59.003	109.93	Man.	56.098	Man.	Man.
116.78	41.812	59.849	39.244	Man.	77.426	113.32	Man.	Man.	57.545	113.01	Man.	54.828	Man.	Man.
116.27	40.795	59.642	39.452	Man.	77.055	115.17	Man.	Man.	56.453	111.55	Man.	55.665	Man.	Man.
118.68	38.992	59.731	39.255	Man.	76.59	117.32	Man.	Man.	56.772	111.93	Man.	56.715	Man.	Man.
117.97	39.912	59.744	38.449	Man.	77.115	116.53	Man.	Man.	56.642	110.96	Man.	55.859	Man.	Man.
118.14	39.659	59.844	39.646	Man.	77.82	114.77	Man.	Man.	58.852	112.98	Man.	56.57	Man.	Man.
117.8	40.071	59.924	40.256	Man.	76.662	115.47	Man.	Man.	54.96	111.45	Man.	57.156	Man.	Man.
118.89	39.039	59.889	39.259	Man.	77.036	117.02	Man.	Man.	57.369	110.92	Man.	55.101	Man.	Man.
116.59	40.262	60.042	38.783	Man.	79.377	115.17	Man.	Man.	59.049	111.79	Man.	56.13	Man.	Man.
118.88	40.262	59.313	39.232	Man.	75.344	115.57	Man.	Man.	59.689	112.89	Man.	55.332	Man.	Man.
116.68	41.411	59.814	39.238	Man.	75.784	115.74	Man.	Man.	58.602	112.55	Man.	56.214	Man.	Man.
116.19	40.923	59.758	39.053	Man.	77.623	115.24	Man.	Man.	58.06	112.43	Man.	56.067	Man.	Man.
118.86	39.663	59.955	39.723	Man.	74.77	114.02	Man.	Man.	56.267	111.52	Man.	57.323	Man.	Man.
118	39.147	59.663	38.741	Man.	77.152	115.46	Man.	Man.	58.685	110.19	Man.	56.714	Man.	Man.
117.3	39.893	60.129	39.508	Man.	75.282	114.36	Man.	Man.	57.115	111.94	Man.	56.092	Man.	Man.

Table F.17: Throughput Simulation Scaled Picking Times (Non-Overlapping Waves).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
39.02	109.771	67.72	19.33	76.39	37.35	108.52	53.53	61.64	92.524	18.15	53.93	21.23	68.94	53.39
39.32	92.5401	48.96	19.24	63.89	37.82	109.19	86	57.31	86.85	19.27	50.21	19.05	79.55	49.74
39.88	101.02	57.4	19.69	63.7	37.33	109.81	91.78	57.01	97.219	18.64	50.88	19.45	67.21	41.31
39.46	88.9527	65.04	20.59	57.32	36.55	109.93	62.03	59.37	80.903	18.71	55.73	20.56	79.13	55.12
38.92	107.838	52.9	19.69	76.41	37.28	109.4	67.43	55.14	80.136	19.33	52.57	19.37	79.38	53.23
39.01	98.6416	52.44	19.9	44.88	38.31	109.26	86.77	54.5	100.32	18.82	47.81	19.11	89.52	55.66
39.31	104.341	68.71	18.65	63.77	37.42	109.38	62.25	58.21	97.256	19.36	41.96	18.86	70.66	53.91
38.78	110.881	60.14	19.7	58.59	37.85	109.37	77.02	56.66	104.69	19.01	51.81	19.67	79.75	54.53
39.18	104.107	62.01	19.97	67.1	37.85	109.66	66.54	66.91	92.252	19.67	46.04	18.77	77.25	45.88
39.56	98.7624	56.64	17.97	59.07	37.19	109.88	75.05	57.71	105.24	20.61	58.53	18.98	66.66	57.37
39.78	103.471	62.61	19.73	65.77	38.26	109.71	58.34	57.86	96.317	18.66	49.48	19.87	77.33	51.64
39.26	89.8118	47.51	18.54	59.23	37.24	109.24	80.89	63.7	84.047	20.15	49.12	19	73.88	66.7
39.44	91.0965	59.79	19.63	64.2	37.17	109.82	73.05	58.26	93.544	17.13	59.86	19.87	60.48	52.47
39.13	89.5472	57.09	20.2	55.75	37.66	109.7	79.1	58.32	98.105	20.21	61.82	19.32	71.12	47.98
40.12	87.6955	61.41	18.97	60.27	37.27	109.8	73.17	54.64	89.573	18.58	57.59	18.25	67.11	51.14

Table F.17: Throughput Simulation Scaled Picking Times (Non-Overlapping Waves) —
continued.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
39.13	106.503	60.71	19.7	61.97	38.1	109.43	86.8	50.55	88.282	20.16	54.69	20.81	83.83	49.14
39.54	95.6937	64.19	19.22	50.21	37	109.58	79.13	59.11	93.976	18.59	55.74	19.58	82.3	44.69
38.76	106.371	63.67	19.51	67.85	36.85	109.26	76.47	57.26	100.25	19.28	61.44	19.74	76.91	59.72
39.95	88.8949	72.2	17.77	56.78	37.58	109.1	77.09	60.56	93.26	20.56	69.49	18.36	84.16	45.26
39.07	110.456	56.9	18.61	71.16	37.73	109.2	67.57	58.29	78.703	18.88	56.15	20.91	82.97	59.08
38.17	93.0562	63.95	18.09	58.23	38.47	109.29	80.08	58.03	99.222	19.52	53.53	18.76	60.06	57.3
39.07	97.5033	54.38	20.72	46.83	39.09	109.72	76.21	56.76	97.398	19.24	56.03	18.89	83.57	42.13
40.12	96.589	67.56	19.71	60.89	36.2	109.5	63.66	57.96	81.798	20.59	53.27	20.85	77.03	56.08
38.9	92.5648	63.45	19.42	56.05	38.07	109.18	88.9	56.54	94.22	17.85	59.35	20.27	74.07	61.62
40.02	91.4534	64.6	19.12	65.55	38.07	108.81	52.37	51.3	89.685	19.28	52.52	19.34	70.82	44.97
39.49	90.6439	67.14	19.68	55.73	37.31	108.96	86.71	58.44	91.511	19.64	61.63	18.64	76.83	50.79
39.58	101.915	55.73	19.86	59.71	36.91	109.71	79.36	59.92	91.459	18.42	51.8	17.89	64.86	48.66
38.77	118.413	54.89	18.87	73.26	37.8	109.2	82.88	58.65	94.83	21.69	53.27	19.58	76.07	48.68
39.17	91.4432	56.34	17.83	56.53	37.49	109.96	72.18	61.25	88.169	18.75	51.93	19.81	81.9	60.36
39.75	96.0741	66.11	20.29	57.09	37.37	109.46	78.96	58.41	94.689	19.67	53.81	19.47	75.45	54.42
38.42	96.8714	62.78	20.34	45.13	38.07	109.65	80.1	54.26	90.763	19.17	56.86	19.33	72.59	50.95
40.23	94.741	63.67	19.11	55.71	37.37	108.9	82.76	58.28	88.985	19.53	54.83	19.97	78.03	45.02
39.13	97.1351	67.53	19.9	67.32	38.58	109.46	74.85	56.88	86.948	22	58.39	19.3	86.59	47.91
39.6	95.3865	55.58	20.65	65.22	37.47	108.47	77.09	57.8	80.599	20.16	49.07	18.83	82.15	54.95
39.52	93.6732	67.78	20.56	69.71	38.42	109.09	61.3	53.67	92.227	18.6	48.76	21.03	70.85	57.42
38.9	104.559	69.62	19.65	66.91	39.15	109.8	75.43	55.38	94.397	18.23	58.09	19.61	68.92	51.94
39.92	98.9651	59.49	18.73	50.36	37.64	109.3	77.4	48.9	74.272	20.15	48.71	19.86	81.77	56.62
40.33	107.104	51.94	17.55	57.81	37.42	109.7	72.79	56.89	88.383	18.81	59.14	19.42	73.46	52.13
39.23	90.6587	59.32	20.28	60.2	36.27	109.44	70.71	54.23	102.78	19.86	62.98	20.5	79.67	55.39
38.97	88.0106	63.48	19.66	60.7	37.54	109.58	80.1	55.49	99.664	19.32	49.29	19.1	69.61	51.28
39.2	86.128	57.52	19.45	59.38	37.99	109.61	85.3	58.73	89.627	18.47	53.44	19	82.37	49.43
38.88	109.513	54.46	19.84	63.35	38.26	109.93	74.9	61.12	80.62	19.96	53.62	21.85	72.52	63.99
39.82	101.652	62.74	19.17	61.59	37.77	109.83	81.42	56.23	93.433	20.4	45.04	20.83	78.59	66.75
39.57	104.407	54.26	19.82	57.57	36.35	110	77.48	61.66	100.69	18.65	57.71	18.07	78.33	51.36
39.84	100.445	72.8	19.89	61.71	36.72	108.75	86.64	58.04	93.893	18.52	48.58	18.17	89.89	65.03
39.44	95.8998	66.07	18.97	62.01	37.44	109.62	83.59	62.27	91.165	19.13	48.35	19.02	66.39	49.62
38.15	89.1839	47.02	20.31	53.39	37.24	109.39	68.2	54.7	88.202	19.8	49.22	20.89	79.9	52.34
39.66	113.584	60.85	19.48	70.37	37.64	109.07	79.33	59.31	98.614	19.07	55.74	18.05	74.97	57.42
39.57	104.443	55.72	20.54	63.73	36.7	109.84	65.18	68.44	99.74	18.06	61.53	19.28	71.42	57.56
38.44	101.87	56.03	20.13	63.39	38.29	109.21	80	61.03	56.285	19.96	48.99	18.78	75.37	49.88
39.67	95.7448	57.63	19.2	55.83	37.65	109.27	72.62	61.62	94.761	20.38	45.58	20.54	78.36	46.92
39.79	95.6011	64.26	18.04	51.57	37.62	109.27	70.72	52.61	81.464	19.36	51.86	18.31	86.92	44.59
39.46	104.739	54.74	18.62	54.53	37.22	109.28	69.42	50.77	81.099	18.34	52.49	19.88	71.73	54.03
39.4	110.277	49.72	18.68	50.48	36.53	109.16	69.9	57.68	105.78	19.72	58.64	19.37	63.79	56.59
39.19	107.811	59.16	18.84	52.17	37.42	110.01	76.46	56.35	91.001	19.96	65.34	19.73	69.7	42.2
38.15	97.1264	67.62	19.13	54.27	36.98	108.72	71.09	58.88	87.91	19.13	53.22	19.73	79.39	58.67
39.24	100.966	67.91	20.86	64.87	37.32	109.86	82.29	53.13	92.189	20.35	52.61	19.16	75.68	55.65
39.48	100.215	59.09	20.13	68.61	38.23	109.38	72.51	49	87.516	18.21	51.15	18.73	89.81	50.56
39.43	111.05	64.35	19.99	64.15	37.44	109.36	82.64	54.33	96.826	19.19	68.23	17.89	83.83	64.52
39.56	101.655	57.85	19.38	58.82	38.38	109.6	76.47	53.11	102.67	19.61	50.77	19.08	82.18	56.59
39.26	116.38	54.02	19.42	57.54	37.43	109.13	86.76	59.33	89.09	18.73	59.27	19.24	78.83	55.14
38.68	105.645	59.89	18.86	51.83	37.98	109.25	85.33	59.48	82.983	18.95	57.97	19.03	72.72	57.63
39.09	98.5079	60.68	20.57	60.91	37.48	109.56	78.34	50.59	99.362	20	64.54	18.48	59.51	48.75
39.39	107.741	57.76	18.87	64.64	37.19	108.69	78.79	61.66	94.612	19.71	50.76	18.72	72.16	60.28
39.49	113.743	68.35	20.25	62.61	37.89	109	56.65	60.05	88.287	18.8	44.4	19.26	89.12	59.04
39.52	97.9526	55.37	19.45	53.57	38.55	109.67	82.29	61.23	100.45	18.37	64.16	19.86	82.05	56.23
39.77	103.76	62.48	18.05	59.92	37.36	108.99	85.93	51.17	88.947	18.33	52.17	20.17	66.51	66.13
39.9	101.537	57.13	19.7	66.74	37.25	109.81	78.27	53.65	84.899	19.79	46.08	18.88	88.62	64.14
39.24	77.9577	55.73	17.49	73.11	38.16	109.81	79.82	54.14	87.741	19.35	53.63	19.64	87.44	56.61
39.81	92.6132	58.18	18.8	62.43	37.05	109.31	85.12	61.78	103.27	17.91	60.94	19.56	86.21	52.78
39.24	107.607	55.96	19.39	51.77	38.33	109.46	70.06	53.64	87.98	19.63	58.3	19.65	76.67	62.76
38.94	92.422	59.48	19.78	53.73	37.32	109.66	88.75	54.48	96.618	19.64	57.71	20.82	70.31	57.79
39.41	86.0805	53.91	16.39	54.15	37.82	109.4	64.96	57	90.244	18.78	66.95	18.34	68.49	74.19

Table F.17: Throughput Simulation Scaled Picking Times (Non-Overlapping Waves) —
continued.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
39.59	92.6521	68.28	19.04	61.11	38.24	108.7	76.85	54.73	107.44	18.32	49.47	19.12	77.81	50.37
39.62	87.6035	56.59	19.47	56.19	37.08	109.73	76.68	58	97.62	20.14	48.48	19.52	62.95	52.82
39.61	110.647	62.69	19.7	49.97	38.55	109.8	68.05	62.34	97.538	20.56	52.57	19.68	73.6	60.35
38.85	97.7612	68.7	19.74	52.21	36.97	109.69	92.47	57.82	97.265	19.28	61.08	18.6	79.03	45.69
39.41	108.66	58.03	20.46	68.89	36.89	109.77	83.35	64.8	105.8	19.65	52.09	20.14	85.87	66.03
39.45	96.91	56.7	18.25	52.95	37.76	109.02	82.05	64.2	96.127	18.68	48.91	19.16	73.58	47.44
40.41	112.633	58.45	20.15	74.65	38.39	109.62	60.67	56.91	96.982	20.07	55.21	19.27	75.67	59.2
39.34	97.5731	58.52	19.51	63.93	38.49	109.86	79.14	53.55	82.948	19.25	56.33	19.92	84.18	60.73
38.9	107.277	61.13	19.54	68.07	38.24	109.94	79.83	54.39	106.32	19.57	51.45	19.93	69.94	47.73
39.18	92.2154	60.22	19.62	68.59	38.16	109.7	86.43	62.34	90.627	19.34	56.82	17.72	81.65	53.62
39.92	89.0886	56.39	20.47	58.16	37.04	109.32	66.41	57.55	99.566	19.56	42.29	18.89	81.84	55.73
39.17	104.795	59.39	19.17	63.41	36.77	109.1	76.43	58.55	105.5	18.93	56.35	19.36	77.3	51.13
38.87	90.3038	60.8	18.83	55.39	38.25	109.37	77.89	60.58	102.28	19.47	51.49	19.27	80.9	61.32
38.63	110.501	57.96	18.94	64.38	37.66	108.92	66.28	57.4	100.9	19.07	50.13	19.55	73.94	57.57
39.18	110.185	64.88	19.64	52.59	36.97	109.84	73.1	57.53	88.4	19.02	49.98	17.77	74.53	53.83
38.66	109.475	58.4	19.97	57.85	37.96	108.79	62.97	54	99.044	20	49.72	19.38	83.2	58.46
39.86	72.9368	61.93	18.82	55.75	38.72	108.84	79.64	67.38	91.876	19.1	53.35	18.44	68.1	49.04
39.86	92.799	70.78	21.04	59.74	38.4	108.97	82.27	60	102.49	19.89	48.26	20.01	84.05	54.24
39.51	107.656	63.24	21.1	68.36	36.87	109.13	74.36	58.64	85.997	19.87	57.5	19.44	81.21	47.77
39.98	104.212	64.15	18.43	59.08	38.35	109.8	79.48	60.07	94.99	17.85	52.93	19.27	83.76	53.73
40.49	102.03	68.07	20.16	63.66	37.57	108.95	84.48	58.05	92.276	18.77	58.52	19.01	67.2	52.32
38.86	98.5128	61.17	17.68	62.93	37.77	109.34	90	55.39	105.06	19.53	62.99	19.04	67.01	44.06
39.24	101.603	66.17	19.16	61.53	37.71	109.79	86.37	56.83	86.341	17.71	60.44	19.28	78.23	52.72
39.47	102.93	57.45	18.57	61.31	38.03	109.55	70.9	65.13	102.68	21.27	52.49	19.2	81.96	50.92
39.06	104.83	63.24	19.71	63.18	37.37	109.87	67.23	54.41	109.06	20.55	64.12	20.27	81.64	59.53
38.34	104.896	50.24	19.13	59.29	36.47	109.95	68.02	56.52	100.24	21.32	58.9	20.05	76.04	43.85
39.54	92.0295	59.68	18.64	53.83	38.04	109.51	79.2	55.48	104.92	19.71	54.22	19.84	79.34	54.8

Table F.18: Throughput Simulation Scaled Packing Times (Non-Overlapping Waves).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
38.605	Man.	Man.	19.874	Man.	38.954	121.7	Man.	Man.	Man.	20.686	Man.	22.233	Man.	Man.
41.149	Man.	Man.	20.253	Man.	40.357	119.04	Man.	Man.	Man.	20.052	Man.	19.378	Man.	Man.
35.874	Man.	Man.	19.385	Man.	39.065	119.24	Man.	Man.	Man.	19.639	Man.	20.638	Man.	Man.
39.397	Man.	Man.	18.382	Man.	34.26	121.6	Man.	Man.	Man.	21.668	Man.	18.491	Man.	Man.
38.253	Man.	Man.	20.21	Man.	36.877	118.82	Man.	Man.	Man.	20.258	Man.	21.274	Man.	Man.
39.744	Man.	Man.	20.096	Man.	41.377	118.85	Man.	Man.	Man.	22.984	Man.	19.227	Man.	Man.
39.814	Man.	Man.	20.004	Man.	41.131	117.02	Man.	Man.	Man.	19.879	Man.	19.901	Man.	Man.
38.13	Man.	Man.	19.893	Man.	41.198	114.66	Man.	Man.	Man.	20.247	Man.	19.65	Man.	Man.
38.859	Man.	Man.	21.543	Man.	40.669	117.28	Man.	Man.	Man.	20.218	Man.	19.764	Man.	Man.
38.88	Man.	Man.	19.702	Man.	39.953	118.83	Man.	Man.	Man.	19.51	Man.	19.46	Man.	Man.
40.623	Man.	Man.	19.667	Man.	39.448	120.28	Man.	Man.	Man.	20.592	Man.	20.448	Man.	Man.
38.988	Man.	Man.	20.231	Man.	37.312	119.38	Man.	Man.	Man.	23.124	Man.	20.152	Man.	Man.
37.115	Man.	Man.	19.172	Man.	40.457	122.16	Man.	Man.	Man.	18.533	Man.	20.669	Man.	Man.
37.732	Man.	Man.	19.579	Man.	39.386	121.38	Man.	Man.	Man.	20.577	Man.	20.814	Man.	Man.
37.563	Man.	Man.	19.585	Man.	41.635	121.39	Man.	Man.	Man.	19.736	Man.	21.135	Man.	Man.
38.989	Man.	Man.	20.581	Man.	39.566	122.07	Man.	Man.	Man.	20.836	Man.	19.796	Man.	Man.
36.919	Man.	Man.	19.835	Man.	40.299	119.09	Man.	Man.	Man.	20.063	Man.	20.785	Man.	Man.
35.886	Man.	Man.	20.692	Man.	37.955	120.79	Man.	Man.	Man.	19.975	Man.	20.755	Man.	Man.
37.132	Man.	Man.	20.938	Man.	39.602	117.94	Man.	Man.	Man.	20.14	Man.	20.733	Man.	Man.
38.924	Man.	Man.	20.82	Man.	40.067	121.08	Man.	Man.	Man.	20.623	Man.	20.279	Man.	Man.
36.214	Man.	Man.	20.729	Man.	40.777	121.7	Man.	Man.	Man.	19.554	Man.	20.238	Man.	Man.
38.637	Man.	Man.	19.79	Man.	39.744	118.3	Man.	Man.	Man.	21.444	Man.	21.563	Man.	Man.
37.534	Man.	Man.	20.974	Man.	41.573	118.99	Man.	Man.	Man.	20.915	Man.	21.65	Man.	Man.
37.649	Man.	Man.	20.104	Man.	38.467	123.17	Man.	Man.	Man.	19.749	Man.	19.69	Man.	Man.
39.281	Man.	Man.	19.921	Man.	38.405	123.69	Man.	Man.	Man.	20.138	Man.	18.616	Man.	Man.
37.977	Man.	Man.	20.09	Man.	40.581	119.87	Man.	Man.	Man.	20.145	Man.	20.134	Man.	Man.

Table F.18: Throughput Simulation Scaled Packing Times (Non-Overlapping Waves) —
continued.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
39.063	Man.	Man.	20.01	Man.	39.966	120.99	Man.	Man.	Man.	19.566	Man.	22.338	Man.	Man.	
38.092	Man.	Man.	19.846	Man.	43.633	119.23	Man.	Man.	Man.	20.503	Man.	19.93	Man.	Man.	
38.669	Man.	Man.	20.077	Man.	40.232	117.93	Man.	Man.	Man.	19.4	Man.	20.242	Man.	Man.	
38.491	Man.	Man.	21.213	Man.	41.448	117.45	Man.	Man.	Man.	20.576	Man.	19.052	Man.	Man.	
39.081	Man.	Man.	20.037	Man.	37.114	120.42	Man.	Man.	Man.	21.388	Man.	20.765	Man.	Man.	
38.212	Man.	Man.	18.622	Man.	38.019	114.23	Man.	Man.	Man.	20.557	Man.	22.482	Man.	Man.	
38.405	Man.	Man.	20.694	Man.	39.555	117.55	Man.	Man.	Man.	19.695	Man.	21.633	Man.	Man.	
38.814	Man.	Man.	20.097	Man.	37.527	120.25	Man.	Man.	Man.	20.101	Man.	17.775	Man.	Man.	
39.295	Man.	Man.	19.93	Man.	37.713	115.77	Man.	Man.	Man.	20.807	Man.	20.921	Man.	Man.	
38.181	Man.	Man.	19.298	Man.	42.605	114.85	Man.	Man.	Man.	21.791	Man.	20.786	Man.	Man.	
37.673	Man.	Man.	20.923	Man.	38.822	117.7	Man.	Man.	Man.	20.288	Man.	20.802	Man.	Man.	
37.935	Man.	Man.	21.16	Man.	39.93	120.05	Man.	Man.	Man.	20.349	Man.	19.957	Man.	Man.	
37.64	Man.	Man.	19.989	Man.	36.488	118.79	Man.	Man.	Man.	18.951	Man.	21.196	Man.	Man.	
38.706	Man.	Man.	20.324	Man.	39.784	113.73	Man.	Man.	Man.	21.792	Man.	20.408	Man.	Man.	
36.74	Man.	Man.	20.669	Man.	38.268	120.05	Man.	Man.	Man.	21.206	Man.	20.857	Man.	Man.	
38.321	Man.	Man.	20.97	Man.	39.859	119.8	Man.	Man.	Man.	19.862	Man.	20.569	Man.	Man.	
38.64	Man.	Man.	20.22	Man.	42.091	118.86	Man.	Man.	Man.	19.919	Man.	19.417	Man.	Man.	
37.516	Man.	Man.	19.805	Man.	40.797	120.32	Man.	Man.	Man.	20.598	Man.	19.53	Man.	Man.	
38.346	Man.	Man.	20.441	Man.	39.354	124.36	Man.	Man.	Man.	19.576	Man.	18.051	Man.	Man.	
39.459	Man.	Man.	20.661	Man.	38.489	116.8	Man.	Man.	Man.	18.555	Man.	19.607	Man.	Man.	
38.374	Man.	Man.	19.582	Man.	41.816	121.44	Man.	Man.	Man.	20.223	Man.	21.979	Man.	Man.	
39.496	Man.	Man.	18.122	Man.	39.479	118.76	Man.	Man.	Man.	21.499	Man.	20.649	Man.	Man.	
37.696	Man.	Man.	20.117	Man.	41.686	108.21	Man.	Man.	Man.	20.246	Man.	20.544	Man.	Man.	
38.175	Man.	Man.	20.341	Man.	42.154	117.06	Man.	Man.	Man.	21.982	Man.	18.985	Man.	Man.	
38.651	Man.	Man.	20.775	Man.	35.613	115.92	Man.	Man.	Man.	20.923	Man.	20.377	Man.	Man.	
38.991	Man.	Man.	19.744	Man.	38.128	117.58	Man.	Man.	Man.	18.931	Man.	21.483	Man.	Man.	
38.614	Man.	Man.	19.995	Man.	39.041	119.33	Man.	Man.	Man.	21.291	Man.	20.305	Man.	Man.	
38.64	Man.	Man.	20.292	Man.	38.58	119.01	Man.	Man.	Man.	20.846	Man.	21.681	Man.	Man.	
40.114	Man.	Man.	20.068	Man.	40.584	119.39	Man.	Man.	Man.	20.417	Man.	20.775	Man.	Man.	
38.948	Man.	Man.	20.561	Man.	39.15	119.21	Man.	Man.	Man.	19.416	Man.	19.8	Man.	Man.	
37.72	Man.	Man.	20.188	Man.	38.969	113.91	Man.	Man.	Man.	22.525	Man.	20.561	Man.	Man.	
37.615	Man.	Man.	21.263	Man.	42.359	111.42	Man.	Man.	Man.	22.044	Man.	20.385	Man.	Man.	
37.994	Man.	Man.	20.36	Man.	39.626	119.47	Man.	Man.	Man.	21.95	Man.	21.307	Man.	Man.	
39.594	Man.	Man.	20.057	Man.	39.799	121.06	Man.	Man.	Man.	20.365	Man.	21.326	Man.	Man.	
38.54	Man.	Man.	20.941	Man.	38.061	117.84	Man.	Man.	Man.	21.804	Man.	20.519	Man.	Man.	
38.272	Man.	Man.	19.827	Man.	40.252	121.06	Man.	Man.	Man.	21.18	Man.	21.212	Man.	Man.	
38.987	Man.	Man.	20.075	Man.	41.06	114.65	Man.	Man.	Man.	20.514	Man.	20.342	Man.	Man.	
39.937	Man.	Man.	19.85	Man.	35.625	119.37	Man.	Man.	Man.	21.007	Man.	21.146	Man.	Man.	
39.144	Man.	Man.	21.394	Man.	40.663	121.78	Man.	Man.	Man.	23.054	Man.	19.95	Man.	Man.	
38.724	Man.	Man.	19.799	Man.	39.641	119.17	Man.	Man.	Man.	19.387	Man.	20.415	Man.	Man.	
38.04	Man.	Man.	19.641	Man.	40.313	114.63	Man.	Man.	Man.	20.9	Man.	18.452	Man.	Man.	
39.581	Man.	Man.	20.357	Man.	38.106	119.42	Man.	Man.	Man.	21.432	Man.	20.976	Man.	Man.	
37.741	Man.	Man.	20.997	Man.	39.52	121.35	Man.	Man.	Man.	23.047	Man.	22.014	Man.	Man.	
39.666	Man.	Man.	20.136	Man.	37.763	117.16	Man.	Man.	Man.	19.534	Man.	20.777	Man.	Man.	
38.561	Man.	Man.	20.296	Man.	37.466	118.67	Man.	Man.	Man.	19.69	Man.	21.651	Man.	Man.	
38.685	Man.	Man.	20.63	Man.	39.479	119.25	Man.	Man.	Man.	20.96	Man.	20.031	Man.	Man.	
38.289	Man.	Man.	20.286	Man.	37.458	119.09	Man.	Man.	Man.	20.535	Man.	19.852	Man.	Man.	
37.973	Man.	Man.	20.359	Man.	39.885	121.23	Man.	Man.	Man.	19.119	Man.	19.843	Man.	Man.	
37.971	Man.	Man.	20.299	Man.	40.903	119.97	Man.	Man.	Man.	19.212	Man.	19.684	Man.	Man.	
38.947	Man.	Man.	19.722	Man.	42.951	118.75	Man.	Man.	Man.	20.688	Man.	19.87	Man.	Man.	
38.033	Man.	Man.	20.63	Man.	39.422	118.78	Man.	Man.	Man.	20.881	Man.	20.747	Man.	Man.	
39.649	Man.	Man.	20.338	Man.	38.912	118.39	Man.	Man.	Man.	19.168	Man.	20.39	Man.	Man.	
37.694	Man.	Man.	21.251	Man.	38.51	118.68	Man.	Man.	Man.	21.977	Man.	20.847	Man.	Man.	
38.99	Man.	Man.	21.034	Man.	38.932	117.97	Man.	Man.	Man.	19.949	Man.	20.981	Man.	Man.	
38.339	Man.	Man.	20.933	Man.	37.566	117.56	Man.	Man.	Man.	20.442	Man.	19.564	Man.	Man.	
38.417	Man.	Man.	20.321	Man.	38.582	120.83	Man.	Man.	Man.	22.19	Man.	20.264	Man.	Man.	
39.182	Man.	Man.	20.433	Man.	38.028	118.51	Man.	Man.	Man.	20.091	Man.	20.452	Man.	Man.	
37.769	Man.	Man.	21.104	Man.	39.498	119.13	Man.	Man.	Man.	21.87	Man.	20.652	Man.	Man.	

Table F.18: Throughput Simulation Scaled Packing Times (Non-Overlapping Waves) —
continued.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
38.674	Man.	Man.	18.652	Man.	36.263	117.46	Man.	Man.	Man.	20.457	Man.	21.253	Man.	Man.
38.12	Man.	Man.	19.746	Man.	40.061	116.8	Man.	Man.	Man.	20.19	Man.	19.038	Man.	Man.
37.947	Man.	Man.	19.554	Man.	38.214	116.29	Man.	Man.	Man.	19.894	Man.	21.926	Man.	Man.
38.297	Man.	Man.	19.582	Man.	38.916	118.34	Man.	Man.	Man.	20.009	Man.	21.523	Man.	Man.
38.688	Man.	Man.	19.94	Man.	43.348	118.64	Man.	Man.	Man.	20.164	Man.	21.573	Man.	Man.
39.265	Man.	Man.	20.008	Man.	35.422	119.44	Man.	Man.	Man.	18.918	Man.	19.877	Man.	Man.
38.921	Man.	Man.	19.92	Man.	42.914	118.65	Man.	Man.	Man.	21.697	Man.	19.94	Man.	Man.
39.298	Man.	Man.	20.658	Man.	38.769	118.5	Man.	Man.	Man.	21.498	Man.	21.676	Man.	Man.
38.015	Man.	Man.	20.371	Man.	39.121	119.28	Man.	Man.	Man.	21.124	Man.	20.721	Man.	Man.
38.061	Man.	Man.	19.566	Man.	37.96	119.34	Man.	Man.	Man.	19.889	Man.	20.136	Man.	Man.
38.152	Man.	Man.	19.312	Man.	39.843	116.86	Man.	Man.	Man.	20.843	Man.	19.293	Man.	Man.
37.671	Man.	Man.	19.903	Man.	39.256	125.66	Man.	Man.	Man.	19.765	Man.	22.097	Man.	Man.
40.441	Man.	Man.	20.625	Man.	41.361	119.48	Man.	Man.	Man.	20.245	Man.	20.634	Man.	Man.
39.232	Man.	Man.	20.343	Man.	40.39	123.51	Man.	Man.	Man.	19.977	Man.	21.338	Man.	Man.
37.836	Man.	Man.	21.97	Man.	39.815	122.23	Man.	Man.	Man.	20.892	Man.	19.757	Man.	Man.
39.423	Man.	Man.	19.933	Man.	39.611	118.04	Man.	Man.	Man.	21.254	Man.	20.504	Man.	Man.

Table F.19: Throughput Simulation Induction Times (Overlapping Waves – c.v. = 0.2).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
90.00	30.01	60.00	36.46	Man.	37.76	66.00	Man.	Man.	55.26	28.35	Man.	27.20	Man.	Man.
90.01	30.00	60.00	36.44	Man.	37.68	66.00	Man.	Man.	55.85	28.33	Man.	27.58	Man.	Man.
90.00	30.00	60.00	36.40	Man.	37.60	66.00	Man.	Man.	55.82	28.29	Man.	27.57	Man.	Man.
90.00	30.01	60.00	36.56	Man.	37.50	66.00	Man.	Man.	55.88	28.17	Man.	27.40	Man.	Man.
90.01	30.00	59.99	36.47	Man.	37.87	66.00	Man.	Man.	55.79	28.41	Man.	27.48	Man.	Man.
90.00	30.00	59.99	36.41	Man.	37.77	66.00	Man.	Man.	55.43	28.43	Man.	27.42	Man.	Man.
90.01	30.01	59.99	36.36	Man.	37.56	66.00	Man.	Man.	55.78	28.25	Man.	27.27	Man.	Man.
90.01	30.01	60.00	36.33	Man.	37.81	66.00	Man.	Man.	55.73	28.30	Man.	27.25	Man.	Man.
90.01	30.00	60.00	36.46	Man.	37.65	66.00	Man.	Man.	55.57	28.34	Man.	27.39	Man.	Man.
90.01	30.00	59.99	36.52	Man.	37.61	66.00	Man.	Man.	55.26	28.24	Man.	27.33	Man.	Man.
90.01	30.00	59.99	36.46	Man.	37.70	66.00	Man.	Man.	55.66	28.34	Man.	27.45	Man.	Man.
90.00	30.01	59.99	36.49	Man.	37.59	66.00	Man.	Man.	55.63	28.24	Man.	27.41	Man.	Man.
90.00	30.01	59.99	36.38	Man.	37.86	66.00	Man.	Man.	55.62	28.46	Man.	27.65	Man.	Man.
90.00	30.00	59.99	36.46	Man.	37.74	66.00	Man.	Man.	55.82	28.25	Man.	27.77	Man.	Man.
90.01	30.01	60.00	36.45	Man.	37.51	66.00	Man.	Man.	55.57	28.13	Man.	27.53	Man.	Man.
90.01	30.01	59.99	36.50	Man.	37.67	66.00	Man.	Man.	55.54	28.30	Man.	27.50	Man.	Man.
90.00	30.01	59.99	36.48	Man.	37.67	66.00	Man.	Man.	55.71	28.34	Man.	27.64	Man.	Man.
90.01	30.00	59.99	36.59	Man.	37.52	66.00	Man.	Man.	55.70	28.09	Man.	27.57	Man.	Man.
90.00	30.00	59.99	36.34	Man.	37.53	66.00	Man.	Man.	55.85	28.17	Man.	27.43	Man.	Man.
90.00	30.00	59.99	36.41	Man.	37.77	66.00	Man.	Man.	54.88	28.35	Man.	27.54	Man.	Man.
90.01	30.01	59.99	36.48	Man.	37.64	66.00	Man.	Man.	55.83	28.16	Man.	27.49	Man.	Man.
90.00	30.01	60.00	36.44	Man.	37.68	66.00	Man.	Man.	55.35	28.24	Man.	27.51	Man.	Man.
90.01	30.00	59.99	36.46	Man.	37.50	66.00	Man.	Man.	55.89	28.05	Man.	27.50	Man.	Man.
90.01	30.01	59.99	36.43	Man.	37.68	66.00	Man.	Man.	55.49	28.34	Man.	27.40	Man.	Man.
90.00	30.00	59.99	36.53	Man.	37.39	66.00	Man.	Man.	55.52	28.07	Man.	27.67	Man.	Man.
90.00	30.01	60.00	36.30	Man.	37.65	66.00	Man.	Man.	55.41	28.24	Man.	27.25	Man.	Man.
90.00	30.00	59.99	36.59	Man.	37.88	66.00	Man.	Man.	55.22	28.29	Man.	27.47	Man.	Man.
90.00	30.00	60.00	36.35	Man.	37.79	66.00	Man.	Man.	55.90	28.41	Man.	27.45	Man.	Man.
90.01	30.01	60.00	36.44	Man.	37.86	66.00	Man.	Man.	55.62	28.38	Man.	27.31	Man.	Man.
90.01	30.01	60.00	36.48	Man.	37.63	66.00	Man.	Man.	55.60	28.25	Man.	27.45	Man.	Man.
90.00	30.00	60.00	36.46	Man.	37.65	66.00	Man.	Man.	56.05	28.19	Man.	27.55	Man.	Man.
90.00	30.00	60.00	36.47	Man.	37.63	66.00	Man.	Man.	55.44	28.29	Man.	27.47	Man.	Man.
90.00	30.00	59.99	36.38	Man.	37.49	66.00	Man.	Man.	54.89	28.19	Man.	27.53	Man.	Man.
90.01	30.01	60.00	36.42	Man.	37.59	66.00	Man.	Man.	55.47	28.18	Man.	27.57	Man.	Man.
90.01	30.00	59.99	36.42	Man.	37.38	66.00	Man.	Man.	55.03	28.01	Man.	27.63	Man.	Man.
90.01	30.00	60.01	36.47	Man.	37.81	66.00	Man.	Man.	55.46	28.39	Man.	27.49	Man.	Man.
90.00	30.00	59.99	36.40	Man.	37.53	66.00	Man.	Man.	55.59	28.07	Man.	27.57	Man.	Man.

Table F.19: Throughput Simulation Induction Times (Overlapping Waves - c.v. = 0.2) —
continued.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
90.01	30.00	60.00	36.35	Man.	37.78	66.00	Man.	Man.	55.57	28.28	Man.	27.37	Man.	Man.
90.00	30.01	59.99	36.44	Man.	37.41	66.00	Man.	Man.	54.97	28.09	Man.	27.61	Man.	Man.
90.00	30.00	59.99	36.47	Man.	37.71	66.00	Man.	Man.	55.86	28.26	Man.	27.47	Man.	Man.
90.00	30.01	60.00	36.51	Man.	37.81	66.00	Man.	Man.	54.95	28.45	Man.	27.45	Man.	Man.
90.00	30.00	59.99	36.53	Man.	37.62	66.00	Man.	Man.	55.23	28.28	Man.	27.62	Man.	Man.
90.00	30.00	60.00	36.43	Man.	37.57	66.00	Man.	Man.	55.76	28.09	Man.	27.45	Man.	Man.
90.00	30.00	59.99	36.36	Man.	37.86	66.00	Man.	Man.	55.55	28.44	Man.	27.29	Man.	Man.
90.01	30.00	59.99	36.51	Man.	37.60	66.00	Man.	Man.	55.77	28.14	Man.	27.47	Man.	Man.
90.00	30.00	59.99	36.39	Man.	37.80	66.00	Man.	Man.	55.68	28.22	Man.	27.29	Man.	Man.
90.00	30.00	60.00	36.41	Man.	37.66	66.00	Man.	Man.	55.41	28.14	Man.	27.38	Man.	Man.
90.01	30.00	60.00	36.32	Man.	37.62	66.00	Man.	Man.	55.67	28.22	Man.	27.75	Man.	Man.
90.01	30.00	60.00	36.36	Man.	37.55	66.00	Man.	Man.	55.94	28.20	Man.	27.19	Man.	Man.
90.00	30.01	60.00	36.43	Man.	37.62	66.00	Man.	Man.	55.42	28.26	Man.	27.51	Man.	Man.
90.00	30.00	59.99	36.41	Man.	37.65	66.00	Man.	Man.	55.85	28.19	Man.	27.34	Man.	Man.
90.00	30.01	59.99	36.42	Man.	37.73	66.00	Man.	Man.	55.70	28.27	Man.	27.28	Man.	Man.
90.00	30.00	59.99	36.42	Man.	37.57	66.00	Man.	Man.	55.55	28.12	Man.	27.59	Man.	Man.
90.00	30.01	59.99	36.49	Man.	37.60	66.00	Man.	Man.	56.23	28.29	Man.	27.51	Man.	Man.
90.00	30.00	60.00	36.47	Man.	37.51	66.00	Man.	Man.	55.54	28.24	Man.	27.43	Man.	Man.
90.01	30.00	59.99	36.42	Man.	37.80	66.00	Man.	Man.	56.10	28.28	Man.	27.67	Man.	Man.
90.01	30.01	60.01	36.54	Man.	37.75	66.00	Man.	Man.	55.74	28.41	Man.	27.71	Man.	Man.
90.00	30.00	59.99	36.35	Man.	37.74	66.00	Man.	Man.	55.79	28.38	Man.	27.59	Man.	Man.
90.01	30.00	60.00	36.44	Man.	37.62	66.00	Man.	Man.	55.62	28.20	Man.	27.41	Man.	Man.
90.00	30.00	60.00	36.40	Man.	37.89	66.00	Man.	Man.	56.17	28.44	Man.	27.33	Man.	Man.
90.01	30.01	60.01	36.57	Man.	37.82	66.00	Man.	Man.	55.76	28.39	Man.	27.44	Man.	Man.
90.01	30.01	60.00	36.54	Man.	37.35	66.00	Man.	Man.	55.86	28.20	Man.	27.54	Man.	Man.
90.00	30.01	59.99	36.52	Man.	37.40	66.00	Man.	Man.	55.95	28.12	Man.	27.59	Man.	Man.
90.01	30.01	60.00	36.42	Man.	37.83	66.00	Man.	Man.	55.88	28.31	Man.	27.54	Man.	Man.
90.01	30.00	60.00	36.37	Man.	37.45	66.00	Man.	Man.	55.62	28.21	Man.	27.42	Man.	Man.
90.01	30.01	60.00	36.46	Man.	37.64	66.00	Man.	Man.	55.80	28.26	Man.	27.50	Man.	Man.
90.00	30.00	59.99	36.43	Man.	37.55	66.00	Man.	Man.	55.85	28.18	Man.	27.51	Man.	Man.
90.00	30.01	59.99	36.44	Man.	37.61	66.00	Man.	Man.	55.77	28.25	Man.	27.26	Man.	Man.
90.01	30.01	60.00	36.39	Man.	37.45	66.00	Man.	Man.	55.63	28.06	Man.	27.55	Man.	Man.
90.01	30.01	59.99	36.36	Man.	37.91	66.00	Man.	Man.	55.71	28.36	Man.	27.53	Man.	Man.
90.00	30.01	60.00	36.38	Man.	37.48	66.00	Man.	Man.	54.99	28.02	Man.	27.49	Man.	Man.
90.00	30.01	60.00	36.34	Man.	37.59	66.00	Man.	Man.	55.80	28.08	Man.	27.73	Man.	Man.
90.00	30.00	59.99	36.37	Man.	37.57	66.00	Man.	Man.	55.56	28.23	Man.	27.29	Man.	Man.
90.00	30.00	60.01	36.48	Man.	37.56	66.00	Man.	Man.	55.70	28.11	Man.	27.53	Man.	Man.
90.01	30.01	60.00	36.44	Man.	37.69	66.00	Man.	Man.	55.87	28.28	Man.	27.48	Man.	Man.
90.00	30.01	59.99	36.39	Man.	37.86	66.00	Man.	Man.	55.75	28.41	Man.	27.43	Man.	Man.
90.00	30.00	60.00	36.45	Man.	37.83	66.00	Man.	Man.	55.83	28.54	Man.	27.77	Man.	Man.
90.01	30.00	59.99	36.48	Man.	37.72	66.00	Man.	Man.	55.86	28.31	Man.	27.23	Man.	Man.
90.00	30.01	59.99	36.45	Man.	37.44	66.00	Man.	Man.	55.65	28.06	Man.	27.19	Man.	Man.
90.00	30.00	60.00	36.50	Man.	37.62	66.00	Man.	Man.	55.67	28.20	Man.	27.57	Man.	Man.
90.00	30.01	59.99	36.51	Man.	37.69	66.00	Man.	Man.	55.59	28.34	Man.	27.66	Man.	Man.
90.00	30.01	60.00	36.48	Man.	37.81	66.00	Man.	Man.	55.82	28.36	Man.	27.35	Man.	Man.
90.00	30.01	60.00	36.39	Man.	37.72	66.00	Man.	Man.	56.18	28.30	Man.	27.40	Man.	Man.
90.01	30.01	60.00	36.44	Man.	37.65	66.00	Man.	Man.	55.69	28.29	Man.	27.58	Man.	Man.
90.00	30.01	59.99	36.37	Man.	37.94	66.00	Man.	Man.	55.66	28.43	Man.	27.37	Man.	Man.
90.01	30.00	60.00	36.55	Man.	37.60	66.00	Man.	Man.	55.89	28.24	Man.	27.29	Man.	Man.
90.00	30.00	59.99	36.43	Man.	37.67	66.00	Man.	Man.	55.59	28.17	Man.	27.48	Man.	Man.
90.00	30.00	59.99	36.47	Man.	37.53	66.00	Man.	Man.	55.76	28.16	Man.	27.53	Man.	Man.
90.00	30.00	59.99	36.36	Man.	37.74	66.00	Man.	Man.	55.62	28.30	Man.	27.86	Man.	Man.
90.00	30.00	60.00	36.45	Man.	37.62	66.00	Man.	Man.	55.91	28.23	Man.	27.53	Man.	Man.
90.01	30.00	60.00	36.39	Man.	37.59	66.00	Man.	Man.	55.50	28.07	Man.	27.49	Man.	Man.
90.00	30.01	60.00	36.43	Man.	37.52	66.00	Man.	Man.	55.63	28.23	Man.	27.37	Man.	Man.
90.00	30.01	60.00	36.36	Man.	37.51	66.00	Man.	Man.	55.62	28.12	Man.	27.63	Man.	Man.
90.00	30.00	59.99	36.41	Man.	37.58	66.00	Man.	Man.	55.94	28.08	Man.	27.36	Man.	Man.
90.00	30.01	59.99	36.35	Man.	37.67	66.00	Man.	Man.	55.68	28.25	Man.	27.68	Man.	Man.

Table F.19: Throughput Simulation Induction Times (Overlapping Waves - c.v. = 0.2) —
continued.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
90.00	30.00	59.99	36.39	Man.	37.61	66.00	Man.	Man.	55.69	28.28	Man.	27.48	Man.	Man.
90.00	30.01	60.00	36.35	Man.	37.58	66.00	Man.	Man.	55.95	28.07	Man.	27.59	Man.	Man.
90.00	30.00	60.00	36.46	Man.	37.57	66.00	Man.	Man.	55.59	28.20	Man.	27.27	Man.	Man.
90.00	30.00	60.00	36.24	Man.	37.86	66.00	Man.	Man.	55.74	28.44	Man.	27.71	Man.	Man.
90.01	30.00	59.99	36.42	Man.	37.61	66.00	Man.	Man.	55.86	28.32	Man.	27.59	Man.	Man.

Table F.20: Throughput Simulation Induction Times (Non-Overlapping Waves - c.v. = 0.2).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
30.00	Man.	Man.	18.23	Man.	18.99	66.00	Man.	Man.	Man.	4.68	Man.	9.17	Man.	Man.
30.00	Man.	Man.	18.09	Man.	18.59	66.00	Man.	Man.	Man.	4.67	Man.	9.25	Man.	Man.
30.00	Man.	Man.	18.22	Man.	18.66	66.00	Man.	Man.	Man.	4.65	Man.	9.11	Man.	Man.
30.01	Man.	Man.	18.22	Man.	18.78	66.00	Man.	Man.	Man.	4.72	Man.	9.20	Man.	Man.
30.00	Man.	Man.	18.22	Man.	18.88	66.00	Man.	Man.	Man.	4.65	Man.	8.99	Man.	Man.
30.00	Man.	Man.	18.17	Man.	18.71	66.00	Man.	Man.	Man.	4.65	Man.	9.19	Man.	Man.
30.00	Man.	Man.	18.22	Man.	18.89	66.00	Man.	Man.	Man.	4.67	Man.	9.19	Man.	Man.
30.01	Man.	Man.	18.25	Man.	18.84	66.00	Man.	Man.	Man.	4.73	Man.	9.25	Man.	Man.
30.01	Man.	Man.	18.20	Man.	18.88	66.00	Man.	Man.	Man.	4.77	Man.	9.35	Man.	Man.
30.00	Man.	Man.	18.35	Man.	18.80	66.00	Man.	Man.	Man.	4.67	Man.	9.19	Man.	Man.
30.00	Man.	Man.	18.20	Man.	18.78	66.00	Man.	Man.	Man.	4.69	Man.	9.31	Man.	Man.
30.01	Man.	Man.	18.28	Man.	18.81	66.00	Man.	Man.	Man.	4.80	Man.	9.19	Man.	Man.
30.00	Man.	Man.	18.25	Man.	18.78	66.00	Man.	Man.	Man.	4.75	Man.	9.07	Man.	Man.
30.00	Man.	Man.	18.28	Man.	18.96	66.00	Man.	Man.	Man.	4.68	Man.	9.14	Man.	Man.
30.00	Man.	Man.	18.33	Man.	18.99	66.00	Man.	Man.	Man.	4.71	Man.	9.13	Man.	Man.
30.01	Man.	Man.	18.33	Man.	18.93	66.00	Man.	Man.	Man.	4.71	Man.	8.95	Man.	Man.
30.01	Man.	Man.	18.18	Man.	18.97	66.00	Man.	Man.	Man.	4.72	Man.	9.23	Man.	Man.
30.01	Man.	Man.	18.23	Man.	18.81	66.00	Man.	Man.	Man.	4.70	Man.	9.05	Man.	Man.
30.00	Man.	Man.	18.22	Man.	18.92	66.00	Man.	Man.	Man.	4.67	Man.	9.20	Man.	Man.
30.00	Man.	Man.	18.24	Man.	18.55	66.00	Man.	Man.	Man.	4.62	Man.	9.14	Man.	Man.
30.00	Man.	Man.	18.18	Man.	18.52	66.00	Man.	Man.	Man.	4.69	Man.	9.28	Man.	Man.
30.01	Man.	Man.	18.20	Man.	18.84	66.00	Man.	Man.	Man.	4.66	Man.	9.13	Man.	Man.
30.00	Man.	Man.	18.30	Man.	18.65	66.00	Man.	Man.	Man.	4.65	Man.	9.11	Man.	Man.
30.00	Man.	Man.	18.27	Man.	18.74	66.00	Man.	Man.	Man.	4.74	Man.	9.20	Man.	Man.
30.00	Man.	Man.	18.18	Man.	18.76	66.00	Man.	Man.	Man.	4.62	Man.	9.16	Man.	Man.
30.00	Man.	Man.	18.09	Man.	18.93	66.00	Man.	Man.	Man.	4.75	Man.	9.09	Man.	Man.
30.00	Man.	Man.	18.25	Man.	18.83	66.00	Man.	Man.	Man.	4.77	Man.	9.05	Man.	Man.
30.01	Man.	Man.	18.23	Man.	18.87	66.00	Man.	Man.	Man.	4.68	Man.	9.03	Man.	Man.
30.01	Man.	Man.	18.13	Man.	18.69	66.00	Man.	Man.	Man.	4.70	Man.	9.25	Man.	Man.
30.00	Man.	Man.	18.27	Man.	18.91	66.00	Man.	Man.	Man.	4.71	Man.	9.15	Man.	Man.
30.00	Man.	Man.	18.30	Man.	18.85	66.00	Man.	Man.	Man.	4.71	Man.	9.32	Man.	Man.
30.01	Man.	Man.	18.23	Man.	19.13	66.00	Man.	Man.	Man.	4.76	Man.	9.17	Man.	Man.
30.00	Man.	Man.	18.29	Man.	18.76	66.00	Man.	Man.	Man.	4.71	Man.	9.20	Man.	Man.
30.01	Man.	Man.	18.18	Man.	18.73	66.00	Man.	Man.	Man.	4.75	Man.	9.17	Man.	Man.
30.01	Man.	Man.	18.13	Man.	18.80	66.00	Man.	Man.	Man.	4.69	Man.	9.15	Man.	Man.
30.01	Man.	Man.	18.17	Man.	18.77	66.00	Man.	Man.	Man.	4.68	Man.	9.19	Man.	Man.
30.00	Man.	Man.	18.29	Man.	18.78	66.00	Man.	Man.	Man.	4.70	Man.	9.10	Man.	Man.
30.01	Man.	Man.	18.26	Man.	18.84	66.00	Man.	Man.	Man.	4.78	Man.	9.11	Man.	Man.
30.01	Man.	Man.	18.23	Man.	18.79	66.00	Man.	Man.	Man.	4.68	Man.	9.16	Man.	Man.
30.01	Man.	Man.	18.33	Man.	18.72	66.00	Man.	Man.	Man.	4.76	Man.	9.09	Man.	Man.
30.00	Man.	Man.	18.23	Man.	18.96	66.00	Man.	Man.	Man.	4.78	Man.	9.03	Man.	Man.
30.00	Man.	Man.	18.20	Man.	18.83	66.00	Man.	Man.	Man.	4.64	Man.	9.25	Man.	Man.
30.00	Man.	Man.	18.17	Man.	18.95	66.00	Man.	Man.	Man.	4.68	Man.	9.09	Man.	Man.
30.00	Man.	Man.	18.22	Man.	18.75	66.00	Man.	Man.	Man.	4.69	Man.	9.11	Man.	Man.
30.01	Man.	Man.	18.34	Man.	18.74	66.00	Man.	Man.	Man.	4.70	Man.	9.19	Man.	Man.
30.00	Man.	Man.	18.24	Man.	18.69	66.00	Man.	Man.	Man.	4.74	Man.	9.25	Man.	Man.
30.00	Man.	Man.	18.35	Man.	18.96	66.00	Man.	Man.	Man.	4.77	Man.	9.21	Man.	Man.

Table F.20: Throughput Simulation Induction Times (Non-Overlapping Waves – c.v. = 0.2) — *continued*.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
30.01	Man.	Man.	18.21	Man.	18.67	66.00	Man.	Man.	Man.	4.68	Man.	9.25	Man.	Man.
30.01	Man.	Man.	18.24	Man.	18.79	66.00	Man.	Man.	Man.	4.55	Man.	9.32	Man.	Man.
30.01	Man.	Man.	18.24	Man.	18.71	66.00	Man.	Man.	Man.	4.67	Man.	9.17	Man.	Man.
30.00	Man.	Man.	18.14	Man.	18.84	66.00	Man.	Man.	Man.	4.74	Man.	9.15	Man.	Man.
30.00	Man.	Man.	18.22	Man.	18.61	66.00	Man.	Man.	Man.	4.61	Man.	9.15	Man.	Man.
30.00	Man.	Man.	18.20	Man.	18.87	66.00	Man.	Man.	Man.	4.72	Man.	9.11	Man.	Man.
30.01	Man.	Man.	18.17	Man.	18.81	66.00	Man.	Man.	Man.	4.72	Man.	9.05	Man.	Man.
30.00	Man.	Man.	18.18	Man.	18.74	66.00	Man.	Man.	Man.	4.76	Man.	9.04	Man.	Man.
30.01	Man.	Man.	18.22	Man.	18.75	66.00	Man.	Man.	Man.	4.65	Man.	9.10	Man.	Man.
30.00	Man.	Man.	18.17	Man.	18.66	66.00	Man.	Man.	Man.	4.70	Man.	9.24	Man.	Man.
30.00	Man.	Man.	18.32	Man.	18.87	66.00	Man.	Man.	Man.	4.65	Man.	9.13	Man.	Man.
30.00	Man.	Man.	18.31	Man.	18.92	66.00	Man.	Man.	Man.	4.71	Man.	9.09	Man.	Man.
30.00	Man.	Man.	18.26	Man.	18.82	66.00	Man.	Man.	Man.	4.69	Man.	9.20	Man.	Man.
30.00	Man.	Man.	18.27	Man.	18.87	66.00	Man.	Man.	Man.	4.72	Man.	9.25	Man.	Man.
30.00	Man.	Man.	18.20	Man.	18.64	66.00	Man.	Man.	Man.	4.72	Man.	9.20	Man.	Man.
30.01	Man.	Man.	18.18	Man.	18.89	66.00	Man.	Man.	Man.	4.69	Man.	9.16	Man.	Man.
30.00	Man.	Man.	18.11	Man.	18.85	66.00	Man.	Man.	Man.	4.66	Man.	9.07	Man.	Man.
30.00	Man.	Man.	18.22	Man.	18.75	66.00	Man.	Man.	Man.	4.74	Man.	9.27	Man.	Man.
30.00	Man.	Man.	18.19	Man.	18.70	66.00	Man.	Man.	Man.	4.60	Man.	9.18	Man.	Man.
30.01	Man.	Man.	18.30	Man.	18.65	66.00	Man.	Man.	Man.	4.67	Man.	9.19	Man.	Man.
30.01	Man.	Man.	18.14	Man.	18.70	66.00	Man.	Man.	Man.	4.60	Man.	9.23	Man.	Man.
30.00	Man.	Man.	18.18	Man.	18.69	66.00	Man.	Man.	Man.	4.71	Man.	9.25	Man.	Man.
30.01	Man.	Man.	18.18	Man.	18.75	66.00	Man.	Man.	Man.	4.64	Man.	9.18	Man.	Man.
30.00	Man.	Man.	18.27	Man.	18.96	66.00	Man.	Man.	Man.	4.74	Man.	9.11	Man.	Man.
30.00	Man.	Man.	18.21	Man.	18.79	66.00	Man.	Man.	Man.	4.62	Man.	9.23	Man.	Man.
30.01	Man.	Man.	18.18	Man.	18.78	66.00	Man.	Man.	Man.	4.69	Man.	9.17	Man.	Man.
30.00	Man.	Man.	18.23	Man.	18.75	66.00	Man.	Man.	Man.	4.65	Man.	9.09	Man.	Man.
30.01	Man.	Man.	18.20	Man.	18.67	66.00	Man.	Man.	Man.	4.73	Man.	9.27	Man.	Man.
30.00	Man.	Man.	18.32	Man.	18.98	66.00	Man.	Man.	Man.	4.77	Man.	8.98	Man.	Man.
30.01	Man.	Man.	18.18	Man.	18.89	66.00	Man.	Man.	Man.	4.77	Man.	9.15	Man.	Man.
30.01	Man.	Man.	18.30	Man.	18.96	66.00	Man.	Man.	Man.	4.66	Man.	9.17	Man.	Man.
30.00	Man.	Man.	18.27	Man.	18.78	66.00	Man.	Man.	Man.	4.75	Man.	9.33	Man.	Man.
30.00	Man.	Man.	18.39	Man.	18.84	66.00	Man.	Man.	Man.	4.72	Man.	9.19	Man.	Man.
30.01	Man.	Man.	18.22	Man.	18.70	66.00	Man.	Man.	Man.	4.67	Man.	9.07	Man.	Man.
30.00	Man.	Man.	18.33	Man.	18.69	66.00	Man.	Man.	Man.	4.67	Man.	9.16	Man.	Man.
30.01	Man.	Man.	18.22	Man.	18.87	66.00	Man.	Man.	Man.	4.73	Man.	9.14	Man.	Man.
30.01	Man.	Man.	18.29	Man.	18.84	66.00	Man.	Man.	Man.	4.68	Man.	9.19	Man.	Man.
30.01	Man.	Man.	18.21	Man.	18.89	66.00	Man.	Man.	Man.	4.73	Man.	9.19	Man.	Man.
30.00	Man.	Man.	18.21	Man.	18.81	66.00	Man.	Man.	Man.	4.70	Man.	9.28	Man.	Man.
30.00	Man.	Man.	18.32	Man.	18.70	66.00	Man.	Man.	Man.	4.70	Man.	9.10	Man.	Man.
30.00	Man.	Man.	18.23	Man.	18.79	66.00	Man.	Man.	Man.	4.73	Man.	9.05	Man.	Man.
30.01	Man.	Man.	18.24	Man.	18.78	66.00	Man.	Man.	Man.	4.72	Man.	9.03	Man.	Man.
30.01	Man.	Man.	18.24	Man.	18.66	66.00	Man.	Man.	Man.	4.63	Man.	9.09	Man.	Man.
30.01	Man.	Man.	18.30	Man.	18.83	66.00	Man.	Man.	Man.	4.66	Man.	9.15	Man.	Man.
30.00	Man.	Man.	18.17	Man.	18.70	66.00	Man.	Man.	Man.	4.78	Man.	9.03	Man.	Man.
30.00	Man.	Man.	18.19	Man.	18.83	66.00	Man.	Man.	Man.	4.77	Man.	9.16	Man.	Man.
30.00	Man.	Man.	18.12	Man.	18.71	66.00	Man.	Man.	Man.	4.72	Man.	9.11	Man.	Man.
30.00	Man.	Man.	18.22	Man.	18.88	66.00	Man.	Man.	Man.	4.75	Man.	9.24	Man.	Man.
30.00	Man.	Man.	18.28	Man.	18.99	66.00	Man.	Man.	Man.	4.71	Man.	9.21	Man.	Man.
30.00	Man.	Man.	18.20	Man.	18.87	66.00	Man.	Man.	Man.	4.60	Man.	9.14	Man.	Man.
30.00	Man.	Man.	18.24	Man.	18.91	66.00	Man.	Man.	Man.	4.66	Man.	8.99	Man.	Man.
30.00	Man.	Man.	18.17	Man.	18.81	66.00	Man.	Man.	Man.	4.75	Man.	9.16	Man.	Man.
30.01	Man.	Man.	18.28	Man.	18.81	66.00	Man.	Man.	Man.	4.68	Man.	9.15	Man.	Man.

Table F.21: Throughput Simulation Induction Times (Overlapping Waves – c.v. = 0.4).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
90.00	30.00	60.00	37.45	Man.	35.42	66.00	Man.	Man.	56.09	26.55	Man.	27.15	Man.	Man.
90.01	30.00	60.00	37.45	Man.	35.18	66.00	Man.	Man.	55.75	26.38	Man.	27.45	Man.	Man.
90.00	30.00	60.00	37.25	Man.	35.53	66.00	Man.	Man.	55.66	26.77	Man.	27.52	Man.	Man.
90.00	30.00	60.00	37.23	Man.	35.21	66.00	Man.	Man.	56.35	26.42	Man.	27.67	Man.	Man.
90.00	30.00	60.00	37.32	Man.	35.17	66.00	Man.	Man.	56.15	26.41	Man.	27.37	Man.	Man.
90.00	30.00	59.99	37.23	Man.	35.19	66.00	Man.	Man.	55.62	26.31	Man.	27.55	Man.	Man.
90.00	30.00	60.00	37.40	Man.	35.18	66.00	Man.	Man.	55.94	26.45	Man.	27.25	Man.	Man.
90.01	30.01	60.00	37.28	Man.	35.35	66.00	Man.	Man.	55.01	26.43	Man.	27.10	Man.	Man.
90.00	30.00	59.99	37.32	Man.	35.38	66.00	Man.	Man.	55.04	26.60	Man.	27.29	Man.	Man.
90.00	30.01	60.00	37.60	Man.	35.38	66.00	Man.	Man.	54.94	26.51	Man.	27.10	Man.	Man.
90.00	30.00	59.99	37.70	Man.	35.50	66.00	Man.	Man.	56.35	26.63	Man.	27.51	Man.	Man.
90.00	30.01	60.00	37.38	Man.	35.33	66.00	Man.	Man.	54.79	26.50	Man.	27.43	Man.	Man.
90.00	30.00	59.99	37.24	Man.	34.98	66.00	Man.	Man.	55.68	26.38	Man.	27.84	Man.	Man.
90.00	30.00	59.99	37.27	Man.	35.14	66.00	Man.	Man.	56.03	26.42	Man.	27.96	Man.	Man.
90.01	30.01	60.00	37.25	Man.	35.25	66.00	Man.	Man.	56.04	26.43	Man.	27.61	Man.	Man.
90.00	30.00	59.99	37.37	Man.	35.42	66.00	Man.	Man.	56.06	26.54	Man.	27.35	Man.	Man.
90.00	30.01	60.00	37.17	Man.	35.45	66.00	Man.	Man.	54.67	26.52	Man.	27.55	Man.	Man.
90.01	30.00	60.00	37.70	Man.	35.34	66.00	Man.	Man.	55.54	26.45	Man.	27.70	Man.	Man.
90.00	30.00	60.01	37.52	Man.	35.23	66.00	Man.	Man.	56.08	26.46	Man.	27.51	Man.	Man.
90.00	30.00	60.00	37.56	Man.	35.58	66.00	Man.	Man.	55.93	26.60	Man.	27.58	Man.	Man.
90.00	30.00	59.99	37.21	Man.	35.27	66.00	Man.	Man.	55.45	26.47	Man.	27.42	Man.	Man.
90.00	30.01	60.00	37.54	Man.	35.46	66.00	Man.	Man.	55.49	26.61	Man.	27.39	Man.	Man.
90.00	30.00	59.99	37.18	Man.	35.20	66.00	Man.	Man.	54.80	26.43	Man.	27.47	Man.	Man.
90.01	30.01	59.99	37.68	Man.	35.31	66.00	Man.	Man.	56.15	26.52	Man.	27.35	Man.	Man.
90.00	30.01	59.99	37.38	Man.	35.19	66.00	Man.	Man.	55.81	26.45	Man.	27.61	Man.	Man.
90.00	30.01	60.00	37.61	Man.	35.33	66.00	Man.	Man.	56.30	26.55	Man.	27.20	Man.	Man.
90.00	30.00	59.99	37.42	Man.	35.36	66.00	Man.	Man.	55.70	26.48	Man.	27.22	Man.	Man.
90.00	30.00	59.99	37.53	Man.	35.37	66.00	Man.	Man.	55.10	26.48	Man.	27.64	Man.	Man.
90.00	30.01	60.00	37.43	Man.	35.39	66.00	Man.	Man.	56.19	26.47	Man.	27.16	Man.	Man.
90.00	30.01	60.01	37.44	Man.	35.54	66.00	Man.	Man.	55.58	26.66	Man.	27.66	Man.	Man.
90.00	30.00	60.00	37.54	Man.	35.46	66.00	Man.	Man.	55.58	26.67	Man.	27.69	Man.	Man.
90.00	30.00	60.01	37.29	Man.	35.11	66.00	Man.	Man.	55.90	26.34	Man.	27.29	Man.	Man.
90.00	30.00	59.99	37.48	Man.	34.91	66.00	Man.	Man.	55.26	26.11	Man.	27.37	Man.	Man.
90.01	30.00	60.01	37.34	Man.	35.48	66.00	Man.	Man.	55.93	26.59	Man.	27.59	Man.	Man.
90.00	30.00	60.00	37.83	Man.	35.26	66.00	Man.	Man.	55.81	26.29	Man.	27.63	Man.	Man.
90.01	30.00	60.00	37.36	Man.	35.54	66.00	Man.	Man.	56.29	26.61	Man.	27.27	Man.	Man.
90.00	30.00	59.99	37.50	Man.	35.11	66.00	Man.	Man.	54.94	26.33	Man.	27.57	Man.	Man.
90.01	30.00	60.00	37.30	Man.	35.48	66.00	Man.	Man.	56.33	26.53	Man.	27.27	Man.	Man.
90.00	30.00	59.99	37.37	Man.	35.32	66.00	Man.	Man.	55.88	26.41	Man.	27.68	Man.	Man.
90.00	30.00	60.00	37.22	Man.	35.29	66.00	Man.	Man.	55.76	26.42	Man.	27.55	Man.	Man.
90.00	30.01	60.00	37.27	Man.	35.63	66.00	Man.	Man.	55.89	26.67	Man.	27.43	Man.	Man.
90.00	30.00	59.99	37.23	Man.	35.21	66.00	Man.	Man.	55.86	26.38	Man.	27.64	Man.	Man.
90.00	30.00	60.01	37.25	Man.	35.31	66.00	Man.	Man.	56.25	26.62	Man.	27.38	Man.	Man.
90.00	30.00	59.99	37.27	Man.	35.52	66.00	Man.	Man.	54.83	26.62	Man.	27.01	Man.	Man.
90.01	30.00	59.99	37.24	Man.	35.28	66.00	Man.	Man.	55.87	26.61	Man.	27.57	Man.	Man.
90.00	30.00	59.99	37.27	Man.	35.77	66.00	Man.	Man.	55.44	26.71	Man.	27.21	Man.	Man.
90.00	30.00	60.00	37.30	Man.	35.45	66.00	Man.	Man.	56.17	26.57	Man.	27.17	Man.	Man.
90.00	30.00	59.99	37.31	Man.	35.41	66.00	Man.	Man.	55.58	26.58	Man.	27.77	Man.	Man.
90.00	30.00	59.99	37.66	Man.	35.29	66.00	Man.	Man.	55.35	26.51	Man.	27.04	Man.	Man.
90.00	30.01	60.00	37.39	Man.	35.47	66.00	Man.	Man.	55.96	26.52	Man.	27.47	Man.	Man.
90.00	30.00	60.00	37.72	Man.	35.45	66.00	Man.	Man.	56.07	26.57	Man.	27.29	Man.	Man.
90.00	30.00	59.99	37.37	Man.	35.45	66.00	Man.	Man.	55.54	26.62	Man.	27.15	Man.	Man.
90.00	30.00	60.01	37.34	Man.	35.24	66.00	Man.	Man.	55.63	26.44	Man.	27.83	Man.	Man.
90.00	30.01	59.99	37.29	Man.	35.32	66.00	Man.	Man.	56.14	26.49	Man.	27.59	Man.	Man.
90.00	30.00	60.00	37.42	Man.	35.42	66.00	Man.	Man.	55.54	26.54	Man.	27.36	Man.	Man.
90.00	30.00	60.00	37.42	Man.	35.44	66.00	Man.	Man.	55.36	26.62	Man.	27.65	Man.	Man.
90.01	30.00	60.01	37.31	Man.	35.40	66.00	Man.	Man.	55.73	26.57	Man.	27.91	Man.	Man.
90.00	30.00	59.99	37.59	Man.	35.55	66.00	Man.	Man.	56.42	26.64	Man.	27.61	Man.	Man.

Table F.21: Throughput Simulation Induction Times (Overlapping Waves - c.v. = 0.4) —
continued.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
90.01	30.00	60.00	37.53	Man.	35.08	66.00	Man.	Man.	55.20	26.28	Man.	27.45	Man.	Man.
90.00	30.00	59.99	37.22	Man.	35.31	66.00	Man.	Man.	55.65	26.66	Man.	27.11	Man.	Man.
90.01	30.00	60.01	37.32	Man.	35.34	66.00	Man.	Man.	55.42	26.42	Man.	27.21	Man.	Man.
90.00	30.01	60.01	37.19	Man.	35.22	66.00	Man.	Man.	56.35	26.44	Man.	27.58	Man.	Man.
90.00	30.01	60.00	37.17	Man.	35.36	66.00	Man.	Man.	55.95	26.52	Man.	27.77	Man.	Man.
90.01	30.01	60.00	37.48	Man.	35.24	66.00	Man.	Man.	55.48	26.32	Man.	27.80	Man.	Man.
90.01	30.00	60.00	37.53	Man.	35.37	66.00	Man.	Man.	55.89	26.50	Man.	27.25	Man.	Man.
90.01	30.00	60.00	37.34	Man.	35.31	66.00	Man.	Man.	55.70	26.41	Man.	27.42	Man.	Man.
90.00	30.00	60.01	37.19	Man.	35.27	66.00	Man.	Man.	55.87	26.35	Man.	27.47	Man.	Man.
90.01	30.01	59.99	37.35	Man.	35.29	66.00	Man.	Man.	55.50	26.62	Man.	27.13	Man.	Man.
90.01	30.00	60.00	37.26	Man.	35.19	66.00	Man.	Man.	54.98	26.34	Man.	27.59	Man.	Man.
90.00	30.00	59.99	37.28	Man.	35.59	66.00	Man.	Man.	55.77	26.75	Man.	27.49	Man.	Man.
90.00	30.00	60.00	37.69	Man.	35.00	66.00	Man.	Man.	55.97	26.34	Man.	27.59	Man.	Man.
90.00	30.01	60.00	37.25	Man.	35.23	66.00	Man.	Man.	55.89	26.40	Man.	27.77	Man.	Man.
90.00	30.00	60.00	37.28	Man.	35.36	66.00	Man.	Man.	55.24	26.54	Man.	27.11	Man.	Man.
90.00	30.01	60.00	37.53	Man.	34.96	66.00	Man.	Man.	55.91	26.19	Man.	27.74	Man.	Man.
90.00	30.01	60.01	37.18	Man.	35.53	66.00	Man.	Man.	55.08	26.62	Man.	27.43	Man.	Man.
90.00	30.01	59.99	37.17	Man.	35.74	66.00	Man.	Man.	56.01	26.66	Man.	27.44	Man.	Man.
90.00	30.00	60.01	37.54	Man.	35.65	66.00	Man.	Man.	56.07	26.65	Man.	27.85	Man.	Man.
90.01	30.01	60.00	37.64	Man.	35.33	66.00	Man.	Man.	55.85	26.43	Man.	27.21	Man.	Man.
90.00	30.01	60.00	37.55	Man.	35.07	66.00	Man.	Man.	55.18	26.25	Man.	27.18	Man.	Man.
90.00	30.01	59.99	37.79	Man.	35.44	66.00	Man.	Man.	55.77	26.47	Man.	27.46	Man.	Man.
90.00	30.01	60.00	37.30	Man.	35.32	66.00	Man.	Man.	55.98	26.39	Man.	27.89	Man.	Man.
90.00	30.01	60.01	37.67	Man.	35.55	66.00	Man.	Man.	55.50	26.61	Man.	27.31	Man.	Man.
90.00	30.01	60.01	37.07	Man.	35.32	66.00	Man.	Man.	55.23	26.56	Man.	27.39	Man.	Man.
90.01	30.01	59.99	37.65	Man.	35.34	66.00	Man.	Man.	55.63	26.56	Man.	27.79	Man.	Man.
90.00	30.01	60.00	37.15	Man.	35.39	66.00	Man.	Man.	55.74	26.47	Man.	27.48	Man.	Man.
90.00	30.00	59.99	37.33	Man.	35.19	66.00	Man.	Man.	55.50	26.37	Man.	27.31	Man.	Man.
90.00	30.00	60.00	37.22	Man.	35.54	66.00	Man.	Man.	56.01	26.63	Man.	27.71	Man.	Man.
90.00	30.00	59.99	37.28	Man.	35.22	66.00	Man.	Man.	55.73	26.43	Man.	27.36	Man.	Man.
90.01	30.00	59.99	37.28	Man.	35.55	66.00	Man.	Man.	56.04	26.57	Man.	27.80	Man.	Man.
90.00	30.00	59.99	37.44	Man.	35.21	66.00	Man.	Man.	56.03	26.40	Man.	27.49	Man.	Man.
90.01	30.00	60.00	37.31	Man.	35.24	66.00	Man.	Man.	55.34	26.39	Man.	27.35	Man.	Man.
90.00	30.01	60.01	37.23	Man.	35.43	66.00	Man.	Man.	55.04	26.42	Man.	27.18	Man.	Man.
90.00	30.01	60.00	37.51	Man.	35.43	66.00	Man.	Man.	55.82	26.59	Man.	27.73	Man.	Man.
90.00	30.00	60.00	37.23	Man.	35.44	66.00	Man.	Man.	55.12	26.57	Man.	27.29	Man.	Man.
90.00	30.00	59.99	37.24	Man.	35.40	66.00	Man.	Man.	56.02	26.68	Man.	27.79	Man.	Man.
90.00	30.00	59.99	37.24	Man.	35.42	66.00	Man.	Man.	54.98	26.60	Man.	27.17	Man.	Man.
90.00	30.01	60.00	37.22	Man.	35.26	66.00	Man.	Man.	55.76	26.45	Man.	27.81	Man.	Man.
90.00	30.00	59.99	37.30	Man.	35.27	66.00	Man.	Man.	55.96	26.45	Man.	26.89	Man.	Man.
90.00	30.00	60.00	37.36	Man.	35.32	66.00	Man.	Man.	56.24	26.43	Man.	27.95	Man.	Man.
90.01	30.01	60.01	37.30	Man.	35.41	66.00	Man.	Man.	55.66	26.54	Man.	27.67	Man.	Man.

Table F.22: Throughput Simulation Induction Times (Non-Overlapping Waves - c.v. = 0.4).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
30.00	Man.	Man.	18.74	Man.	17.69	66.00	Man.	Man.	Man.	4.41	Man.	9.15	Man.	Man.
30.00	Man.	Man.	18.68	Man.	17.64	66.00	Man.	Man.	Man.	4.32	Man.	9.21	Man.	Man.
30.01	Man.	Man.	18.59	Man.	17.75	66.00	Man.	Man.	Man.	4.51	Man.	9.01	Man.	Man.
30.01	Man.	Man.	18.72	Man.	17.51	66.00	Man.	Man.	Man.	4.46	Man.	9.09	Man.	Man.
30.00	Man.	Man.	18.91	Man.	17.50	66.00	Man.	Man.	Man.	4.40	Man.	8.91	Man.	Man.
30.00	Man.	Man.	18.61	Man.	17.51	66.00	Man.	Man.	Man.	4.40	Man.	9.19	Man.	Man.
30.00	Man.	Man.	18.78	Man.	17.65	66.00	Man.	Man.	Man.	4.41	Man.	9.25	Man.	Man.
30.01	Man.	Man.	18.67	Man.	17.69	66.00	Man.	Man.	Man.	4.39	Man.	9.39	Man.	Man.
30.00	Man.	Man.	18.71	Man.	17.57	66.00	Man.	Man.	Man.	4.45	Man.	9.55	Man.	Man.
30.00	Man.	Man.	18.75	Man.	17.75	66.00	Man.	Man.	Man.	4.41	Man.	9.23	Man.	Man.

Table F.22: Throughput Simulation Induction Times (Non-Overlapping Waves – c.v. = 0.4) — *continued*.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
30.00	Man.	Man.	18.74	Man.	17.64	66.00	Man.	Man.	Man.	4.46	Man.	9.35	Man.	Man.
30.01	Man.	Man.	18.63	Man.	17.66	66.00	Man.	Man.	Man.	4.45	Man.	9.12	Man.	Man.
30.00	Man.	Man.	18.79	Man.	17.57	66.00	Man.	Man.	Man.	4.33	Man.	9.02	Man.	Man.
30.00	Man.	Man.	18.63	Man.	17.65	66.00	Man.	Man.	Man.	4.36	Man.	9.16	Man.	Man.
30.00	Man.	Man.	18.73	Man.	17.67	66.00	Man.	Man.	Man.	4.39	Man.	8.99	Man.	Man.
30.00	Man.	Man.	18.69	Man.	17.64	66.00	Man.	Man.	Man.	4.39	Man.	8.84	Man.	Man.
30.01	Man.	Man.	18.59	Man.	17.72	66.00	Man.	Man.	Man.	4.45	Man.	9.23	Man.	Man.
30.01	Man.	Man.	18.74	Man.	17.76	66.00	Man.	Man.	Man.	4.41	Man.	9.03	Man.	Man.
30.00	Man.	Man.	18.87	Man.	17.59	66.00	Man.	Man.	Man.	4.34	Man.	9.26	Man.	Man.
30.00	Man.	Man.	18.61	Man.	17.54	66.00	Man.	Man.	Man.	4.49	Man.	9.25	Man.	Man.
30.00	Man.	Man.	18.66	Man.	17.64	66.00	Man.	Man.	Man.	4.40	Man.	9.21	Man.	Man.
30.01	Man.	Man.	18.80	Man.	17.57	66.00	Man.	Man.	Man.	4.39	Man.	9.13	Man.	Man.
30.00	Man.	Man.	18.77	Man.	17.51	66.00	Man.	Man.	Man.	4.34	Man.	9.11	Man.	Man.
30.00	Man.	Man.	18.85	Man.	17.60	66.00	Man.	Man.	Man.	4.31	Man.	9.27	Man.	Man.
30.00	Man.	Man.	18.68	Man.	17.83	66.00	Man.	Man.	Man.	4.39	Man.	9.16	Man.	Man.
30.00	Man.	Man.	18.68	Man.	17.73	66.00	Man.	Man.	Man.	4.45	Man.	9.07	Man.	Man.
30.00	Man.	Man.	18.76	Man.	17.76	66.00	Man.	Man.	Man.	4.43	Man.	9.04	Man.	Man.
30.00	Man.	Man.	18.89	Man.	17.60	66.00	Man.	Man.	Man.	4.49	Man.	8.91	Man.	Man.
30.00	Man.	Man.	18.78	Man.	17.61	66.00	Man.	Man.	Man.	4.45	Man.	9.15	Man.	Man.
30.00	Man.	Man.	18.70	Man.	17.88	66.00	Man.	Man.	Man.	4.50	Man.	9.11	Man.	Man.
30.00	Man.	Man.	18.63	Man.	17.72	66.00	Man.	Man.	Man.	4.43	Man.	9.47	Man.	Man.
30.01	Man.	Man.	18.96	Man.	17.68	66.00	Man.	Man.	Man.	4.48	Man.	9.10	Man.	Man.
30.00	Man.	Man.	18.70	Man.	17.55	66.00	Man.	Man.	Man.	4.34	Man.	9.31	Man.	Man.
30.01	Man.	Man.	18.78	Man.	17.76	66.00	Man.	Man.	Man.	4.46	Man.	9.29	Man.	Man.
30.00	Man.	Man.	18.76	Man.	17.38	66.00	Man.	Man.	Man.	4.40	Man.	9.21	Man.	Man.
30.01	Man.	Man.	18.59	Man.	17.62	66.00	Man.	Man.	Man.	4.37	Man.	9.25	Man.	Man.
30.00	Man.	Man.	18.69	Man.	17.64	66.00	Man.	Man.	Man.	4.34	Man.	9.05	Man.	Man.
30.00	Man.	Man.	18.72	Man.	17.70	66.00	Man.	Man.	Man.	4.44	Man.	9.02	Man.	Man.
30.01	Man.	Man.	18.91	Man.	17.54	66.00	Man.	Man.	Man.	4.45	Man.	9.17	Man.	Man.
30.00	Man.	Man.	18.65	Man.	17.60	66.00	Man.	Man.	Man.	4.40	Man.	9.10	Man.	Man.
30.00	Man.	Man.	18.77	Man.	17.59	66.00	Man.	Man.	Man.	4.48	Man.	8.96	Man.	Man.
30.00	Man.	Man.	18.61	Man.	17.54	66.00	Man.	Man.	Man.	4.38	Man.	9.35	Man.	Man.
30.01	Man.	Man.	18.60	Man.	17.65	66.00	Man.	Man.	Man.	4.42	Man.	9.06	Man.	Man.
30.00	Man.	Man.	18.72	Man.	17.65	66.00	Man.	Man.	Man.	4.38	Man.	9.16	Man.	Man.
30.01	Man.	Man.	18.84	Man.	17.76	66.00	Man.	Man.	Man.	4.44	Man.	9.13	Man.	Man.
30.00	Man.	Man.	18.65	Man.	17.70	66.00	Man.	Man.	Man.	4.46	Man.	9.31	Man.	Man.
30.00	Man.	Man.	18.91	Man.	17.46	66.00	Man.	Man.	Man.	4.36	Man.	9.29	Man.	Man.
30.00	Man.	Man.	18.53	Man.	17.65	66.00	Man.	Man.	Man.	4.38	Man.	9.28	Man.	Man.
30.00	Man.	Man.	18.78	Man.	17.59	66.00	Man.	Man.	Man.	4.39	Man.	9.35	Man.	Man.
30.00	Man.	Man.	18.74	Man.	17.73	66.00	Man.	Man.	Man.	4.42	Man.	9.17	Man.	Man.
30.00	Man.	Man.	18.71	Man.	17.80	66.00	Man.	Man.	Man.	4.42	Man.	9.13	Man.	Man.
30.00	Man.	Man.	18.84	Man.	17.69	66.00	Man.	Man.	Man.	4.49	Man.	9.20	Man.	Man.
30.00	Man.	Man.	18.61	Man.	17.78	66.00	Man.	Man.	Man.	4.39	Man.	9.06	Man.	Man.
30.01	Man.	Man.	18.72	Man.	17.71	66.00	Man.	Man.	Man.	4.39	Man.	9.00	Man.	Man.
30.01	Man.	Man.	18.57	Man.	17.51	66.00	Man.	Man.	Man.	4.42	Man.	9.01	Man.	Man.
30.01	Man.	Man.	18.95	Man.	17.62	66.00	Man.	Man.	Man.	4.45	Man.	8.93	Man.	Man.
30.00	Man.	Man.	18.55	Man.	17.52	66.00	Man.	Man.	Man.	4.45	Man.	9.32	Man.	Man.
30.00	Man.	Man.	18.63	Man.	17.65	66.00	Man.	Man.	Man.	4.42	Man.	9.14	Man.	Man.
30.00	Man.	Man.	18.95	Man.	17.64	66.00	Man.	Man.	Man.	4.47	Man.	9.04	Man.	Man.
30.00	Man.	Man.	18.74	Man.	17.66	66.00	Man.	Man.	Man.	4.35	Man.	9.24	Man.	Man.
30.00	Man.	Man.	18.64	Man.	17.51	66.00	Man.	Man.	Man.	4.39	Man.	9.36	Man.	Man.
30.00	Man.	Man.	18.85	Man.	17.56	66.00	Man.	Man.	Man.	4.30	Man.	9.20	Man.	Man.
30.01	Man.	Man.	18.57	Man.	17.79	66.00	Man.	Man.	Man.	4.53	Man.	9.11	Man.	Man.
30.00	Man.	Man.	18.50	Man.	17.54	66.00	Man.	Man.	Man.	4.40	Man.	8.97	Man.	Man.
30.00	Man.	Man.	18.74	Man.	17.72	66.00	Man.	Man.	Man.	4.45	Man.	9.30	Man.	Man.
30.00	Man.	Man.	18.77	Man.	17.59	66.00	Man.	Man.	Man.	4.34	Man.	9.22	Man.	Man.
30.01	Man.	Man.	18.69	Man.	17.63	66.00	Man.	Man.	Man.	4.37	Man.	9.21	Man.	Man.
30.00	Man.	Man.	18.64	Man.	17.79	66.00	Man.	Man.	Man.	4.47	Man.	9.47	Man.	Man.

Table F.22: Throughput Simulation Induction Times (Non-Overlapping Waves – c.v. = 0.4) — *continued.*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
30.00	Man.	Man.	18.58	Man.	17.77	66.00	Man.	Man.	Man.	4.54	Man.	9.41	Man.	Man.
30.00	Man.	Man.	18.58	Man.	17.74	66.00	Man.	Man.	Man.	4.43	Man.	9.24	Man.	Man.
30.00	Man.	Man.	18.73	Man.	17.66	66.00	Man.	Man.	Man.	4.38	Man.	9.12	Man.	Man.
30.00	Man.	Man.	18.78	Man.	17.54	66.00	Man.	Man.	Man.	4.48	Man.	9.23	Man.	Man.
30.00	Man.	Man.	18.58	Man.	17.57	66.00	Man.	Man.	Man.	4.38	Man.	9.13	Man.	Man.
30.00	Man.	Man.	18.75	Man.	17.75	66.00	Man.	Man.	Man.	4.52	Man.	9.13	Man.	Man.
30.01	Man.	Man.	18.76	Man.	17.59	66.00	Man.	Man.	Man.	4.42	Man.	9.31	Man.	Man.
30.00	Man.	Man.	18.65	Man.	17.51	66.00	Man.	Man.	Man.	4.38	Man.	8.85	Man.	Man.
30.01	Man.	Man.	18.61	Man.	17.54	66.00	Man.	Man.	Man.	4.38	Man.	9.08	Man.	Man.
30.01	Man.	Man.	18.70	Man.	17.66	66.00	Man.	Man.	Man.	4.43	Man.	9.15	Man.	Man.
30.00	Man.	Man.	18.61	Man.	17.56	66.00	Man.	Man.	Man.	4.38	Man.	9.31	Man.	Man.
30.00	Man.	Man.	18.83	Man.	17.62	66.00	Man.	Man.	Man.	4.28	Man.	9.35	Man.	Man.
30.01	Man.	Man.	18.75	Man.	17.71	66.00	Man.	Man.	Man.	4.41	Man.	9.03	Man.	Man.
30.00	Man.	Man.	18.68	Man.	17.74	66.00	Man.	Man.	Man.	4.43	Man.	9.29	Man.	Man.
30.00	Man.	Man.	18.78	Man.	17.61	66.00	Man.	Man.	Man.	4.50	Man.	9.22	Man.	Man.
30.00	Man.	Man.	18.63	Man.	17.89	66.00	Man.	Man.	Man.	4.45	Man.	9.24	Man.	Man.
30.01	Man.	Man.	18.53	Man.	17.64	66.00	Man.	Man.	Man.	4.45	Man.	9.25	Man.	Man.
30.00	Man.	Man.	18.54	Man.	17.72	66.00	Man.	Man.	Man.	4.37	Man.	9.33	Man.	Man.
30.00	Man.	Man.	18.68	Man.	17.95	66.00	Man.	Man.	Man.	4.45	Man.	9.07	Man.	Man.
30.00	Man.	Man.	18.67	Man.	17.63	66.00	Man.	Man.	Man.	4.37	Man.	8.86	Man.	Man.
30.01	Man.	Man.	18.58	Man.	17.55	66.00	Man.	Man.	Man.	4.31	Man.	8.99	Man.	Man.
30.00	Man.	Man.	18.56	Man.	17.68	66.00	Man.	Man.	Man.	4.39	Man.	9.05	Man.	Man.
30.01	Man.	Man.	18.61	Man.	17.78	66.00	Man.	Man.	Man.	4.37	Man.	9.13	Man.	Man.
30.00	Man.	Man.	18.59	Man.	17.52	66.00	Man.	Man.	Man.	4.39	Man.	9.03	Man.	Man.
30.00	Man.	Man.	18.71	Man.	17.42	66.00	Man.	Man.	Man.	4.37	Man.	9.26	Man.	Man.
30.00	Man.	Man.	18.67	Man.	17.66	66.00	Man.	Man.	Man.	4.39	Man.	9.12	Man.	Man.
30.00	Man.	Man.	18.91	Man.	17.66	66.00	Man.	Man.	Man.	4.36	Man.	9.21	Man.	Man.
30.00	Man.	Man.	18.68	Man.	17.65	66.00	Man.	Man.	Man.	4.36	Man.	9.17	Man.	Man.
30.01	Man.	Man.	18.69	Man.	17.74	66.00	Man.	Man.	Man.	4.36	Man.	9.14	Man.	Man.
30.00	Man.	Man.	18.61	Man.	17.61	66.00	Man.	Man.	Man.	4.44	Man.	8.91	Man.	Man.
30.00	Man.	Man.	18.70	Man.	17.58	66.00	Man.	Man.	Man.	4.44	Man.	9.09	Man.	Man.
30.01	Man.	Man.	18.63	Man.	17.50	66.00	Man.	Man.	Man.	4.43	Man.	9.15	Man.	Man.

Appendix G

Adjusted Induction Model

In order to calculate the number of inductors needed to meet demand in a system, the effective induction rate for each inductor must be used. The effective induction rate for each inductor decreases as the number of inductors increases. That is, the first inductor can reach its maximum induction rate, while the second, third, and fourth inductors successively will be blocked. Tables G.1 through G.3 present the effective rates of the inductors in a system for three different conveyors speeds (100, 150, and 200 trays per minute) and induction rates ranging from 10 to 120 trays per minute. The left column defines the number of induction stations in the system, and the next column is the nominal induction rate. The first set of data is the effective rates of each inductor (1-4). The second set of data is the percentage of the actual rate that the inductor can achieve.

The number of inductors is now calculated by first determining the number of items that must be inducted per minute in order to meet demand, $\frac{D*N_d}{60}$. Using the appropriate table based on the conveyor speed, the number of inductors is determined by first selecting the number of stations and then the nominal inductor rate. The number of stations required is determined by the following equation (as presented in Chapter 4).

$$r_s = \begin{cases} 1 & \text{if } x \leq s, \\ \lceil x/(2s - x) \rceil & \text{if } x > s. \end{cases} \quad (\text{G.1})$$

Dividing the required throughput per minute needed to meet demand by r_s yields the total effective induction rate needed at each station. Finally, the effective rates for one inductor, two inductors, etc., are added until the required demand per minute is met. This model assumes that only four inductors can be placed at one station, and a sorter can have no more than four induction stations.

In order to illustrate, consider a system with a demand level of 3300 orders per hour, a sorter speed of 150 trays per minute, and an induction rate of 60 trays per minute. Spreadsheet calculations based on the total throughput required per minute and (G.1) result in the requirement of two induction stations. Looking at Table G.2 (sorter speed of 150 trays per minute), we first find data corresponding to two induction stations. Then, we calculate the required number of items per minute that must be inducted at each station in order to meet demand, $\frac{1}{2}(3300 * 3/60)$, or 82.5 items per minute at each station. Using the data for two induction stations, we look at the effective rate of the first inductor with an actual rate of 60 items per minute. The rate for the first inductor is 40 items per minute. Since this is less than 82.5, we must add another inductor. With two inductors, the total effective rate is 74.5 items per minute at each station. Three inductors are therefore required to meet demand, at a total effective induction rate of 100 items per minute at each station. With six inductors total (three at each station), this results in 200 items per minute total, which exceeds the demand requirements of 165 items per minute.

The following examples were developed in order to test the adjusted induction model with more than one induction station. Each of the examples tested in the throughput simulations required only one induction station. The examples presented in this appendix provide us with confidence that this model accurately predicts the number of inductors and induction stations necessary to meet demand. Table G.4 provides the details of the example experiments. Tables G.5 and G.6 present the results for each example. Finally, Table G.7 provides the time to induct the assigned items for each replication.

Table G.1: Effective Induction Rates for Conveyor Speed of 100 Trays per Minute.

	Nominal Induction Rate (tpm)	Effective Induction Rate (tpm)				% of Nominal Induction Rate (%)			
		1	2	3	4	1	2	3	4
1 Station	10	10.00	9.90	9.80	9.60	100.00	99.00	98.00	96.00
	20	20.00	19.20	18.00	16.40	100.00	96.00	90.00	82.00
	30	30.00	27.50	23.60	18.70	100.00	91.67	78.67	62.33
	40	40.00	34.50	25.50	0.00	100.00	86.25	63.75	0.00
	50	50.00	40.00	10.00	0.00	100.00	80.00	20.00	0.00
	60	60.00	40.00	0.00	0.00	100.00	66.67	0.00	0.00
	70	70.00	30.00	0.00	0.00	100.00	42.86	0.00	0.00
	80	80.00	20.00	0.00	0.00	100.00	25.00	0.00	0.00
	90	90.00	10.00	0.00	0.00	100.00	11.11	0.00	0.00
	100	100.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
	110	100.00	0.00	0.00	0.00	90.91	0.00	0.00	0.00
	120	100.00	0.00	0.00	0.00	83.33	0.00	0.00	0.00
2 Stations	10	9.30	9.20	9.10	9.00	93.00	92.00	91.00	90.00
	20	16.40	15.70	14.80	13.40	82.00	78.50	74.00	67.00
	30	20.00	18.40	15.70	12.50	66.67	61.33	52.33	41.67
	40	26.70	23.00	17.00	0.00	66.75	57.50	42.50	0.00
	50	33.30	26.70	6.70	0.00	66.60	53.40	13.40	0.00
	60	40.00	26.70	0.00	0.00	66.67	44.50	0.00	0.00
	70	46.70	20.00	0.00	0.00	66.71	28.57	0.00	0.00
	80	53.30	13.30	0.00	0.00	66.63	16.63	0.00	0.00
	90	60.00	6.70	0.00	0.00	66.67	7.44	0.00	0.00
	100	66.70	0.00	0.00	0.00	66.70	0.00	0.00	0.00
	110	66.70	0.00	0.00	0.00	60.64	0.00	0.00	0.00
	120	66.70	0.00	0.00	0.00	55.58	0.00	0.00	0.00
3 Stations	10	8.50	8.40	8.30	8.20	85.00	84.00	83.00	82.00
	20	13.10	12.60	11.80	10.80	65.50	63.00	59.00	54.00
	30	15.00	13.80	11.80	9.40	50.00	46.00	39.33	31.33
	40	20.00	17.20	12.80	0.00	50.00	43.00	32.00	0.00
	50	25.00	20.00	5.00	0.00	50.00	40.00	10.00	0.00
	60	30.00	20.00	0.00	0.00	50.00	33.33	0.00	0.00
	70	35.00	15.00	0.00	0.00	50.00	21.43	0.00	0.00
	80	40.00	10.00	0.00	0.00	50.00	12.50	0.00	0.00
	90	45.00	5.00	0.00	0.00	50.00	5.56	0.00	0.00
	100	50.00	0.00	0.00	0.00	50.00	0.00	0.00	0.00
	110	50.00	0.00	0.00	0.00	45.45	0.00	0.00	0.00
	120	50.00	0.00	0.00	0.00	41.67	0.00	0.00	0.00
4 Stations	10	7.70	7.60	7.50	7.40	77.00	76.00	75.00	74.00
	20	10.80	10.40	9.70	8.90	54.00	52.00	48.50	44.50
	30	12.00	11.00	9.40	7.50	40.00	36.67	31.33	25.00
	40	16.00	13.80	10.20	0.00	40.00	34.50	25.50	0.00
	50	20.00	16.00	4.00	0.00	40.00	32.00	8.00	0.00
	60	24.00	16.00	0.00	0.00	40.00	26.67	0.00	0.00
	70	28.00	12.00	0.00	0.00	40.00	17.14	0.00	0.00
	80	32.00	8.00	0.00	0.00	40.00	10.00	0.00	0.00
	90	36.00	4.00	0.00	0.00	40.00	4.44	0.00	0.00
	100	40.00	0.00	0.00	0.00	40.00	0.00	0.00	0.00
	110	40.00	0.00	0.00	0.00	36.36	0.00	0.00	0.00
	120	40.00	0.00	0.00	0.00	33.33	0.00	0.00	0.00

Table G.2: Effective Induction Rates for Conveyor Speed of 150 Trays per Minute.

	Nominal Induction Rate (tpm)	Effective Induction Rate (tpm)				% of Nominal Induction Rate (%)			
		1	2	3	4	1	2	3	4
1 Station	10	10.00	9.96	9.90	9.84	100.00	99.56	99.01	98.38
	20	20.00	19.70	19.10	18.50	100.00	98.50	95.50	92.50
	30	30.00	28.85	27.05	24.64	100.00	96.15	90.15	82.13
	40	40.00	37.34	33.10	27.64	100.00	93.36	82.75	69.09
	50	50.00	45.00	37.18	17.82	100.00	90.00	74.36	35.64
	60	60.00	51.70	38.30	0.00	100.00	86.17	63.83	0.00
	70	70.00	57.48	22.52	0.00	100.00	82.12	32.17	0.00
	80	80.00	62.28	7.72	0.00	100.00	77.85	9.65	0.00
	90	90.00	60.00	0.00	0.00	100.00	66.67	0.00	0.00
	100	100.00	50.00	0.00	0.00	100.00	50.00	0.00	0.00
	110	110.00	40.00	0.00	0.00	100.00	36.36	0.00	0.00
	120	120.00	30.00	0.00	0.00	100.00	25.00	0.00	0.00
2 Stations	10	9.67	9.63	9.58	9.52	96.72	96.30	95.76	95.16
	20	17.90	17.60	17.10	16.50	89.50	88.00	85.50	82.50
	30	24.55	23.60	22.13	20.16	81.82	78.68	73.77	67.20
	40	28.97	27.05	23.97	20.01	72.42	67.61	59.93	50.04
	50	33.33	30.00	24.79	11.88	66.67	60.00	49.57	23.76
	60	40.00	34.50	25.50	0.00	66.67	57.50	42.50	0.00
	70	46.67	38.32	15.01	0.00	66.67	54.74	21.45	0.00
	80	53.33	41.52	5.14	0.00	66.67	51.90	6.43	0.00
	90	60.00	40.00	0.00	0.00	66.67	44.44	0.00	0.00
	100	66.67	33.33	0.00	0.00	66.67	33.33	0.00	0.00
	110	73.33	26.67	0.00	0.00	66.67	24.24	0.00	0.00
	120	80.00	20.00	0.00	0.00	66.67	16.67	0.00	0.00
3 Stations	10	9.25	9.21	9.16	9.10	92.54	92.13	91.61	91.04
	20	15.50	15.30	14.90	14.40	77.50	76.50	74.50	72.00
	30	19.64	18.89	17.71	16.13	65.48	62.96	59.03	53.78
	40	21.73	20.28	17.98	15.01	54.32	50.71	44.95	37.53
	50	25.00	22.50	18.59	8.91	50.00	45.00	37.18	17.82
	60	30.00	25.90	19.10	0.00	50.00	43.17	31.83	0.00
	70	35.00	28.74	11.26	0.00	50.00	41.06	16.08	0.00
	80	40.00	31.14	3.86	0.00	50.00	38.93	4.82	0.00
	90	45.00	30.00	0.00	0.00	50.00	33.33	0.00	0.00
	100	50.00	25.00	0.00	0.00	50.00	25.00	0.00	0.00
	110	55.00	20.00	0.00	0.00	50.00	18.18	0.00	0.00
	120	60.00	15.00	0.00	0.00	50.00	12.50	0.00	0.00
4 Stations	10	8.80	8.76	8.71	8.66	88.02	87.63	87.15	86.60
	20	13.50	13.30	12.90	12.50	67.50	66.50	64.50	62.50
	30	16.16	15.54	14.57	13.28	53.88	51.81	48.58	44.25
	40	17.38	16.23	14.38	12.01	43.45	40.57	35.96	30.02
	50	20.00	18.00	14.87	7.13	40.00	36.00	29.74	14.26
	60	24.00	20.70	15.30	0.00	40.00	34.50	25.50	0.00
	70	28.00	22.99	9.01	0.00	40.00	32.85	12.87	0.00
	80	32.00	24.91	3.09	0.00	40.00	31.14	3.86	0.00
	90	36.00	24.00	0.00	0.00	40.00	26.67	0.00	0.00
	100	40.00	20.00	0.00	0.00	40.00	20.00	0.00	0.00
	110	44.00	16.00	0.00	0.00	40.00	14.55	0.00	0.00
	120	48.00	12.00	0.00	0.00	40.00	10.00	0.00	0.00

Table G.3: Effective Induction Rates for Conveyor Speed of 200 Trays per Minute.

	Nominal Induction Rate (tpm)	Effective Induction Rate (tpm)				% of Nominal Induction Rate (%)			
		1	2	3	4	1	2	3	4
1 Station	10	10.00	9.98	9.95	9.91	100.00	99.75	99.45	99.13
	20	20.00	19.80	19.50	19.20	100.00	99.00	97.50	96.00
	30	30.00	29.34	28.36	27.09	100.00	97.80	94.54	90.31
	40	40.00	38.46	36.06	32.85	100.00	96.15	90.15	82.13
	50	50.00	47.06	42.37	36.22	100.00	94.12	84.73	72.44
	60	60.00	55.00	47.20	37.50	100.00	91.67	78.67	62.50
	70	70.00	62.36	50.54	17.09	100.00	89.09	72.21	24.42
	80	80.00	68.97	51.03	0.00	100.00	86.21	63.79	0.00
	90	90.00	74.84	35.16	0.00	100.00	83.16	39.06	0.00
	100	100.00	80.00	20.00	0.00	100.00	80.00	20.00	0.00
	110	110.00	84.45	5.55	0.00	100.00	76.78	5.04	0.00
	120	120.00	80.00	0.00	0.00	100.00	66.67	0.00	0.00
2 Stations	10	9.81	9.78	9.76	9.72	98.09	97.85	97.56	97.24
	20	18.70	18.50	18.20	17.90	93.50	92.50	91.00	89.50
	30	26.22	25.65	24.79	23.68	87.41	85.49	82.64	78.94
	40	32.73	31.47	29.51	26.88	81.82	78.68	73.77	67.20
	50	37.96	35.72	32.16	27.49	75.91	71.45	64.32	54.99
	60	40.10	36.80	31.50	25.00	66.83	61.33	52.50	41.67
	70	46.67	41.57	33.70	11.40	66.67	59.39	48.14	16.28
	80	53.33	45.98	34.02	0.00	66.67	57.47	42.53	0.00
	90	60.00	49.90	23.44	0.00	66.67	55.44	26.04	0.00
	100	66.67	53.33	13.33	0.00	66.67	53.33	13.33	0.00
	110	73.33	56.30	3.70	0.00	66.67	51.18	3.36	0.00
	120	80.00	53.30	0.00	0.00	66.67	44.42	0.00	0.00
3 Stations	10	9.57	9.54	9.52	9.48	95.68	95.44	95.15	94.85
	20	17.00	16.90	16.60	16.30	85.00	84.50	83.00	81.50
	30	22.25	21.76	21.04	20.09	74.16	72.53	70.12	66.98
	40	26.19	25.19	23.61	21.51	65.48	62.96	59.03	53.78
	50	28.47	26.79	24.12	20.62	56.93	53.58	48.24	41.24
	60	30.00	27.60	23.60	18.80	50.00	46.00	39.33	31.33
	70	35.00	31.18	25.27	8.55	50.00	44.54	36.10	12.21
	80	40.00	34.48	25.52	0.00	50.00	43.10	31.90	0.00
	90	45.00	37.42	17.58	0.00	50.00	41.58	19.53	0.00
	100	50.00	40.00	10.00	0.00	50.00	40.00	10.00	0.00
	110	55.00	42.23	2.77	0.00	50.00	38.39	2.52	0.00
	120	60.00	40.00	0.00	0.00	50.00	33.33	0.00	0.00
4 Stations	10	9.30	9.28	9.25	9.22	93.02	92.79	92.51	92.21
	20	15.40	15.30	15.10	14.80	77.00	76.50	75.50	74.00
	30	19.02	18.60	17.98	17.17	63.39	61.99	59.93	57.25
	40	21.55	20.72	19.43	17.70	53.88	51.81	48.58	44.25
	50	22.77	21.43	19.30	16.50	45.55	42.87	38.59	32.99
	60	24.00	22.10	18.90	15.00	40.00	36.83	31.50	25.00
	70	28.00	24.94	20.22	6.84	40.00	35.63	28.88	9.77
	80	32.00	27.59	20.41	0.00	40.00	34.48	25.52	0.00
	90	36.00	29.94	14.06	0.00	40.00	33.26	15.62	0.00
	100	40.00	32.00	8.00	0.00	40.00	32.00	8.00	0.00
	110	44.00	33.78	2.22	0.00	40.00	30.71	2.02	0.00
	120	48.00	32.00	0.00	0.00	40.00	26.67	0.00	0.00

Table G.4: Input Data for Example Experiments.

Trial No.	Demand (orders/hr)	Wave Length (min)	Reqd Throughput (items/wave)	Sorter Speed (trays/min)	Induction Rate (items/min)	Required Inductors	Required Stations
Example 1	1500	40	3000	100	20	6	2
Example 2	3000	40	6000	100	20	16	4
Example 3	2200	40	4400	100	20	8	2

Table G.5: Induction Results from Example Experiments.

	c.v. = 0.2			c.v. = 0.4		
	Example 1	Example 2	Example 3	Example 1	Example 2	Example 3
Inductor Utilization	0.7142	0.9416	0.8877	0.7245	0.9448	0.9005
Maximum Time (min)	28.86	38.13	35.87	29.48	38.26	36.51
Minimum Time (min)	28.27	37.22	35.12	28.67	37.14	35.64

Table G.6: Inductor Throughput for Example Experiments.

Station	Inductor	Number of Items Inducted					
		c.v. = 0.2			c.v. = 0.4		
		Ex. 1	Ex. 2	Ex. 3	Ex. 1	Ex. 2	Ex. 3
1	1	542.9	589.2	661.8	549.2	589.3	672.9
1	2	505.6	469.1	609.8	506.9	465.5	611.0
1	3	451.4	305.1	527.5	441.8	303.3	522.2
1	4		135.6	398.5		141.6	390.9
2	1		590.8			592.2	
2	2		469.0			464.9	
2	3		305.5			302.4	
2	4		137.7			141.5	
3	1	542.5	590.4	662.4	551.2	591.9	670.9
3	2	505.7	467.9	608.5	507.1	465.0	613.2
3	3	451.9	304.9	530.5	443.7	303.9	524.6
3	4		137.6	401.1		142.1	394.4
4	1		589.9			591.3	
4	2		467.0			462.8	
4	3		303.0			299.9	
4	4		137.3			142.4	

Table G.7: Induction Times for Example Experiments.

c.v. = 0.2			c.v. = 0.4		
Example 1	Example 2	Example 3	Example 1	Example 2	Example 3
28.38	37.41	35.41	28.91	37.63	36.25
28.66	37.80	35.37	29.12	37.88	35.81
28.74	37.82	35.51	28.99	37.77	36.17
28.46	37.44	35.28	28.80	37.14	35.93
28.82	37.94	35.46	29.21	38.02	36.09
28.48	37.95	35.48	28.76	38.26	35.89
28.43	37.71	35.68	28.82	37.72	36.09
28.36	37.47	35.41	28.82	37.78	36.11
28.62	38.04	35.84	29.01	38.13	36.13
28.85	37.56	35.30	29.10	37.84	36.00
28.57	38.02	35.47	28.89	38.17	36.07
28.61	37.70	35.43	28.83	37.78	35.90
28.68	37.74	35.46	28.81	38.03	35.96
28.50	37.89	35.87	29.21	37.94	36.19
28.54	37.63	35.58	28.95	37.59	36.04
28.46	38.04	35.48	28.84	37.72	36.11
28.67	37.79	35.53	28.89	37.91	36.16
28.61	37.72	35.56	28.92	37.62	36.14
28.54	37.74	35.34	29.16	37.53	35.89
28.71	37.40	35.54	28.89	37.52	35.73
28.46	37.72	35.38	28.94	37.78	36.11
28.60	37.29	35.34	29.10	37.70	36.04
28.69	37.47	35.53	28.75	37.78	36.19
28.76	37.69	35.51	29.07	37.62	36.03
28.41	37.53	35.59	28.91	37.61	36.11
28.42	37.71	35.37	28.94	37.80	36.29
28.56	37.70	35.69	29.25	37.81	36.25
28.86	37.54	35.59	29.12	37.40	36.21
28.58	37.67	35.42	28.83	37.84	36.14
28.49	37.98	35.61	28.99	37.98	35.76
28.54	37.60	35.48	29.14	37.70	35.93
28.63	37.87	35.43	28.92	38.02	35.91
28.48	37.45	35.37	29.25	37.80	36.22
28.50	37.62	35.64	28.98	37.91	36.24
28.53	37.61	35.64	29.06	37.58	35.86
28.52	37.93	35.56	29.00	37.84	36.09
28.57	37.36	35.50	28.82	37.71	35.90
28.61	37.54	35.56	28.87	37.62	36.10
28.42	38.08	35.53	28.74	38.14	35.93
28.54	37.45	35.63	28.83	37.55	36.07
28.69	37.94	35.36	28.82	37.94	35.82
28.46	37.90	35.43	28.71	38.13	36.00
28.63	38.13	35.73	28.88	38.15	35.97
28.58	37.59	35.64	28.95	37.77	35.89
28.48	37.83	35.12	29.21	37.76	36.01
28.60	37.55	35.61	28.92	37.67	36.17
28.44	37.73	35.47	29.25	37.89	36.02
28.56	37.57	35.56	28.85	37.74	35.93
28.64	37.72	35.81	29.00	37.61	35.99
28.79	37.40	35.36	28.99	37.86	35.86
28.65	37.62	35.43	29.15	37.60	35.64
28.45	37.40	35.46	29.18	37.66	35.90
28.38	37.53	35.84	28.87	37.60	36.39
28.41	37.70	35.54	29.02	37.96	35.74
28.58	37.40	35.76	28.76	37.64	36.51
28.60	37.26	35.63	29.11	37.71	36.08
28.48	37.97	35.39	29.06	38.01	36.16

Table G.7: Induction Times for Example Experiments — *continued*.

c.v. = 0.2			c.v. = 0.4		
Example 1	Example 2	Example 3	Example 1	Example 2	Example 3
28.73	37.60	35.32	29.16	37.80	35.81
28.50	37.89	35.61	28.82	37.91	36.20
28.60	37.56	35.34	28.84	37.85	35.89
28.48	37.96	35.87	29.20	37.75	36.07
28.61	37.48	35.72	29.14	37.82	36.43
28.33	37.64	35.49	28.70	37.66	35.89
28.52	37.87	35.58	28.72	38.12	36.29
28.40	37.75	35.48	28.99	37.91	36.12
28.55	37.42	35.68	29.02	37.67	36.20
28.51	37.65	35.54	29.22	37.51	36.08
28.74	37.49	35.67	29.06	37.86	36.22
28.60	37.86	35.65	28.82	37.89	36.25
28.70	37.44	35.39	29.20	37.87	35.75
28.47	37.45	35.55	29.04	37.57	35.86
28.61	37.37	35.54	28.96	37.69	35.91
28.59	37.61	35.25	28.80	37.83	35.94
28.51	37.42	35.49	28.83	37.88	35.94
28.57	37.68	35.39	29.48	37.95	35.96
28.71	37.84	35.48	29.03	37.77	36.03
28.48	37.59	35.38	29.04	37.92	35.78
28.65	37.73	35.57	29.06	38.05	36.11
28.65	37.50	35.44	28.97	37.46	36.11
28.84	37.91	35.72	29.25	37.95	36.01
28.43	37.46	35.68	28.85	37.84	36.14
28.45	37.47	35.44	29.15	37.66	35.97
28.81	37.86	35.38	29.18	38.17	36.09
28.60	37.22	35.25	28.95	37.29	35.92
28.51	37.51	35.23	28.98	37.70	35.94
28.60	37.79	35.78	29.07	37.81	36.14
28.60	37.91	35.62	29.19	37.92	36.21
28.56	37.69	35.27	28.85	37.85	36.14
28.51	37.50	35.51	28.89	37.69	35.84
28.77	37.77	35.41	29.10	38.17	35.98
28.70	37.47	35.54	28.96	37.40	36.03
28.69	37.50	35.48	28.85	37.82	35.80
28.50	37.95	35.31	28.67	37.71	35.99
28.43	37.58	35.59	29.26	37.48	35.85
28.53	37.41	35.27	28.98	37.81	35.90
28.27	37.79	35.49	29.11	37.87	35.80
28.58	37.57	35.78	28.79	37.95	35.91
28.57	37.60	35.33	28.73	37.45	35.79
28.49	37.80	35.67	29.04	37.82	35.78
28.40	38.03	35.26	28.81	38.04	35.89
28.57	37.66	35.51	28.98	37.79	36.02

Vita

Mardi Russell was born and raised in Decatur, Alabama. She is the daughter of Kay and Fuller Russell. In May of 1999, she graduated Summa Cum Laude with a Bachelor of Science in Industrial Engineering from Mississippi State University. She began graduate school at Virginia Tech in the Fall of 1999 in the Industrial and Systems Engineering Department with an emphasis in Operations Research. While at Virginia Tech, she received a Material Handling Education Foundation scholarship from FKI Logistex, and won second place in the 2000 team Material Handling Design Competition sponsored by the College-Industry Council on Material Handling Education. She also served as treasurer of the Virginia Tech Student Chapter of INFORMS. She received a Master's degree from the Virginia Tech Grado Department of Industrial and Systems Engineering in May, 2001.