The effect of order release scheduling in sequential zone picking systems

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1. Research Motivation and Research Questions

Zone picking is a commonly used manual order picking system in which the warehouse is divided into multiple picking zones. This reduces walking distance and congestion in aisles. Zone picking is flexible in order volume, product size and the number of order pickers.

The drawbacks of an automated (sequential) zone picking system include blocking and congestion under heavy use. This leads to long order lead-times and higher costs, begging the question: how to deal with these drawbacks?

Can order release scheduling be an easy and simple solution to blocking and congestion? What influence has this decision of when and which customer order to release into the system? And how to determine the best order to release, using what criteria? All these questions are answered within the general research question:

What is the effect of order release scheduling (sequencing) on the performance of an automated sequential zone-picking system?

Performance is measured in overtime, average waiting time, average throughput-time, average lead-time, average tardiness and unfinished orders.

2. Method

Simulation is used to answer the research question. Thirty-three different order release rules have been tested using a 3D simulation package called Material Handling Simulation Package (MHSP). The tested rules where adapted from job shop scheduling and flexible manufacturing systems scheduling or where newly devised. Day-to-day operations have been simulated for three types of zone-picking configurations and twelve demand patterns with the objective to find robustly performing scheduling rules. Each scenario is run 50 times.

The scheduling rules are used to order the list of waiting orders, determining which order is allowed into the system. First come, first served is used as the default rule. An order enters the zone-picking system in its own private order-bin. The order picking system is filled up to an optimal number of order-bins that can be processed at the same time. This number varies among the different zone-picking configurations. The order-bin travels past zones depending on the routing configuration, and only visits segments and zones that it needs to visit, i.e. if an item needs to be picked there.

All zone-picking configurations consist of eight zones with one order picker per zone. Zones have 5 single sided aisles with each 4 shelves (20 shelves in total). Among the zone-picking configurations the routing is the only difference. The first order picking system has a serial layout. Order-bins always follow the same route (the same sequence of zones) without the possibility to recirculate. The second layout allows for recirculation. There is one recirculating loop that passes by every zone. This layout referred to as a single-segment layout. The third and last layout has multiple recirculating loops. This is a multi-segment layout, in which there are multiple small loops, consisting of two zones each, and one main recirculation loop (see figure 1).

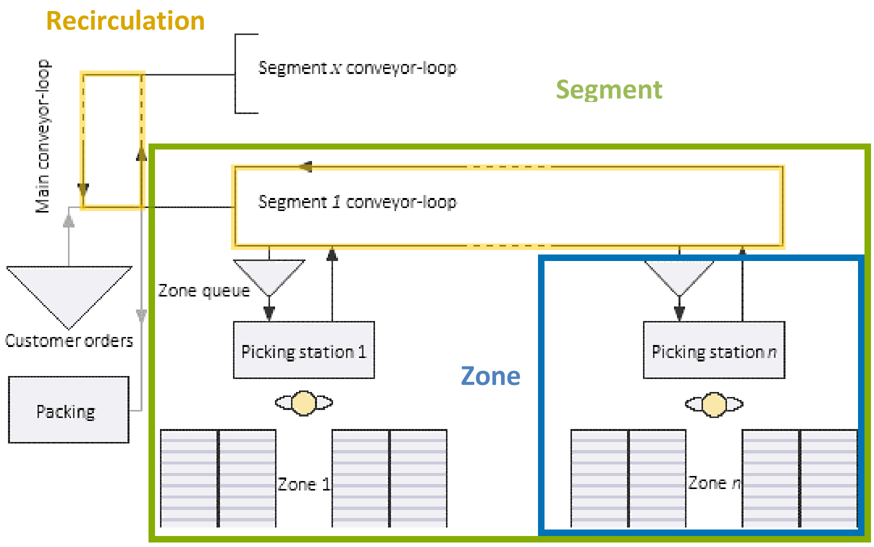


Figure 1: Multi-segment zone-picking configuration

The arrival of orders, as well as the order picking and packing process, are stochastic processes, each having a known distribution. Stochasticity is used to model the uncertainty in the different warehouse operations because warehouse operations contain many uncertainties on both internal (e.g. order picking accuracy) and external (demand uncertainty) factors (Gong, 2009).

Demand patterns vary on order-size, arrival rate distribution and workload distribution. Orders can be small (number of items is uniformly distributed between 1 and 5), large (uniform distribution between 10 and 30) or a 50% mix of both distributions. Small orders represent direct-to-customer distribution while large orders represent typical retail distribution (Parikh and Meller, 2008). Arrival rate is constant (homogeneous) or varies over time (non-homogeneous). Orders arrive during the first seven hours of the day, leaving one hour extra to complete unfinished orders. Ten percent of all daily orders arrive before operation is started, providing an initial list to start with. Workload is distributed evenly over time and zones, or is partly dependent on arrival time, depending on the scenario.

Six performance measures are used. Overtime is the time that is needed to complete all orders after the last order is received. Average waiting time is the time between the arrival of an order, and the release of the order into the order picking system. Average throughput-time is the time between the release and the completion of an order. The combination of waiting time and throughput-time is order lead-time, and is thus the time between order arrival and order completion. Average tardiness is determined by the due date of an order (determined by the constant slack (CONSLK) method) and the actual completion of the order. If the order is completed before due, tardiness is zero, if completed past due, tardiness is the time between completion and due time. The amount of orders that remain unfinished after the eight-hour workday is represented by the unfinished orders measure. Order lead-time and tardiness are considered to be the most important performance measures.

Parameter		Values
Routing configuration		Serial, **Single-segment**, Multi-segment
Demand pattern	Order-size	**small: U[1,5]**, large: U[10,30], mix: 50/50
	Arrival rate	Homogeneous, **non-homogeneous**
	Item location	**All random (uniform)**, 10% dependent on arrival

Scheduling rules		RAND, **FCFS**, FCFS-50, FCFS-100, EDD, SPT, SPiT, STT, SWT, LPT, LPiT, LTT, LWT, COVERT, ATC, CR+SPT, WINQ, XWINQ, MDD, CR+Lb, CR+Lo, CR+Lp, SPT/TOT, L-SPT/TOT, MODSQ, NWF, STD, BWL, FFD, FFD+PT, QD, SWD, HLQD

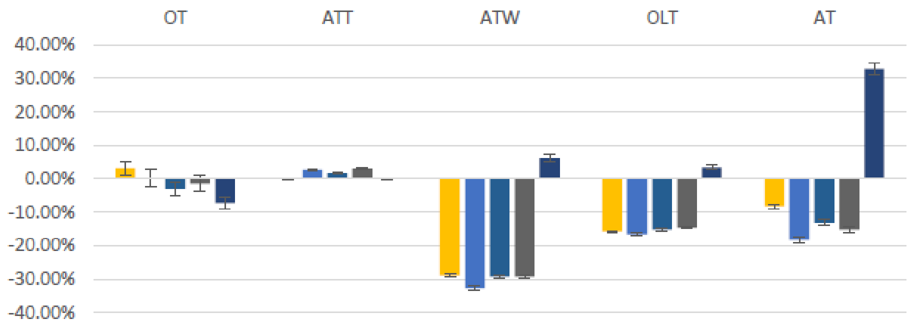
Table 1: Scenario design (bold is default value)

3. Results

Order lead-time is decreased up to 50% and tardiness is decreased up to 65%. Using the best performing rule for each scenario results in an average decrease of 17% in order lead-time and 24% in tardiness.

Overtime, being determined by the speed of the bottleneck, is difficult to decrease. The amount of orders in the system was usually enough to keep all zones busy. Average throughput-time is mainly dependent on the maximum number of order-bins allowed in the system, and remains unaffected by the scheduling rules most of the time. Due to large decreases in average time waited, average order lead-time decreases significantly.

Figure 2 shows the performance of well-performing scheduling rules in the multi-segment warehouse. This is one of the 36 tested scenario and shows the general picture of no or only slight decreases in overtime (OT) and throughput-time (ATT), and significant decreases in time waited (ATW), order lead-time (OLT) and tardiness (AT).



	OT	ATT	ATW	AOLT	AT	UO
FCFS	48:42	13:07	15:42	28:49	09:58	0
XWINQ.2	3.14%	0.06%	-28.93%	-15.74%	-8.25%	0
WINQ.2	0.19%	2.69%	-32.60%	-16.54%	-18.26%	0
HLQD.1	-2.96%	1.72%	-29.26%	-15.16%	-13.11%	0
BARA.3	-1.47%	2.99%	-29.22%	-14.56%	-15.14%	0
LPT/TOT.1	-7.28%	0.08%	6.12%	3.37%	32.71%	0

Figure 2: Performance overview of scheduling rules in the multi-segment warehouse

The rules that perform well overall are the expected work in next queue (XWINQ) rule, the block-and-recirculate avoidance (BARA) rule, the shortest processing time (SPT) rule and the critical ratio plus shortest processing time (CR+SPT) rule. In table 2 the frequency of rules performing best or within 2.5% of the best rule is shown for the best 16 rules, sorted on the sum of all performance indicators.

The XWINQ rule, that releases the next customer order that needs to visit the zones with the least (expected) amount of work, performs the most robust. The BARA rule aims to minimize throughput-time by avoiding an order arriving at a fully occupied zone-queue. It only releases orders that do not need to visit a full zone, and performs well in terms of average throughput-time. The SPT rule releases the order with the shortest processing time, and performs well in reducing order lead-time.

The CR+SPT rule combines shortest processing time with the critical ratio (i.e. time left before due divided by the time needed to complete). This rule is a known robust performing rule in job shops (Kemppainen, 2005) and performs better on tardiness than other (single-attribute) SPT rules.

Rule	Number of times among best							Rule	Number of times among best						
	OT	ATT	ATW	OLT	AT	UO	SUM		OT	ATT	ATW	OLT	AT	UO	SUM
XWINQ	8	6	21	19	13	15	82	MDD	5	7	2	8	4	14	40
BARA	8	23	0	19	10	13	73	RAND	6	4	4	6	5	14	39
SPiT	1	10	9	23	15	15	73	L-SPT/TOT	6	8	0	6	4	15	39
CR+SPT	3	8	7	21	17	13	69	STD	2	5	1	14	4	13	39
SPT	2	9	8	21	14	14	68	FFD	0	28	0	0	0	10	38
WINQ	8	1	16	13	9	18	65	FFD+PT	0	25	0	0	0	10	35
CR+Lb	7	16	0	6	3	13	45	FCFS-200	8	7	0	3	1	14	33
STT	3	5	1	14	5	13	41	FCFS-50	9	6	0	3	1	13	32

Table 2: Frequency of rules performing best or within 2.5% of the best rule, sorted on sum (out of 36 scenarios)

Considering the design parameters, the following remarks can be made: (1) order release scheduling has most effect when handling small or a mix of small and large orders, and (2) when workload is unbalanced, the benefit of the well-performing scheduling rules increases significantly, compared with first come, first served.

4. Practical relevance

The results show that a low cost solution is able to increase the performance of a zone picking system. Using simple but smart scheduling rules it is possible to increase order picking performance significantly. These performance increases mean a quicker warehouse response and higher customer service level (shorter order lead-time).

Many influencing factors have not been tested in this thesis, but this first exploration into the effect of order release scheduling reveals that the performance of the zone-picking system can be increased significantly with the use of these scheduling rules. More research is needed to determine the effect of untested factors (queue size, zone size, etc.) and the interaction between other warehouse processes, e.g. the shipping process.

With this extra research, clear recommendations can be formulated on which scheduling rule to use in which environment. These are necessary in order to convince managers to use scheduling rules other than first come, first served. Currently the democracy and fairness of first come, first served, and the importance of certain customers play the major role in sequencing decisions.

References

Gong, Y. (2009). *Stochastic modelling and analysis of warehouse operations*. Erasmus University Rotterdam.

Kemppainen, K. (2005). *Priority Scheduling Revisited: Dominant Rules, Open Protocols, and Integrated Order Management*. Helsinki School of Economics.

Parikh, P. J., and Meller, R. D. (2008). Selecting between batch and zone order picking strategies in a distribution center. *Transportation Research Part E: Logistics and Transportation Review*, *44*(5), 696-719.