WHITE PAPER

A Win-Win

Pushing Your Sortation System Further

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INFORM

Driving return on investment (ROI), optimization, milking assets, etc. – there are many ways to describe a parcel operator's need to generate revenue above cost for asset investments. This includes both software and hardware investments. This paper will explore how parcel operators can increase the efficiency and subsequently the handling capacity of their sortation systems without changing anything in their sorter but rather through the optimized allocation of load units to unloading docks via their yard management system (YMS).

This paper summarizes a simulation run by INFORM where we sought to explore the flow-on possibilities of improved yard management system decision making. We found that, with minimal effort, parcel operators can generate tremendous value from improvements in their sortation system without modifying the asset, but rather by allowing a YMS empowered with AI to make better overall routing decisions that strongly considered the impact on the peripheral sortation system.

The Goals of a Yard Management System

When we think of yard management systems and their aims, a few general goals come to mind.

YMS-centric Goals:

- Manage inbound and outbound load units/transports
- Maximize efficiency
- Minimize excess travel.

There are no surprises here. With these goals in mind, a well-performing YMS can achieve a broad range of operational improvements out of the box, including:

- Increased yard vehicle efficiency
- Improved facility communication
- Improved gate processes
- Improved yard transparency
- Improved dock door management.

All of these are good outcomes on their own, but really, this only scratches the surface of parcel center operational needs. We decided we had to look deeper into the sortation facilities to derive added value. When we did, a new set of goals emerged.

Excluding the bricks and mortar of parcel operators' sorting facilities, in most cases, their sortation system (sorter) represents the single largest investment they've made. From this perspective, it doesn't make sense to measure performance goals of the yard management system from a YMS-centric perspective. Instead, what we proposed and subsequently tested in the simulation, was that we flip yard management on its head and review the goals from the sorting system's perspective.

Sorter-centric Goals:

- Balance sorting workload to sub-90% capacity
- Minimize latest completion time
- Minimize simultaneous changes at pre-sorters
- Minimize simultaneous changes at adjacent dock doors.

Queueing Theory

Now, it would pay to have a quick "educational detour" to understand why balancing a hub's sorter's workload to sub-90% is important. The answer, of course, is queueing theory (also known as the "study of waiting systems").

Queueing theory was originally developed to describe and improve the Copenhagen telephone exchange. Since then, the models have been refined in the field of operations research (OR) and applied to many areas of business including telecommunications, traffic engineering, computer science, and, in particular, to industrial engineering through the design of factories, hospitals, and, for our purposes, parcel center sortation systems and yard management systems.

Queuing theory tells us that the expected delay grows exponentially in correlation with an increase in utilization. Our research and experience tell us that the practical capacity of sortation systems is typically 85 to 90% of its theoretical capacity (see Figure 1).

What's more, various scheduling policies can be used at queuing nodes:

- First-in, first-out (commonly known as "first-come, first-serve" or "FIFO")
- Last-in, first-out (LIFO)
- Processor sharing (capacity is shared equally)
- Priority
- Shortest job first.

The list goes on with each type being sub-divided and, in some cases, divided again. The simplest by far, and the one seen most often in yard management systems is first-come, first-serve. More advanced YMS systems are capable of some priority decision making; however, this is generally done via manual overrides vs. intuitive system decision making.

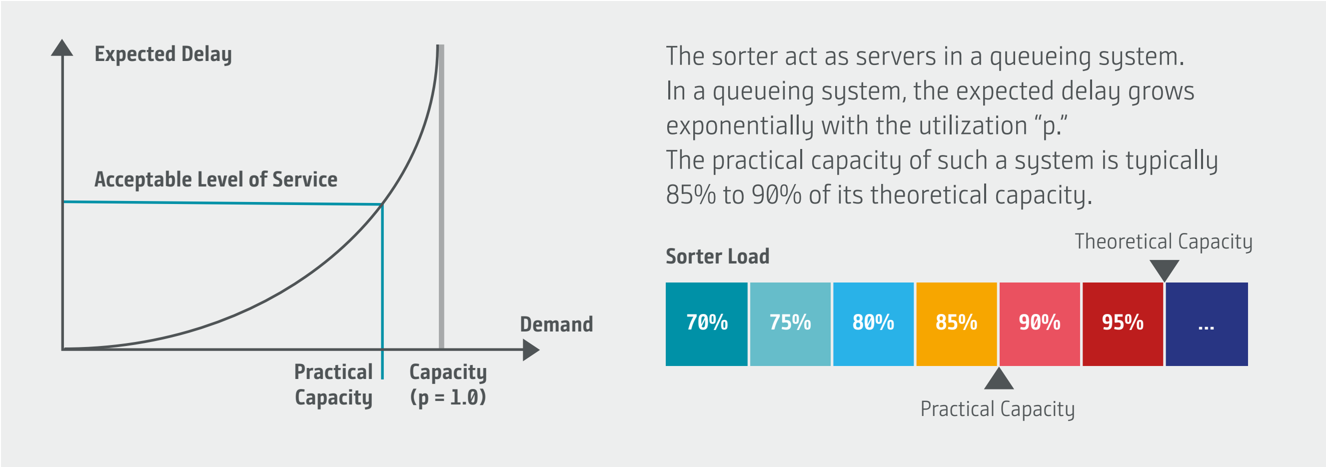

Figure 1: A brief look at queueing theory.

Simulation Input Variables, Assumptions, and Process

Input Variables

The main inputs of an optimized plan are:

- The sortation system model
- The load units to be unloaded
- The predetermined allocation of outbound tours to loading docks.

Sortation System Model – This model clearly identifies all unloading and loading docks with a clear typography of the sortation systems configuration connecting them. This includes all pre-sorters and sorters along with their connection to associated dock doors.

Figure 2 shows the structure of the small sortation model used in our simulation. Load units (shown in light grey) are discharged from the three unloading docks (U1, U2, U3). Parcels flow from the unloading docks via one pre-sorter (P1) to one of the three sorters (S1, S2, S3) to one of the nine loading docks (L1 to L9) that are grouped by threes and associated with a designated sorter. While simple, the small sortation model allows one to see that even in the simplest of models, a good deal of complexity can arise in decision making.

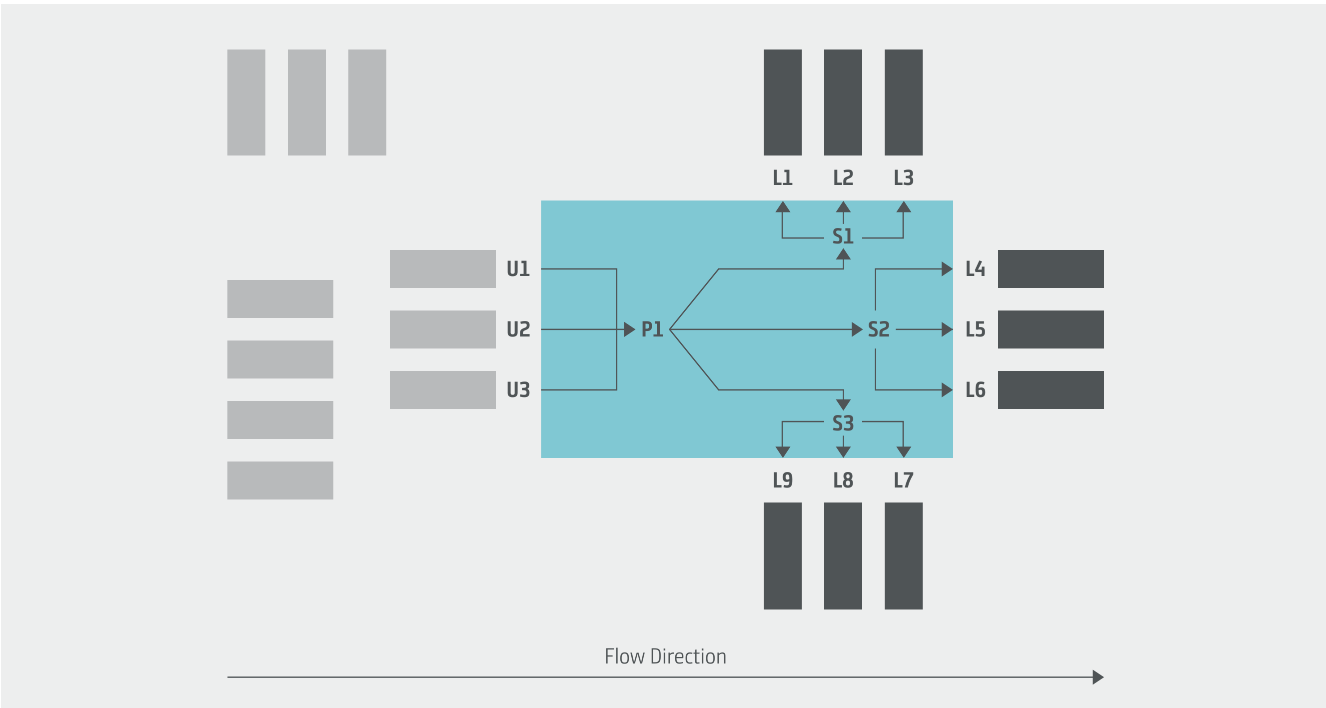

Figure 2: Flow in a sortation system from light grey input load units to dark grey outbound load units.

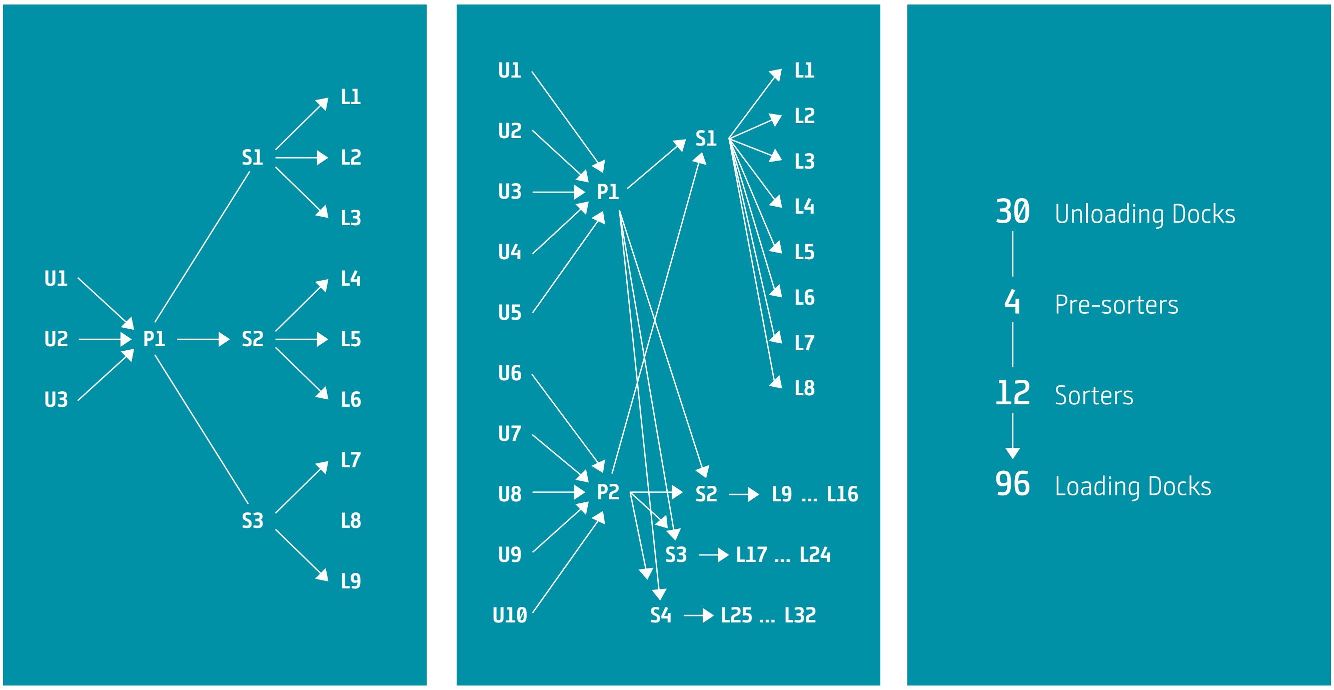

Figure 3: Examples of networks outlining the parcel flow from unloading to loading docks within a sortation system, including a small, medium, and large network.

The topology of a sorting system with the unloading nodes and the connections to the pre-sorters, sorters, and boading nodes is configured via the master data of the system and displayed as a network. Figure 3 illustrates by way of example with reference to three networks of varying sizes with 9, 32, and 96 loading docks. The flow of the parcels is from left to right, respectively, from the unloading nodes "U" to the loading nodes "L." The possible throughput (maximum processing power) is stored in parcels-per-time-interval for the individual levels or nodes of the network.

Inbound Load Units – The load-unit volume contains the containers that are currently being used for unloading, the load units on the yard, and the inbound load units. The containers are characterized by:

1. The time at which a load unit will, or is expected to, arrive.
2. Information on the total quantity of parcels contained in a load unit and, when possible, subdivided by the number of parcels per sorter (group of loading docks) or per loading dock.
3. The container type for determining the appropriate unloading dock.

Outbound Tours – This is the assignment of the outbound tours to the loading docks within the sortation system. Generally, this is adopted from the bigger-picture transport plans.

Assumptions

There were two prerequisites that are assumed within the simulation:

1. The YMS receives data providing load-unit content awareness and %-Fill.
2. The YMS receives real-time sorter capacity utilization data.

In addition, we worked within the following constraints:

1. An optimized plan is determined as part of a rolling plan.
2. The planning horizon comprises a single sorting wave.
3. The triggering events for a new plan included:
   a. Initial planning of a sorting shift
   b. Updating of the plan when the data situation changes. In particular, if there are changes in the expected arrival time of known load units, if additional load units arrive, if load units expected do not arrive, or when discharging loaded load units.

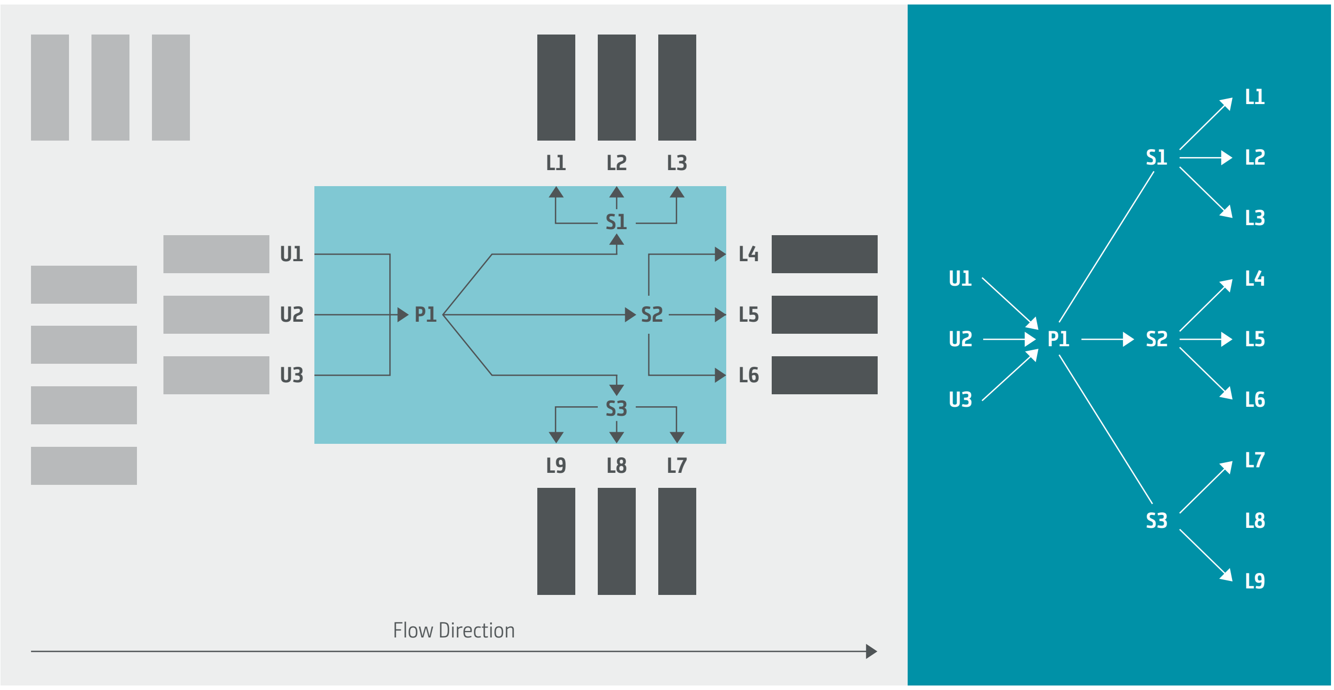

Figure 4: Example of converting the typographical layout of the small network into a decision tree.

Process

The simulation was run across three distinct size sortation networks: a small, a medium, and a large network. We started by translating these various sorter networks into their respective decision trees (see Figure 4 as an example). This basic decision tree formulates the beginning of INFORM's process to write an algorithm to optimize the workload and process flow for sorters.

From here, we ran repetitive simulations and aggregated the data into a reliable model. The simulations were run under a "First-Come, First-Serve Plan," where as soon as a load unit was empty, the next sequential load unit was assigned to the available unloading dock. In the "Optimized Plan," the AI algorithm developed in the first step above using OR techniques was tasked with making decisions about load unit assignment.

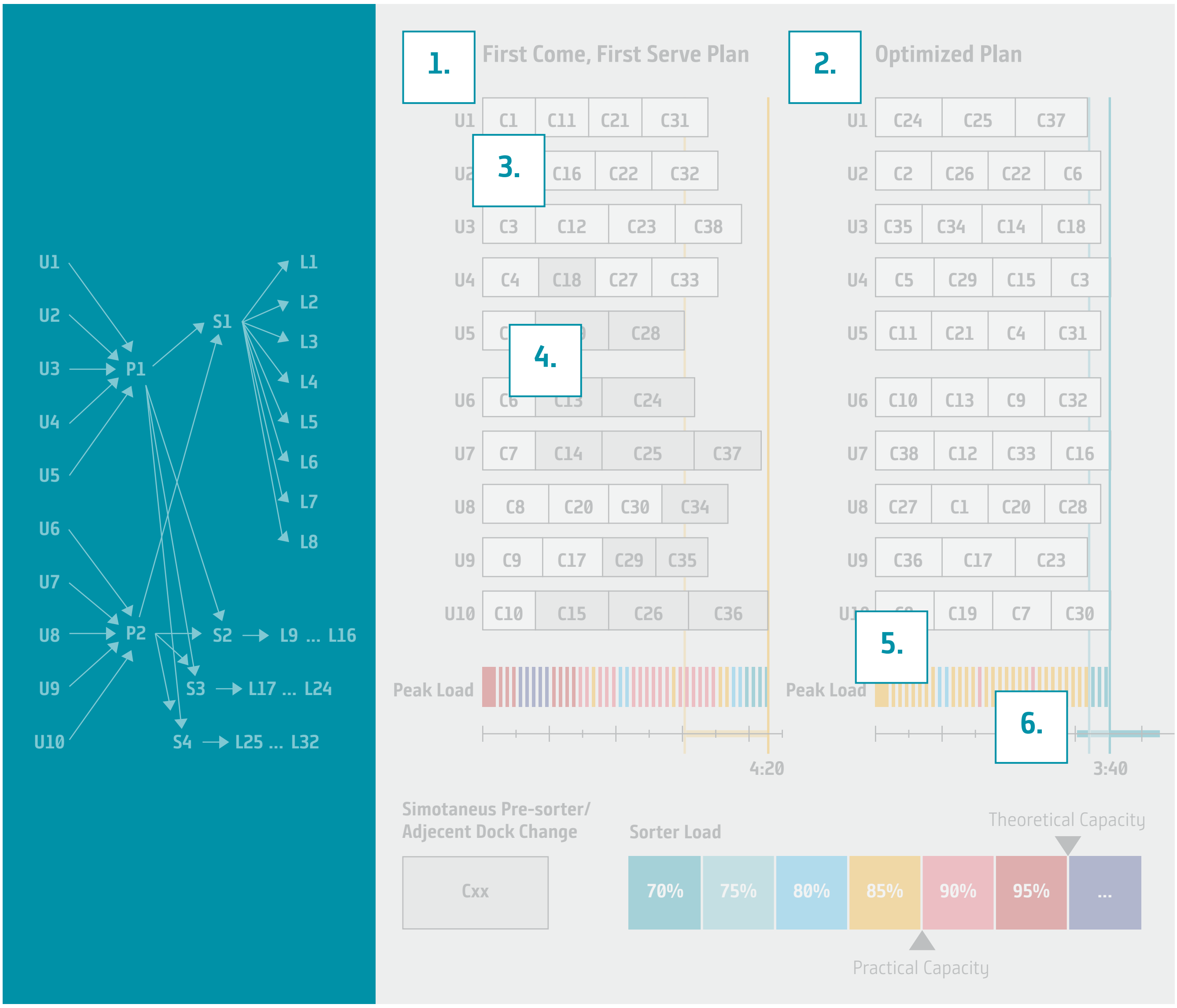

Figure 5: Overview of how to interpret the results.

The Results

The results of each of the three distinct size sortation networks are presented below. The figures accompanying each consist of:

1. On the left, we have a common queue processing model: "First Come, First Serve Plan."
2. On the right, we have an "Optimized Plan" calculated by the AI algorithm we wrote to resolve the challenge.
3. At the top, the numbered rectangles indicate which load units were assigned to which unloading docks. Their size indicates duration to unload – the larger the rectangle, the longer it took.
4. In addition, simultaneous load unit changes at a single pre-sorter or at adjacent dock doors are shaded in grey.
5. The capacity, or load, for each sorter is indicated below with colored bars that are keyed at the bottom. The aim was to keep the individual and peak load below 90% (e.g., no pink or red bars).
6. Below the overall sorter capacity are two colored bars, one lighter than the other. This indicates the first unloading dock to be completed, and the darker line indicates the last unloading dock to be completed – the difference is the end shift variance.

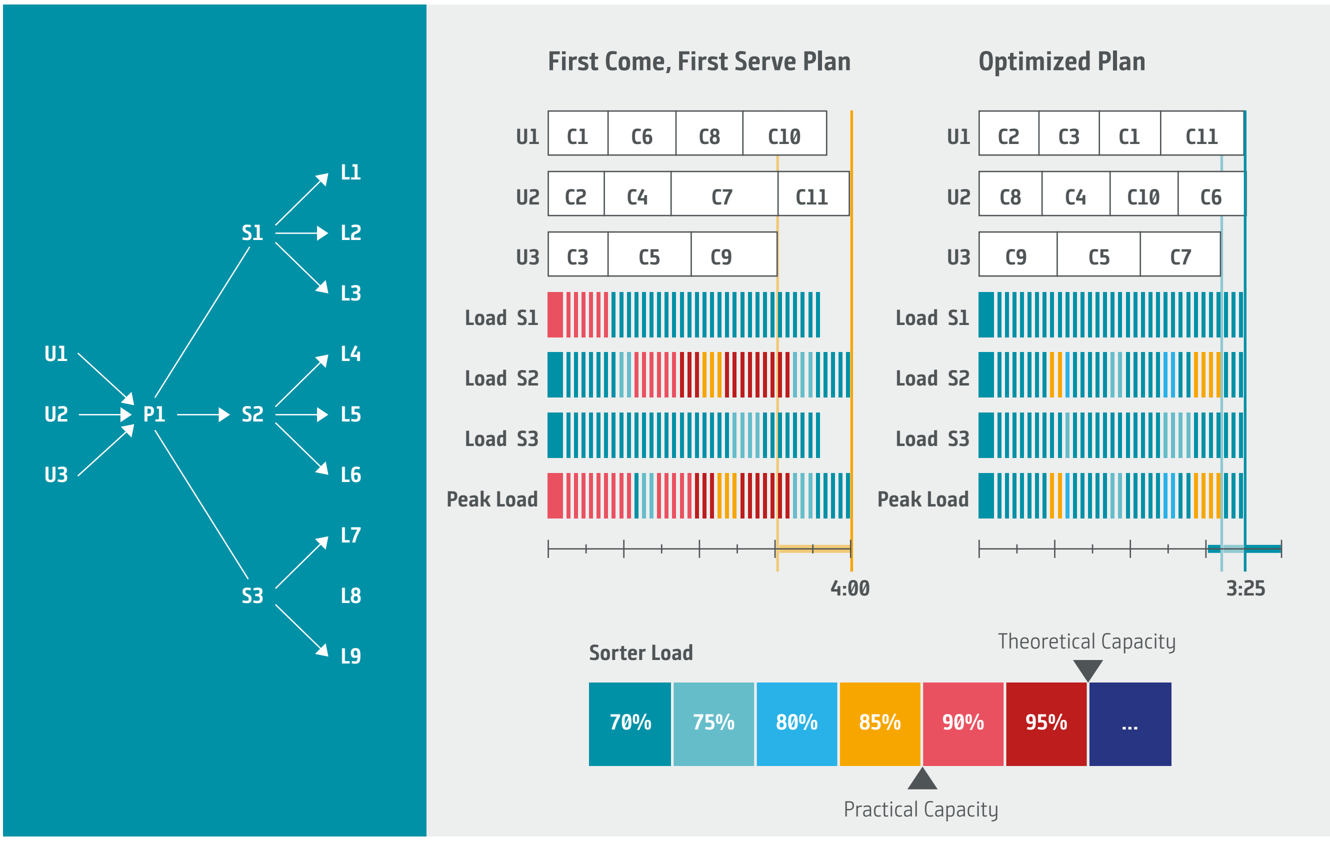

Figure 6: Sorting simulation results – small network.

Small Sortation Network

Figure 6 shows the small network and our simulation results. The small network consisted of:

- 3 unloading docks
- 1 pre-sorter
- 3 sorters feeding
- 3 loading docks each, for a total of 9 loading docks.

It was tasked with handling 11 load units, or containers, of inbound parcels. Even in such a small simulation example, we saw improvements across the board.

Sorter Workload Stats

Sorter utilization peaks at 81%, down from 92%. Average workload drops to 75%, down from 88%.

Total Time

There is a 10% reduction in total task time for all staff as the shift end variance is reduced by 35 minutes. (Note: Reducing end shift variance was not a goal of the project but emerged as an advantage across all network sizes simulated).

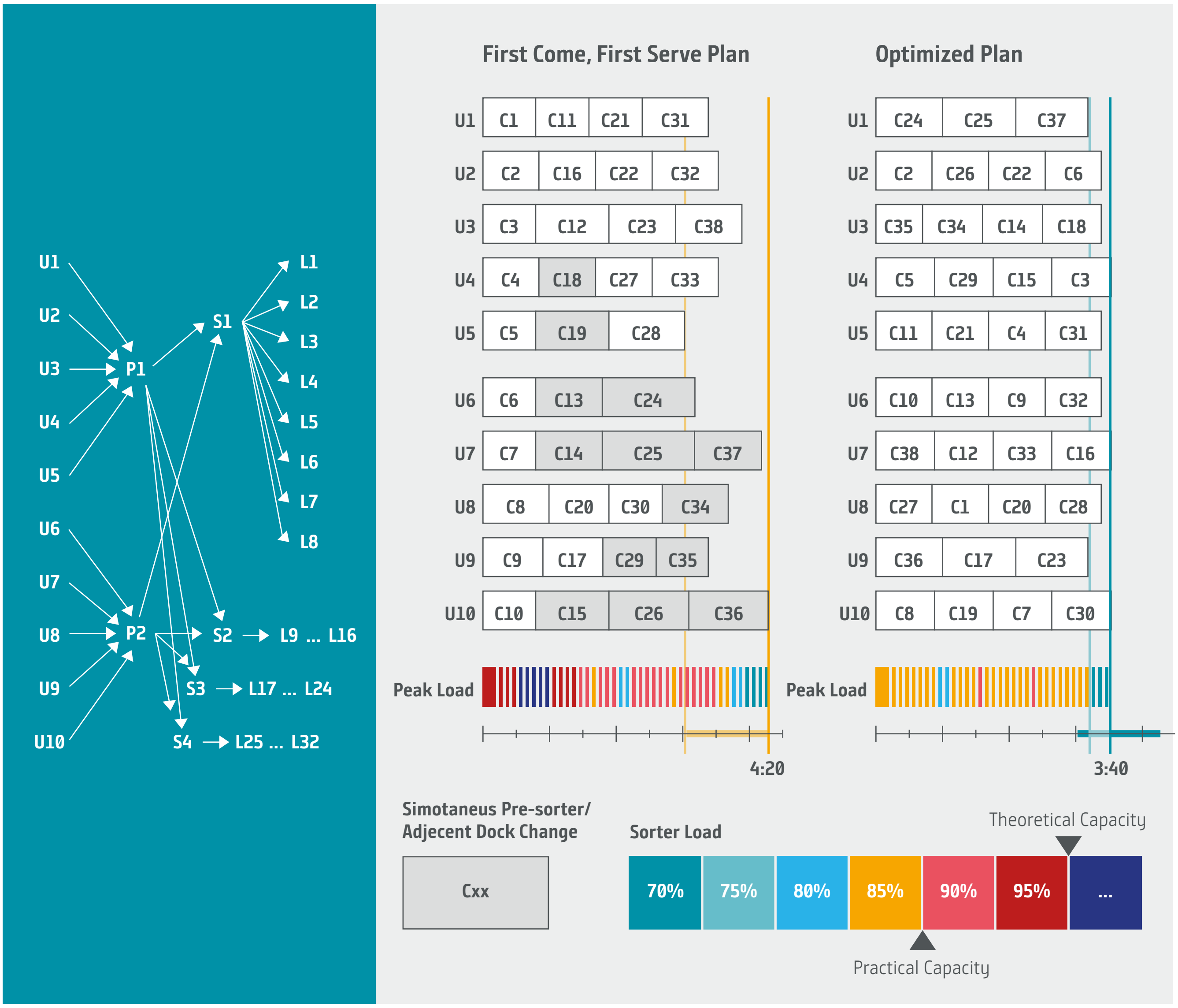

Figure 7: Sorting simulation results – medium network.

Medium Sortation Network

Figure 7 shows the medium network and our simulation results. The medium network was typified as a sorter center with:

- 10 unloading docks
- 2 pre-sorters
- 4 sorters feeding
- 8 loading docks each, for a total of 32 loading docks.

We then tasked it to handle 38 inbound load units.

Sorter Workload Stats

The optimized plan peaks at 89%, down from 97%. Average workload drops to 84%, down from 92%.

Total Time

The total time to complete the peak period reduced by 15% from 4:20 to 3:40. End shift variance is reduced by 75 minutes.

Safety Improvements

One can see in the “First Come, First Serve Plan” that there are 13 instances where simultaneous load unit changes at a single pre-sorter or at an adjacent dock door is an issue. In the “Optimized Plan,” these issues are all resolved, resulting in both a more productive sorter and safer overall yard environment.

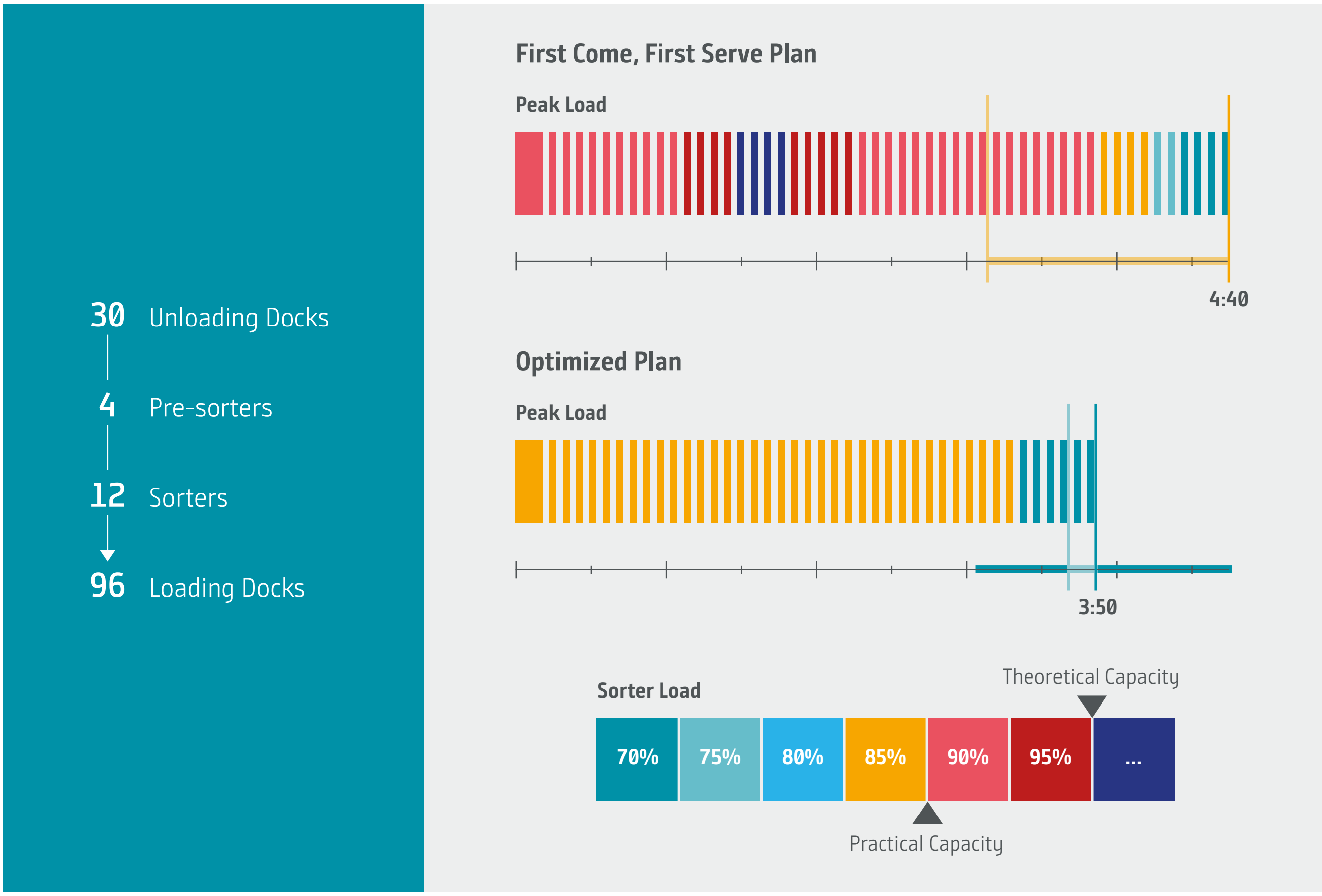

Figure 8: Sorting simulation results – large network.

Large Sortation Network

Figure 8 shows the large network and our simulation results. The large network was exemplified as:

- 30 unloading docks
- 4 pre-sorters
- 12 sorters feeding
- 8 loading docks each, for a total of 96 loading docks.

This simulation was tasked with handling 96 inbound load units.

Sorter Workload Stats

The optimized plan peaks at 85%, down from 98%.

Total Time

The total time to complete the peak period is 3:50 down from 4:40 – a staggering 18% reduction in total task time with a 90-minute reduction in end shift variance.

Summary

By utilizing container %-Fill and content awareness data paired with real-time sorter utilization data, a yard management system empowered with AI algorithms can improve decision making for inbound load unit dock assignment, which has the effect of balancing sorter efficiency to sub-90% levels. Through an intelligent allocation of load units in parcel operators' yards, they enable their existing sortation equipment to handle current load requirements more efficiently and allow for growth in their facilities' overall capacity without new infrastructure investment while delivering a higher return on investment for both their YMS and sorter equipment.

It's what we call a

"Win-Win."

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