THE DISTRIBUTION EXPERTS™
Fortna Thought Leadership Series

Decisions to Make When Implementing a Goods-to-Person System for eCommerce Fulfillment

WHY CONSIDER GOODS-TO-PERSON (GTP) FOR ECOMMERCE FULFILLMENT?

Amazon's sprawling fulfillment center network allows next In many distribution centers, the picking operation requires the most labor of any activity. The picking process itself is often composed of substantial time spent walking between storage locations to retrieve items. This is especially true for eCommerce operations with low lines per order. Goods-to-Person (GTP) systems eliminate this unproductive walking by bringing the product to the picker, rather than having the picker spend time moving to the product. This improves productivity, decreases labor, and often has additional benefits such as increased space efficiency.

Deploying a capital-intensive system like a GTP will require a business case. In addition to the tradeoff of capital vs. labor savings, GTP systems also typically consume less floor space. In general, they also reduce an operation's dependency on labor, although they may require more from a maintenance staff. There is also the issue of flexibility to adapt to changes in storage and throughput requirements. There are many factors that must be considered, and each situation is unique. The focus of this article is to compare and contrast the different types of GTP systems for eCommerce, but not to illustrate the full business case for implementation.

With many different technology variations available, it can seem daunting to choose the right one for your eCommerce operation. In this article, we break the decision down into a few concepts and discuss those concepts using first principles. First principles are statements that are categorically true and serve as the basis for logical reasoning. For example, if you add carriers or levels to a carousel, first principles dictate this must increase the storage capacity of each carousel and therefore drive down the total number of carousels needed from a storage perspective. At the same time, increasing the size of the carousel must also decrease the throughput capacity of each carousel and therefore drive up the number of carousels needed from a throughput perspective.

Our design methodology uses first-principles-based reasoning to arrive at a solution by transforming higher-level questions that can only be answered with, "it depends" (e.g., what is the best GTP system?), to lower-level questions that are directly answered with first principles (e.g., does adding levels increase storage and throughput ... and, if so, by how much?). This process ensures solutions are fully understood and tailored to completely address each business problem.

WHAT IS A GOODS-TO-PERSON (GTP) SYSTEM?

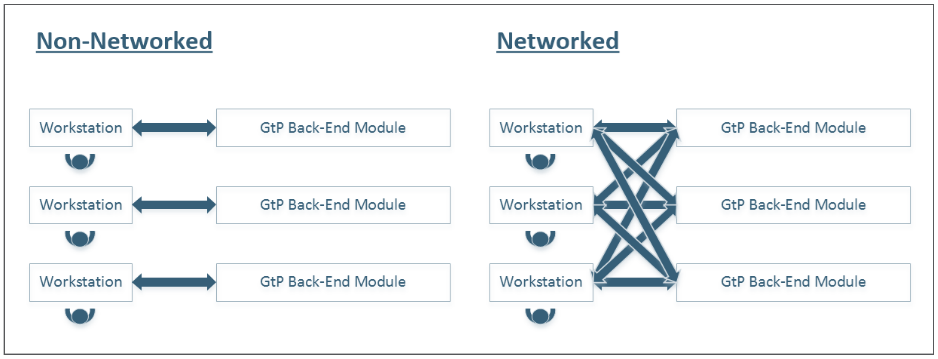
In general, a GTP system consists of three components:

- An automated storage and retrieval system, where the product is stored in totes, cases, or trays[1] and retrieved with an automated technology
- The GTP workstations, where operators[2] pick products from donor totes of SKUs and put them into order totes, and
- A transport system (conveyor or autonomous mobile robots) that connects the automated storage/retrieval technology and the workstations.

THE DECISIONS

Decision #1: Networked or Non-networked?

One of the first decisions to make is whether the system should be networked. Is it important that any tote in the storage/retrieval system can be routed to any GTP workstation? If yes, you will need a transport network for routing totes between the storage/retrieval system and the GTP workstations, or you will need to store every SKU in each aisle of the storage/retrieval system. The primary advantage of the conveyor network is that you can decouple the storage/retrieval functions from the workstations. This means that less inventory needs to be in storage, thus reducing inventory cost – though those savings may be offset by the cost of conveyor[3].



Non-networked GTPs have a one-to-one correspondence between aisles and workstations and non-networked GTPs can send any SKU in any aisle to any workstation.

[1] For simplicity, we will use tote throughout.

[2] These functions can also be performed by a pick-and-place robotic arm.

[3] For the remainder of this paper, we assume a networked GTP system. The concepts of this paper still apply to non-networked systems; however, the application of the concepts differs slightly.

Decision #2: How many GTP workstations?

If the system is networked, designing the workstation capacity and the storage/retrieval technology is independent. To determine how many GTP workstations you'll need, you can use the number of order lines to be fulfilled, and the expected productivity of the GTP workstations[4]. For example, assume the workstation productivity will be 500 lines per hour (LPH) or 750 units per hour (UPH) based on the work content, order profile, and personal fatigue and delay allowance. If the design-day requirements are 2,900 LPH, that would indicate that a system operating at 85% utilization[5] would require seven workstations. It's a simple calculation where the capacity of the GTP workstations is independent of setting the capacity of the storage/ retrieval system.

Decision #3: How much storage capacity?

All storage/retrieval technologies have two basic functions: providing storage locations for the inventory in the system and to enable the retrieval of the product when it's needed for an order. We think of storage positions in terms of capacity (e.g., the system needs to store 25,000 totes). We think of retrieving the product in terms of throughput capacity (typically measured in the number of dual cycles – a storage and a retrieval in the same cycle – the system can perform).

But the number of retrieval lines doesn't need to equal the number of order lines. That is, the number of retrieval lines needed is always less than or equal to the number of order lines. How much less is dependent on a factor called the lines reduction factor: the number of order lines satisfied for every retrieval line. How many order lines can we pick from the tote before sending it back to be stored? For example, earlier we stated a need of 2,900 order lines per hour. With a lines reduction factor of 1.33, that would equal 2,180 retrieval lines per hour needed.

Decision #4 – Which storage/retrieval system?

Now comes the interesting part … taking the storage/ retrieval requirements you've just identified (e.g., 25,000 tote storage positions and 2,180 dual cycles needed per hour) and deciding on an automated storage/retrieval technology.

[4] GTP workstation productivity rates are dependent on the work content of the activity. That is, the work content may include value-added-services, bubble wrapping the product, weighing the product, etc., in addition to the pick and put activities.

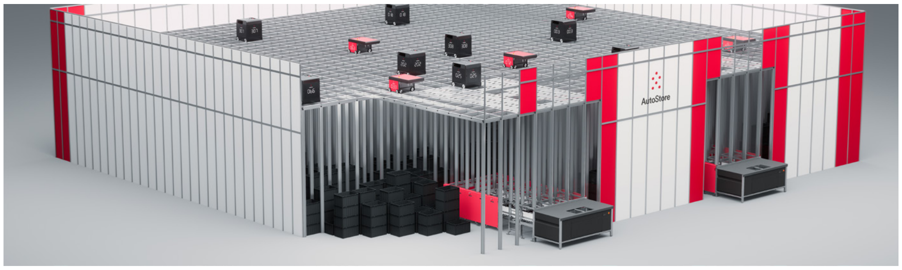
[5] There are many reasons why one should not design a system with an assumption of 100% utilization. Choosing the correct utilization level requires a detailed understanding of how work will be allocated to the GTP over time.

Before we begin the discussion, make sure you're familiar with the technologies listed below.

A bot used to horizontally move pods of inventory to pick locations

Automated storage/retrieval technologies for GTP

There has been an explosion in recent years of technologies capable of automatically moving product from a storage location to an operator. Most of these technologies fall within a few standard categories that we describe in more detail below. These conventional GTP technologies have been on the market for years and there are multiple examples that have provided a good return on investment.



A high-density storage system

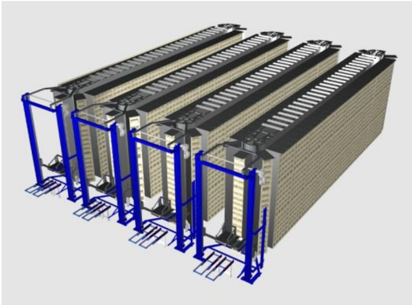
There are also automation companies bringing mobile robotic solutions to the market that use fleets of autonomous mobile robots (bots) to horizontally move pods of inventory to pick locations as well as high-density storage systems that use mobile robots to traverse vertical space to maximize the storage density of a building. Other companies are bringing specialized systems capable of handling garments and small items, or gantry systems designed for larger, bulkier products.

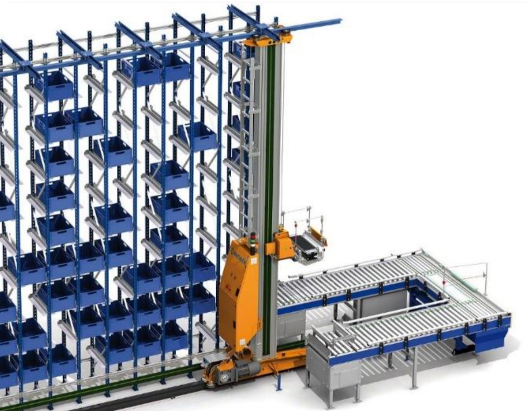
The following discussion will focus on the three most common storage/retrieval technologies because they are widely deployed, have long track records of success, and are available from a variety of suppliers. Furthermore, the concepts discussed for these technologies can be expanded to address any of the other technologies on the market.

> **"Conventional GTP technologies have been on the market for years and there are multiple examples that have provided a good return on investment."**

Horizontal Carousels with Automated Extractors

With this technology, totes are stored in horizontal carriers that can accommodate many storage levels in either a single-deep or a double-deep storage configuration. The carriers are connected by chain conveyors at the top and the bottom, so that carriers can be rotated to access any storage location. Automated extractors move vertically to extract one tote from a storage location and deliver the tote to a pickup and deposit (P&D) station. The extractor moves independently of the rotating carousel, delivering totes to the P&D station while the carousel rotates to the next location.



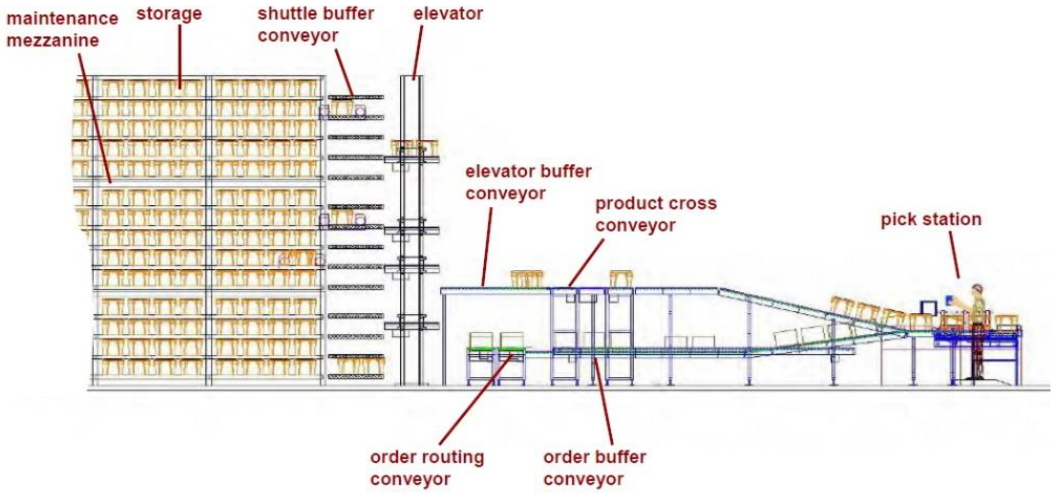


Mini-load cranes

With this technology, storage racks hold totes in either single-deep or multi-deep configurations. There are generally storage racks on both sides of an aisle. A crane travels in both the horizontal direction and the vertical direction simultaneously to access any location and deliver any requested tote to the P&D station. Typically, there is only one crane per aisle.

Shuttle-based systems

With this technology, as with mini-load crane systems, storage racks hold totes in either single-deep or multi-deep configurations. There are storage racks on either side of an aisle. However, in a shuttle-based system, the horizontal and vertical travel are accomplished by two independent technologies. The horizontal travel is accomplished via a shuttle; small robots that travel within one level and one aisle of a shuttle-based system. The shuttles deliver the totes to the end of an aisle, where the tote transfers to a vertical lift that then moves the tote vertically as necessary, including to the P&D station. The robots and the lift operate independently of one another.



The first step is to evaluate how each of the three storage/retrieval technologies would handle your requirements. Next, we examine the "first principles" that will drive your storage/retrieval selection, realizing that storage and throughput capacity must both be met for a design to be acceptable.

As can be seen from the previous section, each storage/retrieval system has its own concept of storage and throughput capacity determination.

Horizontal carousels with automated extractors
For horizontal carousels, for a given number of carriers, height, and whether a single-deep or double-deep configuration is used, it is straightforward to determine the minimum number of carousels needed from a storage requirement perspective. Likewise, for this configuration, an estimate of the throughput capacity of a carousel can be determined, which will allow us to determine what is the minimum number of carousels needed from a throughput requirement perspective. The overall number of carousels required will be the maximum of these two minimums.

For example, let's assume that we have configured our carousels to have 72 carriers with 13 levels per carrier and we will utilize double-deep storage. This means that each carousel provides 1,872 storage positions. This implies that 14 carousels will be needed to provide enough storage positions to meet or exceed our need for 25,000 positions. Let's further assume that we have determined the capacity of each carousel in this configuration to be 200 dual cycles per hour. This implies that 11 carousels will be needed to meet or exceed the 2,180 dual-cycles per hour. Therefore, we will need to provide at least 14 carousels with this configuration of storage depth, number of carriers, and levels.

By changing the configuration of each carousel by adding carriers or levels to each carrier will drive down the number of carousels needed from a storage perspective. However, this will also decrease the throughput capacity of each carousel and drive up the number of carousels needed from a throughput perspective. The system cost is proportional to the number of storage positions provided and the number of extractors. Thus, for a given number of storage positions, we'd like the configuration that leads to the fewest number of extractors that meet the throughput requirements of the system. This implies that the optimal horizontal carousel configuration in this example is likely larger than the initial configuration above.

"We examine the 'first principles' that will drive your storage/retrieval selection, realizing that storage and throughput capacity must both be met for a design to be acceptable."

Mini-load cranes

For mini-load crane systems, for a given number of levels, columns, and whether a single-deep or multi-deep configuration is used, we can determine the minimum number of aisles needed from a storage requirement perspective. Likewise, for this configuration, an estimate of the throughput capacity of a mini-load crane can be determined, which will allow us to determine what is the minimum number of cranes needed from a throughput requirement perspective. The overall number of aisles required will be the maximum of these two minimums.

For example, let's assume that we have configured our mini-load aisles to have 80 columns with 14 levels per storage rack and we will utilize a double-deep storage. This means that each aisle provides 4,480 storage positions. This implies that six aisles will be needed to provide enough storage positions to meet or exceed our need for 25,000 positions. Let's further assume that we have determined the capacity of each crane in this configuration to be 80 dual cycles per hour. This implies that 28 aisles will be needed to meet or exceed the 2,180 dual-cycles per hour. Thus, we will need to provide at least 28 aisles of this configuration.

By changing the configuration of each aisle by reducing the number of columns or levels in each rack will drive up the number of racks (and cranes) needed. However, first principles tell us that this will also increase the throughput capacity of each crane and drive down the number of aisles needed from a throughput perspective. The system cost is proportional to the number of storage positions provided and the number of cranes. Thus, for a given number of storage positions, we'd like the configuration that leads to the fewest number of cranes, meeting the throughput requirements of the system. This implies that the optimal mini-load aisle configuration in this example is likely smaller than the initial configuration above.

Shuttle-based systems

As with a mini-load system, the storage capacity of a shuttle aisle is dependent on the number of columns, levels, and depth of storage. We can then determine the number of aisles needed for the overall system storage requirements. However, shuttle systems differ from a mini-load in the way throughput capacity of a system is affected by its configuration. Because throughput is dependent on shuttles performing horizontal movement and lifts providing vertical movement, the overall throughput is the lesser of the throughput of these two components. In practice, it is usually the lift that is the constraint. The throughput of the aisle can be used to determine the number of aisles needed. As with the other systems, the overall number of aisles required will be the maximum of the values calculated based on storage and throughput.

For example, let's assume that we have configured our shuttle aisles to have 100 columns with 13 levels per storage rack and we will utilize a double-deep storage and one lift per aisle, meaning that each aisle provides 5,200 storage positions. This implies that five aisles will be needed to provide enough storage positions to meet or exceed our need for 25,000 positions. Let's further assume that we have determined the capacity of each shuttle in this configuration to be 90 dual cycles per hour. This implies that with our 13 levels, each aisle has the capacity for 1,170 dual cycles per hour. Let's also assume with this configuration, each lift can achieve 500 dual cycles per hour. This implies that the throughput capacity of an aisle in this configuration is 500 dual cycles and that five aisles would also be needed from a throughput perspective. Therefore, we will need to provide at least five aisles of this configuration.

By changing the configuration of each aisle by adding a lift, we can reduce the number of aisles needed from a throughput perspective. However, the number of aisles needed from a storage perspective remains unchanged. And given that the system cost is proportional to the number of storage positions provided, the number of shuttles and the number lifts, considering only that change in the configuration for this example would not be beneficial for the cost of the above system.

THE EVOLUTION OF GTP

The lines between the systems described above continue to blur as incremental advances are brought to market. These variant systems come in a number of flavors, but all of them can be examined using the same analytical processes described above. Some of the changes that are taking place include the following:

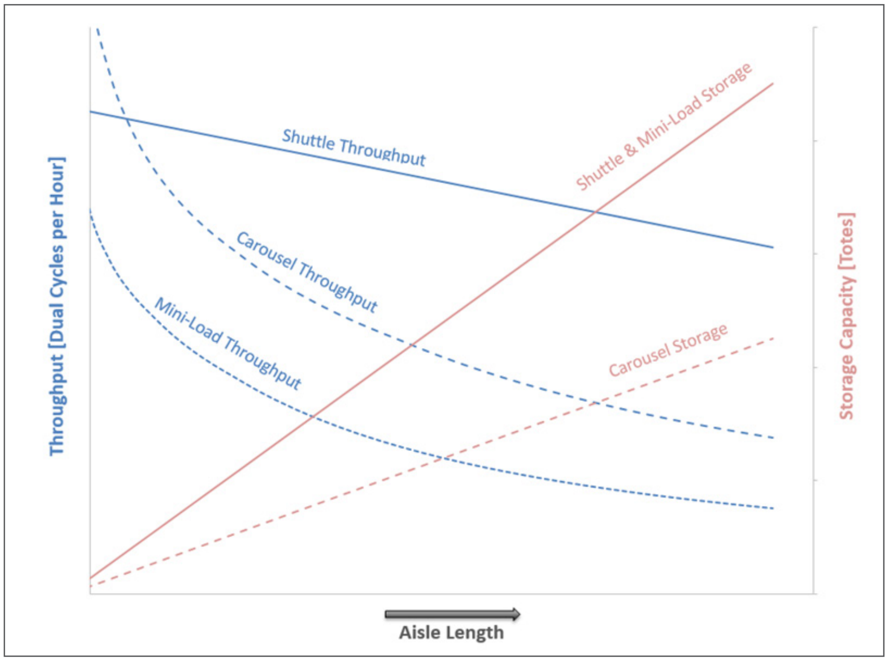
Roaming shuttles, multi-tier shuttles
The above shuttle example leads us to a variation to the one shuttle per level design used in the discussion above. That is, shuttle-based systems can be implemented with shuttles that roam between levels or even between aisles. Utilizing roaming shuttles in the above example, where our total shuttle capacity was more than 2x the lift capacity, can allow us to reduce the cost of the system. Note that to enable roaming shuttles adds cost to a system (on a per shuttle basis) and so it is not always optimal to perfectly match total shuttle capacity with lift capacity. There are also related systems that have shuttles that can access inventory on two different levels.

Multi-crane mini-load systems
Some mini-load systems have developed methods to allow multiple cranes to work within the same aisle, allowing for greater throughput at the expense of more crane units.

Bot-based vertical transport
Several systems on the market now use shuttle-like bots to handle both the horizontal movement of product as well as the vertical movement. Depending on the specific configuration, these systems can either be used to address very slow-moving or very fast-moving product.

It is clear that these technologies have a “profile” or “sweet spot” based on how they are configured. That is, each technology has a certain storage and transaction cost profile that can be characterized in terms of the cost to provide a storage location and the cost to execute a throughput transaction. Likewise, each SKU has a storage and a throughput need. So, the problem can be thought of not only in terms of comparing each automated/storage technology against each other, but also a mapping of each SKU to the technology that aligns best with the transaction velocity, dimensions, and SKU order profile.

Although the different technologies typically address different SKU populations, they can sometimes be configured to address the same SKU population at similar cost. For example, the table below illustrates the storage and throughput performance of one unit for two different technologies (one modular mini-load aisle or one standard horizontal carousel with robotic extractor) for a particular configuration from two different companies.



An illustration of the fundamental throughput and storage tradeoffs in carousels, mini-load, and shuttle-based systems as aisle length increases. This is supplemented with cost data not represented.

METRIC	MODULAR MINI-LOAD	STANDARD HORIZONTAL CAROUSEL
Tote Positions	1500	1360
DCs/hour/Unit	200	225
Cost ($/Unit)	$235k	$250k
$/Tote Position	$157	$183
$/DC/hour	$1,175	$1,111

DECIDING WHICH AUTOMATED STORAGE/ RETRIEVAL TECHNOLOGY

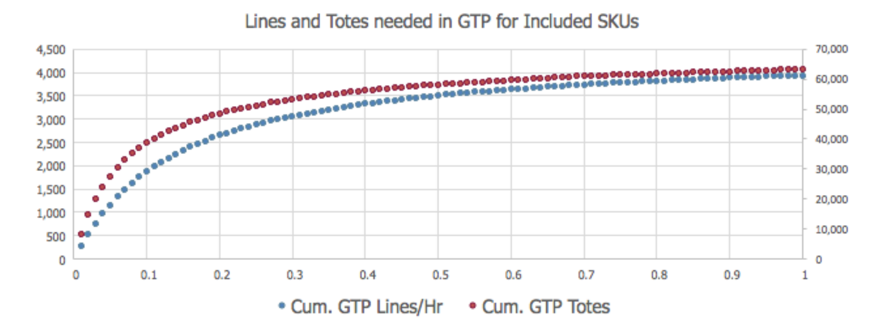
As can be seen above, the decision of which automated/ storage technology/ies to deploy is multi-faceted. Each technology addresses a specific order/SKU profile, and no one manufacturer produces all types of GTP technologies. For static storage and throughput requirements, the above first-principles-based thought process will drive you towards the optimal answer to this decision.

But another way to think about this decision is in terms of the certainty of the storage and throughput requirements. Uncertainty requires the thought process to be expanded to consider the sensitivity of the decision to this uncertainty as well as the tipping point in moving from one type of technology to another. This is where resources that allow you to consider multiple scenarios are especially valuable.

THINKING BEYOND GTP

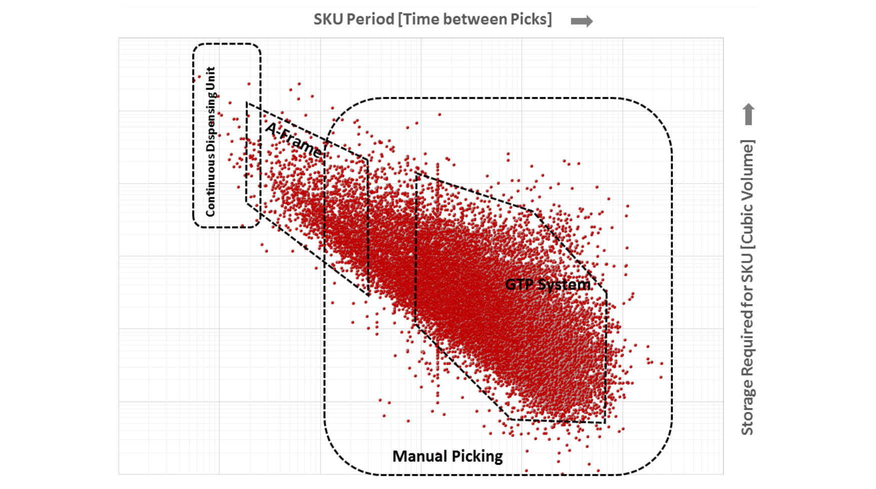
GTP systems provide significant benefits when the percent of time an operator spends walking is high due to low pick density and/or there is a premium on the value of the floor space. In addition, a GTP can reduce the time to access SKUs while still providing a shared inventory storage strategy, which can be costly in a conventional system as SKU proliferation increases.

On the other hand, there are many other technologies and processes that should be considered before deciding a GTP system is the answer. Often, a well-designed operation that uses an appropriate balance of manual labor supplemented with the right technologies will yield the best business case and the most efficient operation. Assuming that higher automation solutions are the best solution can sometimes lead down the wrong path. It is also important to note that GTP systems are not the pinnacle of high automation solutions. Although they eliminate the travel time associated with picking, the picking task itself still accounts for a significant portion of the labor in a distribution center. As alluded to above, many companies are developing robotic picking systems capable of reliably picking individual items into a container, thereby automating the entirety of the picking process.



	All SKUs	Exclude Top-1%	Exclude Top-2%	Exclude Top-5%	Exclude Top-10%
Total GTP Lines/Hr	3,944	3,666	3,416	2,779	2,066
Total GTP Totes	63,375	54,975	48,525	35,775	24,675
GTP Lines/Hr as % of All-SKUs Total	100%	93%	87%	70%	52%
GTP Totes as % of All-SKUs Total	100%	87%	77%	56%	39%

An output from the GTP Report™ illustrating how differences in which SKUs are included in the GTP can impact the throughput and storage positions required in the GTP



An output from the Automated Fulfillment Optimizer™ illustrating a mapping of SKUs to relevant fulfillment approaches.

"GTP systems provide significant benefits when the percent of time an operator spends walking is high due to low pick density and/or there is a premium on the value of the floor space."

RESOURCES AVAILABLE AT FORTNA TO HELP

Fortna has experts available to navigate the complex process of designing the optimal fulfillment process. In addition, Fortna has developed proprietary software to help with this decision process. Our data analysis package, FortnaDCmodeler®, has been extended to include a GTP Report™, which provides a perspective on how many tote storage locations must be provided based on various splits of the SKUs being included in the GTP. This report also provides the corresponding throughput values for those SKUs. These values form the basis for input into our GTP Optimizer™, which applies investment figures to the thought process outlined above to arrive at the optimaGTP for given storage and throughput requirements.

We have also developed an analysis package that is more comprehensive than GTP, the Automation Fulfillment Optimizer™, which provides a mapping of SKUs to a broad array of fulfillment technologies (GTP, A-frames, continuous dispensing units, Bot-assisted picking, manual picking, etc.).

This combination of software and industry expertise allows Fortna to provide a detailed and unique analysis to aid the decision-maker in evaluating the business case for a GTP to fulfill eCommerce orders.

For more information, contact The Distribution Experts at info@fortna.com.

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