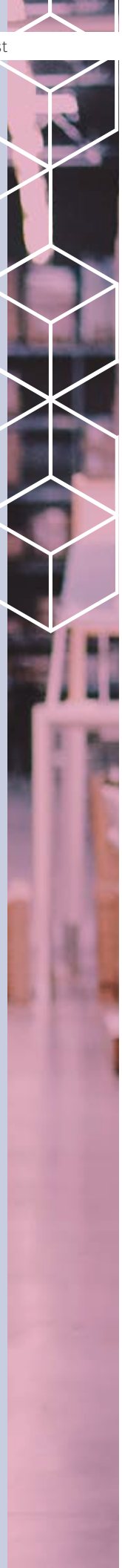
# Cost-Optimal Parcel Packing

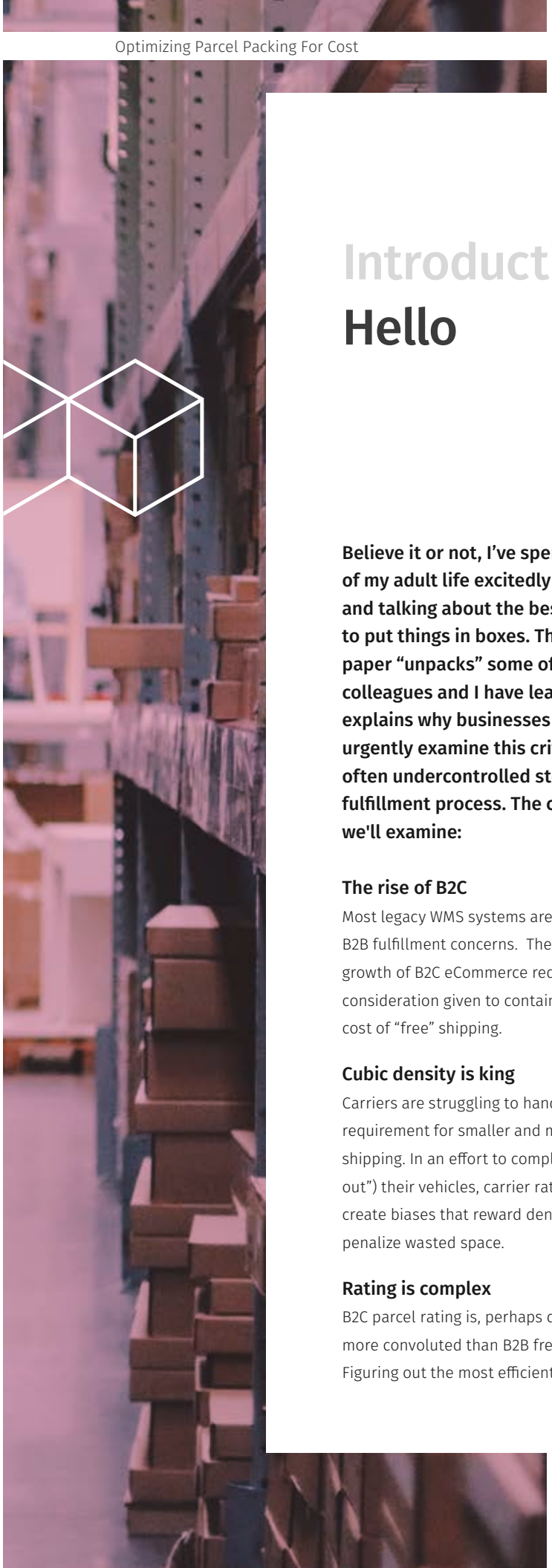
## Complex, Nonintuitive, but Finally Within Reach

An insight paper exploring how myriad and sometimes obscure cost factors affect optimal packing configurations, and how new cartonization technology can help reduce costs and waste.

# Cost-Optimal Parcel Packing




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# Introduction
# Hello

**Believe it or not, I've spent half of my adult life excitedly thinking and talking about the best way to put things in boxes. This white paper "unpacks" some of what my colleagues and I have learned, and explains why businesses need to urgently examine this critical but often undercontrolled step in the fulfillment process. The challenges we'll examine:**

### The rise of B2C

Most legacy WMS systems are designed for B2B fulfillment concerns. The explosive growth of B2C eCommerce requires more consideration given to contain the rising cost of "free" shipping.

### Cubic density is king

Carriers are struggling to handle the B2C requirement for smaller and more frequent shipping. In an effort to completely fill ("cube out") their vehicles, carrier rate structures create biases that reward dense packing and penalize wasted space.

### Rating is complex

B2C parcel rating is, perhaps deceptively, more convoluted than B2B freight rating. Figuring out the most efficient, sustainable and transportation cost-effective way to pack items of various sizes and weights into different-sized cartons (while accounting for negotiated rates, materials, labor, and other business rules) is complex and beyond the ability of real-time human judgment.

### Pack for profits

Rules of thumb amount to costly guesswork. Only a controlled, algorithmic approach to cartonization can automate consideration of the many factors that determine the best way to pack orders.

We created our cartonization engine, Paccurate, as a way to automate box selection for businesses that ship things. Our algorithms have taught us a lot about the best way to pack when there are myriad variables to consider, much of it counterintuitive.

Even if you or your organization chooses not to use Paccurate, I hope that you'll find some actionable insights in this white paper that can help you pack a little better.

James Malley
CEO and Co-Founder
Paccurate

# Introduction
# Unprecedented Volume

## +30.1%

In the first six months of 2020, consumers spent $347.26 billion online with U.S. retailers, up 30.1% from $266.84 billion for the same period in 2019.

"How the coronavirus is changing ecommerce" DigitalCommerce360

**In 2020, eCommerce volumes exploded* and shipping costs shot up**. As a result, warehouse workers are packing more cartons, faster, to keep up with unprecedented levels of consumer demand. For many shippers, the challenge has exposed packing as an undercontrolled step in their fulfillment process. That a business may be incurring unnecessary fulfillment costs is an uncomfortable realization for Supply Chain Managers, made worse by the daunting complexity of the problem: With a long list of cost factors to contend with, how do you ensure that the right cartons are used for every shipment?**

**"Cartonization" is a clumsy term. It is a generally accepted word in logistics, though you won't find it in the dictionary. It also means different things to different people. In this white paper, we'll seek to define cartonization as a method of selecting and packing cartons in a way that optimizes around three key areas:**

- **Transportation cost**
- **Process Efficiency**
- **Sustainability**

**Along the way, we'll measure and triage those cost factors and show how Narrow (or Focused) Artificial Intelligence democratizes packing efficiency for shippers of all sizes—not just the largest few.**

* Online orders up $52 billion in May 2020, or 4-6 years ahead of previous forecasts. Forbes

** Indefinite surcharges instituted by FedEx and UPS put even more of a strain on margins. Saddle Creek Logistics



## The Wild West

It might be obvious that packing is a fundamental part of fulfillment, but even before the challenges that 2020 brought, it's always been the most chaotic step in the Order to Cash flow. Although new analog methodologies have come in vogue, many warehouses still rely on proverbial (or literal) post-it notes or laminated memos taped to the warehouse wall in an attempt to tame the otherwise unruly process.

Tribal knowledge can help keep the ship afloat, but as seasonal retailers know, an influx of inexperienced warehouse staff can throw a wrench in the works. This is an acute issue for suppliers that have scrambled to pivot from B2B to B2C since the beginning of the COVID-19 pandemic, suddenly having to contend with "eaches" instead of caseloads.

Historically, for all but the largest 3–4 retailers in the US, packing cost-optimally has been an elusive goal with few available solutions. It hasn't been for lack of trying on businesses' part; carrier rates get negotiated, box inventory is analyzed, and internal IT is tasked with automation projects. Despite efforts, supply chain stakeholders are stymied by several issues:

Even well-negotiated carrier rate structures are complex, and providing rule-of-thumb directives to warehouse staff or swapping out box sizes are only marginally effective. Legacy WMS cartonization features, typically based on liquid fill, are not designed to deal with modern shipping cost factors and are inadequate in practice. Warehouse robots and box-on-demand machines aren't yet smart enough to understand transportation costs.

The reason these projects produce underwhelming results is that they are more akin to Band-Aids than a cure. Cost-efficient packing has to be holistic, considering how every conceivable cost factor intersects for *every single order.* Even marginal reductions in shipping spend make a difference for a business's bottom line, and every effort should be made to achieve them without sacrificing throughput.



# One: Packing to reduce transportation costs

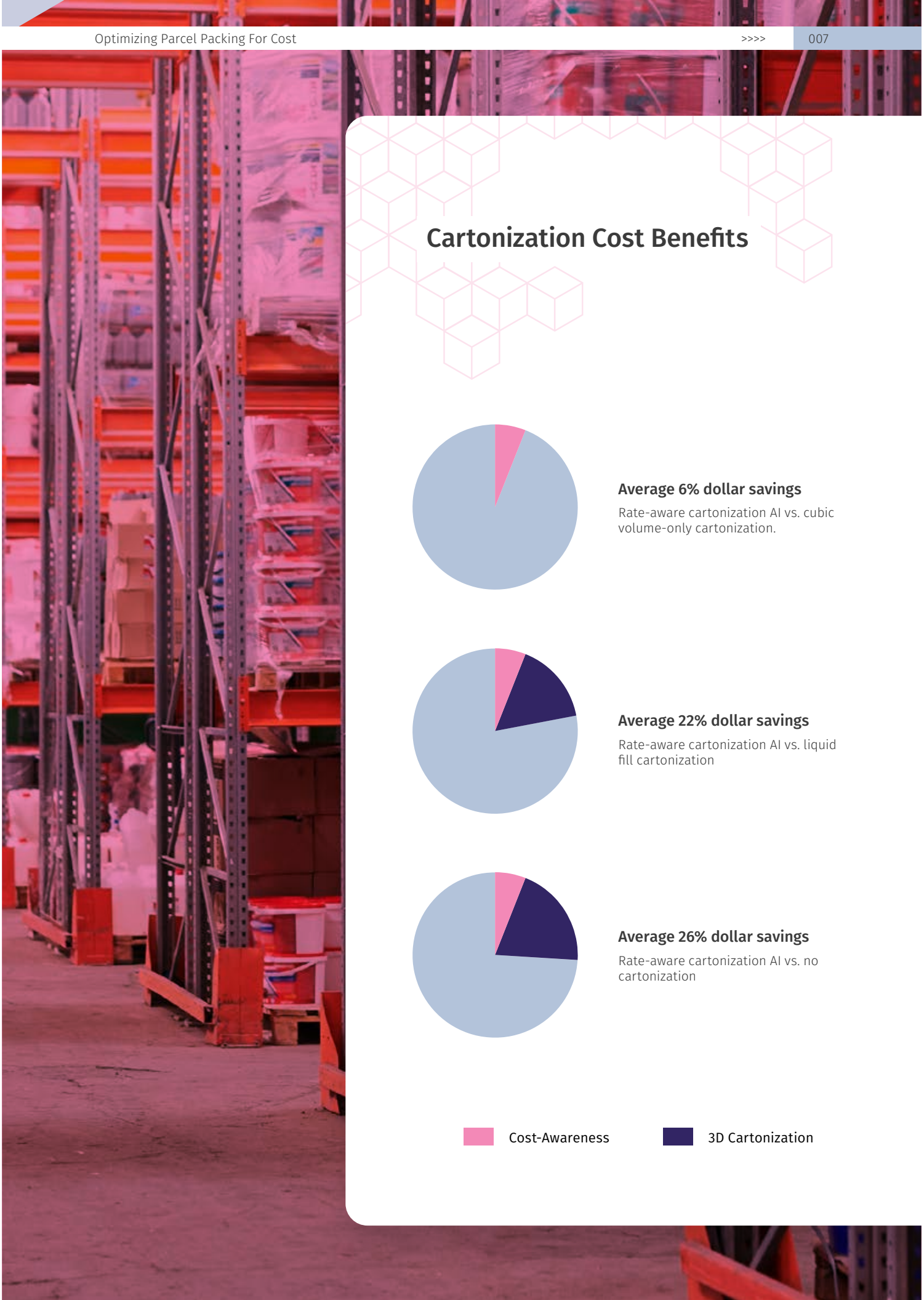
## Tracking rate-based packing incentives is anything but intuitive.

Transportation is often one of the biggest expenses in any B2B or B2C operation, especially in the age of free shipping. It's no wonder that negotiating effectively with carriers is a coveted skill among supply chain managers. After negotiations, however, most shippers don't have a strategy for maximizing those hard-earned discounts, or enforcing the recommendations from expensive consultancies.

There's no getting around it: carrier rate tables, even enviably negotiated ones, have variable incentives built in to pack a certain way depending on the weight and destination of a shipment. Those incentive patterns can't consistently be met with a rule-of-thumb objective like fewest boxes, or smallest boxes.

Rate incentives tend to align closely with the capabilities of the carrier infrastructure that will touch a shipment somewhere along its journey. Carriers strive to "cube out" whatever vehicles will be used as much as possible. As a result, optimal packing configurations often differ by carrier, and even by distance and service type.

To illustrate these incentives, in the next few pages we'll explore two real-world examples where rate tables and fees led to some unintuitive cost-optimal packing solutions.



## Cartonization Cost Benefits



**Average 6% dollar savings**

Rate-aware cartonization AI vs. cubic volume-only cartonization.



**Average 22% dollar savings**

Rate-aware cartonization AI vs. liquid fill cartonization



**Average 26% dollar savings**

Rate-aware cartonization AI vs. no cartonization

Cost-Awareness

3D Cartonization

# Packing to reduce transportation costs

## Comparing Carriers



Shippers that use multiple carriers can realize unexpected savings by packing differently depending on what carrier is chosen for a shipment.

This is because disparate carrier rate tables usually scale differently by price per carton and pound. Consider the aforementioned incentives that are represented in those tables: For a specific weight and zone, Carrier A may want you to minimize the number of boxes, while Carrier B may want you to minimize dimensional weight. Both carriers want both of those things, but they reveal their priorities by how they structure their rates.

# Case Study #1: Comparing Carriers

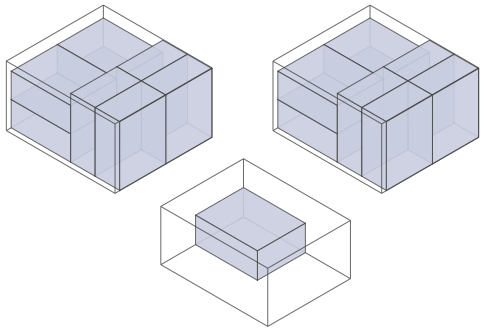
A recent analysis of shipping data provided by a popular online retailer revealed multiple examples that illustrated carrier-optimal packing. Cartonizing one of these orders with a cost-aware algorithm and rate shopping the results with FedEx and UPS revealed distinct optimal solutions depending on which carrier was selected. Here's why:

For this particular shipment, the FedEx rate table had a higher base box cost but a lower relative cost increase per pound. In other words, FedEx incentivized consolidating the items into fewer, and then smaller boxes. Based on the available boxes, the correct box selection was 1 large box and 1 small box.

On the other hand, UPS had a relatively lower base box cost but a higher relative cost increase per pound, i.e., UPS was discouraging both dim weighted and very full boxes. The correct box selection for UPS was 2 medium boxes and 1 small box.

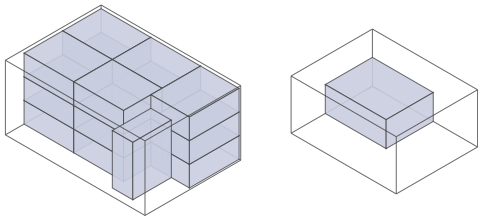
**If the shipper had used UPS for the FedEx-optimal packing solution, they would have overpaid by $1.93.**

UPS Optimal Packing



61lbs (dim. weight), 8,385 vol.

FedEx Optimal Packing



69lbs (dim. weight), 9,443 vol.

GROUND ZONE 2

This level of optimization has implications for businesses that do rate shopping before shipping an order; it's inefficient to rate a single box configuration with multiple carriers. Ideally, the optimal packing solution for each carrier should be determined before comparing rates to determine which is cheaper—in the example above, the optimal packing for FedEx against the optimal packing for UPS. We actually *want* to be comparing apples to oranges.

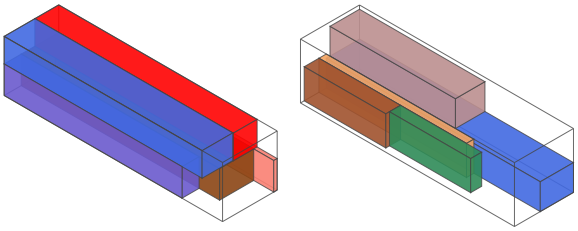
# Packing to reduce transportation costs

## Comparing Zones

The optimal packing solution might differ depending on the shipment zone.

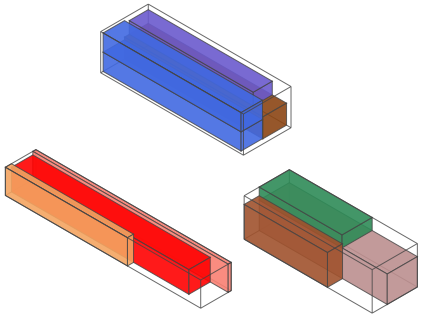
**Much like the divergences between carriers discussed previously, one carrier might offer different incentives depending on where and/or how far a shipment is going. Although analysis suggests this is a less common savings opportunity in practice, the savings are more dramatic—often tens of dollars per order.**

FedEx Zone 2



118lbs (dim. weight), $18.77

FedEx Zone 8



110lbs (dim. weight), $44.44

## Case Study #2: Comparing Zones

This example comes from a large retailer with well-negotiated rates: Two identical orders going FedEx Ground, one to Zone 2 and one to Zone 8. For this order in **Zone 2**, after the base box cost of $7.80, there were relatively small price increases per pound. We can surmise that for this zone, FedEx would rather have you condense your items into fewer (and/or smaller) boxes. Presumably because fewer/smaller boxes are easier for their employees to actually handle.

Compare that to this order in **Zone 8**, where the per pound price increases at 2.8 times the rate of zone 2. This tells us that for longer distances the total billable weight, dimensional or otherwise, is much more of a concern than the number of boxes. This makes sense; greater distances mean more fuel and vehicle wear and tear, and dimensional weight is critical if a shipment ends up as air cargo.

For this shipment, in zone 2, the cost-optimal solution was one large and one medium box, which represents the incentive (fewest boxes and then the smallest additional box if needed), even though in this case it incurs a dim weight fee (118 lb. and $18.77 total).

For zone 8, the optimal solution was three medium sized boxes in order to more aggressively minimize weight (remember, dimensional weight is still weight, from a cost perspective). Zone 8 rates penalize dim rated and very full cartons more (110 lb. and $44.44 total).

These are the cheapest ways of packing for each of these zones. We can prove it by swapping these pack solutions: If you take the packing solution for zone 2 and rate it for zone 8, you would lose about $1.10. And if you took the packing solution for zone 8 and rated it for zone 2, you would lose a much more substantial $8.07.

Not every shipment will have these optimization anomalies, but it happens often enough that the largest shippers, like Walmart, account for it in their cartonization calculations.

Shippers that use real (non-liquid) cartonization to minimize cubic volume do achieve a reduction in freight spend and fees compared to no cartonization at all, saving an average 16% of cubic volume. However, data also shows they can go further if they factor in carrier incentives to uncover unintuitive optimizations like the above examples. For shippers that moved from cubic volume-only cartonization to rate-aware cartonization, analysis has shown the average reduction in parcel spend was ~6%, regardless of the number of annual shipments fulfilled.

## Rate-aware cartonization achieved 6% savings vs. cubic volume-only cartonization

# Two: Packing for Process Effficiency

# Labor

Even experienced personnel make mistakes without consistent controls in place.

"The cost to value ratio is off the charts. I've never seen anything like it."

- Lionel CIO Rick Gemereth

Lionel trains, the beloved 100-year-old model train maker, doubles its workforce every year before the holidays to keep up with demand. They employ cartonization AI to assist the temporary workforce and avoid costly errors, and it enabled them to handle a 20% increase in outbound B2C traffic without hiring additional workers.

Cartonization algorithms, especially those sophisticated enough to be considered Narrow AI, are useful for assisting warehouse personnel (not necessarily replacing them), and they need the help. A study recently showed that 62.3% of inventory fulfillment issues are from human error from manual process management*. Even experienced personnel make mistakes without consistent controls in place.

Although an average dollar savings from AI-assisted labor is a difficult metric to quantify across all businesses, it is feasible to estimate for a single organization. If the data is readily available, labor costs can be calculated by measuring time spent per shipment and errors made in carton selection.

This brings up an important point about optimizing the cubic space of a carton—how much is too much of a good thing? The academic approach (the “bin packing problem”, as it’s typically referred to in masters’ thesis papers) seeks to use every conceivable cubic inch of space in a container. While the math is interesting, it’s not practical for a production environment. If a worker has to sit there for 15 minutes trying to piece together an intricate Tetris®-like SKU and box configuration, it’s not efficient. A cartonization AI must consider this when generating a packing solution.

* “What Is The Most Frequent Cause Of Inventory Fulfillment Issues?” Stitchlabs

# Rules

As in art, the best results are often achieved when constraints are enforced. A cartonization engine should be able to contend with multiple, sometimes competing requirements before calculating the best packing solution. For example:

» What are some creative ways that a SKU can be packed? Can it be nested, stacked, rolled, or otherwise combined with other SKUs in interesting ways to save space? Can it be rotated on all axes or compacted? Does it have an internal void space that can be used?

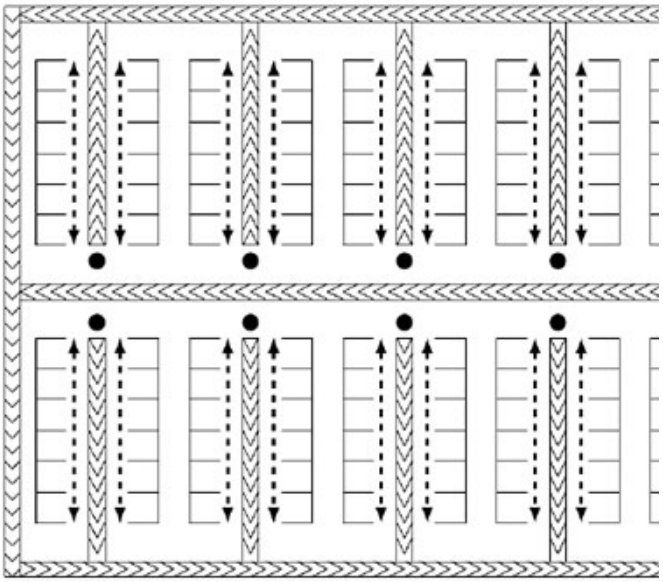
» Does the order have reseller requirements like branded boxes? Amazon has started charging fees if their sellers don't comply with Frustration Free Packaging specifications, some of which can be controlled by cartonization.

» Are there hazmat requirements? Should certain SKUs be kept together or apart?

Instead of relying on tribal knowledge to reconcile these disperate concerns, consider automation to speed up carton selection and reduce errors.

Rules can also apply to *where* an item is in the warehouse. Order picking is the most labor-intensive process in the warehouse*, but some savings can be realized simply by considering economy of worker movement when cartonizing. For example, does it make sense for a given order to send a single picker to the other end of a large DC for one of the items, or is it cheaper to split the shipment up so it can be boxed in two separate pack stations? Where's the breakpoint where it does make sense for the picker to take a longer walk? Are some workers rated to handle more weight? As with the other factors discussed, these decisions need to be guided by an intelligent system that is aware of both rates and worker movement.

Allowing shipment cost to drive picking activity, at least in part, has some interesting implications for economy of worker movement. Pick zones can become fluid, allowing a greater distance of travel only for final box configurations that benefit from it. This strategy can be implemented as a process augment, and doesn't have to usurp whatever picking process the WMS may already driving.



* "A Study on Picking Process Time" Science Direct

# Packing for Process Effficiency
# Damage Reduction

If you can quantify fragility, you can automate safe shipping.



Despite their negative impact on profit margins, returned orders are a fact of life for an online retailer. Many returns are unavoidable; surveys show 30% of ecommerce shoppers buy variations of a product with a plan to return the ones they don't like*. There's not much shippers can do about that. However, damaged goods are the reason behind 20% of returns**, and are a perfect target for process improvement.

If we consider potential damage to be just one characteristic that a product or product category has, we can objectively identify it to automate safe and efficient packing. For example, maybe an item should be packed alone, or only allow a max weight on top of it, or not be rotated along a certain axis, etc. If fragile items are overprotected, however, we risk wasted fill and precious cubic volume. As with other packing optimizations, the goal is to find a balance between a product/business requirement, and cost-efficiency.

Perishable goods require more complex planning to mitigate damage, and cold shippers know how challenging packaging requirements can get. To cartonize groceries or medicine, many more variables about a shipment need to be factored in, such as what the weather is like between the origin and destination.

* "Emergence of Serial Returners" BarclayCard

** "E-Commerce Product Return Rate" Invesp

# Box On Demand

Among fervent efforts to automate packing, some businesses have turned to specialized equipment that produces boxes as needed. Unfortunately, while this has sped up some aspects of pick and pack, many shippers don't change their methods of selecting the size or quantity of boxes, they just do it faster. The breed of box-on-demand machine that wraps corrugated around a pile of items on a conveyor belt is a more recent (and very cool) innovation, but to get the most value out of it, some level of intelligence still needs to direct workers to place the right number of items on the conveyor, and in the right configuration.

Box machine hardware, when combined with the right intelligent software, can be a powerful upgrade to a high-throughput operation. A large retailer recently implemented cartonization AI to direct the workers operating each of their 7 box-on-demand machines. The company estimated it saves them an average $585,000 per year in labor alone, just by reducing one headcount at each machine, while still receiving all the benefits the machines provide.

A large retailer recently implemented cartonization AI to direct the workers operating each of their 7 box-on-demand machines. The company estimated it saves them an average $585,000 per year in labor alone, just by reducing one headcount at each machine.

## Three: Packing for Sustainability

# What's good for business is good for the planet.

Competent 3D cartonization algorithms are able to reduce cubic volume of shipments by at least 16%, compared to liquid fill or other rudimentary cartonization techniques.

Material waste is often the most visible result of warehouse inefficiency, but is often regarded as a necessary byproduct of essential processes. The aforementioned box-on-demand machines are a common culprit behind piles of unusable corrugated scrap that are hard to ignore. But what about the material that actually makes it out the door?

One “fun fact” about cost-optimal box selection is that it’s correlated with tare weight, meaning a more optimal pack equals less material used*. Among shippers that factor costs into their packing, an average 13% less corrugated is used. While not the most glamorous point of savings depending on how cheaply a shipper is able to acquire corrugated cardboard, it is measurable and has a compounding effect over time.

Over 100 billion corrugated boxes are used every year in the US alone**, so from one standpoint there will always be a certain amount of waste. The good news is that new trends in the supply chain are cause for hope—the popularity of more sustainable fill materials is a good example. Humans have also gotten very efficient at recycling cardboard, with 75% of all boxes shipped made up of recycled material.

The bad news is that most modes of freight transport still pollute heavily. This makes it a critical corporate responsibility to always use the smallest cartons that a shipment allows. In the aggregate, smaller and fewer boxes means fewer trucks and planes in transit, which leads to a reduction in carbon emissions.

The major parcel carriers are acutely aware of their carbon footprint, and while dimensional weight fees are primarily a mechanism to maximize revenue and capacity, there is an honest environmental motivation too. FedEx in particular has made a special effort to measure how their fee structure translates to emission reductions, and view their dimensional weight fees as a crucial incentive for their customers to pack more efficiently***.

* Analysis of new Paccurate customers during and after onboarding, 2020

** "Amazing Facts About Cardboard" CardboardBalers

*** " FedEx 2020 Global Citizenship Report" FedEx

"Optimizing packaging by making weight, size and content adjustments helps customers ship more efficiently, such as through dimensional, or dim, weight pricing based on package volume. This allows us to make the best use of space in our aircraft, vehicles, and distribution centers; improves loading efficiency; and reduces emissions. Dim weight pricing also encourages customers to make packaging adjustments that maximize product density and reduce packaging materials."

- FedEx 2020 Global Citizenship Report

# Insight Summary

- Cost-aware cartonization is relevant to shippers of all sizes, but because of the specialized nature of the problem only the largest companies in the US have the bandwidth to develop internal solutions.
- Dimensional weight fees are one mechanism that carriers use to “cube out” their vehicle capacity, but other packing incentives woven into negotiated rate tables are often unintuitive to account for on a per-shipment basis.
- Real multidimensional cartonization reduces the cubic volume of multi-item orders by an average 16% compared to liquid fill strategies, and up to 20% vs no cartonization at all.
- Reducing cubic volume does not track perfectly with reducing material waste, but best-in-class cartonization saves an average ~13% of corrugated in most implementations.
- Cartonization that accounts for carrier rate incentives and other cost factors saves an additional ~6% of parcel spend on average, compared to cartonizing for cubic volume minimization only.
- Legacy WMS systems, if they have cartonization, are not designed to deal with modern shipping cost structures, especially for eCommerce fulfillment.
- Box on demand machines deliver speed improvements, but are not smart enough to optimize around transportation costs out of the box.
- Economy of worker movement should be factored into packing decisions, especially in large DCs.
- Damage thresholds for SKUs can be characterized objectively, and factored into automated packing decisions.
- In the context of parcel packing, sustainability concerns are linked both to carbon footprint and lowered spend.

# Conclusion
# Thanks

Because it's a multi-faceted challenge, packing inefficiency is pervasive and seldom addressed adequately in the warehouse. It's not that Supply Chain Managers and warehouse personnel don't care—quite the contrary—it's that packing in a way that accounts for every conceivable transportation cost factor is difficult in a fast-paced fulfillment process.

A warehouse worker doesn't have time to sit down in front of an order with a cup of coffee and consider every packing possibility before putting it in cartons. Supply Chain Managers are aware of the issue, but have historically approached it with incremental improvement projects, addressing what is seen as the most flagrant issue of the day (such as rate negotiation or box selection) without taking a holistic approach.

Artificial intelligence is a loaded term, but the "narrow," specialized kind that can optimize packing costs isn't magic. Rather, its most basic function is to simulate how a human would pack, if that human had unlimited time to consider every variable for a given shipment. Modern parcel costs have grown increasingly dynamic, making AI a valuable ally to reduce costs while not hindering throughput.

**Paccurate is a real-time packing decision-maker, focused on minimizing every conceivable cost associated with packing—from labor to materials to obscure incentives in negotiated rate tables, it considers every angle to determine the most cost-efficient way of packing every order.**

**The Paccurate API is flexible and fast, and can be used tactically (and unobtrusively) throughout your order to cash or procure to pay process. You may even be using our algorithms without knowing it: Paccurate powers the cartonization functionality in many of the top enterprise packing and multi-carrier shipping software suites on the market.**

**Try the API free or find a Paccurate-powered software at [paccurate.io](paccurate.io)**

# Cost-Optimal Parcel Packing

## Complex, Nonintuitive, but Finally Within Reach

paccurate

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Pick zone diagram: scielo.org.za