Box size does matter  

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The right assortment of carton sizes will improve operational efficiency and reduce material, freight, and labor costs. Shippers can determine the right mix by analyzing order history data and examining the frequency of use for current carton sizes.

If you are responsible for warehousing and distribution operations, then you probably have considered the following questions at some point: How many and what sizes of shipping cartons should you purchase? Should you get by with a few, carefully selected carton sizes, or should you keep a larger assortment on hand to cover every shipping contingency?

These appear to be straightforward questions, yet finding the right answer is far from simple. A cost-benefit analysis of the two choices quickly becomes quite complicated when you consider such packing-related factors as material suppliers’ volume discounts, freight charges, damage claims, order history, throughput rates, and the cost of void filler, to name just a few.

For many companies, using a limited selection of cartons makes the most sense. Consider the example of a distributor of CDs, DVDs, and other entertainment media that ships several thousand random piece orders each day. When the distributor switched from a large number of different-sized cartons to just four sizes, it realized a number of benefits. For one thing, operators’ efficiency and productivity improved. For another, using a small selection of cartons made it economical to further automate packing by pre-erecting cartons and allowing them to flow through the packing stations. As a result, the company was able to increase its daily shipments while controlling labor costs. Excess material costs resulting from operators choosing the wrong cartons also decreased because the farther apart cartons are in size, the less likely it is that an operator will choose the incorrect one.

In addition to achieving operational improvements, the distributor is spending much less on packing materials. Because it now orders large volumes of just a few carton sizes, it has been able to negotiate competitive volume discounts with its consumables supplier. As a result, the company is saving US $15,000 to $20,000 a year on cardboard costs alone. Cutting back on carton sizes also helped it save money by reducing the amount of void fill required, and because both freight charges and damage claims declined.
Although this example makes the case for cutting down the number of different cartons, it also raises some questions: How are material, labor, and freight costs affected by shifting the carton sizes around, adding another size, or cutting out a superfluous size? What number of carton sizes is most efficient? What are the best carton sizes to use? When does the cost of adding another carton size exceed the benefit of reduced void space? This article will outline some ways to answer those questions.

"What if" and how often?

Careful analysis is necessary to determine the advantages of reducing the number of carton sizes while maintaining efficient carton utilization. An important step is to perform a quantitative analysis of a warehouse's or distribution center's order history, using dimensional and weight data for each item the facility stores and ships. With that information and a selection of actual orders for a given span of time, you can repeatedly model "what if" scenarios and determine what your material and freight costs would have been if those orders had been packed in different numbers and sizes of cartons.

Examining these scenarios can be done using frequency distributions. This is a statistical analysis method that identifies the frequency with which variables meet specified conditions. The frequency distribution of order sizes depicted in Figures 1 and 2 show the smallest possible cartons a population of orders could fit. The blue-shaded regions show the subset populations that fit inside of a particular carton size. The arrows point to the largest segment of the order population within each carton size. The location of each arrow provides an indication of the carton's efficiency (how closely matched in size are the carton and the order items inside). Orders that are close to the right side of a carton's range take up the most space in the carton and hence are an efficient fit.

Looking at these distributions can guide you in selecting carton sizes. For instance, a parabolic distribution (such as the subset for carton size 4 in Figure 1) strongly suggests splitting the population between two carton sizes. A downwardsloping distribution (such as the subset for carton size 3 in Figure 1) indicates relatively low efficiency and a high cost per carton, suggesting that a different carton size should be chosen.

Finding the perfect carton size

For each carton and order, there is a total liquid volume of the carton (the product of a carton's dimensions) and a total liquid volume of the order (the product of the items' dimensions). The difference between them is the amount of void space remaining.

Whenever an order is placed in a carton, there is almost always leftover space requiring void fill. However, for every order there is a theoretically perfect carton size that leaves the smallest amount of void space. This can be visualized as packing the items together as tightly as possible and then drawing a cuboid around the resulting combination.
Previous attempts to determine perfect carton sizes have focused on liquid volume. But that method has drawbacks. For one thing, it does not provide a sufficient degree of precision, because liquid volume fails to consider information about the shape of each item to be contained in the carton. For another, an infinite number of cartons could have identical volumes yet not all accommodate products of various shapes.

Liquid-volume estimates represent a "top down" approach: they help operators choose the right carton from a predetermined set of carton sizes by volume. A more effective route is a "ground up" approach that determines optimal carton sizes for a given order population based on individual items' and orders' characteristics.

Frequency distributions can be helpful here. In addition to providing a good estimate of how many orders on average would fit a particular carton, they also can show the carton's efficiency relative to void space. With the proper software, it is possible to generate a frequency distribution of perfect carton sizes for a particular order population. This involves applying algorithms that examine the shapes of each item in an order and keep track of the ideal cartons (the cuboid drawn around each combination) for every possible arrangement of those items. It is important to identify all possible arrangements, not just the one with the lowest total volume; for every order ratio chosen for examination there may be more than one ideal carton, depending on the arrangement of the items inside the carton.

One caveat: to generate frequency distributions of ideal carton sizes for an order population you must choose a fixed ratio of the carton's dimensions. While this necessitates analyzing multiple frequency distributions, a systematic approach to this analysis can readily determine the ideal combination of cartons.

For any order population that is compatible with a specific carton size and shape, there will be a distribution of orders by volume showing how many will leave the most and the least void space. The best possible scenario will look something like those in Figure 2: an upward-sloping distribution with a peak at the end, meaning that most orders that are packed in that carton leave little void space. In such a case, the efficiency of the carton is high and the average carton cost per order is at the optimal level.

Another objective of these frequency distributions is to isolate large populations (peaks) and choose a carton size that accommodates them. Several apparent peaks suggest optimum carton sizes for those orders; orders that are not ideal may be better suited for a carton with a different ratio of dimensions.

Once you have identified a carton size that is most efficient for a segment of the order population, you can remove those orders from consideration to simplify further examination. This method—looking for peaks in distributions, assigning an ideal carton size to that peak, removing those orders from the population under consideration, and then reexamining the remaining population—can be repeated until all of the order possibilities have been addressed. To be
successful, this method requires a structured approach for examining many different combinations of carton sizes using many different carton-dimension ratios. Thus, the order-population frequency distribution in Figures 1 and 2 represents just one of many for a given fixed ratio.

To analyze multiple ratios, start with a cube-shaped ratio (1:1:1) and work outward. This ratio has the largest volume per square inch of cardboard, making cube-shaped cartons the best value. Isolate order populations, and then examine the remaining orders by looking at distributions for carton-dimension ratios that become increasingly elongated rectangles (thus increasing the cost per cubic inch of the carton). Although this is a complex process, it has the advantage of allowing you to objectively compare two different sets of cartons and identify which set can best accommodate the greatest assortment of orders. The final result of this rigorous analysis is the identification of a set of carton sizes that would accommodate the largest number of orders with the least amount of void in the box. Because you are quantifying the benefits that would have accrued if you had used those cartons for actual orders handled in your distribution center, the results will be realistic.

Bear in mind, though, that carton-size analysis should not be a one-time exercise. Regular re-evaluation is required to reflect changes in the order population and make adjustments to prevent waste and inefficiencies caused by less-than-optimal carton sizes. This dynamic re-evaluation, applied at time intervals ranging from quarterly to every couple of years, can significantly increase efficiency. There are times when it is better not to wait for a scheduled review, however. If you know that the order population is going to change—because of the addition of a new product category or a new customer segment, for example—conducting an analysis beforehand can help avoid a costly trial-and-error period during the start-up phase.

Proven benefits

The benefits of conducting a carton-size analysis—and of subsequently stocking the right assortment of cartons—have been shown again and again:

- When operators select from a large assortment of cartons, they are more likely to choose the wrong size. They may place the order in cartons that are too big and end up filling them mostly with void-fill materials. Each time this occurs, it can cost you an extra US $1 or more per order. A carton that is too large but is not adequately cushioned with void fill increases the instance of damage claims and product returns. When well-suited carton sizes are used, there is less void space and operators are less likely to overuse or underuse void fill.
- Carton assortment affects productivity. When given too many choices, operators may choose one that is too small and waste time starting over with a larger size, or vice versa. In addition, operators who are under
pressure to work quickly often disregard efficient material consumption. Having the right cartons on hand helps operators get it right the first time.

- For random piece orders, matching orders with the optimal sized cartons boosts pallet and truck capacity, which translates to freight savings over time. Moreover, for any business that frequently ships orders that are billed by dimensional weight, trimming only one or two inches off carton dimensions can generate extraordinary savings.

On-site observation suggests that even the most finely tuned warehouses and distribution centers would realize significant savings on at least one-third of the orders they ship if they conducted a carton-size analysis. The per-carton savings varies for each facility, of course, but even a 25-cent to 35-cent material savings on only one-third of orders would add up to a large sum for most warehouses.

Almost any warehouse or distribution center, then, is likely to benefit from an examination of the usage frequency for its current carton sizes. In high-volume warehouses in particular, careful shifts in carton sizes can significantly improve material, labor, and freight costs. For supply chain professionals looking at ways to cut packaging expenses, carton-size analysis should become a standard practice.

MAYBE YOU DON'T EVEN NEED CARTONS...

The increase in electronic commerce means that many companies are experiencing rapid growth in direct-to-consumer shipments. They're also finding that the cartons they use for business-to-business orders are too large and costly for consumer orders, which are often very small.

This was the case for the large distributor of entertainment media mentioned at the beginning of this article. As part of an overall review of its packaging processes, materials, and labor, the distributor examined its fast-growing direct-to-consumer business—and determined that the most cost-effective choice was no cartons or void fill at all. Instead, it switched to a cold-seal packaging system that measures the dimensions of the order and seals packaging material around the items.

The change in packing material reduced the overall package weight by 1 ounce, which saved approximately US $0.09 on freight charges per order. That may not sound like much, but at an average rate of 5,000 consumer orders per day, this equated to savings of US $450.00 daily, or $135,000.00 per year (300 business days). Not only did it save on shipping, but the cold-seal machine allowed the company to reduce the number of packaging operators from 23 to 1, a 95-percent reduction in packaging labor costs.