Abstract

Supply Chain Cube Cost (SC^3) is the cost associated with physical space that must be bought or rented to move a product from the point of manufacturing to the customer. For typical consumer electronics, the driver of supply chain cube cost is overall package size, which in turn is driven by five specific product design parameters: product size, product ruggedness, product orientation, location of accessories, and weight. This paper explores how the variability of these product parameters affect cube cost. An automated tool that combines and analyzes the five parameters is described and an example of how it is used is illustrated.

Keywords

Supply Chain, Cube Cost, Packaging, Product Design

Introduction: Supply Chain Cube Cost (SC^3)[1]

Consider a simplified international supply chain for a typical consumer electronics product in Figure 1. The packaged product is handled within each node and between each node. Supply chain analysis typically looks at three broad categories: how long the product is in or between the nodes (time element), how much product is in and between the nodes (availability and value element), and how much space the product consumes in and between the nodes (cube element). The focus of this paper is the last element, referred to as Supply Chain Cube Cost. In simple terms, a product being shipped from one location to another occupies space which must be purchased or rented.

Cube cost would include freight, warehouse space and the cost of pallet and packaging materials. Larger, heavier products result in fewer units per pallet load, translating into higher freight, warehousing and packaging material costs (assuming the load cubes out before weighing out in a container). In the case of a typical electronics product, the packaging size might be close to twice the dimensions of the product itself, yet the cube cost for the disposable packaging is the same as the product itself.

There is a finite amount of cubic volume available in and between nodes. These include fixed vehicle sizes, fixed standard pallet sizes, fixed warehouse space, and to some degree finite and fixed shelf space in a retail store. Vehicle sizes can be easily found by checking websites [2] or contacting the company logistics department. There are only a few standard pallet sizes worldwide. The most common are the 48 inch x 40 inch, 120 cm x 100 cm, and the 120 cm x 80 cm pallet sizes. Assuming the package must fit one of these standard pallet sizes, it can be shown that only a few optimal package footprint sizes are possible (Table 1; not an exhaustive list). Package height would be determined by the vehicle and/or warehouse heights. The goal then is to work within

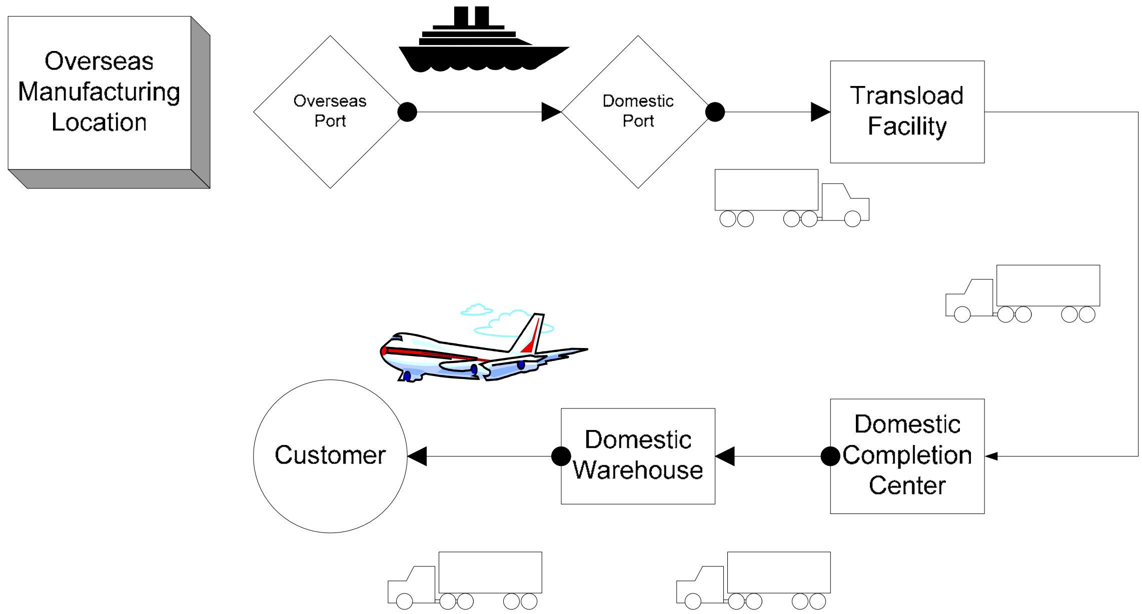


Figure 1. Simplified International Supply Chain.

these established package sizes to minimize cube costs. In addition it may be easier to reduce the package size to lower overall supply chain costs than to change inventory levels or time elements between nodes.

Table 1. Standard Package Size Outside Dimensions to Fit Standard 120 cm x 100 cm Pallet.

Pallet Layer Pattern	Quantity Per Layer	Box ID		Number of Layers	Quantity per Pallet
		Length (cm)	Width (cm)		
2 x 2	4	60.0	50.0	4	16
3 – 2	5	60.0	40.0	4	20
2 x 3	6	60.0	33.3	4	24
2 x 3	6	50.0	40.0	4	24
3 – 2 – 3	8	43.3	33.3	4	32
2 x 4	8	60.0	25.0	4	32
5 x 5	10	50.0	24.0	4	40

What Drives Package Size?

The question then is, how can we move from a larger package size to a smaller one? Simply put, the product itself drives the package size. Figure 2 shows the relationship between package size and supply chain cube costs. To move from a larger package size to a smaller one, something in the product needs to change (assuming packaging has already been optimized). Instead of viewing product design, package design and supply chain design as separate activities, all three need to be considered to obtain a complete systems cost perspective. Decisions made regarding product design directly affect supply chain costs. In particular, five product parameters drive package size, which in turn drives supply chain cube costs.   They are:

1. **Product size.** Unless the product is extraordinarily fragile and requires thick cushioning, a smaller product has a smaller package. See Figure 3. High value, high density products are exceptions, like memory cards or inkjet cartridges, where a larger package might increase supply chain costs but dramatically lower costs associated with pilferage. But for most consumer electronics, this relationship holds. Product length, width and height all need to be evaluated.
2. **Product fragility.** The measure of a product's ability to withstand shipping hazards (drops, vibration, etc.) is generally referred to as the product's fragility (measured in G's). Standard methods are in wide use to objectively determine a product's fragility [3], and

the process for testing and trading off product fragility and cushion design have been documented [4,5]. If the product is fragile, the package protection system must compensate, usually resulting in a larger package size and more costly packaging materials, and hence a more expensive supply chain. Cushion curves are the industry standard used to select cushion thickness for a given fragility (Figure 4). The cost trade-off between modifying the product to be more robust (less fragile) and the resulting supply chain cube costs can be evaluated. An example of this would be adding a $0.05 metal clip to a product design that avoids the addition of $0.50 of cushion material and an additional $1.00 value of freight costs. Depending on the fragility of the product, cushion thickness and package size is determined. Figure 5 illustrates how supply chain cube cost is affected by product fragility.

3. **Shipping orientation**. Simply rotating the position of the package on a pallet can yield a more efficient pallet and vehicle loading scheme. The product must be designed to withstand the forces when shipped and stored in different orientations. Consider a printer which is designed to sit a particular way on a customer's desk. Special care must be taken when designing the product if it is to be shipped on its front or side. Software programs such as TOPS and CAPE [6, 7] excel at quickly determining pallet layouts with varying package dimensions. Figure 6 shows an example of how changing the shipping orientation of the product improved cube utilization by 17%.

4. **Location of accessories.** Generally electronics products must have a variety of accessories to function, such as a power cord or an ink cartridge. Other items such as manuals and CDs also require package space. One of the more interesting developments in recent years is the pre-installation of toner cartridges in a printer. See Figure 7 [8]. This requires very specific design features, but can result in substantial SC^3 cost savings. In addition, locating accessories in cavities of the product [9] will have a similar affect on package size and cube savings as product geometry (Figure 8).

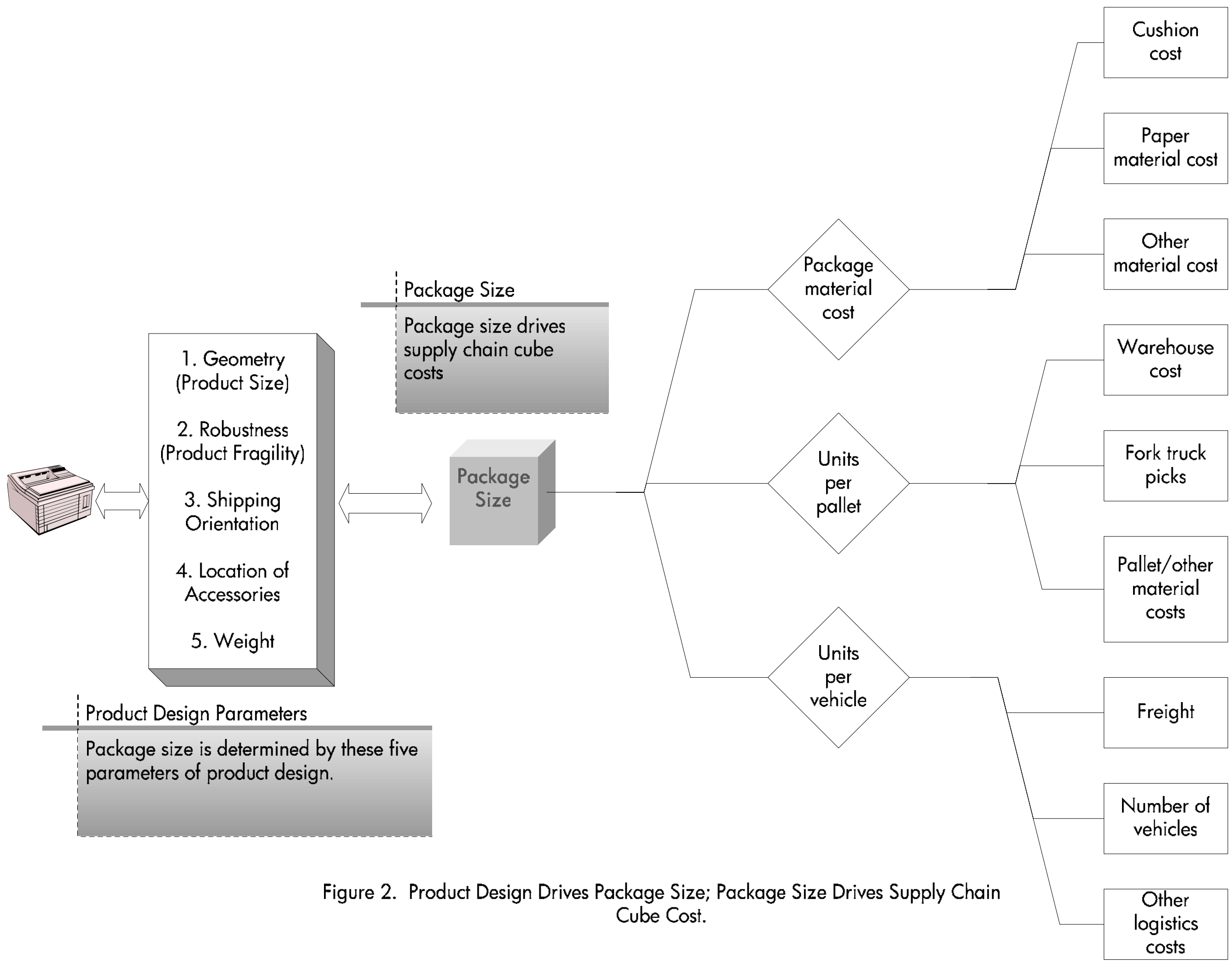
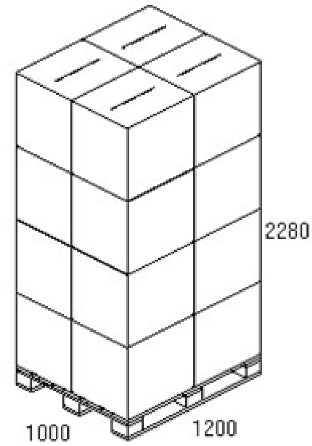


Figure 2. Product Design Drives Package Size; Package Size Drives Supply Chain Cube Cost.

Product Size A: 54.6 cm x 44.0 cm x 46.6 cm

Box Size A: 60.0 cm x 50.0 cm x 53.4 cm

Units per Pallet: 16

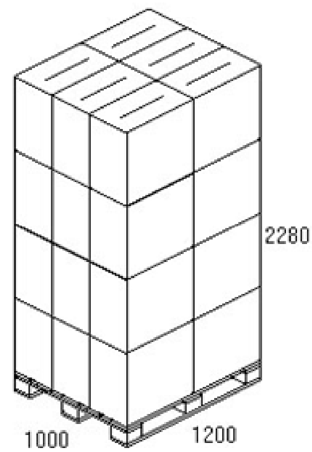


Product Size B: 54.6 cm x **27.3 cm** x 46.6 cm

Box Size B: 60.0 cm x **33.3 cm** x 53.4 cm

Units per Pallet: 24

(Maximum load height = 240 cm)



Result: 50% increase units/pallet
Lower package material cost
Lower supply chain cube cost

Figure 3. Affect of Product Size on Supply Chain Cube Cost.

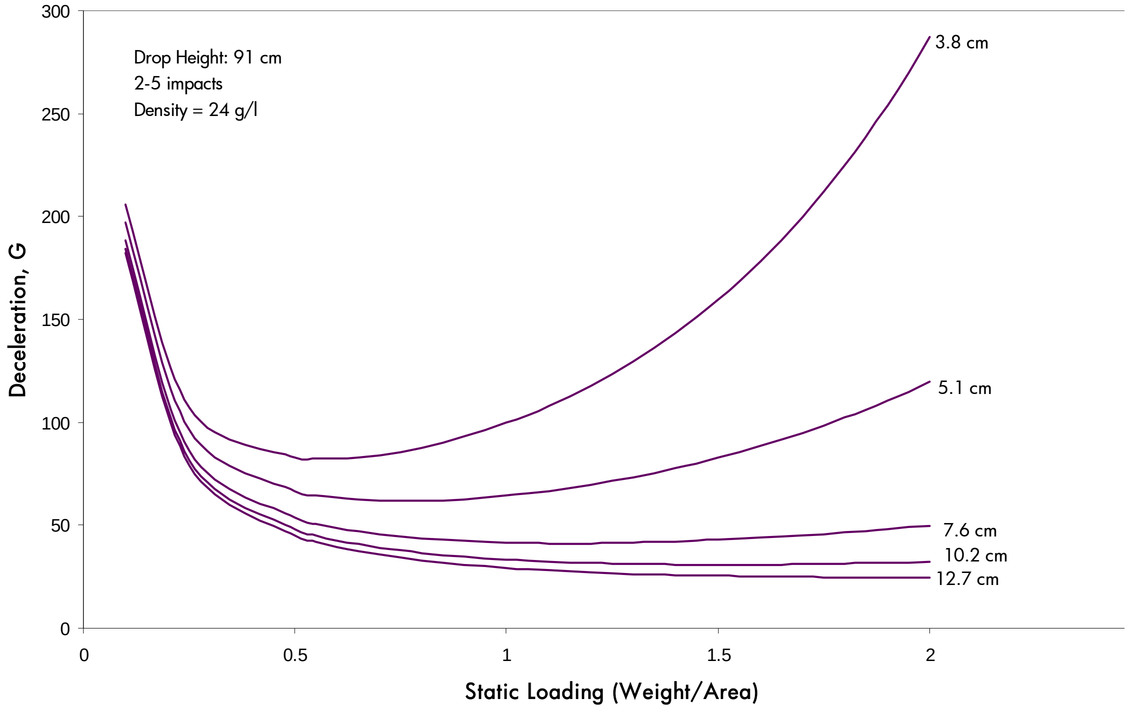
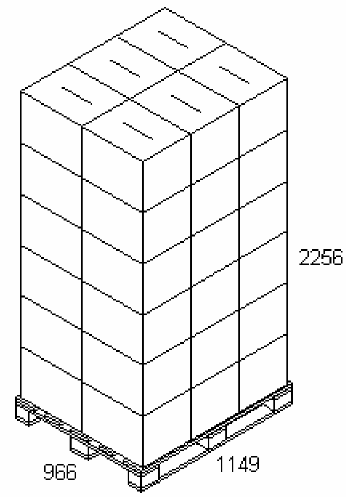


Figure 4. Typical Dynamic Cushion Curve.

Product Size A:	33 cm x 23 cm x 20 cm
Product Fragility:	40 G
Cushion Thickness:	76 cm per face
Package Size:	48 cm x 38 cm x 35 cm
Units Per Pallet:	36



Product Size B:	33 cm x 23 cm x 20 cm
Product Fragility:	**65 G**
Cushion Thickness:	**51 cm per face**
Package Size:	43 cm x 33 cm x 30 cm
Units Per Pallet:	56
Result:	56% increase pallets/unit Lower package material cost Lower supply chain cube cost

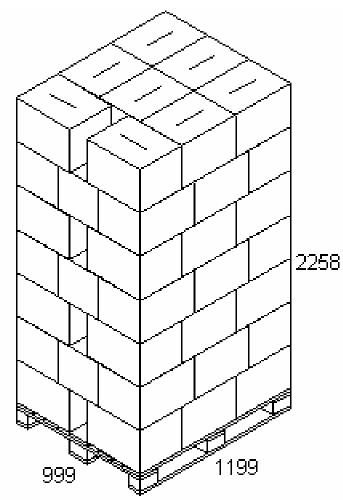


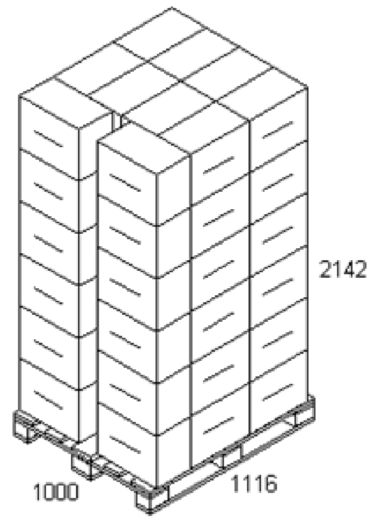
Figure 5. Affect of Product Fragility on Supply Chain Cube Cost.

4. **Weight.** Weight is the fifth product parameter directly affecting package size. However it is generally harder to modify for several reasons. First, cushion thickness depends on product weight because the design drop height depends on weight. See Figure 9. Second, weight can be difficult and expensive to design out of a product. Many times it is more cost effective to change one of the other four parameters. Weight can also affect freight costs if freight is based on weight, not volume. Using Figure 9, Table 2 shows how weight might affect supply chain cube costs. (Note cushion thickness is doubled since it is required for each side of the product). By only changing the weight, drop height changes which in turn requires less cushioning and a smaller overall package size.

Table 2. Affect of Weight on Supply Chain Cube Costs.

	Product A	**Product B**
Product Weight, kg	**18**	**22**
Product Size, cm	281 x 181 x 148	281 x 181 x 148
ISTA Drop Height, cm	61	46
Fragility, G's	30	30
Cushion Thickness, cm	7.6	10.2
Package Size, cm	43.3 x 33.3 x 30.0	48.5 x 38.5 x 35.2
Units per Pallet	56	36
Result	**<BASE>**	**56% increase units/pallet**

Package Size:	43 cm x 25 cm x 33 cm
Orientation:	33 cm vertical
Units Per Pallet:	60



Package Size:	43 cm x 25 cm x 33 cm
Orientation:	**43 cm vertical**
Units Per Pallet:	70

(Maximum pallet load = 240 cm)

Result:	17% increase pallets/unit Lower package material cost Lower supply chain cube cost

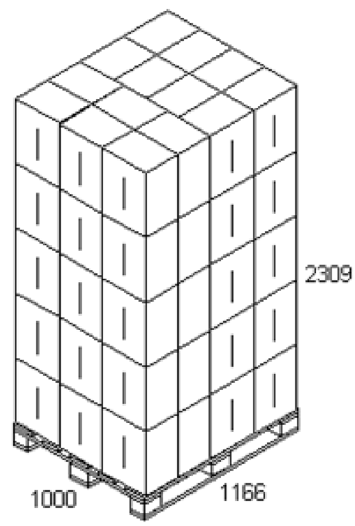


Figure 6. Affect of Shipping Orientation on Supply Chain Cube Cost.

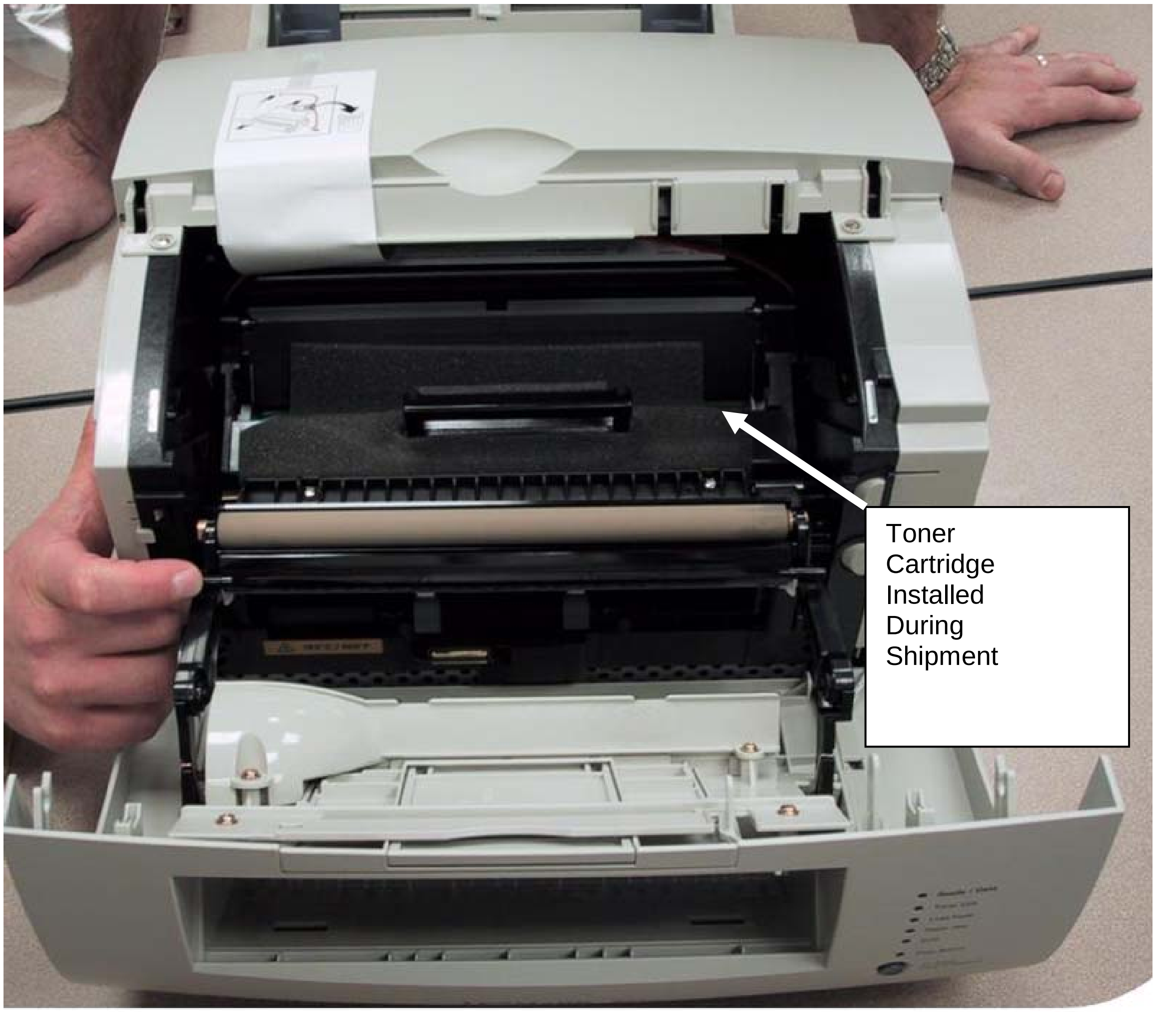


Figure 7. Shipping Toner Cartridge Installed in the Printer.

Figure 8. Shipping Accessories Inside the Product.

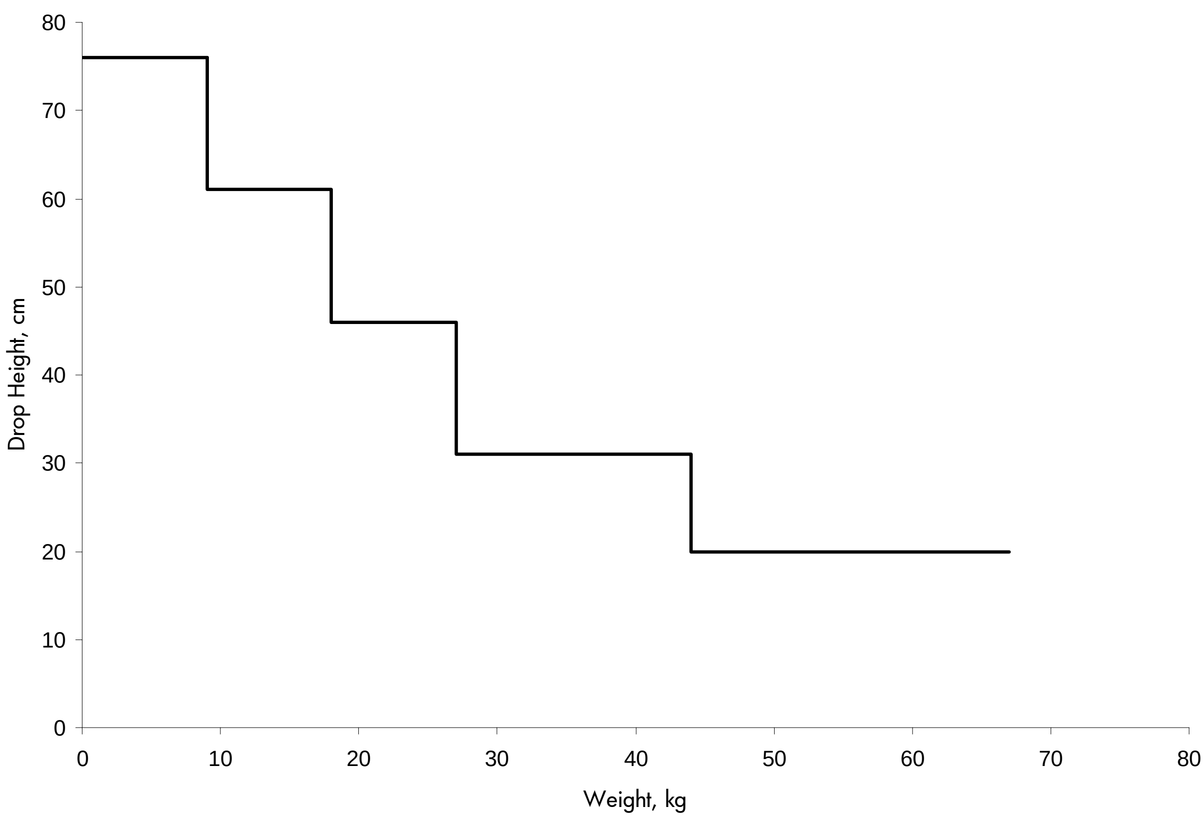


Figure 9. ISTA Drop Height vs. Weight Test Specification.

A Powerful Tool for Evaluating Parameter Combinations

One approach to lowering supply chain cube cost would be to evaluate each one of the five product parameters individually for its effect. A much more useful approach would be to simultaneously evaluate combinations of the parameters. The user could then mix and match various parameter variables and quickly calculate the resultant SC^3 cost difference. The Hewlett-Packard Boise Packaging Team has created such a tool. This tool is referred to as the ROSe (Ruggedness, Orientation, and Size) calculator [10]. The ROSe calculator works in two ways. One way starts with variable product parameters such as size and fragility (G's). The output of the tool is the overall package size and number of units per pallet that result from the variable inputs. The second way starts with a specific overall package size and gives the product dimensions and other product parameters that must be met to fit the specified package size.

A simplified flowchart outlining the various inputs and outputs is shown in Figure 10. Now the connection between product design, package design and SC^3 cost can be established. By evaluating several product parameters, teams can choose which elements are most easily manipulated to produce the lowest resultant SC^3 cost. The resultant packaging material reductions can also be calculated and added to the overall cost savings.

Case Study: Hewlett-Packard LaserJet Example

Using the ROSe calculator tool, the packaging engineer and the product design engineer evaluate several product parameter values (Figure 11). Table 3 shows an example of the different product parameters that might be evaluated. Sometimes 20 or 30 unique combinations will be analyzed. The output would typically be the package size and number of units per pallet that result from the particular variables. The calculator also estmates the package material savings associated with the smaller overall package size. After evaluating several scenarios, the ones most likely to be accepted by the team (cost, schedule, etc.) are distilled to a simple presentation, as shown in Figure 12. The presentation is then used by the product design, packaging, and supply chain teams to make the appropriate trade-offs in each area for the lowest overall systems cost.

Table 3. Example of Product Parameters Evaluated by the ROSe Tool.

Scenario	Length, mm	Width, Mm	Height, Mm	Fragility, G's	Weight, Kg	Orientation	Accy Location
A	300	300	200	30	15	Bottom down	Out
B	300	250	200	30	17	Front down	Out
C	300	250	200	45	15	Front down	In
D	290	245	210	30	17	Bottom down	In

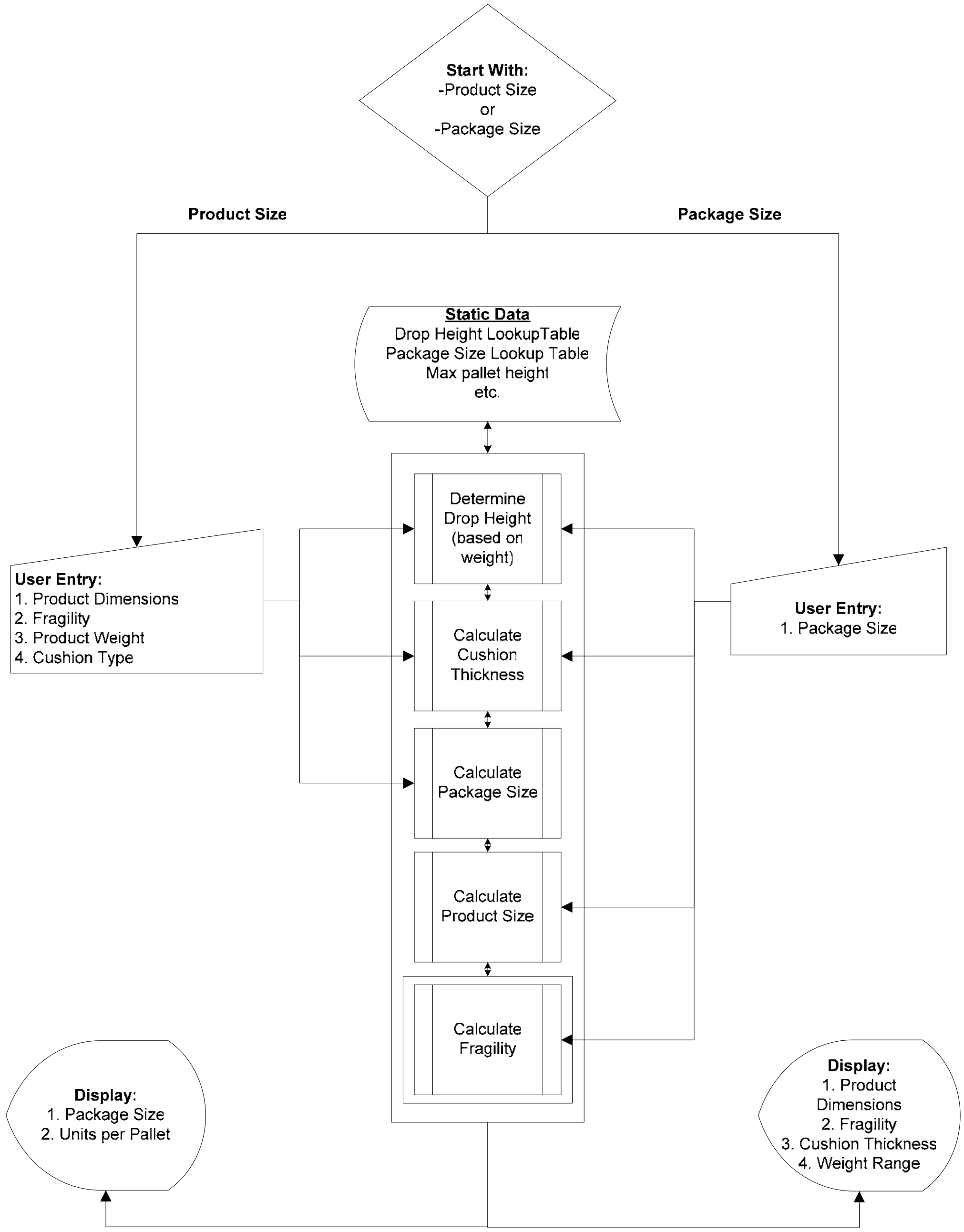


Figure 10. Simplified Flowchart for Evaluating Product Parameter Affect on Supply Chain Cube Costs.

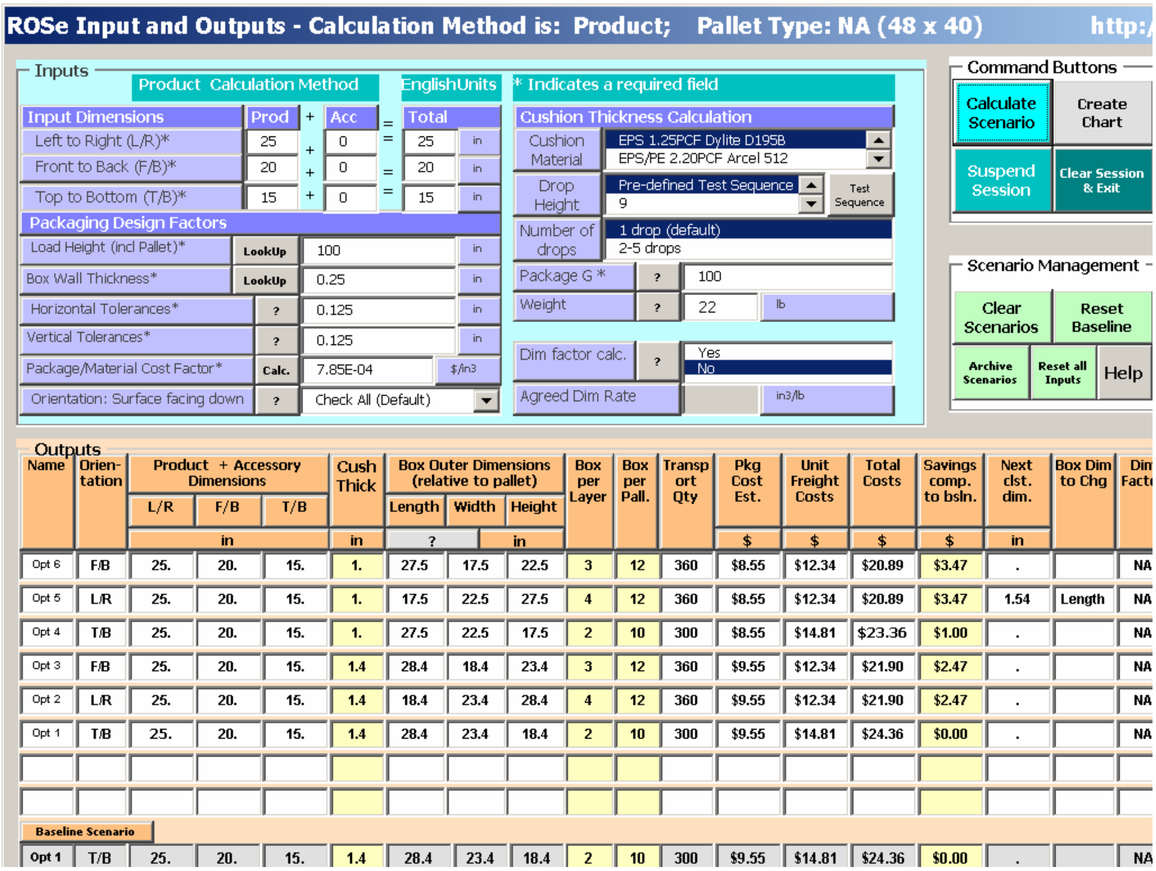


Figure 11. Screenshot of ROSe Tool.

	Product A Supply Chain Cube Options					
	POR	OPT 1	OPT 2	OPT 3	OPT 4	OPT 5
Size	ET	ET	RT	RT	ET	RT
Orientation	BD	RD	BD	BD	BD	BD
Fragility, G's	55	50	60	50	70	70
Accys: CRG	Out	Out	Out	Out	Out	In
Cost Savings	BASE	$ 7.77	$ 8.25	$ 8.32	$ 8.74	$ 10.72

ET = Extended tray   BD = Bottom Down
RT = Recessed Tray   RD = Rear Down

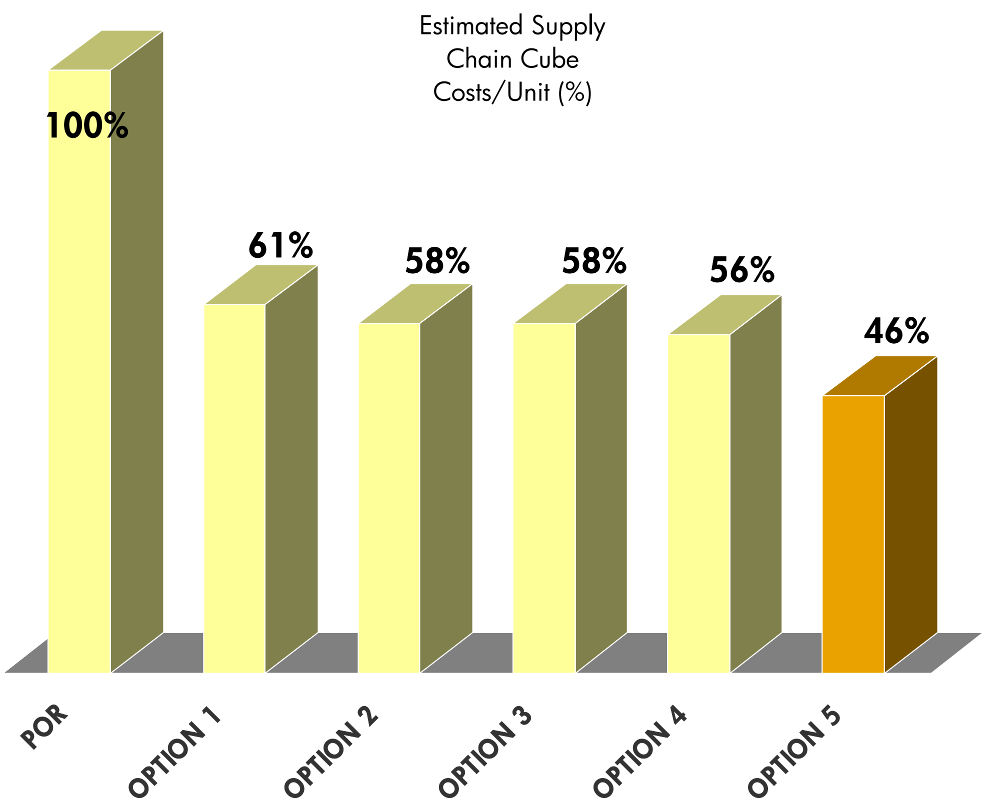


Figure 12. Summary of Product Design Parameter Affect on Supply Chain Cube Costs Resulting From the ROSe Calculator.

Summary

For typical consumer electronics, supply chain cube cost is an important element affecting the company's bottom line. Supply chain cube cost is driven by the overall package size, which in turn is driven by five specific product design parameters: product size, product ruggedness, product orientation, location of accessories, and weight. To lower supply chain cube costs, the product must be deliberately designed to support that goal. The evaluation of these five product parameters can be automated to create a powerful tool that helps teams make informed decisions. The output of the tool shows the overall package size resulting from the chosen parameter variables, or the parameter variables that must be met to achieve a specific overall package size. The results can then be graphically displayed to help teams make informed decisions about product parameters and the effect on supply chain cube costs.

References

1. Russell, Paul Grady. Personal correspondence regarding concept name ideas.
2. Capacities and Dimensions in the Distribution System, URL: http://packaging.hp.com/eips/, 2004.
3. ASTM D-3332, "Standard Test Methods for Mechanical Shock Fragility of Products Using Shock Machines." *2001 Annual Book of Standards*, Volume 15.09, American Society for Testing and Materials, 2001.
4. Leinberger, David A. 2002, "Integrated Package and Product Development, Proceedings of the 13th IAPRI Conference on Packaging," Volume 1, Book 1.
5. D. Root, "6 Step Method for Cushioned Package Design," (1997) Lansmont Corporation website, http://www.lansmont.com/SIXSTEP/6step.htm, 2004.
6. TOPS Engineering, URL: http://www.topseng.com/, 2004.
7. CAPE Systems, URL: http://www.capesystems.com/, 2004.
8. Lexmark E320 Printer Setup Guide, URL: http://www.lexmark.com/publications/pdfs/e320/eng/setupgd.pdf, 2004.
9. HP PSC 1210 All-In-One.
10. Biancavilla, Perry, Daum, Matt, Melia, Jane, and Miles Thorland. HP LaserJet Packaging Group, HP SPaM Team and HP GO-IT Team, 2004.