

## Putting Cost Into the Equation

Money is the 8th dimension. Really. At least in Mathcad.

What is a dimension? In mathematics a dimension describes the number of parameters needed to define a point in space. In engineering, it means any directly measurable physical quantity. These definitions are not incompatible. Both describe something concrete: length, mass, temperature, etc. In fact, SI (from the French, Le Système International d'Unités) declares 7 basic dimensions from which all other physical quantities can be derived. As a reminder, they are: Mass, Length, Time, Current, Temperature, Luminosity, and Substance... and Cost!

$$\begin{aligned}
 D &:= 50000 \cdot \text{kg material} & C &:= 7.75 \cdot \frac{\text{\$}}{\text{gm}} \text{ cost} \\
 S &:= 15 \cdot \text{\$} \text{ order costs} & H &:= 2.75 \cdot \frac{\text{\$}}{\text{kg}} \text{ inventory} \\
 \text{Minimize cost of inventory and sales:} \\
 \text{Tot}(Q) &:= D \cdot C + \frac{D}{Q} S + \frac{Q}{2} H \\
 \text{minorder} &:= \text{Minimize}(\text{Tot}, Q) = 798.334 \cdot \text{kg} \\
 \$ &:= \text{\$} & \text{k\$} &:= 10^3 \cdot \$ & \text{M\$} &:= 10^6 \cdot \$ & \text{¢} &:= \frac{\$}{100} \\
 \text{powercost} &:= 19.2 \cdot \frac{\text{¢}}{\text{kW} \cdot \text{hr}} & \text{energy} &:= 198.7 \cdot \text{kW} \cdot \text{hr} \\
 \text{total} &:= \text{powercost} \cdot \text{energy} = 0.038 \cdot \text{k\$}
 \end{aligned}$$

### Examples of Cost calculations in Mathcad 14

Cost? While not a physical quantity, organizations that make physical objects *are* concerned with cost. Engineers build cost optimizations into their solutions. Engineering companies need to track and associate cost with the goods they design and build. So, engineers would like to represent cost as a dimension, a tag that endows numbers with physical, or at least intellectual, meaning. That's how Money came to be dimension number 8 in Mathcad. If you look on the **Tools > Worksheet Options > Unit System** tab, you'll see it listed under Base Dimensions, right in between Mass and Substance.

Each dimension has one or more units that allow you to say "how much" of that dimension you've got. Eight meters means something different from eight inches -- it's longer, as indicated by its units -- but it means something categorically different from eight seconds or eight kilograms. They're different dimensions. This notion is deeply ingrained in engineers' understanding of how to solve problems.

But not all dimensions are created equal. Let's examine a few. For example, most dimensions have well-defined base units which provide the multiplicative conversion rates to all other units. If we're talking about mass, SI has the kilogram, CGS has the gram, and the US system has the pound. Each is convertible to other units in its system and to each other by multiplicative scaling factors.

Now, look at temperature. It has a linearly scaled base unit of Kelvin, but to recalculate a value to Celsius or Fahrenheit, and you must use functions and inverse functions, and you must also concern yourself with differential temperature vs. absolute temperature.

Despite a few untidy unit conversion corners here and there -- people haven't debated this stuff for hundreds of years for nothing, you know -- it seems that choosing a suitable base unit is key.

What would the "base unit" of Cost be in any of those systems? We might have used the gold standard, if that still had meaning. We could have chosen the US dollar or the UK Pound or the EU Euro. If there were a constant conversion rate between any of these currencies and all other currencies, then it wouldn't have mattered so much what we used as the base symbol. But, in fact, the variability of the conversion rates was the difficulty that kept Monetary units from becoming a standard in Mathcad until recently.

In Mathcad 14, we went ahead and chose a Monetary base unit. It is, in fact, the "Currency Sign" Ⱶ in the UNICODE font set. What this means is that you can track the dimension of Money without implying any particular currency or conversion rate. As with all dimensions in Mathcad, you can keep track of it in calculations, and show imbalances when other dimensions are added to a monetary calculation by mistake.

Tracking dimensions is one of the primary strengths of Mathcad, as explored in previous posts, so this new dimension can be used in all the ways that other dimensions are balanced. Now you can optimize on Money, or return units of Money as part of a larger calculation. For example, suppose you want to determine the minimum cost-effective order quantity of a material, when you know the annual demand. Take a look at the image at the top of this post to see an example of this calculation, or look at the new features section in Tutorials in Mathcad.

So far so good. It just looks a little funny. To make this display by default using some other monetary symbol, choose **Tools > Worksheet Options > Display** tab, and pick another currency symbol. For example, it's possible to stick within one monetary system and do a variety of conversions, if that's useful to you. You can convert in dollars, if you like, and even define some SI style prefixes for your currency. An example of these conversions is also shown in the image.

The creation of a new dimension for Money, while not strictly consistent with the intentions of organizations like the SI, gives you a powerful tool for creating your own self-consistent set of symbols and conversions. It allows the exploration of problems with the cost included in the equation, quite literally.

Even in an era of volatile currency conversion rates, this tool is quite useful for both estimating and updating the cost of projects that involve multiple currencies. Because of Mathcad's ability to recalculate, it's quite easy to create a calculation that shows the cost based on several different currencies, then update the conversion rates as needed to redo the computation. The rates could be changed by hand, or read in from a data file, as needed. Or locked to a particular point in time when the estimate was made.

While the issue of how to represent Money in a dimensional balancing tool that relies on a base value is not quite obvious, the end result is effective. If we ignore what the base is,

and simply say that there is one, we can track and balance this dimension as well as any other, and worry about applying precise values to the results at the end of the process.

Please let us know how you're applying Money in your work.

**Note:** The cost unit was added to Mathcad 14.0 in M010. You can download this free upgrade to Mathcad 14 from <http://www.ptc.com/support/mathcad.htm>. Users with maintenance contracts can click on the link under Downloads. Single users should click on Single-User tab, then Download Mathcad Updates below.