Debunking the Myth of Parametrics
Or
How I learned to stop worrying and to love DFM

It is time to clear the air, to lay out some definitions, to flatly state what is going on behind the scenes, and finally, to shed some light on the SEER-DFM (Design for Manufacturability) software model. Everyone who has ever built a labor standard, or designed and developed a set of standard data, or calculated the cost of a product, has used parametrics. Parametrics, according to definition, is simply a mathematical formula. When you apply a factor, such as a typical 15% Personal-Fatigue-Delay adjustment to the time required to perform work, then you have applied a parametric. Obviously, we can find examples of parametrics that are much more complex. We will not, however, find those examples in the SEER-DFM software model. The model simply has a large set of easily understood building blocks that are used to simplify and automate the often-difficult task of evaluating the cost of manufacturability.

The easiest way to explain the inner workings of the parametrics in SEER-DFM is by example. Everyone understands that the model will generate the effort (or time) requirement to perform work. A simple equation (effort **X** labor rate) is applied to the time element and we then have the labor cost of performing work. As simple as that is, a reasonable question is often posed, “Where does the effort (or time) come from?” Because the SEER-DFM software models more than 70 basic processes, including mechanical assembly, milling, turning, EDM, plasma arc cutting, shearing, printed circuit board fabrication and assembly, etc., a complete description of sources would be lengthy. Let us examine one process… drilling.

The work content of the drilling process is measured by breaking the work into components. There is usually a machine setup component whereby the drill bit is chucked, stops, jigs or fixtures are set in place, and machine feeds and speeds are set. The work material is positioned on the machine bed and following the actual operation, removed. The machine is actuated and the hole is drilled. Finally, the part may or may not receive some form of immediate inspection and rework. These sub elements of the work being performed are measured using inputs that I will refer to as COST DRIVERS.

The factors that effect the effort required to drill a hole are many. They include the obvious and sometimes not so obvious facts and circumstances. These cost drivers include: the diameter of the hole; the depth of the hole, the positioning tolerance; the material being drilled; the machine being used and the tooling and condition of the tooling being used; the experience of the machine operator and the efficiency at which the work is performed; the workplace layout and the degree of mechanization employed; and the standards and practices that must be met to achieve the desired level of quality and documentation. For now, let us focus on the obvious cost drivers and how they impact the time required to remove material.

Many source materials can be found in the Galorath reference library. Those materials include data published by The Institute of Advanced Manufacturing Sciences, Inc. and commonly referred to as Met-Cut or Cut-Data. The reference materials present many, many tables of data, which reflect the results of extensive trials, time and motion studies, and analysis. The information contained in these tables has been distilled into simple algorithms that express the effort required to remove material. More specifically, the tables of data identifying the time required to drill a hole in a given material and at specific feeds and speeds, has been put through non-linear regression analysis. The material machinability factor, hole diameter and hole depths are then input into the generated parametric formula and an effort calculation made. Other factors can then be applied to capture the effect of additional cost drivers.

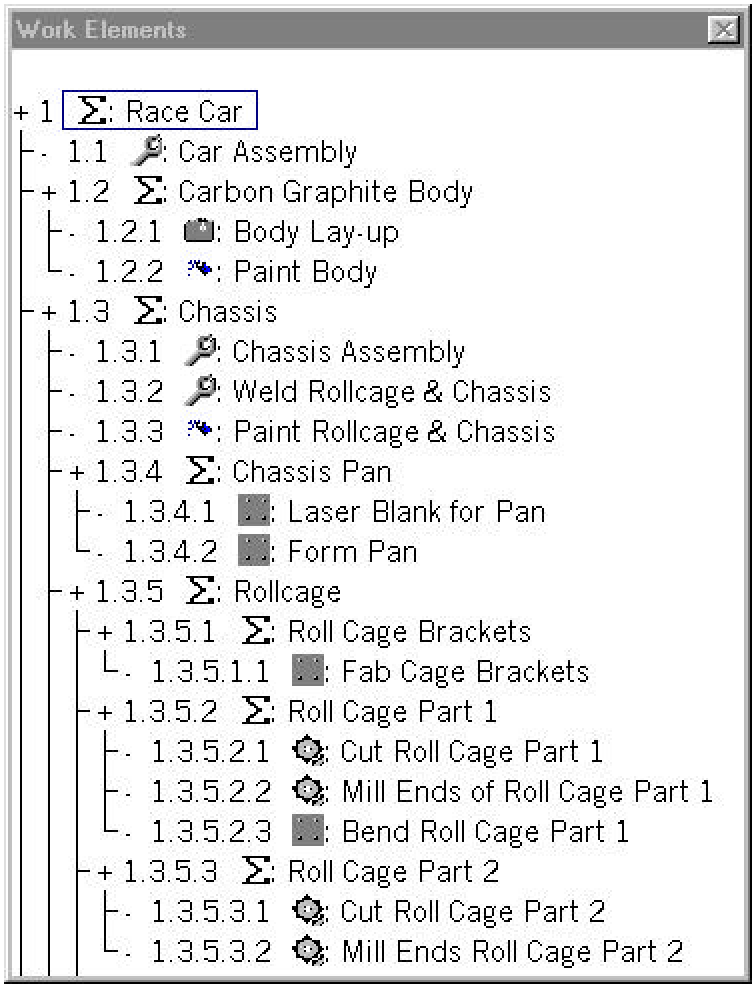
The so-called "black box," a term many people use to describe parametrics, can hardly be used in conjunction with SEER-DFM. It doesn't surprise anyone to learn that the time to drill a ¼" deep hole vs. the time to drill a ½" deep hole can be expressed easily and simply with a mathematical formula. In fact, most of us who have made a living developing time standards, quickly learned the value of developing mathematical formulas rather than using the error prone and time consuming method of table look-up.

Many of the data sources used by Galorath in developing the SEER-DFM software model, such as the one mentioned, are available and can be purchased as reference books. Other data sources are found in the public domain and Galorath has obtained others through co-operative partnering with clients. The math specifications for the SEER software models have been and will continue to be made available for review to licensed users of the software.

With some of the mystery gone, we might want to take a moment to look at the added benefits derived from the SEER-DFM software model. Besides the obvious generation of effort and cost required to perform work, the ease of use provided through the graphical user interface, and the consistent methodology that the model provides, there is a unique element, RISK, that is often overlooked. This added benefit is one borrowed from more sophisticated parametric models, SEER-SEM, Software Evaluation Model, and SEER-H, Hardware Evaluation Model.

The SEER-DFM software model provides "should cost" information. Think of "should cost" in terms of standard cost. Now, answer the question, "Does actual production cost EVER meet the standard cost expectation?" My answer to that question is a resounding, no. There are too many variables and randomness for the "should cost" expectation to be met. It is because of this fact, that the SEER-DFM risk assessment is so important. The software model provides for relevant parameters, or cost drivers, to be input in terms of "Least Likely", "Likely", and "Most Likely." With these inputs, you may build into the cost model the boundaries of probable outcome and with the model's facility to perform a Monte Carlo Analysis on complete products and systems, you find a consistent means to weight your engineering and management decisions.

The SEER-DFM software model employs a work element paradigm. Work elements types are Roll-up, Fabrication, Machining, Electrical Assembly, Mechanical Assembly, Composites, Molding-Casting-Forging, Finishing, Printed Circuit Board, and Additional Items. Each work element types model many processes grouped according to the presence of common cost drivers. An example work element structure is shown:



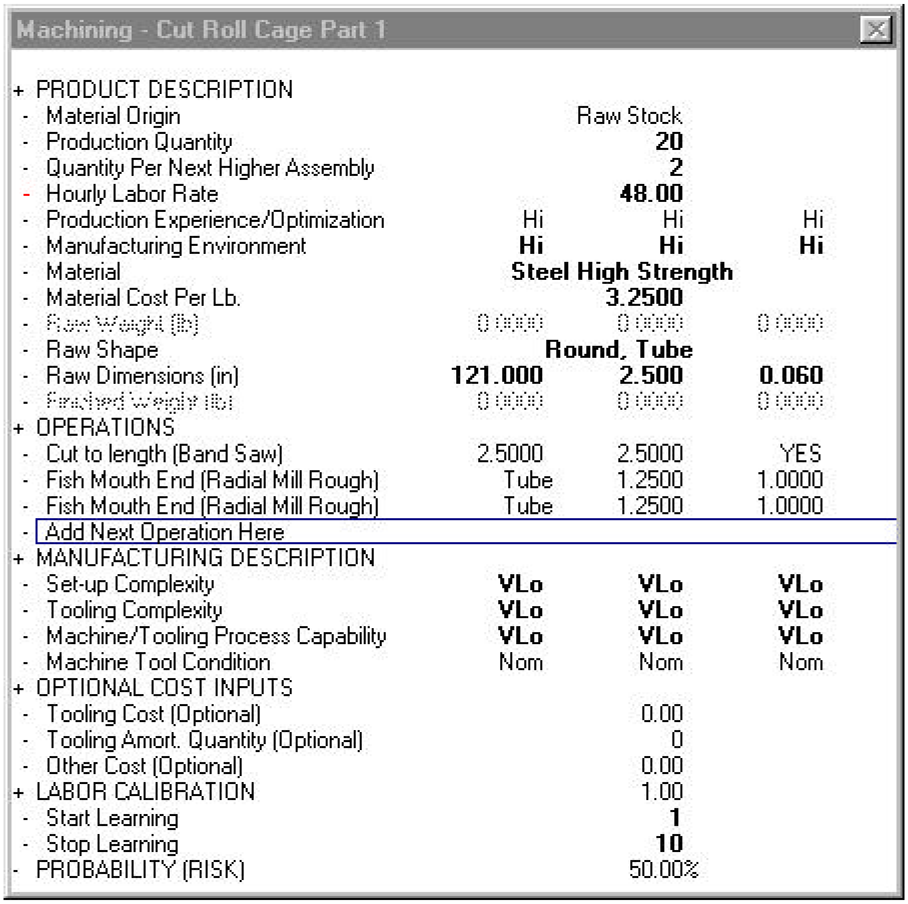
The Work Element window shows a project titled, “SEER Race Car.” The first work element is a Roll-up, as indicated by the summation icon preceding the element name. Each work element with the summation icon represents an assembly or part. The entire project is built as an indented bill-of-material using the Roll-up work elements.

The work elements other than Roll-ups represent the actual work (or processes) that will be performed to build the race car. Together, the Roll-ups and process specific work elements form a manufacturing bill-of-material that describe exactly what work will occur.

Each detailed Work Element has a corresponding set of parameters. Those parameters are the relevant cost drivers for that process.

Many different manufacturing processes share common cost driver parameters. Processes are grouped according to those shared inputs. By example, the Machining Work Element includes the processes: Radial Mill Rough, Radial Mill Finish, End Mill Rough, End Mill Finish, Chemical Mill, Turn Rough, Turn Finish, Shape Rough, Shape Finish, Bore Rough, Bore Finish, Grind Rough, Grind Finish, EDM, Screw Machine, Drill, Ream, Hack Saw, Band Saw, Radial Saw, Broach, Tap, Auto Production Equipment and Additional Items. Besides the shared cost drivers, each of these processes has a unique set of parameter inputs.

Selecting an individual work element, we can look deeper into the model to see the parameter inputs which are the relevant cost drivers. The parameters used to model cost drivers for a machining work element are shown:

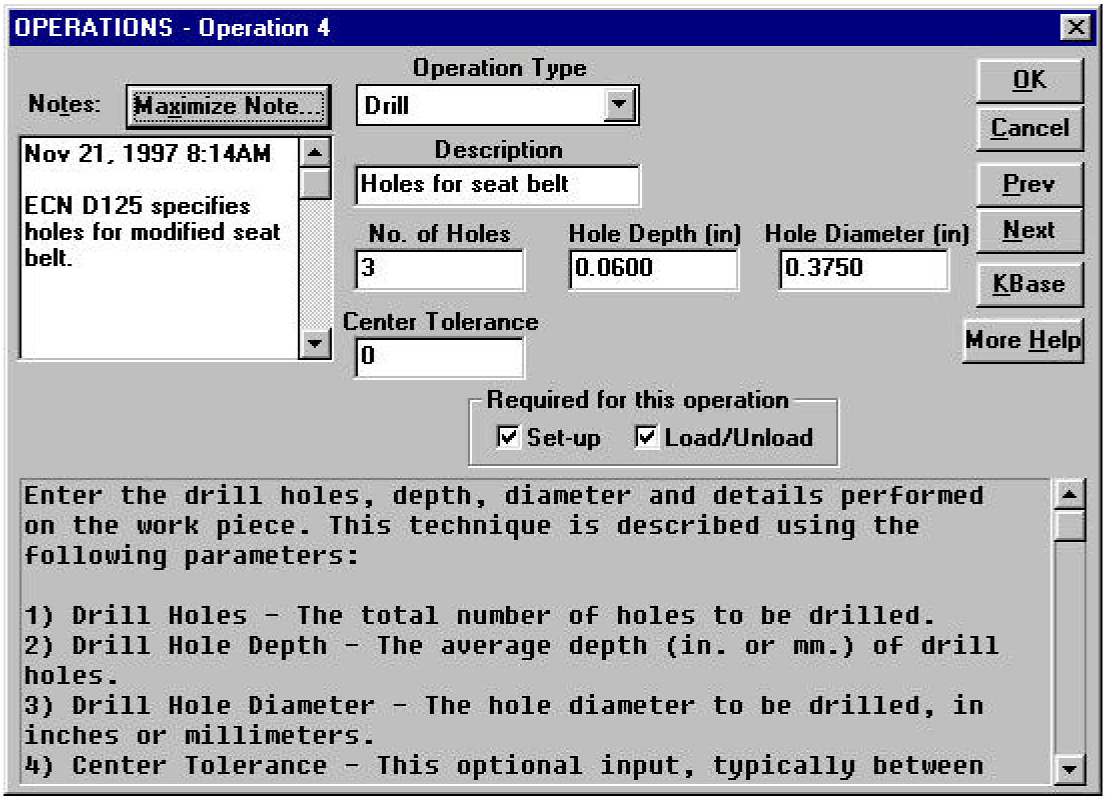


Machining - Cut Roll Cage Part 1

+ PRODUCT DESCRIPTION			
- Material Origin		Raw Stock	
- Production Quantity		**20**	
- Quantity Per Next Higher Assembly		**2**	
- Hourly Labor Rate		**48.00**	
- Production Experience/Optimization	Hi	Hi	Hi
- Manufacturing Environment	**Hi**	**Hi**	**Hi**
- Material		**Steel High Strength**	
- Material Cost Per Lb.		**3.2500**	
- Raw Weight (lb)	0.0000	0.0000	0.0000
- Raw Shape		**Round, Tube**	
- Raw Dimensions (in)	**121.000**	**2.500**	**0.060**
- Finished Weight (lb)	0.0000	0.0000	0.0000
+ OPERATIONS			
- Cut to length (Band Saw)	2.5000	2.5000	YES
- Fish Mouth End (Radial Mill Rough)	Tube	1.2500	1.0000
- Fish Mouth End (Radial Mill Rough)	Tube	1.2500	1.0000
- Add Next Operation Here			
+ MANUFACTURING DESCRIPTION			
- Set-up Complexity	**VLo**	**VLo**	**VLo**
- Tooling Complexity	**VLo**	**VLo**	**VLo**
- Machine/Tooling Process Capability	**VLo**	**VLo**	**VLo**
- Machine Tool Condition	Nom	Nom	Nom
+ OPTIONAL COST INPUTS			
- Tooling Cost (Optional)		0.00	
- Tooling Amort. Quantity (Optional)		0	
- Other Cost (Optional)		0.00	
+ LABOR CALIBRATION		1.00	
- Start Learning		**1**	
- Stop Learning		**10**	
- PROBABILITY (RISK)		50.00%	

Most of the parameters are self-explanatory. Like all of the other SEER software models, SEER-DFM uses Knowledge Bases to assist in populating the cost driver inputs. Input fields appearing in bold typeface have had the Knowledge Base inputs modified. Parameters that are grayed-out are not relevant. This example shows values input into the Raw Shape and Raw Dimensions parameters. As a result, the parameters Raw Weight and Finished Weight are grayed-out. SEER-DFM will calculate those values.

Entry or modification of a parameter is accomplished by selecting a parameter and entering the appropriate data. The following example shows the Parameter Entry window. Entering operation specific data, such as specifying a drilling operation, hole diameter, hole depth and tolerance is a simple step:

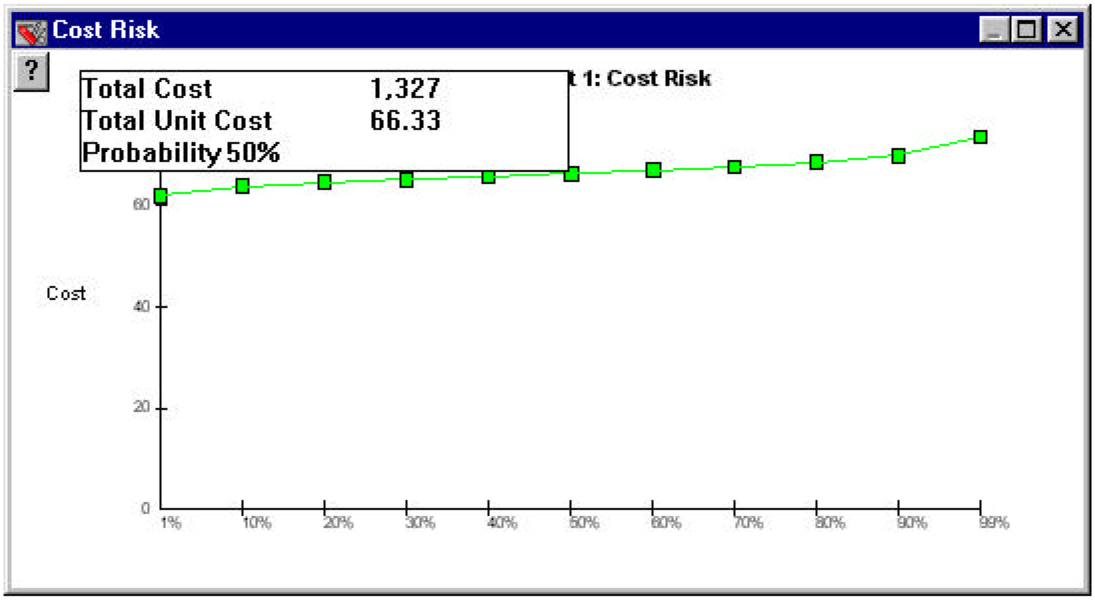


Some of the most noticeable features shown in this example include:

- the ability to document the parameter entries with notes,
- the drop down box selection of process type,
- the ability to include or exclude the setup and load/unload components of the operation,
- the extensive online documentation of the process and cost drivers.

The effort calculation for the drilling process is as simple and straightforward as expected. A machinability factor for High Strength Steel, found in the software's material database, is factored along with the diameter and depth of the hole being drilled. The tolerance required provides an additional time factor to account for the required positioning and inspection labor components.

Beyond the calculation of effort, the SEER-DFM software tool does provide significant added value. Key to every management decision is the probability of accuracy of the core data upon which the decision is being made. The software provides a risk assessment for every work element and also provides a Monte Carlo analysis to predict possible cost results for the complete engineering project. This removes the need to make subjective adjustments to reported costs and identifies the integrity of the analysis. These results are displayed in graphic form and in reports.



The Cost Risk chart shown illustrates the range of likely cost for a specified work element. The total work element cost at 50% probability is shown as $66.33. Best case scenario is $62.07, while the worst case scenario is $ 73.63. This range of possible outcomes allows the decision-maker to consider the uncertainty that might be later reported as a variance to standard cost.

An example of a Project/Rollup Cost Risk report follows:

SEER-DFM (TM) Design for Manufacturability Vers. 3.2.15
Project : Race Car (RACECAR.DFM) 11/21/97
PROJECT: 1: Race Car 10:54:11 AM

Project/Rollup Cost Risk

Work Elements: Confidence Level	Independent Total Cost	Dependent Total Cost
10%	290,436	288,236
20%	291,378	289,750
30%	292,068	290,917
40%	292,780	292,032
50%	293,382	292,829
60%	293,712	293,716
70%	294,225	295,010
80%	294,932	296,324
90%	296,036	298,005

(Based on 100 iteration sampling)

WBS Allocation Of Most Likely Production Cost

	Median Prod Cost	% of Total	(StdDev)
+ 1: Race Car	293,382		(2101.45)
- 1.1: Car Assembly	116,884	39.84%	(595.19)
+ 1.2: Carbon Graphite Body			
- 1.2.1: Body Lay-up	30,239	10.31%	(1827.94)
- 1.2.2: Paint Body	1,994	0.68%	(15.18)
+ 1.3: Chassis			
- 1.3.1: Chassis Assembly	12,971	4.42%	(0.00)
- 1.3.2: Weld Rollcage & Chassis	4,884	1.66%	(0.00)
- 1.3.3: Paint Rollcage & Chassis	326	0.11%	(5.29)
+ 1.3.4: Chassis Pan			
- 1.3.4.1: Laser Blank for Pan	931	0.32%	(9.84)
- 1.3.4.2: Form Pan	33	0.01%	(4.91)
+ 1.3.5: Rollcage			
+ 1.3.5.1: Roll Cage Brackets			
- 1.3.5.1.1: Fab Cage Brackets	109	0.04%	(0.00)
+ 1.3.5.2: Roll Cage Part 1			
- 1.3.5.2.1: Cut Roll Cage Part 1	1,337	0.46%	(48.24)
- 1.3.5.2.2: Mill Ends of Roll Cage Part 1	144	0.05%	(0.00)
- 1.3.5.2.3: Bend Roll Cage Part 1	745	0.25%	(0.00)
+ 1.3.5.3: Roll Cage Part 2			

- 1.3.5.3.1: Cut Roll Cage Part 2	1,641	0.56%	(0.00)
- 1.3.5.3.2: Mill Ends Roll Cage Part 2	294	0.10%	(0.00)
+ 1.3.5.4: Roll Cage Part 3			
- 1.3.5.4.1: Cut Chassis Tubes Part 3	2,740	0.93%	(0.00)
- 1.3.5.4.2: Mill Ends Chassis Tubes Part 3	220	0.07%	(0.00)
- 1.3.5.4.3: Bend Chassis Tubes Part 3	205	0.07%	(0.00)
+ 1.3.5.5: Roll Cage Part 4			
- 1.3.5.5.1: Cut Roll Cage Part 4	448	0.15%	(0.00)
- 1.3.5.5.2: Mill Roll Cage Part 4	327	0.11%	(0.00)
+ 1.3.6: Rear Susp. & Differential Assy			
- 1.3.6.1: Assemble & Weld Rear Suspension	5,964	2.03%	(0.00)
+ 1.3.6.2: Rod Ends			
- 1.3.6.2.1: Rod Ends	94	0.03%	(0.00)
+ 1.3.6.3: Suspension Arms			
- 1.3.6.3.1: Cut Suspension Arm Material	172	0.06%	(5.68)
- 1.3.6.3.2: Bend Suspension Arms	20	0.01%	(3.11)
+ 1.3.6.4: Rear Axle			
- 1.3.6.4.1: Rear Axle Assembly	36,216	12.34%	(0.00)
+ 1.3.6.4.2: Cover Plate			
- 1.3.6.4.2.1: Cast Rear Cover	636	0.22%	(0.00)
- 1.3.6.4.2.2: Machine Rear Cover	164	0.06%	(0.00)
+ 1.3.6.4.3: Machined Rear Axle			
- 1.3.6.4.3.1: Cast Rear Axle	13,005	4.43%	(754.87)
- 1.3.6.4.3.2: Rear Axle - Machine	8,597	2.93%	(0.00)
+ 1.3.6.4.4: Axle			
- 1.3.6.4.4.1: Forge Axles	3,299	1.12%	(0.00)
- 1.3.6.4.4.2: Machine Axles	1,034	0.35%	(164.15)
+ 1.4: Electronic Control Box			
- 1.4.1: Potting	137	0.05%	(0.00)
- 1.4.2: Control Box Assy	49	0.02%	(0.00)
+ 1.4.3: PC Board			
- 1.4.3.1: PC Board Fabrication	5,902	2.01%	(181.38)
- 1.4.3.2: PC Board Assy & Test	39,070	13.32%	(26.66)
+ 1.4.4: Control Box Housing			
- 1.4.4.1: Injection Mold PC Housing	651	0.22%	(26.47)
+ 1.5: Wiring Harness			
- 1.5.1: Harness	1,898	0.65%	(25.52)

The Monte Carlo Analysis provides an in depth look at the projected cost of work. The first section of the report provides the cost at varied levels of possibility, while the second section identifies the component costs, the percentage of the total cost that each component carries, and the standard deviation to the estimated cost. From this data, a level of confidence can be derived that is certainly superior to the random and subjective assessment normally applied to bottoms-up costing efforts.

Finally, a table showing the parameter inputs and the generated output is offered. The listing of inputs is specific for a work element specifying a drilling process. User entered inputs are in bold typeface. Other inputs are provided through Knowledge Base selection and from the software material database. The matrix of input vs. output clearly identifies the cost structure relationships in this example for the drilling process.

OUTPUTS > / INPUTS	Setup Minutes	Direct Minutes	Inspection Minutes	Rework Minutes	Setup Cost	Direct Cost	Inspection Cost	Rework Cost	Material Cost	Tooling Cost	Other Cost	Raw Weight	Finished Weight
Material Origin		x	x	x		x	x	x	x				
Production Quantity										x			
Hourly Labor Rate					x	x	x	x					
Production Experience/Optimization	x	x	x	x	x	x	x	x					
Manufacturing Environment	x	x	x	x	x	x	x	x					
Operator Efficiency		x				x							
Material		x	x	x		x	x	x	x			x	x
Material Density Factor												x	x
Material Machinability Factor		x	x	x		x	x	x	x				
Material Cost Per Pound						x			x				
Raw Weight		x				x			x			-	x
Raw Shape		x				x		x	x			x	x
Raw Dimensions		x				x			x			x	x
Finished Weight		x				x			x			x	-
# Holes Drilled		x	x	x		x	x	x					
Hole Depth		x	x	x		x	x	x					
Hole Diameter		x	x	x		x	x	x					
Center tolerance		x	x	x		x	x						
Setup Complexity	x				x								
Tooling Complexity										x			
Machine Tool Process Capability		x	x	x		x	x	x					
Machine Tool Condition		x	x	x		x	x	x					
Tooling Cost (optional)										x			
Tooling Amortization Qty (optional)										x	x		
Other Cost (optional)											x		
Labor Calibration	x	x	x	x	x	x	x	x					
Start Learning Quantity		x	x	x		x	x	x					
Stop Learning Quantity		x	x	x		x	x	x					
Probability													