# At the corner of Lean Street and Statistics Road

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## ABSTRACT

Manufacturing companies invest huge sums of money in Lean Principles[1] and TWI[2,3] education for their shop floor staff. Results are generally positive with countless anecdotes about measurable process improvements and better employee morale. However, many companies indicate a need for a better return on their training investments and a faster, bigger impact on profits.

This paper will address this need by guiding organizations to the next logical step - **a seamless combination of Lean Principles and applied Statistical Thinking on the production floor**. Companies can expect improved competitive performance, enhanced product quality, better morale, a higher return on their embedded Lean training and higher bottom line profits.

Specifically, this paper was written to provide useful insight to Engineers and Managers that want to work with shop floor staff to attain the new process knowledge needed for dramatic process improvement.

## DEFINITIONS

In the context of this paper, the term *Production Personnel*, *Production Staff or Production People* includes process operators and some supervisors and maintenance personnel, but typically not Plant Managers or Assistant Plant Managers. Likewise, the term *Engineers* includes Manufacturing Engineers, Process Engineers, Quality Engineers and similar. Some, but not all, of the content of this paper applies to R&D Engineers.

In addition, the terms *Production Floor, Production Area, Shop Floor and Lab* are used interchangeably.

## CONTEXT

The recommendations provided herein are based on 23 years of production floor experience in the fiber optic & energy cable, heavy truck, thermoforming and other industries. They'll work well for quality-centric manufacturers. Volume-centric organizations are encouraged to look elsewhere for advice.

It should be noted that the author holds production operators and maintenance staff in the highest possible regard.

## THE LEAN FOUNDATION

Lean Principles serve as the foundation for process improvement because a waste-laden, chaotic process is inherently unstable, thus precluding the use of statistical methods.

A core Lean Principle is that *production operators* are the key to manufacturing success. The fine folks on the production floor make the product that brings in the money. They accrue knowledge of manufacturing processes every single day. During their shifts, they are immersed in the process, its raw materials, its machinery, its sounds, vibrations, odors and quirks. Therefore, an admittedly non-traditional mindset is recommended:

*Engineers should treat production operators as internal customers*

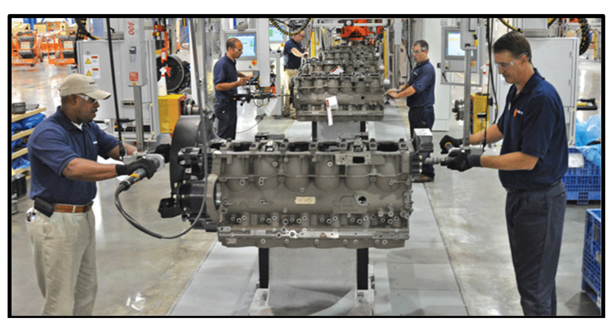


**Figure 1, Production operators, an Engineer's internal customers**


**Figure 2, A profitable customer-supplier relationship**

The remainder of this paper provides guidance for those willing to take this non-traditional approach. In this regard, *The Shingo Prize for Operational Excellence*[4] provides support. Table 1 lists paraphrased excerpts of the *Guiding Principles*[4] used by manufacturers in pursuit of the coveted Shingo Prize.

| **CATEGORY:** *Continuous Improvement* | |
|---|---|
| Seek perfection | ☐ Create permanent fixes<br>☐ Simplify work |
| Embrace scientific thinking | ☐ Use structured problem-solving<br>☐ Help employees explore new ideas without fear of failure |
| Focus on the process | ☐ Improve processes that create errors<br>☐ Ensure operators have good parts, materials, information and support |
| Assure quality at the source | ☐ Organize work places (5S)<br>☐ Stop work to fix errors |
| Improve flow and pull | ☐ Keep the product moving<br>☐ Ensure resources are available when and where they are needed |
| Think systematically | ☐ Eliminate barriers to the flow of ideas, information, product, etc.<br>☐ Ensure the goals and issues for each day are understood by everyone |

**Table 1, The Shingo Prize Guidelines, summarized**

Experience indicates the verbs *create, help, organize* and *eliminate* are strong hints that Engineers and Managers are responsible for improving production systems so that operators can make things safer, easier, better, faster and cheaper. The fine words of a famous quality thought leader corroborate this approach.

*"A bad system will beat a good person every time."*
W. Edwards Deming

## THE STATISTICAL BABEL FISH[5]

Many a fine opportunity to improve processes have been squandered because of terminology. Statistical terminology, technical terminology, jargon and business buzzwords will often turn valuable production operators against the idea of continuous improvement.

In the book *Hitchhiker's Guide to the Galaxy*[5], the character *Babel Fish* was able to translate from any language in the universe to any other language. His previously unknown cousin, *Statistical Babel Fish* is a Lean thinker that provides simplified terminology to help Engineers communicate more clearly in the production area. Use translated terminology (or similar) as listed in Table 2.

| STAT TERM | | TRANSLATION(S) |
|---|---|---|
| Statistics | | Data visualization |
| Average, mean | | Center |
| Distribution | | Shape |
| Standard deviation | | Spread |
| Normal distribution | | Bell shape |
| Response variation | | Buzz, wandering |
| Predictive model | | Predictor chart |
| Run chart | | Time chart |
| Control chart | | Time chart,<br>Voice of the Process |
| Scatterplot | | Correlation chart |
| Prediction Profiler | | Predictor chart |
| Interaction Profiles | | Interaction chart |
| Histogram | | Shape chart |
| Taguchi Loss Function chart | | Burning money chart,<br>Loss chart |
| Ishikawa diagram<br>Cause & effect diagram | | Fishbone diagram<br>(of course ☺) |
| Interaction | | Dependency |
| Factors | | What we can control |
| Responses | | What we want |
| Descriptive statistics | | Data summary |
| Inferential statistics | | Difference tester |
| Hypothesis testing | | Self-check |
| Measurement Systems Analysis | | New gauge check |
| Shewhart Rule #12, 9 | | Don't hide anything |
| Shewhart Rule #23, 9 | | Especially the time scale |
| Upper control limit | | Upper expected limit |
| Lower control limit | | Lower expected limit |
| Requirements | | Voice of the Customer |
| FMEA, PFMEA, etc | | Risk check |

**Table 2, Useful translations for shop floor Engineers**

The main point here is that that the Engineer (*support person*) must adapt her/his terminology to the production people (*internal customer*).

**THE PRIME DIRECTIVE**

In the context of this paper, *The Prime Directive* for process improvement on the Shop Floor is:

***Visualize the data &***
***establish the facts***

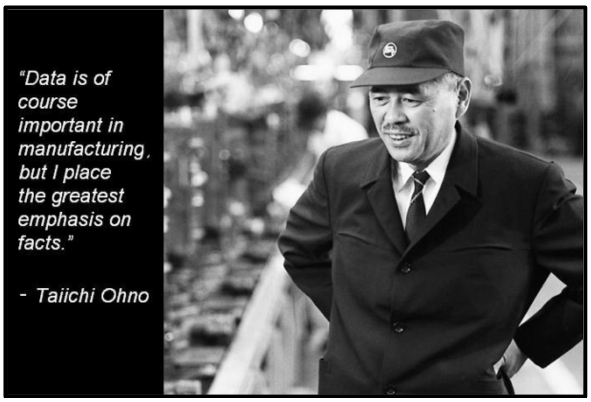



**Figure 3, Useful guidance**

Production personnel are overwhelmingly visual learners thus it is good advice to follow the Lean adage - *keep it simple, keep it visual*. However, the presentation of complex data, including the evaluation of variation, is not treated in detail in many Lean training modules. JMP addresses this gap with easy-to-create, clear, intuitive graphics. In short:

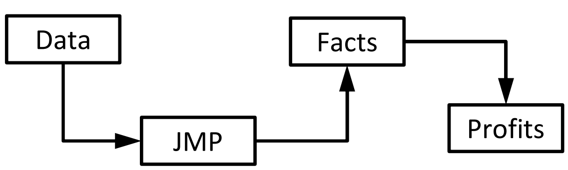



**Figure 4, A logical sequence…**

JMP's fundamental structure, with an emphasis on workflow, rather than statistical tools, is perfect for this approach. The options contained in JMP's hot spots (red triangles) allow teams to start with datasets and basic visualizations and then drill deeper and deeper into the data until the facts willingly reveal themselves.

**TAGUCHI LOSS FUNCTION, UNCHAINED**

It is generally accepted that the (external) customer is satisfied as long as product stays within specification limits and, as soon as the product falls outside the limits, the customer is somehow immediately dissatisfied. This fallacy is a contributing cause of much shop floor chaos and many poor Profit & Loss statements. Changing this pass-fail mindset is perhaps the biggest of all process improvement challenges. The bad news is that years of misguided emphasis to *get-it-out-the-door* makes for entrenched habits and understandably so.

The good news is that nobody likes fire-fighting and low morale, so a spark of motivation is available for the skillful Engineer to kindle into a process improvement firestorm.

*Use graphs that visualize the facts*

Common visualizations of the Taguchi Loss Function are a great teaching aide, but to be useful in the production area, it needs a different spin. For example, the widely used format, as shown in Figure 5, is generic and thus hard for people to put into the context of their daily work.

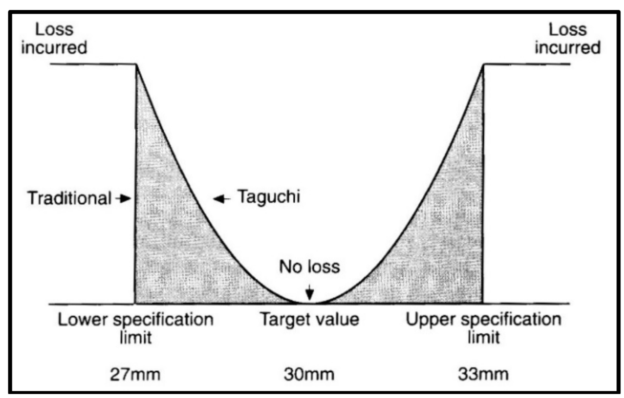
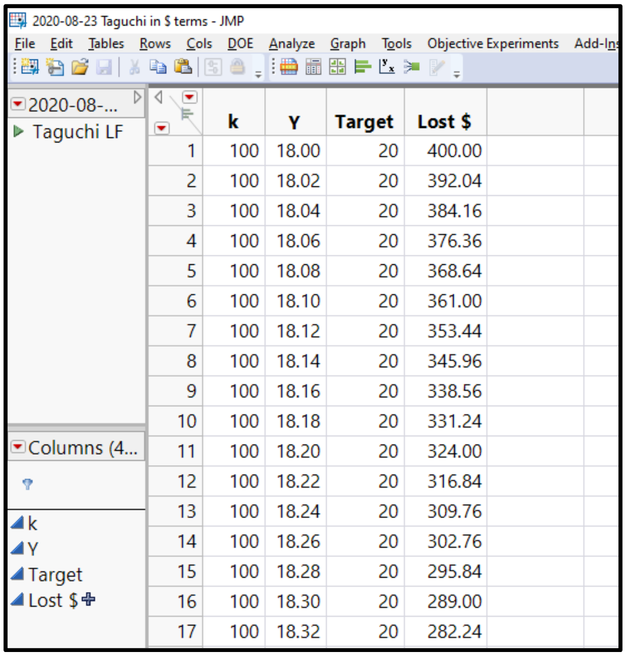



**Figure 5, Common Taguchi Loss Function graphic**

Fortunately, JMP makes custom visualization of the Taguchi Loss Function concept easy. The Taguchi Loss Function is:

$$Loss\ (\$) = k(y-T)^2$$

Where y is the measured value, T is the Target and k is a constant applicable to the process under review. Loss is typically expressed in monetary terms. Figure 6 shows how to set up a JMP Data Table to then create a well-annotated *Burning Money Graph* (or similar) using JMP's vaunted Graph Builder as shown in Figure 7.


2020-08-23 Taguchi in $ terms - JMP

File Edit Tables Rows Cols DOE Analyze Graph Tools Objective Experiments Add-Ins

2020-08-...
Taguchi LF

Columns (4...
k
Y
Target
Lost $

| | k | Y | Target | Lost $ |
|---|---|---|---|---|
| 1 | 100 | 18.00 | 20 | 400.00 |
| 2 | 100 | 18.02 | 20 | 392.04 |
| 3 | 100 | 18.04 | 20 | 384.16 |
| 4 | 100 | 18.06 | 20 | 376.36 |
| 5 | 100 | 18.08 | 20 | 368.64 |
| 6 | 100 | 18.10 | 20 | 361.00 |
| 7 | 100 | 18.12 | 20 | 353.44 |
| 8 | 100 | 18.14 | 20 | 345.96 |
| 9 | 100 | 18.16 | 20 | 338.56 |
| 10 | 100 | 18.18 | 20 | 331.24 |
| 11 | 100 | 18.20 | 20 | 324.00 |
| 12 | 100 | 18.22 | 20 | 316.84 |
| 13 | 100 | 18.24 | 20 | 309.76 |
| 14 | 100 | 18.26 | 20 | 302.76 |
| 15 | 100 | 18.28 | 20 | 295.84 |
| 16 | 100 | 18.30 | 20 | 289.00 |
| 17 | 100 | 18.32 | 20 | 282.24 |

**Figure 6, Data Table Setup**

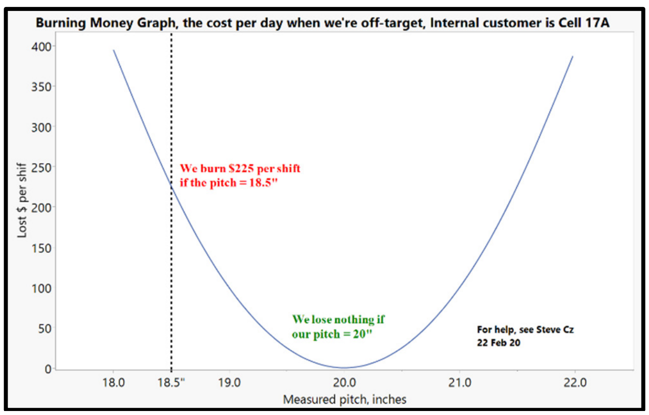



**Figure 7, Graph Builder output**

It is recommended to check axis labels for clarity and add clear annotations after discussions with operators.

For clarity, the term *Taguchi Loss Function* or the Taguchi equation are not recommended for use on the production floor.

*Use hands-on demonstrations*

Another effective method to demonstrate the dangers of the common and destructive pass-fail mentality is with a hands-on exercise. A few low-cost bearings and a gage pin set provide a great visualization opportunity.

**Figure 8, Kit for Taguchi Loss Function demo**

As it turns out, most bearings have a concentric inside diameter and gage pins have accurate and concentric outside diameters. The demonstration kit includes:

☐ smallest no-fit gage pin
☐ the best-fit gage pin
☐ 3-4 gage pins that are "in spec", but smaller than the best-fit pin

In a group setting, participants can see and feel the benefits of a process that is on target with minimum variation.

*Assembly demonstration*

Another effective method applies to those in the assembly business (trucks, automotive systems, aerospace, etc.). It is usually easy to find a set of parts that are all "in spec" but that don't fit together properly, despite Tolerance Stack Up and other precautionary measures. This set of parts make an effective hands-on demonstration of the benefits of a process or supplier process that is on target with minimum variation.

## SHOP FLOOR DATA VISUALIZATIONS

Presenting data in a clear, concise manner isn't easy. However, Donald Wheeler's book *Understanding Variation*[6] and similar books provide superb guidance. Statistical Babel Fish deftly paraphrases Shewhart's two rules[7,8] for the presentation of data as follows:

*Don't hide anything,*
*especially the time scale*

Meanwhile, Donald J. Wheeler's *First Principle for Understanding Data*[6] needs no translation.

*No data have meaning*
*apart from their context*

Statistical Babel Fish also provides a useful summary of Donald Wheeler's *Second Principle for Understanding Data*[9].

*Always separate the signal*
*from the noise*

These snippets are sage advice when pondering data visualizations in the production area. Refer to them often.

*Recommended Visualizations*

JMP graphics help us stick to the Prime Directive, i.e. *visualize the data and get the facts.* They also allows us to simultaneously heed the advice from Shewhart and Wheeler. When used properly, graphics are a powerful process improvement tool.

Experience indicates that production personnel quickly understand and accept many types of charts. Experience also indicates the following essentials regarding the use of graphics on the shop floor:

- ☐ Discuss the baseline graphics with shop floor personnel, then add annotations to summarize shop floor discussions.
- ☐ **Omit annotations at your own peril.**
- ☐ Specify the internal customer on all charts
- ☐ Include version control, a name and date stamp, for example
- ☐ Use large fonts to improve readability. The JMP defaults (Segoe UI, 10) are way too small, so it's best to change them in Preferences.
- ☐ Avoid chart junk[10]

*Shape charts (aka histograms)*

It's highly recommended to use a shape chart (histogram) along with a time chart (see below) as an effective combination for shop floor discussions. The former provides the shape, center and spread of the data while the time chart indicates how the process behaves over time. Their persistent use inexorably changes the way shop floor people view their process output.

Figure 9 and 10 are examples of well-annotated, clear shape charts that shop floor personnel can readily understand.

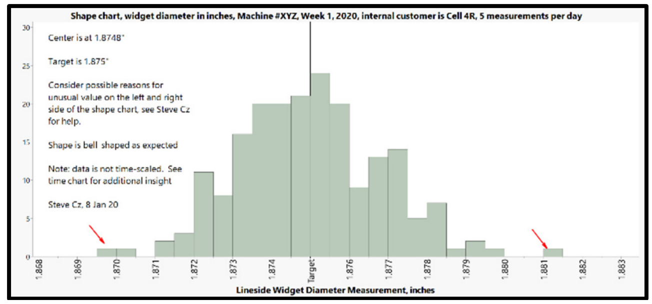



**Figure 9, A well-annotated shape chart**

Shape chart highlights:

- ✓ Use JMP Graph Builder
- ✓ Encourages variation reduction and alternatives to pass-fail mindset
- ✓ Production people prefer vertical orientation by a wide margin
- ✓ Always state the shape chart is **not time-scaled** as shown in Figure 9.
- ✓ A normal distribution or other fit tends to confuse people. If the shape is unclear, add more data or draw a rough fit with pencil during shop floor discussions.

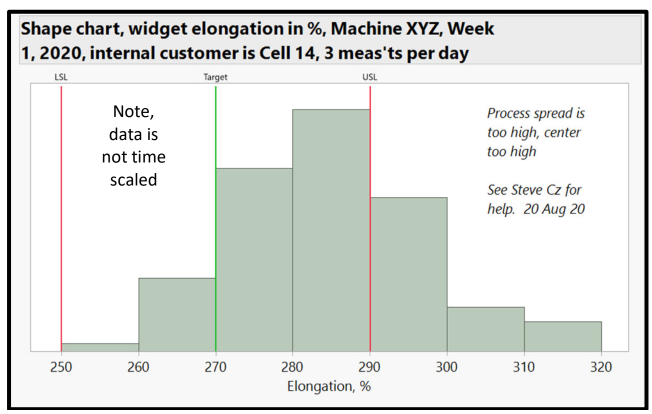



**Figure 10, A shape chart, process capability style**

*Time charts*

Time charts require a phased approach. Generally speaking, it takes about 4-5 months of viewing basic time charts (run charts) for people to then find full value in the use of time charts with expected limits (control limits). Figure 11 and 12 are well-annotated examples

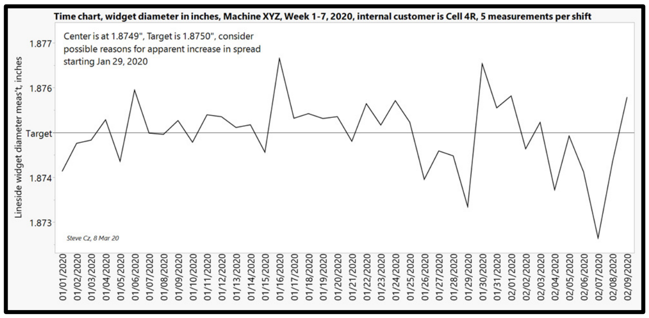



**Figure 11, Time chart (no expected limits)**

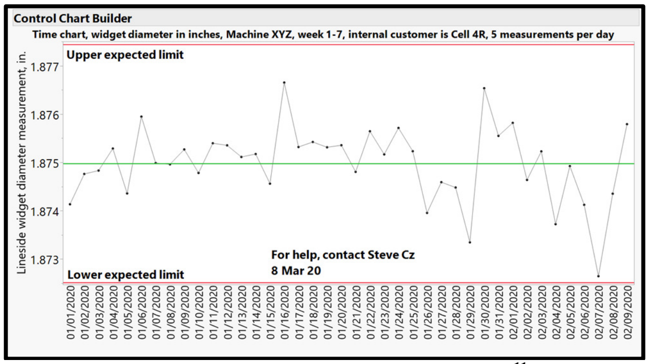



**Figure 12, Time chart (with expected limits)[11]**

It's suggested that Moving Range Charts and Range Charts be used by the Engineer only to determine the validity of the X or X-bar charts. Their use should be generally avoided during shop floor discussions.

*Comparison charts*
The JMP Variability Chart provides an effective way to visualize comparisons to shop floor personnel. Examples include machine-to-machine, plant-to-plant and raw material lot-to-lot comparisons. Case Study 2, below, describes the creation and use of comparison charts with shop floor personnel.

*Correlation charts/matrices*
Scatterplots (correlation charts) provide outstanding visual insight for continuous data. Production personnel typically understand correlation charts quickly and find them to be of great value. Use the Graph Builder and Lambda slider to provide the necessary amount of detail. Too much detail usually leads to unnecessary discussions. Too little detail can hide important process insight. See Figure 13.

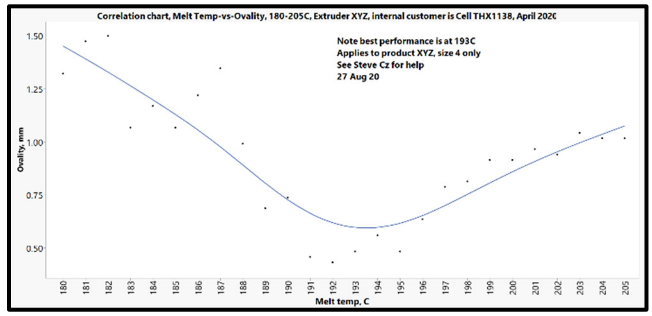



**Figure 13 Correlation chart for extrusion process, Lambda=0.253, spline**

For production people with a good measure of experience with Correlation Charts, well-annotated matrices are an excellent source of complex process insight as shown in Figure 14.

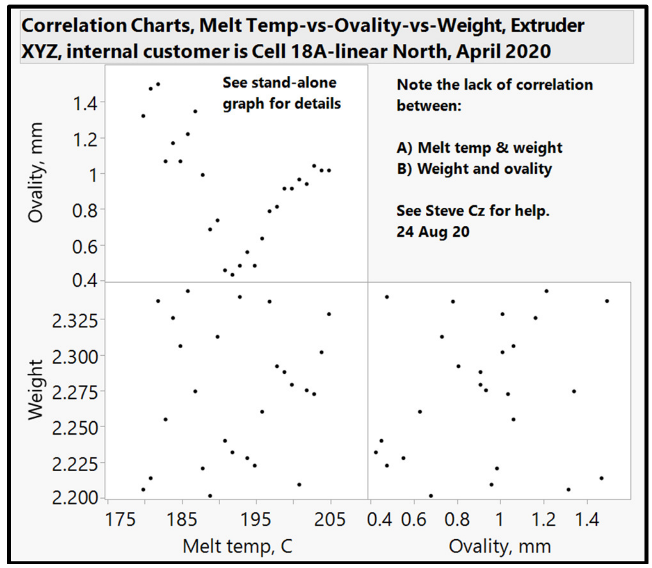
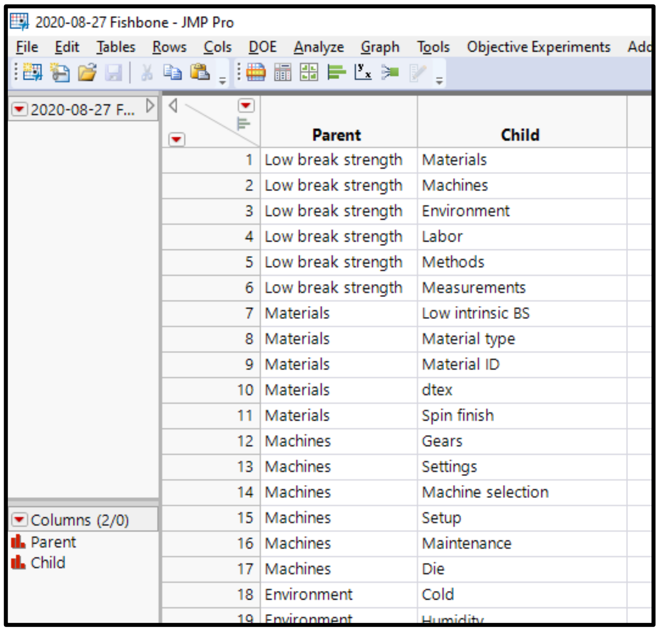



**Figure 14, Correlation matrix for extrusion process**

*Fishbone diagrams*
One of JMP's lesser-known, yet powerful features is the ability to create Fishbone Diagrams (aka Cause-and-Effect Diagrams, Ishikawa Diagrams and the like). Their creation is based on a two column Data Table with one column for the *Parent* and one column for the *Child*. Figure 15 shows an example of the Data Table structure. Figure 16 shows a cropped image of a Fishbone Diagram.





| | Parent | Child |
|---|---|---|
| 1 | Low break strength | Materials |
| 2 | Low break strength | Machines |
| 3 | Low break strength | Environment |
| 4 | Low break strength | Labor |
| 5 | Low break strength | Methods |
| 6 | Low break strength | Measurements |
| 7 | Materials | Low intrinsic BS |
| 8 | Materials | Material type |
| 9 | Materials | Material ID |
| 10 | Materials | dtex |
| 11 | Materials | Spin finish |
| 12 | Machines | Gears |
| 13 | Machines | Settings |
| 14 | Machines | Machine selection |
| 15 | Machines | Setup |
| 16 | Machines | Maintenance |
| 17 | Machines | Die |
| 18 | Environment | Cold |
| 19 | Environment | Humidity |

**Figure 15, Data table for Fishbone Diagram**

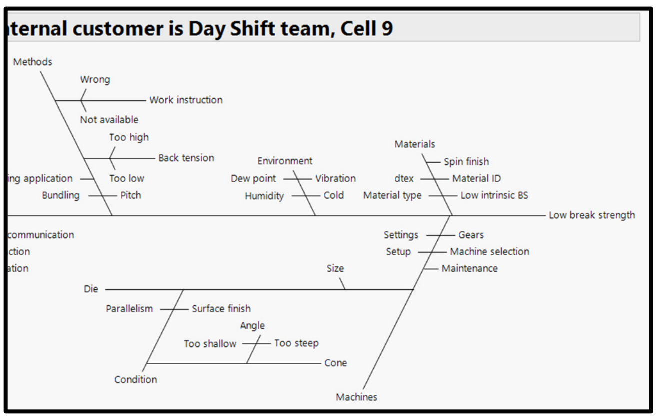




**Figure 16, JMP Fishbone Diagram, cropped to show detail**

Fishbone diagrams can be thought of as a graphical accumulation of process knowledge. They can be used for Root Cause Analysis and factor selection in designed experiments.

*Flow diagrams*

As a side note, the flow diagram (flow chart) is a highly effective visual shop floor graphic. It's best implemented when production people collaboratively create them by hand. The Engineer can create an e-version with a word processor for the final visualization and inclusion in Work Instructions. Figure 17 is an extract of a flow diagram created by a team of production operators in a hydraulic assembly work cell.

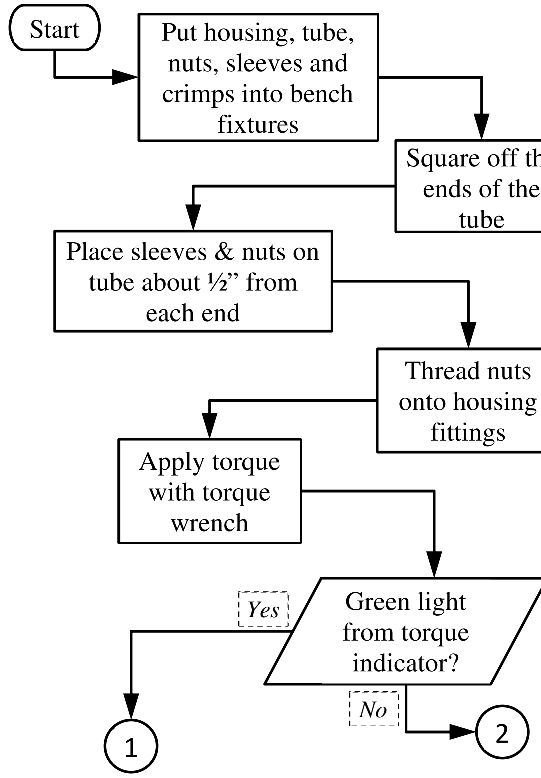




**Figure 17, Operator team flow diagram**

Flow diagrams can help determine work sequences, anomaly handling and the scope of work for time studies.

Other forms of process visualizations are useful for Design of Experiments and other process studies. Figure 18 provides an example.

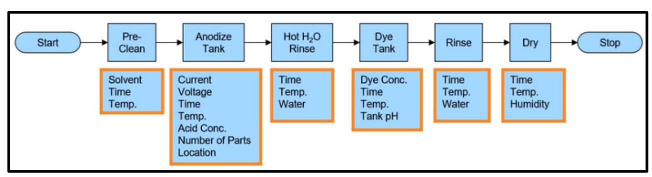




**Figure 18, Process flow and controls diagram**

*Mediocre Visualizations*

Following are visualizations that experience indicates are not effective on the shop floor.

First, Excel spreadsheets or any type of tabular data display is absolutely not recommended for use in the production area.

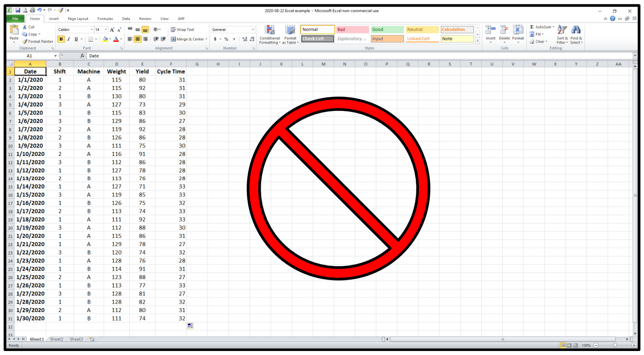


**Figure 19, confusing tabular display of data**

Second, most production people find time-scaled bar charts hard to interpret. Use a time chart instead.

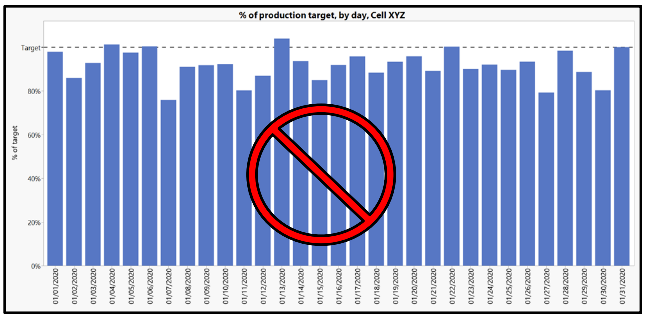



**Figure 21, Time scaled bar charts**

Third, it is not recommended to use PowerPoint slides with production personnel, especially slides those containing text only, nested bullets, orphaned bullets, tiny fonts and business buzzwords.

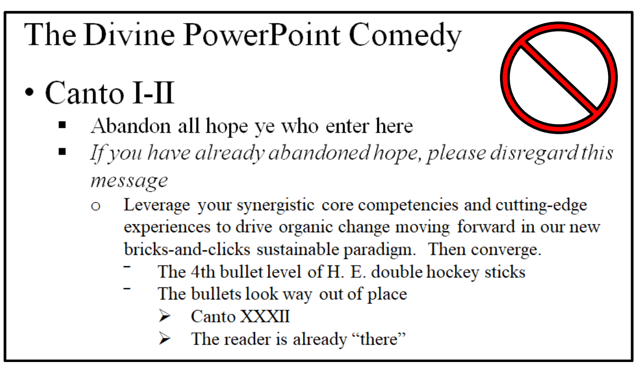



**Figure 21, Using PowerPoint as a sedative**

A superior approach is to use conference rooms with production people only to review graphics and establish the facts.

Finally, teaching statistical tools via Six Sigma Yellow Belt certification is not recommended for many production people.

*Action*

*Hey everyone, we’re going to learn Statistical Tools!*

*Reaction*[12]*:*

*Alternative action*

*Hey everyone, I’ll help you fix what’s bugging you today*

*Reaction*[12]*:*

Instead, use daily shop floor data visualizations to help operators and identify potential Six Sigma Yellow Belt candidates along the way.

*Data Visualization Recap*

With the above in mind, it’s recommended that Engineers work elbow-to-elbow with Production Staff, support them with good data collection guidance followed by clear, useful, well-annotated graphics. Let production people find the facts and identify improvement opportunity.

## REFINING LEAN METRICS

Generally speaking, Lean training includes little discussion of the important subject of variation. Inventory turns, cycle time, OEE and perishable tool lifetime are treated in many Lean courses as static values without an indication of variation. Experience indicates this is a source of many shortcomings of Lean metrics commonly used on the shop floor.

*Value Stream Maps*

Figure 22 shows a Value Stream Map, a powerful Lean graphic. It is an excellent visualization that summarizes process and information flow in an easy-to-understand format. However, metrics like cycle time (C/T) and changeover time (C/O) are shown as summarized values. This provides the perfect opportunity to take Value Stream Maps to the next logical step.

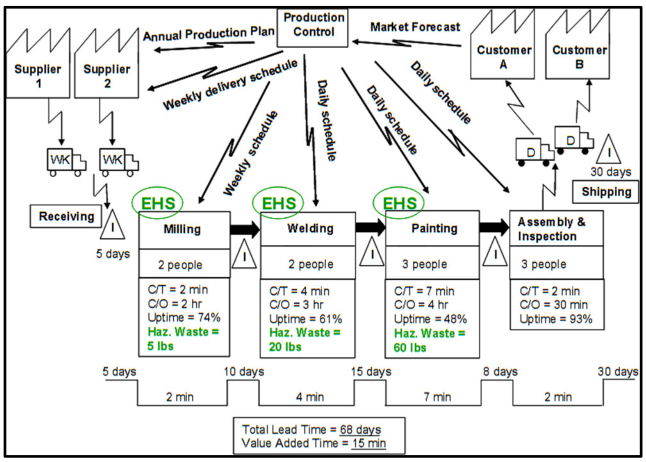



**Figure 22, Variation wasn't invited to this party**

A common Value Stream Map anomaly is confusion over the scope of work to include in the cycle time measurements. For example, what about the painting cycle time for an optional second coat or the difference in cycle time between large and small parts? Process flowcharts, discussed above, are a good visual solution to this problem.

Once the Cycle Time scope of work is clear, measurement summaries should include details of variation. For example, consider the impact of the Welding Cycle Time measurements under two different scenarios as shown in Table 3.

| Sequence | Scenario 1 | Scenario 2 |
|---|---|---|
| 1 | 241 | 223 |
| 2 | 246 | 207 |
| 3 | 235 | 248 |
| 4 | 240 | 245 |
| 5 | 236 | 263 |
| 6 | 245 | 230 |
| 7 | 236 | 271 |
| 8 | 241 | 234 |
| 9 | 244 | 232 |
| 10 | 239 | 251 |
| **Average** | **240** | **240** |
| **StDev** | **3.9** | **19.1** |

**Table 3, An important distinction**

While the Cycle Time averages are the same, it is likely that different decisions would be made depending on the amount of variation. The solution is to drill down on the Cycle Time data with a shape chart and time chart. Figure 23 provides an example for Cycle Time measurements of a gear change process step.

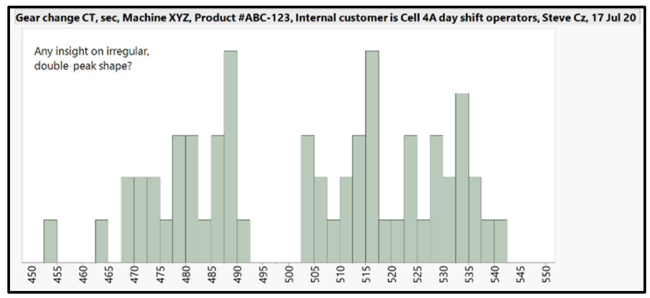



**Figure 23, a clearer view**

The double-peak in this shape chart becomes immediately apparent, indicating different methods might be in use during the collection of the Cycle Time data. Once identified, the issue can be addressed.

*Overall Equipment Efficiency (OEE)*

OEE is another common, valuable Lean metric. It is calculated as the product of machine availability, performance and quality. For example, if all three are 90%, OEE[13] is:

$$OEE = 0.9 * 0.9 * 0.9 = 0.73$$

For automated SCADA systems and the like, a real-time OEE data stream, *including the three components*, is an extremely valuable shop floor management tool. However, in the absence of automatic data collection, OEE is typically kept in a stand-alone spreadsheet and reported as a static scorecard value on a monthly report. Figure 24 is an example.

| OEE Factor | Calculation | Calculated Data | OEE % |
|---|---|---|---|
| Availability | Operating Time / Planned Production Time | 373 / 420 minutes | 0.8881 (88.81%) |
| Performance | (Total Pieces / Operating Time) / Ideal Run Rate | (19,271 pieces / 373 minutes) / 60 pieces per minute | 0.8611 (86.11%) |
| Quality | Good Pieces / Total Pieces | 18,848 / 19,271 pieces | 0.9780 (97.80%) |
| Overall OEE | Availability x Performance x Quality | 0.8881 x 0.8611 x 0.9780 | 0.7479 (74.79%) |

**Figure 24, OEE example**

A better approach is to report OEE and its components in time charts. Figure 25 shows an example.

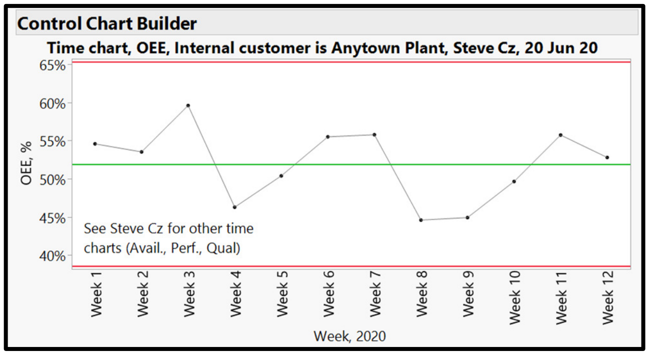



**Figure 25, how does OEE behave over time?**

A chart with calculated OEE should always be supported with similar graphs for the three individual components.

## CASE STUDIES

The following two case studies demonstrate the effective use of JMP graphics on the shop floor.

*Case Study #1, Understanding Interactions*

This case study comes from the cable manufacturing industry. The process in question was a twisting/winding process with chronic package weight and length inconsistency.

<u>What we did</u>

Engineering staff did three one-factor-at-a-time experiments over a period of a few years with little operator involvement due to ill-advised pressure to ship product as fast as possible. Factors studied individually included die selection, running speed, traverse speed and backtension. No clear solution surfaced during the studies due to the presence of a strong interaction.

<u>What we should have done</u>

Engineering ran two designed experiments and insisted on heavy operator involvement. However, the term Design of Experiments was not used on the shop floor. Instead, discussions with operators centered around the identification of process factors, the collection of data and discussion of results using *Predictor Charts*.

While nuanced, sentences like *I'd like your help to develop a Predictor Chart* work far better with operators than *I'd like your help running a designed experiment.*

Discussions centered around JMP Prediction Profilers (Predictor Charts) as shown in Figure 24 and 25. The JMP Prediction Profiler is, in essence, an *interactive* process model and the most powerful industrial process improvement tool available anywhere[14]. Experience indicates that production people see and understand interactions quickly when viewed with this interactive graphic. A strong interaction between RPM and backtension was easily seen and understood by all. See Figures 26 and 27.

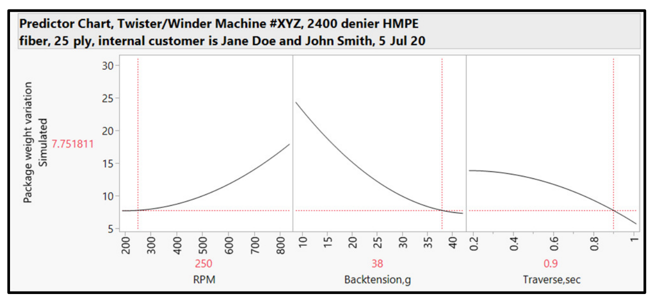



**Figure 26, JMP Prediction Profiler, low RPM**

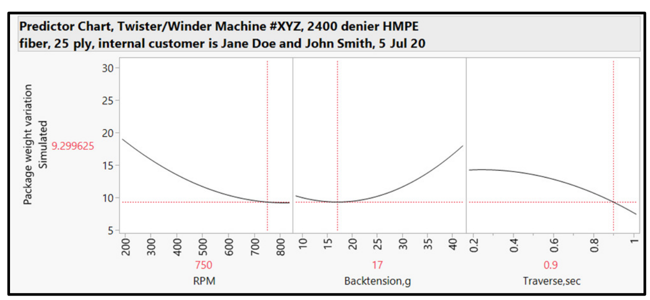



**Figure 27, JMP Prediction Profiler, high RPM**

Here are a few recommendations regarding the use of designed experiments and the JMP Prediction Profiler on the production floor.

- ☐ Experience indicates running designed experiments on a process works best if introduced during a production crisis.

Caution is recommended when considering designed experiments when the process is running reasonably well.

- ☐ The term *interaction* works for some people, but the term *dependency* seems more readily understood.
- ☐ Simplify the Prediction Profiler, take out desirability graphs and confidence interval information. Add useful annotations.
- ☐ Use the JMP Prediction Profiler in group settings with a large screen or monitor.
- ☐ Focus discussions on two-way interactions.
- ☐ Discuss response curvature with operators only if asked.
- ☐ Start with one response and introduce multiple responses at a later date.

Another good shop floor visualization is the JMP Interaction Profiles graph (Interaction Chart). Experienced production people can often interpret this chart matrix and understand why diverging, converging or crossing lines in one or more of the graphs indicates a notable interaction.

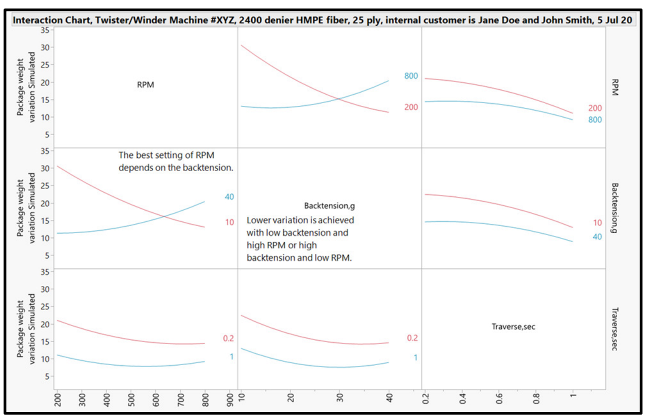


Figure 28, JMP Interaction Chart

<u>What was accomplished</u>

All post-DOE process decisions were made by production personnel with engineering playing a supporting role only. The end result included:

- ☐ Significant reduction in package weight and length variation
- ☐ Process improvement enthusiasm
- ☐ New process knowledge
- ☐ Identified candidates for Six Sigma Yellow Belt certification

*Case Study #2, Understanding Variation*

This study comes from the heavy truck industry. The process in question was a machined part plagued by chronic dimensional inconsistency. The supplied part was used in an assembly.

<u>What we did</u>

Simply stated, process tampering was a standard practice. When a part measured -0.002” in thickness, the target for the next part was set to +0.002”. Likewise, for subsequent parts. This practice is a classic example of Type 2 error in Deming’s Funnel Experiment[15]. The result was difficult assembly.

<u>What we should have done</u>

The root cause of the misguided tampering was the lack of understanding about response variation, a critical concept that is hard to explain. A more palatable term (*measurement buzz,* or similar) and the following hands-on demonstration, supported by JMP graphics, come to the rescue.

First, discreetly get 3 or more paper cups and label them as shown in Figure 29.

**Figure 29, Marked paper cups**

Then, cut out the bottom of all but the last cup in the sequence as shown in Figure 30.

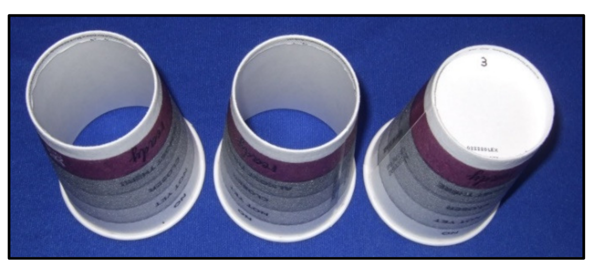


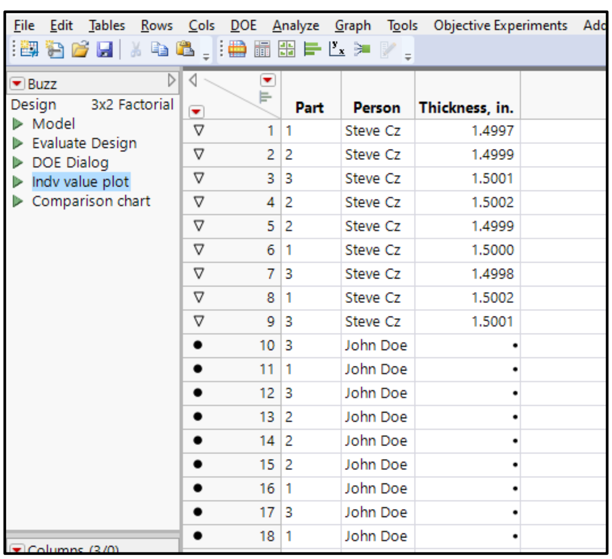
**Figure 30, Modified paper cups**

Sequentially stack the cups and *put in a single part* that's suitable for geometric measurements. A machinist's gage block works well because they typically don't have artifacts that could give away the part identification. Gather the participants and ask for a volunteer with a micrometer or caliper to "measure three parts, one at a time, multiple times each". Indicate that the *cups are needed to keep the parts properly identified.*

The volunteer is instructed to measure in the center of the part to sidestep concerns about within-part variation. The volunteer measures the first part from, say, cup #2 and provides the value for immediate entry into a JMP Data Table. The part is then put back into the stack and another part from (presumably) another cup is provided and so forth. Measurements continue until the volunteer has provided all of the data.

With practice and some sleight-of-hand, the Engineer can get a group of people to think the measurements are from multiple parts, when, in fact, the data is from the same part. If done correctly, **the measurement data provided by the volunteer will contain response variation only.**

The takeaway lesson for attendees is that response variation is expected and measurable.




| | | Part | Person | Thickness, in. |
|---|---|---|---|---|
| ▽ | 1 | 1 | Steve Cz | 1.4997 |
| ▽ | 2 | 2 | Steve Cz | 1.4999 |
| ▽ | 3 | 3 | Steve Cz | 1.5001 |
| ▽ | 4 | 2 | Steve Cz | 1.5002 |
| ▽ | 5 | 2 | Steve Cz | 1.4999 |
| ▽ | 6 | 1 | Steve Cz | 1.5000 |
| ▽ | 7 | 3 | Steve Cz | 1.4998 |
| ▽ | 8 | 1 | Steve Cz | 1.5002 |
| ▽ | 9 | 3 | Steve Cz | 1.5001 |
| ● | 10 | 3 | John Doe | • |
| ● | 11 | 1 | John Doe | • |
| ● | 12 | 3 | John Doe | • |
| ● | 13 | 2 | John Doe | • |
| ● | 14 | 2 | John Doe | • |
| ● | 15 | 2 | John Doe | • |
| ● | 16 | 1 | John Doe | • |
| ● | 17 | 3 | John Doe | • |
| ● | 18 | 1 | John Doe | • |

**Figure 31, JMP data table, prepared in advance**

*Danger Will Robinson, Danger…*
Of course, the volunteer might take offense at the subterfuge, but a Data Table and Comparison Chart (Variability Chart) prepared in advance (Fig 31 & 32) can deftly defuse the situation.

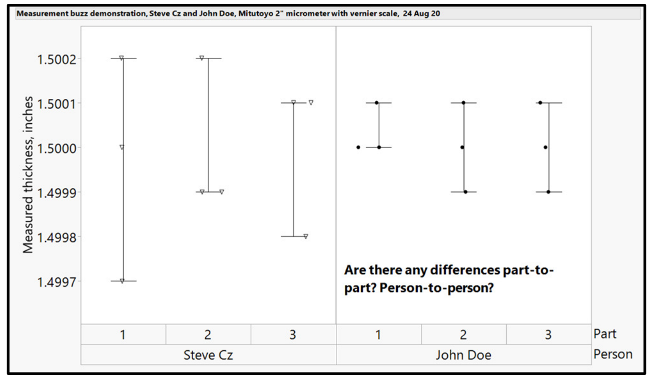



**Figure 32, comparison chart, with new data from John Doe**

Of course, it helps if the baseline data has more measurement buzz than the data collected from the volunteer.

<u>What was accomplished</u>
The process tampering practices were removed from the supplier work instructions. Supplier management and production staff learned a valuable lesson resulting in a significant reduction in geometrical variation of the supplied parts and a dramatic reduction in assembly problems.

## SUMMARY

*Inferno*
Companies often start their process improvement journey from an environment rife with scrap, daily firefighting, substandard process knowledge, disappointing profits and low employee morale. To escape, change is needed.

A great place to start is on the shop floor with the idea that the systems that support the production operator are key and that Engineers and Managers are responsible for the systems, not the Production Operators. Therefore, it is strongly recommended that operators be viewed as an internal customer and that terminology and data visualization be adapted by the Engineer or Manager to suit shop floor discussions.

*Purgatorio*
W. Edwards Deming famously quipped:

> *It doesn't happen all at once, there is no instant pudding.*

Luckily, industry experts like Shigeo Shingo, Taiichi Ohno, W. Edwards Deming, Donald Wheeler, Ron Pereira[16], Bradley Jones[17] and Xan Gregg[18] provide us with a clear and proven way forward. With persistent hard work and a skillfully blended application of Lean principles and JMP-supported statistical methods, progress is virtually assured.

*Paradiso*
How the Engineer will recognize success:

- You will learn something new and useful from Production operators every single day
- Production operators will be your best allies and regularly ask for your help
- Production operators will publicly acknowledge your contributions

## EPILOGUE

It is hoped that this insight provides irresistible incentive for Process Engineers, Manufacturing Engineers and Quality Engineers to adopt a support-mentality and deftly pull operators into data visualization and process improvement discussion. Best of luck and have fun.

## REFERENCES


[1] Shigeo Shingo, *The Fundamental Principle of Lean Manufacturing*, Productivity Press, 2017
[2] Training Within Industry (TWI) was created by the US Department of War during World War II
[3] Patrick Graupp and Robert J. Wrona, *Implementing TWI: Creating and Managing a Skills-Based Culture,* Productivity Press, 2010
[4] See *The Shingo Model*, version 14.5, Utah State University, 2020
[5] Babel Fish is a character from the book *The Hitchhiker's Guide to the Galaxy*, Douglas Adams, Book Club Associates, 1983
[6] Donald J. Wheeler, *Understanding Variation*, 2nd Edition, SPC Press, 2000
[7] *Data should always be preserved in such a way that preserves the evidence in the data for all the predictions that might be made from these data*., Walter Shewhart, various publications
[8] *Whenever an average, range or histogram is used to summarize data, the summary should not mislead the user into taking any action that the user would not take if the data were presented in a time series*., Walter Shewhart, various publications
[9] *While every data set contains noise, some data sets may contain signals. Therefore, before you can detect a signal within any given data set, you must first filter out the noise.* From *Understanding Variation, the Key to Managing Chaos,* Donald Wheeler, SPC Press, 2000
[10] Term from *The Visual Display of Quantitative Information*, Edward Tufte, Graphics Press, 1983
[11] Note that if the upper and lower expected limits are calculated on the first 10 points, signals will appear.
[12] Image is from *JMP Statistical Thinking for Industrial Problem-Solving*, used with permission.
[13] Note that the calculated OEE value can be misleading by itself and should always be viewed with the individual values of availability, performance and quality.
[14] Assuming the model predicts well
[15] W. Edwards Deming Institute®, a 501(c)(3) nonprofit organization.
[16] *Co-founder & Partner* (and Lean Sensei), Gemba Academy
[17] *Distinguished Research Fellow,* (and world-class DOE expert) JMP Division/SAS
[18] *Director of R&D* (and data visualization expert, non-pareil), JMP Division/SAS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