Making Business Decisions Using Trend Information

Prepared for the U.S. Department of Energy

Fluor Daniel Hanford, Inc.
Richland, Washington

Hanford Management and Integration Contractor for the
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Making Business Decisions Using Trend Information

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- Performance Indicator Flow Chart
- Proposed Method to Color-Code Performance Indicator Results for Executive Summary
BUSINESS DECISIONS: Performance Measures, and the trend information that results from their analyses, can help managers in their decision making process. The business decisions that are to be discussed are:

- Assignment of limited Resources, Funding, Budget
- Contractor Rewards / Incentives
- Where to focus Process Improvement, Reengineering efforts
- When to ask "What Happened?!
- Determine if a previous decision was effectively implemented.

Note that the trend information will not make the decision for the manager. Performance Measure results can prompt the decision maker when to ask for more information (what happened here?), but the performance measure data does not tell the decision maker why the data are the way they are. Proper trending of performance measures can cause the proper questions to be asked. Also, performance measures support the mission and vision of the business, not define the mission and vision. An overall plan as to what are the critical business objectives and priorities is needed prior to use of performance measures.

Of Whiz Kids and Seat-of-the-Pants Decision Makers

There are dangers to over-reliance or under-reliance on data. In the 1960's, Robert McNamara (the Secretary of Defense during the Vietnam War) espoused a scientific approach to decision making. Analysts (who became known as "whiz kids") analyzed data, and made decisions for the generals and admirals in the military. The experience and wisdom of the senior officers was overruled by the "facts" in the data. In his book *In Retrospect*, Robert McNamara tells the story of why some of these decisions were "wrong, terribly wrong".

On the other hand, there is a danger to relying solely on experience and intuition (this is what worked last time . . .) and ignoring performance measure data. "Gut feeling" and "seat of the pants" decisions can lead to disastrous consequences. An enlightened decision maker will balance the data analysis results with their experience and intuition. Such an enlightened decision maker is moving toward what Dr. Deming referred to as "Profound Knowledge".

The Business Decision Pendulum
Dr. Deming's Theory of Profound Knowledge is documented in The New Economics, and includes:

- Appreciation for a system
- Knowledge about variation
- Theory of Knowledge
- Psychology

**How can decision makers use trend information?**

As part of the decision making process:

- Determine Areas where Decisions need to be made
  - Find Problem Areas
  - Find Success Areas
  - Find Stagnant Areas
- Predict the Effects of a Decision
- Evaluate the Effects of a Decision

**Management Philosophies**

There are two opposing philosophies on use of performance measure data.
Dr. Deming's Red Bead Experiment.

1. Six "Willing Workers" produce White Beads by dipping a 50 hole paddle into a bucket of red and white beads in four "shifts". They are directed to produce only White Beads. Red Beads are to be avoided, and represent defective product.
2. Various "incentives" (positive and negative) are offered to the workers. Goals and targets are set (such as "Less than 3 Red Beads per paddle"). The "best" workers are praised, the "worst" are laid off.
3. The exercise points out the errors in misinterpreting random variation among workers and from shift to shift, and the fallacy of numerical goals and targets.

Those that have participated in or observed the Red Bead Experiment gain an appreciation for the usefulness of a Total Quality approach versus the traditional Management by Objective approach. Dr. Deming's points 10 and 11 (of his 14 Points) include:

10. Eliminate slogans, exhortations, and targets for the work force asking for zero defects and new levels of productivity. Such exhortations only create adversarial relationships, as the bulk of the causes of low quality and low productivity belong to the system and thus lie beyond the power of the work force.

11a. Eliminate work standards (quotas) on the factory floor. Substitute leadership.

b. Eliminate management by objective. Eliminate management by numbers, numerical goals. Substitute leadership.

The Theory of Variation

Much of Dr. Deming's work was based upon the Theory of Variation. Another term for "variation" is fluctuation. We have all seen variation (fluctuations) in data at our places of work. The Key for Managing a Process is separating

- Significant Change (Trend) from
- Random Fluctuation (No trend).

Definition of a Trend

The word "trend" is a very misused word. Newspapers include headlines referring to the latest "trend", in reference to the latest fad. For purposes of business decision making,

a Trend is a statistically significant change in performance measure data which is unlikely to be due to random variation in the process.
### Process Tampering

There are situations where the best Business Decision is to take no action. Taking action which is not necessary and actually degrades a process is referred to as Process Tampering. Examples of actions which are actually process tampering include:

- React to and take action on the latest datum point when the performance data has been statistically stable.
- Falsify data in order to meet a goal (quota).
- Find the person closest to the problem and blame that person.
- Assume every incident is a "special case", requiring special actions (add more procedures, training).

The typical process tamperer is the manager searching for a special cause, a quick fix to take, when what is actually needed is a fundamental change to the process(es) involved. If there are no trends, there will not be any special causes to find. The search must be for common causes.

Dr. Deming illustrated process tampering using the "funnel experiment" (*The New Economics*, Chapter 9).

### The Control Chart: a tool to detect trends

Statistical Process Control, which makes use of Control Charts:

- Provides a Black and White, technically defensible way to determine if a "trend" exists.
- Minimizes "false alarms" while preserving the capability to detect a trend.

A control chart contains the data for each time period, an average, and three standard deviation control limits. See Guidelines for Statistical Process Control for more details on constructing and analyzing control charts.

See Example Control Charts for actual control charts and discussion of their interpretation.

### Implementing Performance Measures

Choosing what business performance measures to use can be difficult. Some organizations find the process overwhelming, and in their desire to formulate the "perfect" performance measure, they never embark on collecting any data. Performance measures tend to be evolutionary rather than revolutionary.

No one starts with the "perfect" set of measures; successful organizations evolve into their set of measures.

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<table>
<thead>
<tr>
<th>TREND:</th>
<th>NO TREND:</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Special Cause Variation&quot;</td>
<td>&quot;Common Cause Variation&quot;</td>
</tr>
<tr>
<td>Significant changes in the data representing improvement or degradation. There is much to be gained from determining the exact source of this variation.</td>
<td>Ongoing, apparently random fluctuations in the process data. Generally, there is little to be gained from determining the exact sources of this random variation. Instead, must look over the long run performance of the process.</td>
</tr>
</tbody>
</table>
For an overview of a methodology to choose performance measures, see Implementing Performance Measures. Note that involvement and commitment is needed from the line managers and the workers who "own" the processes involved. The owner of the process needs to have ownership of the choice of measures and in their analyses.

Once a candidate set of performance measures has been chosen, the flowchart below provides the methodology for use of the performance measure information.

**GOALS, OBJECTIVES, CONTRACTOR REWARDS and INCENTIVES**

The goal or objective of an organization using this business decision methodology becomes to either

1. Achieve significant improvement or
2. Maintain current performance, with no degradations.

This standard can be used as part of contractual rewards and incentives. One would specify the measure(s), and rewards specified for significant improvement, or for maintenance of current performance. Penalties for significant degradation could also be called for.

**CONCLUSION**

- Trending can provide an input for rational Business Decisions
- Key Element is determination of whether or not a significant trend exists -- Segregating Common Cause from Special Cause
• The Control Chart is the tool for accomplishment of trending and determining if you are meeting your Business Objectives.
• Eliminate Numerical Targets; the goal is Significant Improvement.
• Profound Knowledge requires integrating data results with gut feeling.

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References:

McNamara, Robert S In Retrospect Published by Times Books 1995 ISBN 0-8129-2523-8
Implementing Performance Measures

Introduction. Performance Measures are receiving increased attention and importance by all levels of DOE. This paper provides a suggested methodology for implementing performance measures. This methodology follows the development of three tiers:

1. Mission and Vision (assumed to be in place)
2. Business Objectives (big picture - outcome/results oriented)

1. Develop Business Objective(s) for the organization

- Based upon current Mission and Vision statement
- Identify PRODUCTS and CUSTOMERS
- May include ratios such as productivity (output to input), cost per unit, time per unit, differences such as profit (selling price minus input cost); or a series of individual terms such as quantity produced, rework costs, rework time, and reject/defect rate.
- State and define underlying "values" and quality factors such as safety, rework, environmental soundness, customer satisfaction.
- State optimal direction (Maximize, Minimize)
- DO NOT list activities, processes, or numerical quotas

2. Define Performance Measures for processes within each Business Objective.

Each performance measure should reflect a process. Understanding the performance measure data AND the underlying process is necessary in order to optimize the Business Objective.

Collect performance measure data:

a. If data to support the performance measure already exists:

- Document source of data
- Define parameters for the retrieval of performance data
- Review the source data and clean up anomalies
- Add new parameters to data collection if needed

b. If data to support the performance measure does not exist:

- Explicitly define data to be collected
- Create consistent and verifiable system to input and store data
- Task person(s) to collect data
- Definitions for data collection and processing should be thorough and documented such that ANYONE at ANYTIME in the future should be able to regenerate the performance measure data and get the same results.

3. Analyze the Performance Measure data for trends and significant changes

a. Use Statistical Process Control as the criteria to determine if trends and changes are occurring.
Implementing Performance Measures

If no significant changes are occurring (the process is stable), determine if the performance measure is at an acceptable stable value. Management Theories / Criteria to apply:

- Continual Improvement
- "Zero Defects"
- Risk vs. Benefit Analyses (Taguchi Loss Curve, Probability Risk Assessment)
- Cost-Benefit Analysis
- Comparison against Benchmark (other companies, INPO guideline)

If a statistically significant change occurs, determine "WHY". Based upon the "why" and costs of action vs. inaction, take corrective actions (if the performance measure change was in a negative direction), reinforcing actions (if performance measure change was positive), or no action.

b. If a current process is stable, and a performance change is needed, the PROCESS must be changed.

- Study the process and performance measure data
- Using process improvement tools, root cause analyses, re-engineering, value engineering; develop changes to be made, and the implementation plan.
- Predict the benefits to be gained from the implementation. This prediction MAY be used as a "goal".
- Following implementation, assess for impact of the process change in the performance measure.
- Use Statistical Process Control and/or comparison against the goal as the criteria to determine success of the implementation.
- Review the Business Objective for impact of the change

4. Continual re-evaluation of Business Objectives and their Performance Measures is needed.

Business Objectives need to be changed if the customer's needs change, or if the product can be replaced with a superior product.
EXAMPLE X-CHART

The X-chart

The chart below is one example of the use of this generic chart. The processing times for the first 39 work packages written in 1997 have been gathered and plotted.

An initial average was calculated for all 39 packages, but it revealed that the most recent seven packages in a row were above average. Therefore, the baseline average was cut back to packages 1 through 32. Packages 33 through 39 are annotated as seven months in a row above average.

Note that the average line is annotated with the basis for the average. The control limits were set at three standard deviations above and below the average line. Packages 1 through 32 were also used in the standard deviation calculation.

The x-axis is annotated as being the work package number. It is assumed that this is a time sequence. The next package written will be 97-0039. One warning on cycle time graphs - only plot the cycle times for those items which have completed the cycle. If you plot items which are still within the cycle, their times will be artificially low.

Future Actions: A decision will need to be made as to whether to create a new baseline average for packages 97-0033 through 97-00??, or whether to keep the current average. This decision will depend on if future data returns to the current average or not.
The C-chart

The chart below is an example of a C-chart. It is counting the number of occurrence reports per month. Since there are multiple dates on Department of Energy occurrence reports (discovery date, categorization date, final report date), the date used for the basis of the graph is identified on the x-axis label.

The c-chart is used when counting discrete events, as in a random arrival process. Counting events is a good example of a random arrival process, as long as each of those events are independent from each other, and overall occur at a constant rate. This is also known as a Poisson process.

In this graph, an initial 24 month baseline was established at the end of 1994 for January 1993 through December 1994. This baseline remained valid until the end of 1995. Then a shift occurred, with 10 of the next 11 points below average (starting with November 1995). A new baseline was established for November 1995 through September 1996. Note the gap in the two baselines from January 1995 through October 1995. This is acceptable. One does want to avoid overlaps between adjoining baseline averages, however.

The current baseline (Nov 95 - Sep 96) was based on much less than 25 points. It does appear that the new data is coming in lower than the new baseline (but so far, no statistically significant difference has been detected). If a statistically significant difference does generate, perhaps the choice of November 1995 through September 1996 was insufficient. A better alternative may turn out to be to continue to 21.8 average through March 1996, and calculate a new baseline starting in April 1996. This serves to illustrate how control charts can evolve over time, and baselines with less than 25 points may prove to need to be readjusted.
The P-chart

The chart below is an example of a P-chart. It is graphing the percent of problem reports which were caused by Design Problem. This data is valid for a p-chart as repeated go - no go trials are being conducted; each report was either caused by Design Problem, or was caused by a different cause.

There are two baseline time periods on the graph: December 1993 through April 1995 and May 1995 through September 1996. Note that the current baseline average ends with September 1996. That was when the average was established. New data points have been added each month to this graph, and compared to the 8% baseline. The average has not been (and should not be) recalculated to include each new datum point. The average will only be recalculated once a statistically significant change is detected.

The control limits vary based upon the total number of problem reports each month. The more reports, the less variation expected, and the control limit comes in closer to the baseline average. In this case, the lower control limit was less than zero, so is not shown.

![P-chart example](image-url)
EXAMPLE U-CHART

The U-chart

The chart below is a typical chart used by a safety department - cases per 200,000 hours. Rather than just plotting the number of accidents, this graph plots accidents per 200,000 hours. This allows the rate on the graph to be consistent even with different size work forces.

In this example, the number of cases each month is determined, then divided by the number of hours worked in the month, and finally multiplied by 200,000. The control limits vary from month to month as hours change. When hours worked are low, the control limits are far from the average line. One expects a large amount of variability in the data when there is a small work force. When hours worked are high, the control limits move inward. One expects a small amount of variability.

Note that the initial average was calculated for a time period starting prior to the beginning of the graph. This is typical for an existing graph which has accumulated many years of data, and a decision is made to remove some of the "old" data. In this case, it was decided to remove the data prior to fiscal year 1995. However, the baseline average was left as is, rather than recalculating it for Oct 94 to Jan 95.

There are several significant trends in this graph. First was a decrease from 2.28 to 1.64 in early 1995. The five points from Feb 95 to Jun 95 were greater than one standard deviation below the previous average. However, there was then a significant spike in August 1995. August 1995 reflects special cause variation, and we will assume the cause in question was identified. When developing the proper average to use, it was decided to remove August 1995 from the average. Note the average line cuts through the center of the remaining data for the time interval.
A more recent shift of seven points in a row below average occurred from Sep 96 to Mar 97. As April 1997 remained below the 1.64 previous average rate, an initial baseline was calculated for Sep 96 through Apr 97. During this interval, the Lower Control Limit was mathematically less than zero. Since you cannot have a negative case rate, the Lower Control Limit is not plotted.

This new baseline contains less than 25 points, so it may not be stable. However, this eight point average does provide some basis to determine if a decrease in accidents is continuing, or if the accident rate has steadied out.
Trending Low-Rate Events

It can be difficult to detect trends on infrequent events. However, such infrequent events can also be high severity events that we have the desire to detect significant changes in.

The current DOE-STD-1048-92 states that when trending counts of events, and the average number of events per time interval (month, quarter, year) plotted falls less than 5, one should not use control limits on the chart. This admonition is not commonly accepted in the statistical community, or textbooks. However, there is a practical problem when counting the number of events per time interval when the rate is low.

See the c-chart control chart below. The average rate of the event per month is equal to 1.0. It is difficult to determine if significant changes are occurring, although we do have September 1994 on the Upper Control Limit.

What can be done is to look at the time interval between events. We actually plot the annual rate of the event, based upon this time interval. The calculation process is:

1. Collect the dates of the events
2. Sort the dates in order from oldest to newest
3. Calculate the number of days between events
4. Divide the number of days between events into 365
5. Plot this data on an x-chart.

Below is part of the example set of data:
The resulting control chart is below:

<table>
<thead>
<tr>
<th>Event Date</th>
<th>Days Between Occurrences</th>
<th>Rate of Occurrence per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/17/97</td>
<td>25</td>
<td>0.46</td>
</tr>
<tr>
<td>2/22/96</td>
<td>39</td>
<td>0.76</td>
</tr>
<tr>
<td>3/12/96</td>
<td>39</td>
<td>0.76</td>
</tr>
<tr>
<td>5/4/95</td>
<td>67</td>
<td>1.07</td>
</tr>
<tr>
<td>11/1/95</td>
<td>14</td>
<td>0.46</td>
</tr>
<tr>
<td>2/1/96</td>
<td>13</td>
<td>0.66</td>
</tr>
<tr>
<td>2/22/95</td>
<td>35</td>
<td>0.66</td>
</tr>
<tr>
<td>7/2/95</td>
<td>35</td>
<td>0.66</td>
</tr>
<tr>
<td>2/28/96</td>
<td>48</td>
<td>0.76</td>
</tr>
<tr>
<td>9/6/96</td>
<td>96/61/96</td>
<td>1.07</td>
</tr>
<tr>
<td>12/1/95</td>
<td>36</td>
<td>0.66</td>
</tr>
<tr>
<td>10/12/95</td>
<td>36</td>
<td>0.66</td>
</tr>
<tr>
<td>10/1/94</td>
<td>48</td>
<td>0.76</td>
</tr>
<tr>
<td>2/23/95</td>
<td>50</td>
<td>0.66</td>
</tr>
<tr>
<td>11/9/95</td>
<td>35</td>
<td>0.66</td>
</tr>
<tr>
<td>2/2/95</td>
<td>35</td>
<td>0.66</td>
</tr>
<tr>
<td>7/1/95</td>
<td>35</td>
<td>0.66</td>
</tr>
</tbody>
</table>
Brief Overview of Trending

- Use Statistical Process Control (SPC) control charts to detect if significant changes are occurring in the process data.

- SPC uses an average line for a fixed time interval. Do not change the average with each new data point added. Do not change the average line unless a statistically significant change occurs, then construct a new baseline average.

- Use three standard deviation control limits. This is the best balance between detecting real changes, and avoiding false alarms. (Would changing the sensitivity on your household smoke detector make your house more safe?)

- Apply the following rules to detect statistically significant change:
  One point outside the control limits
  Two out of Three points two standard deviations above/below average
  Four out of Five points one standard deviation above/below average
  Seven points in a row all above/below average
  Ten out of Eleven points in a row all above/below average
  Seven points in a row all increasing/decreasing.

- Plot at least 25 data points on your control chart before discarding "old" historic data.

- If there are no statistically significant changes in the data on the control chart, then you have a stable process. You must change the process in order to change the data results. Numerical Goals will NOT cause a process change, nor a real change in the data.

- If there are statistically significant changes, determine the special causes of these changes. Apply this knowledge to reinforce positive trends, and to correct negative trends.

- After making a process change (management decision), perform statistical trending using SPC to see if a statistically significant change results.

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Trending Home Page: http://www.hanford.gov/safety/vpp/trend.htm
Performance Indicator Process

1. Identify Business Objective
2. Identify and Understand Process
3. Select Performance Indicator
4. Collect Data and Plot Control Chart
   - Benchmarks Management Philosophy Customer Expectations
   - Evaluate Performance (Mean and Variance)
   - Is Data in Statistical Control?
     - Yes: Determine Process Change Needed
     - No: Identify Special Causes
6. Take Action
   - Correct Problem
   - Reinforce Positive
7. If Improvement Needed?
   - Yes: Implement Change
   - No: Is Measure Still Valid?
     - Yes: Repeat
     - No: End
A Method to Color-Code Performance Indicator Results for Executive Summary

1. Collect Initial Data, perform initial baseline control chart
2. Monthly Control Chart Update
3. Does a statistically significant trend exist currently?
4. No
5. Is trend in Improving Direction?
   6. No
   7. WINDOW IS RED
5. Yes
   8. WINDOW IS GREEN
   9. Identify Special Causes
   10. Action - Stress Positives - Correct / Reinforce
   11. Rebaseline Control Chart when appropriate (generally when data stabilizes at new mean and variance)

- From Current Evaluation, is improvement needed?
  - Yes
    - WINDOW IS YELLOW
    - Identify Common Causes
  - No
    - WINDOW IS WHITE
    - Perform Management Assessment, Publish Monthly Report, and continue to next month.

- Determine Process Change Needed and Implement
  - Past 7 months in row Yellow or Red?
    - Yes
      - CHANGE WINDOW TO RED
  - No
    - Past 7 months in row White or Green?
      - Yes
        - CHANGE WINDOW TO GREEN
      - No
INFORMATION CLEARANCE FORM

A. Information Category
- [ ] Abstract
- [ ] Journal Article
- [ ] Summary
- [ ] Internet
- [ ] Visual Aid
- [ ] Software
- [ ] Film
- [ ] Paper
- [ ] Report
- [ ] Other

B. Document Number
- HNF-1787-FP

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D. Internet Address

E. Official Information

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G. Complete for a Presentation

H. Information Clearance Approval

I. Additional Remarks, Please Attach Separate Sheet