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## Finding The Plant Within

# EXPANDING CAPACITY

Using Process Reliability Analysis for Strategic Business Decisions

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**The Scenario** A company, let's call it "ABC" Company, is growing and currently sold out in one of its major businesses. Market demand is expected to increase substantially in the coming 5 years. Current production capacity is limited and not expected to be able to meet the increasing demand within the next 12-24 months. The long range capacity and demand profile is outlined in Figure 1.

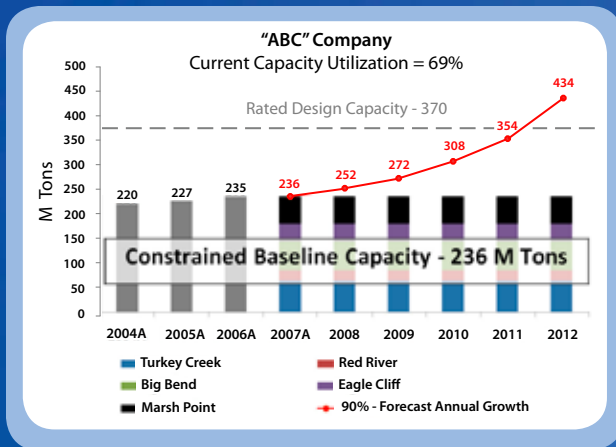


Figure 1 - Production Capacity for ABC Company

**The Options** The company is reviewing its options for supporting this anticipated growth in its markets. These are summarized as follows:

**Option One** - currently in progress - is to invest considerable additional capital into building new capacity. The current estimated investment required to build a new plant or expand existing operations has been determined to be approximately \$300M. The company is proceeding with conceptual design work and planning, using a budget of ~\$1.5M to improve its understanding of the business requirements and capital budget estimates for the additional capacity. This effort thus far has indicated that \$300M is within a +20% band, depending on: a) whether the plant is new, and closer to some of its developing markets, 2) added to existing operations, but farther from

those same markets, 3) whether they pick up more advanced process and control technology in the new plant.

**Option Two** - now being considered - is to acquire some of its competitors' assets. The company has recently been advised that one of its competitors is in financial difficulty and in need of cash, and thus may be willing to be acquired or to have some of its assets acquired. The company also believes that some additional capital will be required to convert some of the technology in their assets into the processes more compatible with the company's. A "due diligence" review will be necessary to better evaluate this option, including the current state of their assets and their historical performance. If they proceed with this, it is expected to cost ~\$1-2M.

**Option Three** - not seriously considered, until now - the company had recently had a review done at its Turkey Creek plant, one of its five plants, and it was concluded that the Turkey Creek plant was currently only operating at 56% of its maximum capacity, and that it could, with minimal additional capital or operating expense (e.g., \$1-5M), perform in a sustained manner at >80% on an annualized basis of that maximum demonstrated production capacity. Members of the management team, who comprise former plant operating managers and/or capital project managers, are skeptical of this option. They don't believe that the plant is performing at 33% less than its inherent capability; or alternatively that they have invested 33% more capital than necessary to produce at current levels. Very intrigued by the possibility of higher capacity, especially if it turns out to be true, not just at the one plant reviewed, but at the other plants as well, they could get all the additional capacity they need for the next 3-5 years without having to invest some \$300M in new capital equipment. The initial assessment of the Turkey Creek plant, including the development of an action plan for achieving 80% annualized production rates, cost some \$150,000. In spite of their skepticism, they have decided to proceed with having the other four plants reviewed as well.

Option one is in process and is adequately described above for the purposes of this paper. Options two and three are discussed in additional detail below.

*Editor's note: This paper is based on the experience of the authors and is an amalgam of that experience. Therefore, the information below bears no particular correlation, real or imagined, to any company, but rather, a fictitious company will be used to illustrate certain principles based on the composite experience of the authors working with many different companies.*

## Buying a Competitor

When buying a competitor, a due diligence review must be performed which includes the usual management, market and financial review of the competitor, subject to the appropriate state and federal laws and proprietary protocols. The management team acknowledges their thinking has been challenged about the Turkey Creek plant's performance and they agree they must review whether or not the competition's assets are performing at a comparable level to theirs. It is suspected that the competitors' assets may be performing even worse, given their current financial difficulty. So, they elected to ask the review team for the Turkey Creek plant to be part of the due diligence team to assess the performance of the competitors assets. The results are shown in Figure 2.

The results of this review were surprising to everyone. The competition's plant is reporting actual performance better than Turkey Creek, but they were typically only operating at about 50% of true facility design capacity. The competition had consistently cut fixed costs over the past 5 years and also lost many of their resources due to retirement and attrition.

It was painfully obvious, that this plant would have a very hard time pushing to meet the original rated design. The plant had identified the Dryer System as deficient with a preliminary estimate of \$25M in capital for a new Dryer system. This company had already reported being strapped for cash, so they have been unsuccessful in selling this Dryer Project to the Engineering Director to secure the capital investment approval.

As a result, a business decision was made several years ago by the business team to reduce the rated capacity to more of a contractual arrangement of 110 Tons/Day vs. 200 Tons/day design capacity to better reflect true capability of the current plant limited operations. This decision also helped the plant meet their capacity and availability performance metrics. The existing Capacity Utilizations for the comparisons are also shown in Figure 2.

After discussing the production profiles with the personnel from Turkey Creek, they reported that they could not do any better

because the highest volume product at this plant runs at a slower output vs. rated design capacity. The customers have convinced the marketing team that this slow running product is much better for their process operations. The marketing team recognizes this value to the customer but has been unsuccessful in negotiating a higher price for this product.

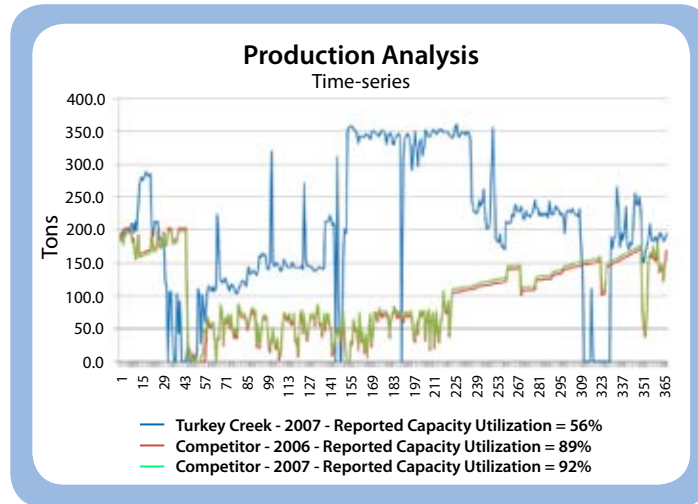


Figure 2 - Production Analysis

The data in Figure 2 was presented to the "ABC" Company Asset Productivity Champion during an executive leadership meeting. The champion was puzzled with this big disparity between the competitor and Turkey Creek, so now the challenge was to figure out WHY.

The "ABC" Manufacturing Director and the champion had recently been exposed to some newly developed statistical approaches to better characterize production output performance by a Leading Service Provider (LSP). These methods are referred to as "Process Reliability Plots". These managers began to have dialog to see if this approach could help them figure out why.

Process Reliability Plot methods were developed in the mid-1990's and are now just gaining significant acceptance throughout the manufacturing community. Utilizing the abundant data found in a plant's assets and operating environment, these non-traditional statistical plots can be used to translate the data into an easy to understand language of improvement opportunity. Most production output data is riddled with special causes leading the data to behave in a non-linear fashion and common causes that are not very well understood.

Daily production output data is always available because it defines the overall production performance of an operating asset. Typically, most companies look at traditional time-series data to analyze performance. Personnel spend countless hours reviewing the performance in an attempt to quantify the potential for improvements. It is very time-consuming to quantify efforts to improve performance simply from looking at time series data and they typically result in requests to spend major capital dollars to address improvement efforts.

After importing the daily production output data into the statistical software, many important characteristics to improve operational performance tend to stand-out more readily. At this point, the data is plotted in rank order on log scale for the "x-axis" vs. a log-of-log scale for the "y-axis". This data has been disconnected from time-series effects and show distinctive patterns of performance. When the data is presented in this fashion, straight

line segments and definitive cusps will appear making it easier to more accurately characterize the overall "hidden plant".

These plots show data plotted in rank order rather than in time series using a method called "Bernard's Median Rank". They provide the user with a quick, visual, assessment of the true process performance and potential. Steep slopes, commonly called "Beta or Production Slope" are desirable and display small variability in process output from small common cause variation. Flatter slopes display large variability from larger common cause variation which is built into the process or from special causes.

The plots will also establish a single point estimate of typical daily production. This single point estimate always occur at the CDF = 63.2% or the R = 36.8 on the plots and will be the best characterization of the typical production output. This characterization is commonly called "ETA" and the magnitude is determined by the size of the physical facility and show how it is managed and operated relative to rated design capacity.

Many plant cultures typically point to equipment failures or asset optimization issues when capacity losses occur. It is a daily no-

win battle to genuinely understand the true causes because no formalized, proven plan exists to determine the origin of ALL the loss. All of this compounds the uncertainty on how best to deliver asset and process optimization and keeps a business in constant flux when trying to target the hidden capacity of their operation, the “hidden factory” that lies beneath.

Over the past several years, a Leading Service Provider (LSP) has refined this method, to understand the potential, reduce both asset and process optimization losses and improve overall profitability for clients. See Figure 3 for an illustrative example of how the LSP has recently incorporated this concept into an improvement offering called “Transformational Analytics Plots”.

Note that because it is on a log plot, most of the losses tend to be under the process optimization area, not the asset (equipment) optimization area.

By working diligently with this model, the approach has been refined and enhanced. Now it is possible to analyze:

**Asset Optimization Losses** - (e.g. equipment failures, raw material supply shortages, etc.) typically includes all major special cause or reliability issues.

**Process Optimization Losses** - (e.g. yield issues, late starts, early quits, poor management decisions, etc.) typically includes efficiency and utilization or common cause or variability issues.

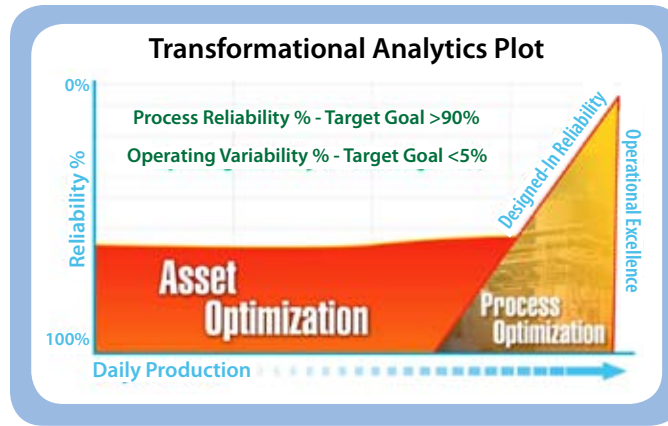


Figure 3 - Transformational Analytics Plot

**Variable Margin** - for a lost unit of production is then utilized and applied to both categories of losses to define \$COUR (Cost of Un-reliability) and \$COV (Cost of Variability) to dollarize the total improvement potential.

“Transformational Analytics” will help to challenge a company’s status quo in driving strategic and tactical decisions to:

- Improve Safety
- Improve Production Output Effectiveness
- Improve Process Reliability
- Reduce Production Variability
- Reduce Costs
- Improve Business and Capital Planning
- Create a Proactive and Can-Do Work Environment

Getting back to our story, the “ABC” management team is concerned about the amount of time it will take to actually make the acquisition, and to integrate the two company cultures. While “ABC” is arguably

not performing at a World Class level, it is seeking to become better and is open to new concepts, notwithstanding the occasional healthy dose of skepticism. Its competitor appears to be intensely driven by cost cutting, and the state of the assets is poor. Years of cost cutting have left the assets in visibly poor condition, and safety and environmental issues appear to be a major risk for any such acquisition. Moreover, the competitor is seeking \$500M, appears unwilling to be acquired in a stock swap, and by seeking mostly cash, would require “ABC” to take on some \$300M in debt.

Leadership within “ABC” have decided to assign a team, including the LSP experts, to utilize “Transformational Analytics” to perform the analysis on the data from Turkey Creek and the competitor site to see if this approach would help to provide more compelling evidence to pursue buying this competitor’s facility. The results of the analysis are shown in Figures 4 and 5.

In this analysis, and based on Figure 5, it appears that the competitor’s site has left \$70M to \$75M profit loss on the table for a \$73M Ton capacity plant. The analysis also yielded an \$80M profit loss for the \$131M Ton capacity at Turkey Creek as shown in Figure 4.

Both facilities are operating at <60% OEE and missing many opportunities to increase the reliability and reduce the operating variability that impact their overall customer dependability. With the clarity of these

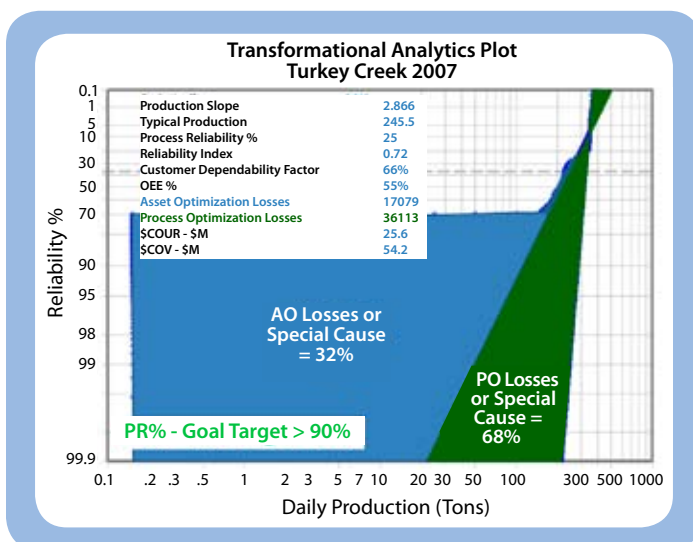


Figure 4 - Turkey Creek Analytics Plot

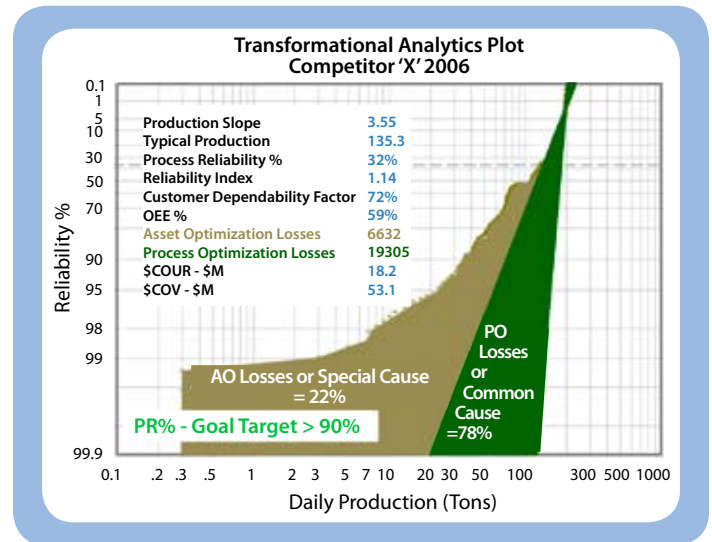


Figure 5 - Competitor 'X' Analytics Plot

results, the leaders instructed the team to complete the “Transformational Analytics” study for the remaining four operating plants in the “ABC” Company. It is anticipated by the leaders, that results of the study will show a clearer short range plan for “ABC” to address capacity needs from their existing assets for the next 2-3 years. This will also allow the Engineering Team to use the results of the competitor study and factor that into a decision to build a new plant or buy the competitor’s plant.

### Improving Existing Assets

Given the above situations, both of which would require \$100’s of millions in capital, the option of improving the performance of existing assets has become increasingly attractive in spite of the initial skepticism. “ABC” thus decided to proceed with a 2007 review of all five plants in its system with results shown in Figure 6 as a simple production vs. capacity profile. It is clear for this plot that production at Turkey Creek and Red River are falling well short of their expected capacity needs from the business.

Also in the chart in Figure 7, Big Bend, Eagle Cliff and Marsh Point all appear to be more stable and able to sustain higher production rates when they are up and running. Marsh Point installed new moisture extraction technology to help with more uniform packaging at this facility in late 2006. This process has definitely shown increased production output since this implementation in 1Q2007.

Lastly, it was noted by the team that Red River, Eagle Cliff and the competitor’s plant in the previous analysis, have exactly the same process technology as Marsh Point. The team also acknowledged that Marsh Point, Big Bend and Turkey

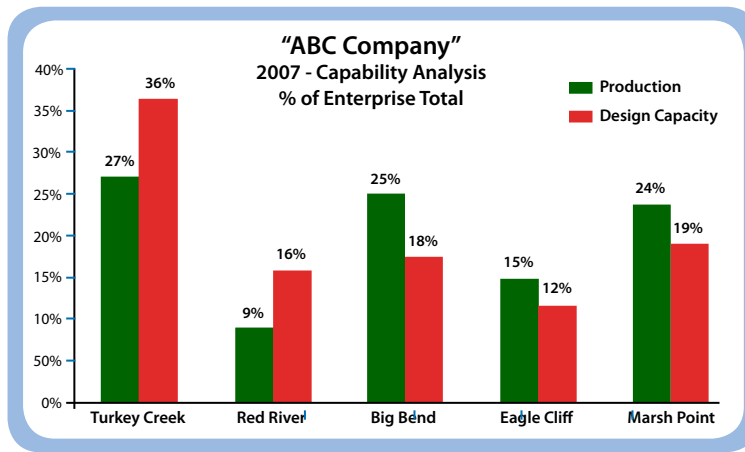


Figure 6 - Capacity Analysis for ABC Company

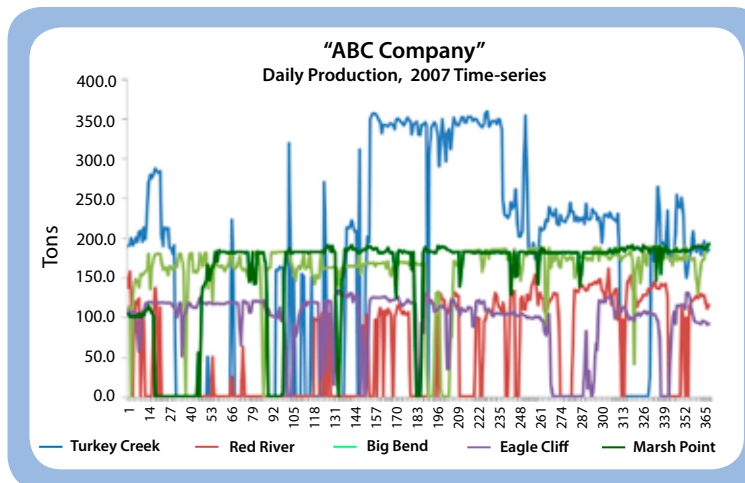


Figure 7 - Daily Production - ABC Company

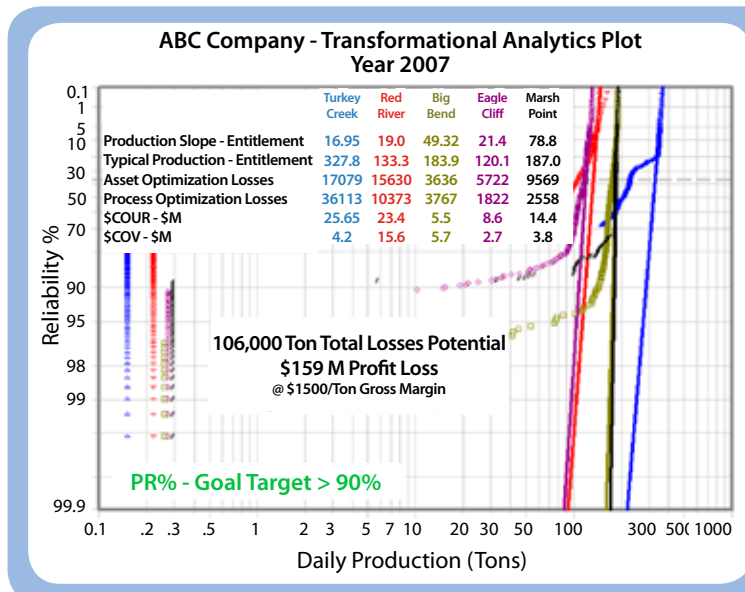


Figure 8 - ABC Company, 2007 Transformational Analytics Plot

Creek have some similar technologies but they are so competitive with each other that they spend very little time leveraging ideas across these plant sites.

The “ABC” team utilized “Transformational Analytics” and the same data for the analysis in Figure 7 to better characterize the actual and entitlement performance of all the plants to define the overall hidden loss profit potential for the “ABC” Company. Some of the combined results are shown in Figure 8.

You can see that the Transformational Analytics analysis has helped to quantify over 106,000 Tons in improvement potential across all five plants. This combined total represents enough capacity potential that is bigger than rated capacities at Red River, Big Bend, Eagle Cliff or Marsh Point on an individual plant basis. In fact, this potential is also larger than the total rated plant capacity of 73,000 Tons for the competitor site.

At this point, the team displayed extreme excitement and alerted the sponsoring leaders to this finding. The WOW factor prompted these leaders to ask the team to drive “Transformational Analytics” down to each individual plant site and develop a business level improvement plan.

In a proactive manner and parallel path, the “ABC” Asset Productivity Champion concluded that “ABC” needed services that could help them identify specific improvement projects they could implement to remove at least 70% of the identified improvement potential gap. This called for a detailed approach that utilizes a few proven Six Sigma, Lean Manufacturing and Reliability tools that the LSP has successfully implemented to help clients improve their overall bot-

tom-line profitability. The Transformational Analytics approach is outlined in Figure 9.

The “ABC” Asset Productivity Champion was

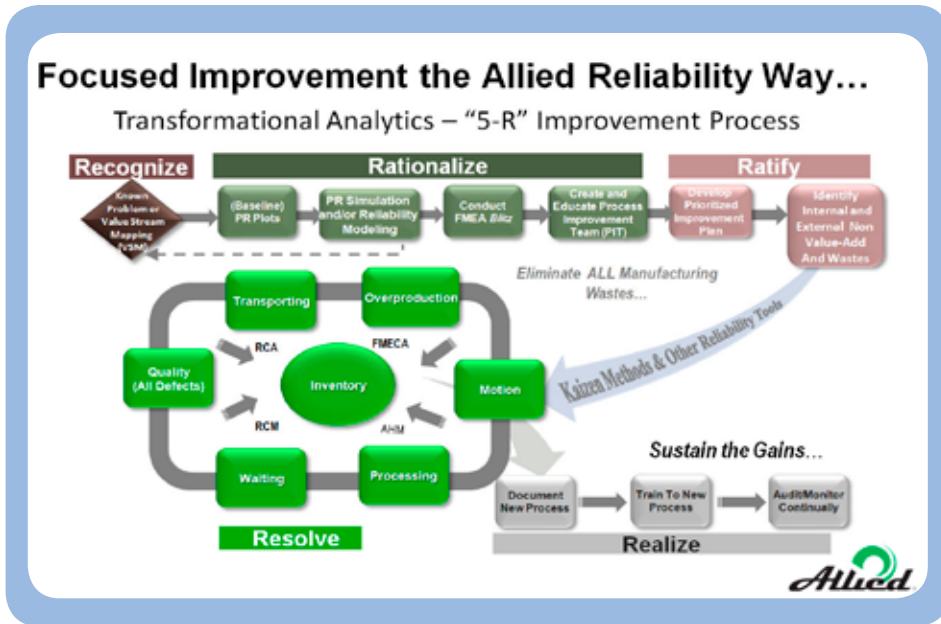


Figure 9 - Transformational Analysis Approach

so intrigued with the Transformation Analytics approach that she attended workshops to learn how to utilize some of the improvement tools to help her develop a business level improvement plan. The scope of this plan focused to deliver at least 75% of the identified loss potential previously identified.

The design of the workshops included representatives from all five plants to encourage increased leveraging and quick implementation of ideas that were beneficial to multiple sites. After conducting the workshops, the business level improvement plan incorporated into the results are shown in Figure 10.

The results of this work quickly helped the “ABC” Business Leadership Team to set clear direction for the capacity growth and priority for the entire company. They decided to:

1. Engage the Service Provider to help the improvement teams to fast track top priority items identified from the workshops.
2. Defer any plans to invest in building a new production line.
3. Deploy a small team to complete a more detailed acquisition study of the competitor’s facility and consider if the current “ABC” improvement plan would minimize

the safety, environmental or economic risks of purchasing this facility. This would defer acquisition of the competitor’s facility until at least 2010.

4. Focus Engineering Team to complete the Front End Loading for a new production line within the next year.

The analysis in Table 1 can be translated into a simple table of current performance against future performance as measured by OEE, these OEE figures and losses being adapted from the Barringer Charts above to more accurately reflect maximum demonstrated sustainable rate. Note that the increase in output is anticipated to be 106,000, going from 236,000 tons per year to 342,000 tons per year over the coming 4 years.

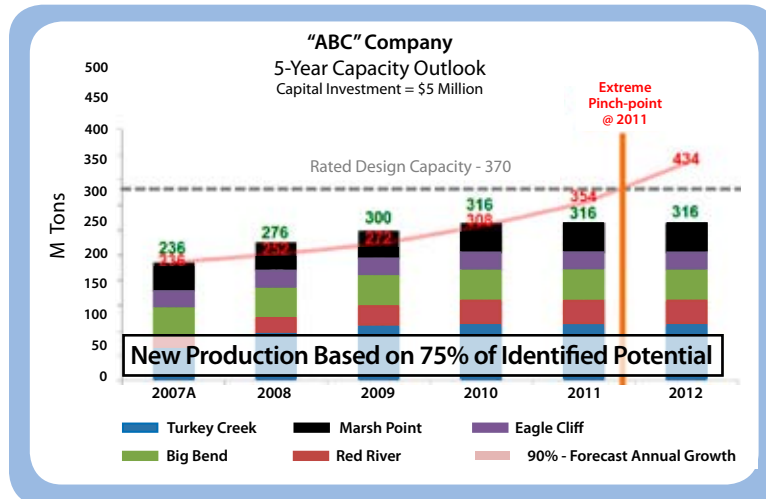


Figure 10 - Capacity Utilization for ABC Company

Performance	Current	Future
OEE	60%	87%
Tons	236,000	342,000
Total Revenue @2,500/te	\$590M	\$855M
Production Cost	\$450M	\$535M
Consisting of:		
Material/Variable	\$250M	\$350M
Other Fixed Costs	\$125M	\$115M
Labor	\$75M	\$70M
Total Gross Profit	\$140M	\$320M
Incremental Gross Profit		\$180M

Table 1 - Example of ABC’s Aggregate OEE Performance and Its Financial Benefits

Note that material and other variable costs do not increase linearly due to anticipated improvements in yield and quality with a more stable process. Likewise, labor and other fixed costs are actually decreased slightly because of improved productivity in the labor force. All in all, the company will more than double gross profit contribution, with existing assets, avoiding the need to purchase a competitor, as well as the need to invest additional capital immediately. It now has options for its future demand requirements and will likely use internal capital vs. taking the risk of acquiring a competitor.

### Action Plan/Next Steps

Now that ABC sees the possibility of meeting market demand with their current assets and accepts that there is only a limited need to invest additional capital, the following questions must be asked: “Where

should we start with our improvement effort?”, and “What improvement tools best apply to our business?” Most companies look for relatively easy ways to identify the biggest opportunities that are the easiest to do for improvement. But, most middle managers are not “systems thinkers”, that is thinking of their manufacturing plant as a complex system that must be fully understood as to inputs, outputs and variables. Rather, most tend to be “event thinkers”, wherein

one reacts to an event without fully appreciating all the actions and circumstances that led to the event occurring.

All of ABC's plants have a site strategy and improvement plan, and the tools they are applying are numerous. They've been bombarded with promotional material and success stories regarding the use of tools and methods such as Lean Manufacturing, Six Sigma, Supply Chain Management, Total Productive Maintenance, Reliability Centered Maintenance, Root Cause Analysis, and Kaizen, just to name some of the more common ones. They've used these in one form or another, and it seems that when properly applied, they work well. The "best" one seems to depend on the particular business situation, and given that, there may not be one "best". The question that many managers ask is, "How do I know which one to apply and where to start?" Explained in the next section is a model for applying Process Mapping to analyze the details of the losses discussed above, and to develop an action plan specific to those losses to focus the management teams on the value to be achieved in the coming 3-4 years.

### The Manufacturing Plant as a Business System

Any manufacturing plant should be thought of as a business system, and management and shop floor must understand the events or defects (anticipated or otherwise) that occur resulting in the loss of capability of that system. In a perfect world our plant would run perfectly all the time. We'd have perfect quality, maximum production rates, no unplanned downtime, and product changeovers would be instantaneous. Of course no one has ever seen that world. With that in mind, we should understand those events or defects that cause us to lose capability, and ask if they are acceptable to the business or not. At times they will be perfectly acceptable, e.g., rapid product changeovers, capital project upgrades, planned maintenance and so on. At times they will not. We must understand the causes of lost capability, and then take appropriate action to minimize them.

As noted above, one of the more common methods for identifying important problems is to measure Overall Equipment Effectiveness (OEE), and particularly the losses from ideal that goes with this measure. The losses from ideal are typically due to planned and unplanned downtime, rate losses, quality losses, changeover losses and other

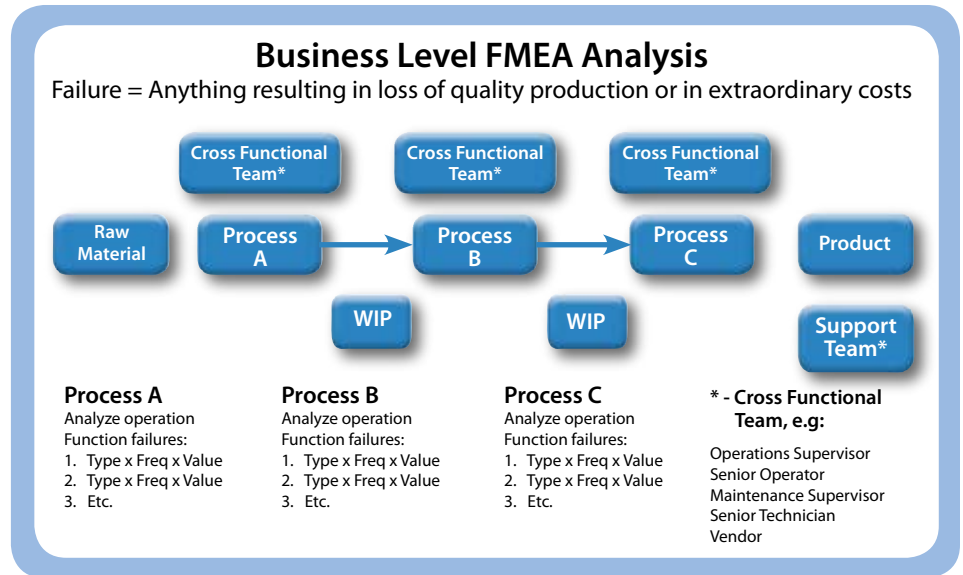


Figure 11 - Business Level FMEA Analysis

losses, some unique to the business. These are then used to select and apply the appropriate improvement tool to reduce the losses being incurred. However, suppose we're not measuring OEE or its equivalent, or don't have confidence in the measure itself (as is the case with ABC demonstrated above), what then? Or suppose we don't have a good understanding of the underlying causes of the losses discussed in the Process Reliability analysis above. What if we'd like to understand the system level interactions and be able to make better decisions on that basis. Neither OEE, nor the above analysis will provide all the details of production losses at a system level. So, let's provide a model for better understanding the system interactions and prioritizing the work to be done, and then selecting the tools to be used.

ABC's costs are too high. How do we know where to focus the resources to lower those costs? Or, perhaps that's the problem, ABC has "too many resources" with their attendant costs, so we cut costs, with the expectation that costs will come down, only to see our production capability suffer. Things are often not what they seem to be. For example, when maintenance costs are too high, companies often, to their detriment, cut them. Rather than cut maintenance costs, perhaps they should understand the source of the defects that are resulting in the failures and the subsequent need for maintenance. Figure 11 provides a step by step process for understanding where the "defects" are (that is, those things that cause us to lose production capability, or incur additional costs), so that we can eliminate the

defects from our business system. It's called a business level Failure Modes and Effects Analysis (FMEA). Here is how to do it:

1. Assemble a cross-functional team from each production area (Area Teams), plus a support function team. The cross functional team from each area typically consists of a senior operator, an operating supervisor, a senior mechanic, electrician, or technician, and a maintenance supervisor. It may also include others, such as the area engineer or a vendor for certain critical equipment. The support team is typically composed of a stores supervisor, a utilities supervisor, a human resource and/or training manager, a purchasing supervisor, and a capital projects engineer.

2. Have each Area Team draw a simple block diagram of the production process.

3. Next, and this is the heart of the analysis process, we define a failure in the business system (the production process) as anything that results in either the loss of quality production output or in extraordinary costs. Loss of production is pretty obvious, but let's give some examples of extraordinary costs. Suppose we have in-line spares for several of our pumps. So, when one fails we don't lose production, but if they fail often, we can incur extra costs. Or, suppose we routinely have yields that are below, or even well below, our ideal target, that represents an extraordinary cost. Or, suppose we are using excess additives or catalyst to assure proper reactions in a chemical process. That represents extraordinary costs as well. Or, suppose our energy consumption

is 20% above the ideal state for conversion of our products. These are all extra costs that we might be able to manage better, and minimize, with a more stable process and reliable plant.

4. Next, the cross-functional team reviews each step of the production process, identifying failures at each step. It's usually best if each area does its analysis independently, and then presents its findings to the other teams at the end of the day. For example, you would ask: "What is your biggest functional failure in Area 1?" Let's say it's a problem with raw material, both quantity and quality. Next question: "How often does this happen?" Let's say weekly. Next question: "What's the consequence of each event?" Let's say it's reduced rate, or lost quality, or literally no production. Next question: "How many hours of equivalent production is typically lost for each event?" Let's say it's about 2 hours at about 100 tons per hour. Next question: "What's that worth, in gross profit contribution?" Let's say it's \$500 per ton of production. Now we have an estimate that poor raw material quality/quantity is occurring once per week, typically resulting in 2 hours of equivalent lost production at 100 tons an hour at \$500 per ton, or \$100,000 per week in lost gross profit (presuming we could sell all we could make). Or, it's costing the company over \$5,000,000 per year in potential gross profits. Two hours a week doesn't seem like much, until you add it up.

5. The support functions must also be reviewed for failures in our business system, e.g., poor quality or quantity spares, insufficient utilities, etc. How often does it happen? What's the consequence to the business in production or additional costs? What's that worth, over a year's time?

6. As discussed above, during the review, the value of each business level production failure is analyzed and estimated/calculated – Type of Failure, and its Frequency Per Year x Losses per Failure x Value per Loss to estimate the dollar value, or quantity of product "lost" per year.

The process is shown in a simplified form in the Model for Performing a Business Level Failure Modes and Effects Analysis (FMEA) in Figure 11.

Each Area Team asks the questions described above and summarized in the Business Level FMEA Questions graphic in Figure 12.

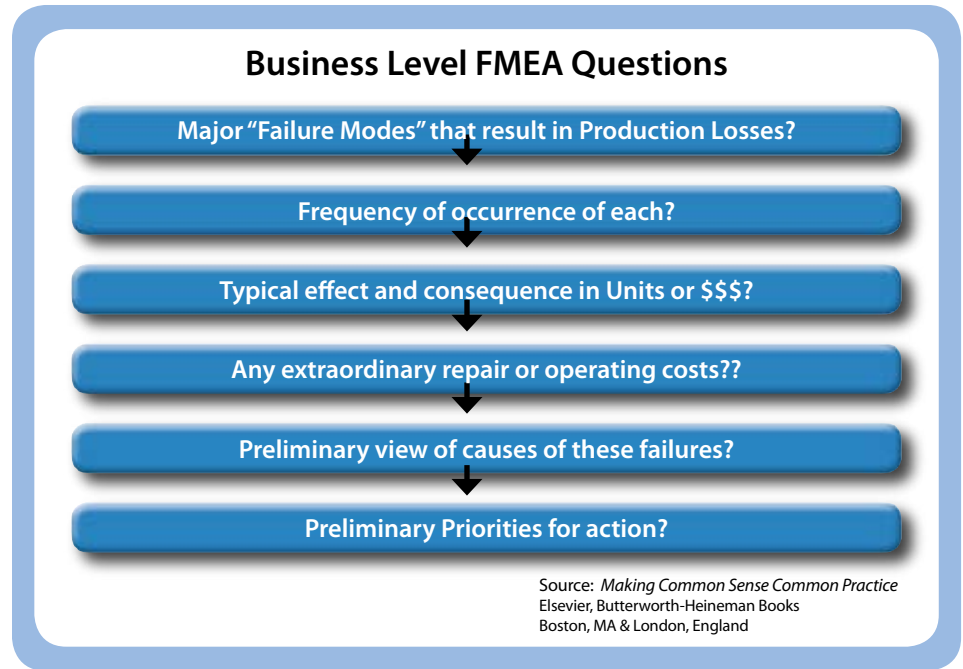


Figure 12 - Business Level FMEA Questions

For example, assume in step one of our production process that we identified supplier quality as a major problem. That is, once a week the supplier provided raw material of substandard quality. This quality problem required adjustment of the process and resulted in lower yields and/or extra costs. Suppose we calculated that this lower yield resulted in the loss of the equivalent of 10 tons of product (or 1000 units or whatever appropriate unit), with each ton having a gross profit of \$500. This would result in a loss of \$260,000 per year. Further suppose other disruptions for accommodating this poor raw material were valued at \$2,500 per event - lost productivity of people, plant re-configuration, and so on. Overall the value of this failure in our system would be estimated at (\$260,000 + \$130,000) or \$390,000 per year, a fairly substantial sum. We continue with this process until we've identified all major losses in each production area, as well as those attributable to the support functions. Next, we prioritize those losses that provide the greatest opportunity for improvement, and select the appropriate tools for eliminating or minimizing them.

Note that at this point we do NOT try to solve any of the problems we identify. We will prioritize the results of our analysis using the model in Figure 13. For example, after we analyze our business level failures and place a nominal value on them, then we'll "plot" them on a chart similar to Figure 13. Tasks that are easy to do and have the most value, get done first; tasks that have less value, and are easy to do get done next; tasks that have high value, but are difficult to do, for example, changing a major technical process or getting capital funding, are done next. The last category, tasks that have low value, and are difficult to do, may not get done at all,

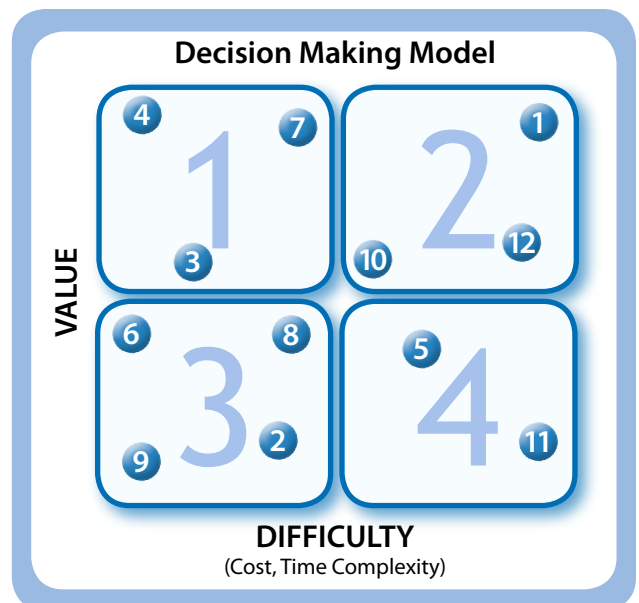


Figure 13 - Decision Making Model

at least not in this round of improvements. For example, at one of ABC's plants, task no. 1 of the Decision Making Model in Figure 13 required a major design change to the process, including considerable capital. It provided high value, but was also difficult to do. Whereas task no. 4 provided high value, but was relatively easy to do. This had to do with getting operators trained to follow a particular procedure, one that they had not been doing because of a lack of training and understanding of its importance.

A word of caution in doing the analysis relates to identifying preliminary or potential causes. Very often the team will want to begin solving the problem after they've suggested some potential causes. This should not be done at this time. The purpose of this question is to get people thinking about potential causes, but not to solve the problem. We won't begin problem solving until after we've plotted the opportunities in the decision making model chart. After that, we can select those problems that provide the highest return for the least effort given our resources, and we can select the right tool for the problem solving. Too often people want to immediately begin problem solving, particularly engineers who like to develop engineering solutions. Hold that until after the analysis is completed. At this point, you're guessing at the value and difficulty of each problem, and need to refine your analysis and plans as you get additional detail and validation of the initial review.

One of the key benefits of this approach is that people are working as a team, using a common strategy that's focused on the success of the production line – it has a business system focus for the teams. And, the team develops an action plan to improve the overall system performance. That, in itself, is invaluable.

## Typical Results

ABC has found the following to be fairly common problems at almost all its plants when doing a business level FMEA. Case studies will be provided later that illustrate these problems:

- Lack of understanding of the pacing or bottleneck unit for setting production requirements; and/or not fully understanding the impact of upstream and downstream area performance on each other, and the plant's overall performance

- In batch and discrete plants – change over time and setup/startup problems; in process plants – transition losses due to changes in products and/or raw material
- In discrete plants – production stops for breaks and lunch; and short stops that do not get counted
- Raw material problems – poor quality and/or insufficient quantity
- Erratic production planning, primarily driven by erratic sales forecasts
- Equipment failures
- Spare parts unavailability or poor quality
- Design/layout features making maintenance difficult
- Poor power quality resulting in electronic problems and failures
- Operator inexperience and lack of training resulting in inconsistencies and failures
- Inadequate lubrication resulting in machinery failures; or lubrication delegated to the operators without adequate training, or buy-in
- Mechanics were in need of training on critical equipment and/or precision skills

## Selecting the Right Tools

Using this approach to better understand and prioritize production losses and extraordinary costs, we can now do a better job selecting the appropriate tool and approach to solve or mitigate the problem. Our strategy will be based on a system level review of our production process. For example:

1. If supplier quality was a top priority, we could work with purchasing to improve their supply, perhaps even applying Six Sigma in an effort to reduce the variability of their supply; or go to an alternative supplier.
2. If the next biggest opportunity was inconsistency in our production process due to a lack of training in our operators, we would probably set up a process conformance model to measure our non-conformances and characterize those; and ask human resources or training to develop a plan to address their skills in operating the system.

3. If the next biggest opportunity was related to a specific machine and its un-reliability, we might apply Reliability Centered Maintenance (RCM) initially, to better understand the machine's functional requirements and the failure modes that are resulting in loss of functionality. Next, and if appropriate, we might apply certain Total Productive Maintenance (TPM) principles, e.g., operator care, or better preventive and predictive maintenance to better manage these failure modes. If the problem with the machine was particularly difficult, we might use Root Cause Analysis (RCA).
4. If the next biggest opportunity was to reduce the erratic nature of production planning and frequent changeovers, we might work with sales and marketing to analyze our product mix, sales and gross profit by product. It may be helpful to enlist key customers' views to better understand, and rationalize, our product mix, and sometimes even our customers. We would probably also want to implement a quick changeover capability, and work to level our production flow, even at the risk of modestly increasing inventory in the short term.
5. If the next biggest opportunity was to reduce spares un-availability, we would probably want to apply RCM methods to understand our most common failure modes, or our highest consequence failure modes, and then work with purchasing and accounting to make sure we had critical spares on hand.

Using the Business Level FMEA to analyze a particular production system at the system level seems to work well in quantifying the opportunities and prioritizing them for further action. We need to understand the business consequence of each of the major failures in our business system, and then select the appropriate tool(s) or strategy to address these opportunities.

## Summarizing

1. It's essential to look at the production process as a system, and fully understand the effects that the different areas within the system have on each other, and have within themselves.
2. It's essential not to assume that you

know where the biggest problem is until you've objectively evaluated the losses in each area and their respective interactions at the system level. Some of the data you have may lead you to the wrong conclusion.

3. It's essential to "go and see" the problems at the shop floor, getting them to help you in your observations as to specifically what is happening in the process and equipment.
4. It's essential to look at your production system as just that, a complex system with many interactions. A good method for doing this analysis is the Business Level FMEA.

Doing a Business Level FMEA should result in:

- Better teamwork
- Lower failure rates and downtime
- Improved output
- Lower operating costs

It's essential that we view our manufacturing process as a highly complex and variable business system, and that we understand the failures in that system. Viewing anything that results in a loss of production capacity or extraordinary costs as a failure in our business system provides a good start for working as a team in quantifying those losses. Quantifying those losses and then applying the appropriate tools on a priority basis will minimize those failures, assuring the success of the business.

However, the tools themselves are not sufficient. Management must provide continuous leadership for creating the environment that supports this approach - the time, tools, training, measures of success, and the sense of teamwork and common purpose needed. Management must align the organization to that purpose and follow up on the findings and action plans, assuring that they are done, measured, and rewarded on a continuous basis. These issues are major topics unto themselves, but for another article. Finally, it's essential that we engage the entire workforce in improvement, not just a few focused on the biggest problems. If we don't resolve the little problems, some of them will become big ones in the future. So, it takes a combination of efforts for world class performance. The business level FMEA helps us sort out the biggest problems, while we begin the process of en-

gaging the entire workforce in solving the little ones.

## Summary

When ABC began the process of reviewing the options for meeting an expanding market, its initial thoughts were to either borrow a tremendous amount of capital to build more plant capacity; or to buy a competitor, also an expensive proposition. After reviewing its current performance using the techniques described above, it concluded that it had adequate capacity in its current assets to meet demand for the next 3-4 years, if a "Best Practice" manufacturing process were implemented to maximize the capability of the existing assets. Improving existing assets will provide essentially all the capacity needed in the coming 3-4 years. Analyzing and addressing the improvement opportunities will be done specifically for each plant using a combination of Process Reliability Charts, OEE data, and the Business Level FMEA also described above. The potential for the business is an additional \$180M in gross profit contribution with minimal additional capital, e.g., \$20-40M per year in sustenance and improvement capital. The investment required is likely in the range of \$2-3M per year in both internal and external resources to facilitate the analysis and the implementation of the improvement process. Every company should be as fortunate as ABC.

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*With over 22 years experience in safety and occupational health, business consulting, engineering and manufacturing, José L. Wilkins, Senior Technical Advisor at Allied Reliability, Inc, is recognized as an expert in finding "hidden capacity" in manufacturing facilities and improving efficiencies in process and operations management. José leads the Allied Reliability TEAM in utilizing non-traditional statistics to characterize overall Process Reliability and help clients to uncover "hidden capacity" in existing operating assets. He holds a BSME, Six Sigma GB, BB and MBB and currently working on certifications in Lean Manufacturing. He has developed an improvement method that uses non-traditional statistics to characterize both safety injury performance and operational performance in production facilities which has quantified billions in savings. His expertise lies in using the basic foundation of six sigma methods to drive improvements in process optimization, engineering management, operations management, systems development and process and reliability modeling. This approach has been applied across small businesses to large corporations in the manufacturing sector. His former employers include DuPont, and Shell Pipeline, and he has held positions in operations and maintenance management, process and product development, various segments of engineering and consulting. José, wife Pamela, and son, Je'len, currently reside in Charlotte, North Carolina.*

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