

A Bolt-on to Overall Equipment Effectiveness: OEE' – Part 1 of 5: Changeovers

I am proposing a new metric for manufacturing organizations called OEE' (OEE Prime). It is a derivation of OEE and a compliment to how companies use OEE to measure their success. I decided to make this a five-part series so that I can properly convey the why and how of this metric.

OEE Overview

OEE (Overall Equipment Effectiveness) is a great tool that has been in the industry for many years, and it has provided leaders with a tool to help them manage their businesses. OEE is simply

$$\text{Availability} * \text{Performance} * \text{Quality}$$

There are definitions for each of these factors and you can check out the full explanation of OEE on Wikipedia and many other sources.

I am not trying to explain what OEE is, that has already been done a million times over. What I want to talk about are some modifications to OEE that I call OEE' and how this metric can be used to focus companies with their improvement projects, create visibility to what is important to your organization, and generate metrics for different teams with the same source data. While OEE is great to show your company progression over time, OEE' can be used to show shorter-term progress with consistency and can be modified to focus on your specific areas of improvement.

Changeovers

OEE treats changeovers as downtime, and understandably so. When you are conducting a changeover you aren't producing anything. However, changeovers are often part of a business model. Not only that, they are also part of the pricing of your product. Changeovers are unavoidable unless you have dedicated equipment and/or production lines. They are a part of business.

As a manager, on changeover days, it is hard to compare your performance because changeovers really dig into your availability, causing your OEE to look awful, even though it was a planned event. Take this example:

The line was scheduled to run for an 8-hour shift and there is an hour of scheduled break time built into the schedule (so 7 hours of planned time). But a line product size change will also occur requiring, on average, two hours of downtime to complete the change. With OEE, changeovers are part of the planned time and are considered to be downtime. Immediately, Availability is cut to 71% (5 divided by 7), and that is planned. If the other two areas of OEE, Quality and Performance, both stay at 100%, the 71% is the best that can be hoped for.

This can complicate business on three fronts.

- 1) If OEE is tracked by shift (which most places do and I think causes more problems than does good) there is no motivation for the team to do the changeover. One may even see a reduction in performance so that the changeover falls on the other shift so that they don't have to do it. Changeovers are hard anyway, why take the hit on OEE? The team could reduce Performance to 80% and still have a better OEE by having a high Availability because they moved the Changeover to the next shift.

- 2) The Changeover had to happen, so the reduction in Availability is inevitable. The only control is to try to schedule to reduce changeovers, which a good management team will do anyway. If the Changeover went well and the team did a good job, it is not reflected in their performance. The team still sees a “bad” OEE for their hard work.
- 3) It can't be compared to anything. If there is a heavy period of changeovers due to varying customer demand the OEE will still look like the team is not doing well, when in fact they may be delivering product to the customer on time with little downtime to show for it. The team may be doing a great job. Additionally, one will see false trending over time which makes it difficult to budget and predict. Managers are more prone to ignore this data point over time because of the inconsistency of the value.

The traditional response is that all of the downtime in the Availability portion of OEE will be Pareto charted and you can see the detail and make decisions there. I agree, and I think that it is the best way to directionally make improvements. However, topline views will show a department in distress and then you will be spending a lot of time defending your work rather than improving it. Additionally, this reduction in OEE is deflating for teams and may cause them to lose interest in doing well on days where their number will be low anyway.

Solution

Pull Changeovers and all other planned downtime out of Availability. OEE' is about measuring success to the plan, anticipating risks, and having mitigation strategies in place to reduce impact. Pulling planned Changeovers out of the Availability metric will help to make that number more in line with the spirit of managing good teams, good processes and good equipment.

However, measuring Changeovers shouldn't be eliminated. Changeovers should be put back into the metric in its own category. This category is called Planned Downtime and measures the actual downtime versus the planned amount.

Using the example above, if the plan was to complete the changeover in 2 hours and it took 150 minutes, assuming no other planned downtime (PMs, Kaizen events, etc.) the Planned Downtime effectiveness would be the planned amount over the actual amount, $120/150$, or 80%. Notice that if the changeover took less time the number could be greater than 100%. However, the standard can be adjusted as improvements are made to refocus the efforts of the team.

Summary

In short, planned downtime, such as changeovers, are exactly that, planned. They shouldn't hurt the morale of an entire team or cause additional justification as to why your department is not performing well.

Put changeovers, PMs, Kaizen events, and other planned events in their own category. You will find that your metrics are more consistent with your actual performance and that your teams will be rewarded for good work.

If you aren't tracking it, yet, create a standard for what “planned” actually means. If your business is prone to radical changes you may want to say that a planned downtime event is scheduled 24 hours in advance. Most companies can stretch that out to 72 hours. Apply this to anything that shuts your line

down on a regular basis: planned maintenance, Kaizen events, changeovers, department meetings, training. Know how long you plan to have the line down and track how long it actually was down. You can start tracking this efficiency of planned downtime immediately and plug it into an OEE' calculation later.

Stay tuned for Part 2: Manpower

Overall Operational Effectiveness (OEE') – Part 2 of 5: Manpower

In Part 1, we talked about Changeovers and Planned Downtime, the effect it has on OEE and how it can be better understood with OEE' (OEE Prime). Today, we are going to talk about Manpower.

Manpower in OEE

Put simply, manpower isn't considered in OEE because OEE looks at the *Equipment* effectiveness. Manpower is usually considered in line standards and accounting functions. Sometimes, manpower isn't considered in line efficiency at all and is lumped into a general direct labor cost for the department. So why should manpower be part of OEE'?

Labor and Manufacturing

The percent cost of direct labor to unit cost can vary wildly depending on the cost of raw materials for your product and the number of products you can produce in a unit of time. In short, if your material is cheap, your labor is a major component of your unit cost. Also, if your production rates are slower, labor is a larger portion of your unit cost. No matter the portion of cost, labor is still something that can and should be tracked.

Putting Labor in OEE'

By adding Manpower to OEE' it can track the impact of adding and removing people from the production line. Let's look at this via example:

A production line is typically crewed with 10 people. But today, there are quality issues with a labelling machine and three additional people have been put on the line for inspection so that it can keep running.

With OEE, one would never see the impact of having the three additional people on the line, even though it is a deviation from normal and an impact to the profitability of the product. If labor is a significant portion of operating costs, this might have been a bad idea. But it would never be seen by looking at OEE and it probably would have been levelized out over the month before anyone looked at labor costs. However, by having Manpower as a component of OEE' it will result in a loss of effectiveness. In OEE', Manpower is its own category.

By seeing this impact on the OEE' number it allows the department to take immediate action and decide if this is a good idea or not. This can also be applied to a different, more common situation.

Examples of Use

Should a line have a mechanical issue, companies will often throw extra labor at the problem to keep things going. For example, a down casepacker may result in the diverting of product to a manual pack station that will be staffed with extra people while the casepacker is being fixed. This is an issue for a couple of reasons (but may still be the best action). Usually the casepacker downtime will not be tracked because the line kept running, which will throw off improvement efforts and potentially make it harder to replace that old machine. Also, the additional crew will not be accounted for.

Let's say the casepacker was down for two hours and that the line had to be crewed with an additional four people to keep it running at its designed rate. If it is normally crewed for an 8-hour shift with 10

people, the manhours are 80. But 4 people were added for 2 hours, taking manhours to 88, resulting in an effectiveness of $80/88$, or 91%.

How to get Started

Start creating crewing standards for your production lines and products. Most companies are doing this already, but a lot of small and midsize companies are still working to implement these tracking methods. Take your current practices and find the number of people you use to make your product. Multiply that by the amount of planned time they are on the line and you have your manhours. Manhours will often change by the product being run and by the line. The same product run on different lines may require different manhours because of the line design. Divide the standard by the actual and you will have your Manpower effectiveness.

Check out Part 1: Changeovers, to read about how Planned Downtime is considered using OEE'.

Look for Part 3: Weighting, where we will talk about how to tailor OEE' to your business.

Overall Operational Effectiveness (OEE') – Part 3 of 5: Weighting

In the last two installments of this 5-part series we talked about Planned Downtime (namely Changeovers) and Manpower. I alluded that there would be a way to influence the impact of these measurements with OEE' (OEE Prime) and in this installment I will go over that method.

Traditional OEE is comprised of Availability, Performance and Quality. We have added Planned Downtime and Manpower as their own sections to create OEE'.

But what happens when one of the sections suffers?

If we use traditional OEE then a percentage point is simply a percentage point. It doesn't matter what section you are looking at. But what if we could weigh these sections to emphasize the impact one has over the other?

Example: Traditional OEE

If I have a line that has the below conditions,

Availability = 90%
Performance = 95%
Quality = 99%

My OEE will be 85% (simply $90 \times 95 \times 99$). But I could also have a line that is performing just the opposite way.

Availability = 99%
Performance = 95%
Quality = 90%

My guess is that this situation does not look nearly as appealing to a company. It probably costs more in so many ways; rework, scrap, customer satisfaction, etc. But the OEE is still 85%.

With OEE' we can create a weighting system that will put the importance on any of the five areas (Availability, Performance, Quality, Manpower and Planned Downtime) that you want. This is done with a point system and using exponential growth to assign the value of those points to each area. See the table below.

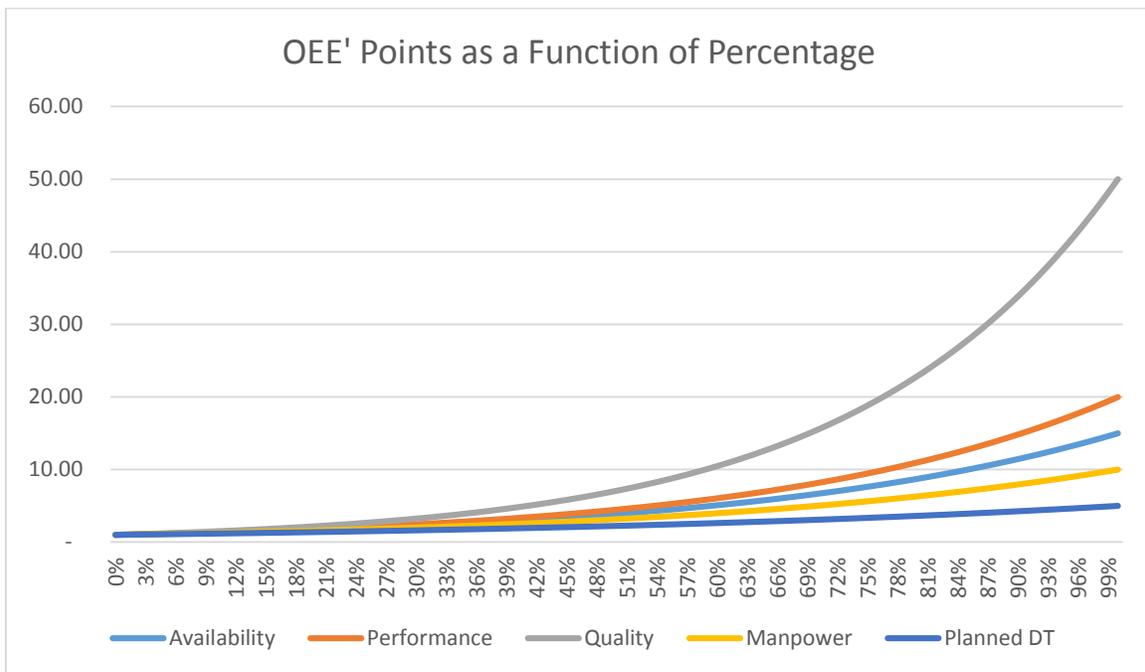
			Points
Availability	90%	99%	15
Performance	95%	95%	20
Quality	99%	90%	50
Manpower	100%	100%	10
Planned Downtime	100%	100%	5
OEE	85%	85%	
OEE'	92%	81%	

Notice that the OEE stays the same while the OEE' shows a marked reduction. The quality metric carries the most weight and influences the overall number.

The formula is relatively simple:

$$OEE' = \frac{\sum Points^{Percent}}{Possible Points}$$

Additionally, the exponential growth equation puts a greater emphasis on the higher end of the percentage. As percentage drops the point reduction is greater until it begins to approach zero. See the chart below for an illustration.



Let's look at the first column from the table above to illustrate the math.

$$Availability = 15^{0.90} = 11.44$$

$$Performance = 20^{0.95} = 17.22$$

$$Quality = 50^{0.99} = 48.08$$

$$Manpower = 10^1 = 10$$

$$Planned Downtime = 5^1 = 5$$

$$OEE' = \frac{11.44 + 17.22 + 48.08 + 10 + 5}{15 + 20 + 50 + 10 + 5} = 91.74\%$$

Looking at the second column:

$$Availability = 15^{0.99} = 14.60$$

$$Performance = 20^{0.95} = 17.22$$

$$Quality = 50^{0.90} = 33.81$$

$$Manpower = 10^1 = 10$$

$$Planned Downtime = 5^1 = 5$$

$$OEE' = \frac{14.60 + 17.22 + 33.81 + 10 + 5}{15 + 20 + 50 + 10 + 5} = 80.63\%$$

This flexibility allows the business to put the emphasis on the right areas for the business model that it needs.

While OEE' is slightly more intense on calculations (but with software, this is really simple), it allows for a more accurate assessment of the conditions in your plant and how you are able to execute to the plan.

1. We moved Changeovers out of the Availability section of OEE and into a new section called Planned Downtime in OEE' that can also be used to track PMs, Kaizens, and other planned events.
2. We included Manpower in the calculation to better understand the impact labor has on the line performance. A variation in labor will affect OEE'.
3. We added a weighting system that allows OEE' to be a better reflection of the true costs of your business.

If you didn't get the chance to read the first two installments of this article please see:

Part 1: Changeovers, and

Part 2: Manpower, to learn more.

Stay tuned for Part 4: Setting the Weighting Scale

Overall Operational Effectiveness (OEE') – Part 4 of 5: Setting the Weighting Scale

So now that we have discussed that OEE' (OEE Prime) can be used to provide emphasis in certain improvement areas by providing weighting, it is important to discuss how to set those priorities. Not every business will be the same and, indeed, your focus may shift over time. But how would you get started in setting these priorities for your business: gut feel, raw financials, or company values? Regardless of your bend, it is helpful to have a starting point.

There are five distinct areas of OEE': Availability, Performance, Quality, Manpower and Planned Downtime. Each of these needs to have points assigned to it. Below is a methodology that can get you started.

1. Start with Quality. Think of Quality as First-Pass Yield rather than the quality of product you are sending to the customer. By doing this we can basically make Quality a quantitative value that depends on scrap and rework. Let your Quality points equal the percent of material cost of the product total cost.
2. Move to Planned Downtime. Look at your percent planned downtime over a representative time for your work center. Use that percentage of planned downtime over total line time to set your number of points for this category.
3. Calculate your Manpower weighting. Divide your crew size by the hourly line speed and multiply the number by 100 to get your Manpower weighting.
4. Set your Performance number by adding the above values and then dividing by 10.
5. Last is Availability. Set your Availability number by adding the above 4 values and dividing by 10.
6. Once all 5 values are calculated, complete a weighted average and then set those percentages as the weighting points.

Let's see how all of this works with an example for one production line.

Assume that the direct product cost of one unit we product is \$1.20, with \$0.72 being material and \$0.48 being labor. There is a crew of 8 people and the standard line speed is 100 units/hour. Let's also say that over the last year there have been 600 hours of planned downtime on this line that is set up for a 5-day workweek for 3-shifts at 50 weeks a year (6000 hours). This is all I need to create my starting point for OEE'.

$$Quality = \frac{\$0.72}{\$1.20} = 0.6$$

Multiply by 100 for 60 points in Quality.

$$Planned Downtime = \frac{600}{6000} = 0.10$$

Multiply by 100 for 10 points in Planned Downtime.

$$Manpower = \frac{8 \text{ people}}{100 \text{ units/hour}} = 0.08$$

Multiply by 100 to get 8 points for Manpower.

$$Performance = \frac{60 + 10 + 8}{10} = 7.8$$

Round to the nearest whole number to get 8 points for Performance.

$$Availability = \frac{60 + 10 + 8 + 8}{10} = 8.6$$

Round to the nearest whole number to get 9 points for Availability.

Category	Calculated Points	Weighted Average
Availability	9	10
Performance	8	8
Quality	60	63
Manpower	8	8
Planned Downtime	10	11
Total	95	100

Notice that by using this method the value you assign to Quality is highly dependent upon your percent cost of materials. As your material cost goes up you will want to have a higher focus on first-pass yield so that you can reduce scrap and rework. As Planned Downtime increases it will become more important to successfully keep those schedules as it will have a greater impact on your available production time.

Keep in mind that this is a starting point. You may find that your numbers will need to be modified depending upon your business needs. However, don't overthink the weighting scale. One of the benefits to OEE' is that it is retroactive, meaning that with the same raw data your past performance can be calculated with the new weighting. It is more important to get started on the improvement process than it is to spend 3 days in a conference room arguing over a point system.

If you didn't get the chance to read the first three installments of this article please see:

Part 1: Changeovers,

Part 2: Manpower, and

Part 3: Weighting, to learn more.

Stay tuned for the final installment, Part 5: OEE' Applications.

Overall Operational Effectiveness (OEE') – Part 5 of 5: OEE' Applications

Just like with OEE, OEE' (OEE Prime) can be used for the entire business, by department, or by individual lines. However, because OEE' uses a weighted scale, it can have a few other applications that are unique to its design.

Guiding Focused Improvement Efforts

OEE' can be a flexible measurement that can be reset over time. Using OEE' can allow for a shift in the weighting scale to provide focus to a certain area of the operation, allowing a team to look at the entire impact of change on that operation with a specific focus.

For example:

If we notice that our Availability metric is sliding for a particular line, we can adjust the OEE' points so that Availability for that line carries a higher weight for a focused improvement team. That team can recalibrate the historical OEE' for the work center to see where the fluctuations are most pronounced and use that data to guide them for their project. They can then use the modified weighting to determine success criteria and understand the impact they have on the line performance.

Creating Department-Specific OEE' for the same Work Center

Since OEE is a constant value that can track overall progress, OEE' can be used to fine-tune metrics for a department.

Maintenance OEE' may want to focus more on Planned Downtime and Availability, as these numbers are stronger indicators for the success of the Maintenance Program. Production may want to model their OEE' to have a stronger emphasis on Quality and Performance since the vast majority of their responsibilities lie in these categories. The beauty is that the other factors can still play a role, requiring departments to work together to solve problems, but it also shows where they have the largest impact on a work center.

Let's see this in action.

	Percent	Production		Maintenance	
		Weighting	Points	Weighting	Points
Availability	70%	10	5	50	15
Performance	80%	30	15	10	6
Quality	98%	50	46	10	10
Manpower	99%	5	5	5	5
Planned Downtime	90%	5	4	25	18
OEE'			75		54

Notice that for the same line results, Production and Maintenance have two different OEE' values. Since Availability weighs so heavily for Maintenance, the lower percent of 70% has a huge impact on the OEE' for that department.

Breaking Down the Different Categories

We can decompose the OEE' metric even further to create deeper detail within each category. This can become cumbersome if done constantly, but can be useful for detail analysis and focused improvement teams. One version of a breakdown could be as follows.

- Availability
 - Downtime Categories
- Performance
 - Line Speed
 - Minor Stops
- Quality
 - Scrap
 - Rework
 - Hold
- Manpower
 - Overtime
 - Straight-time
 - By Pay Scale or Position
- Planned Downtime
 - Changeovers
 - Planned Maintenance
 - Kaizen Events
 - Training

Where each subsection totals the number of points for the entire section, allowing weighting within the category. An application would be where scrap would weigh more than rework if rework costs are minimal and relatively automated as part of the process. Another example would be that Changeovers and Planned Maintenance would be weighted more heavily than Training or Kaizen Events as you would want to make sure that these events are thorough and do not have a time constraint associated with them. This allows for further detail and customization of OEE'. Coupled with an automated form of calculating OEE' it becomes a matter of setup and then adjusted on some frequency rather than a constantly maintained system.

If you want to learn more about my thoughts on OEE' and how to implement this metric for your business please contact me to discuss your unique situation.

I am very interested in your thoughts. Please comment on this article and let me know what you think. I hope this becomes a flexible model for which to better measure manufacturing and allow for the dynamic nature of the packaging and processing industry.

If you didn't get the chance to read the first four installments of this article please see:

Part 1: Changeovers,

Part 2: Manpower,

Part 3: Weighting, and

Part 4: Setting the Weighting Scale, to learn more.