TEEP For 3D Printers

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Total Effective Equipment Performance:

The total effective equipment Performance metric or TEEP, is a measurement of performance that indicates how well a manufacturing operation is utilized. The metric is a percentage of actual output against a theoretical maximum capacity. It is the product of three underlying metrics, availability, quality, and performance.

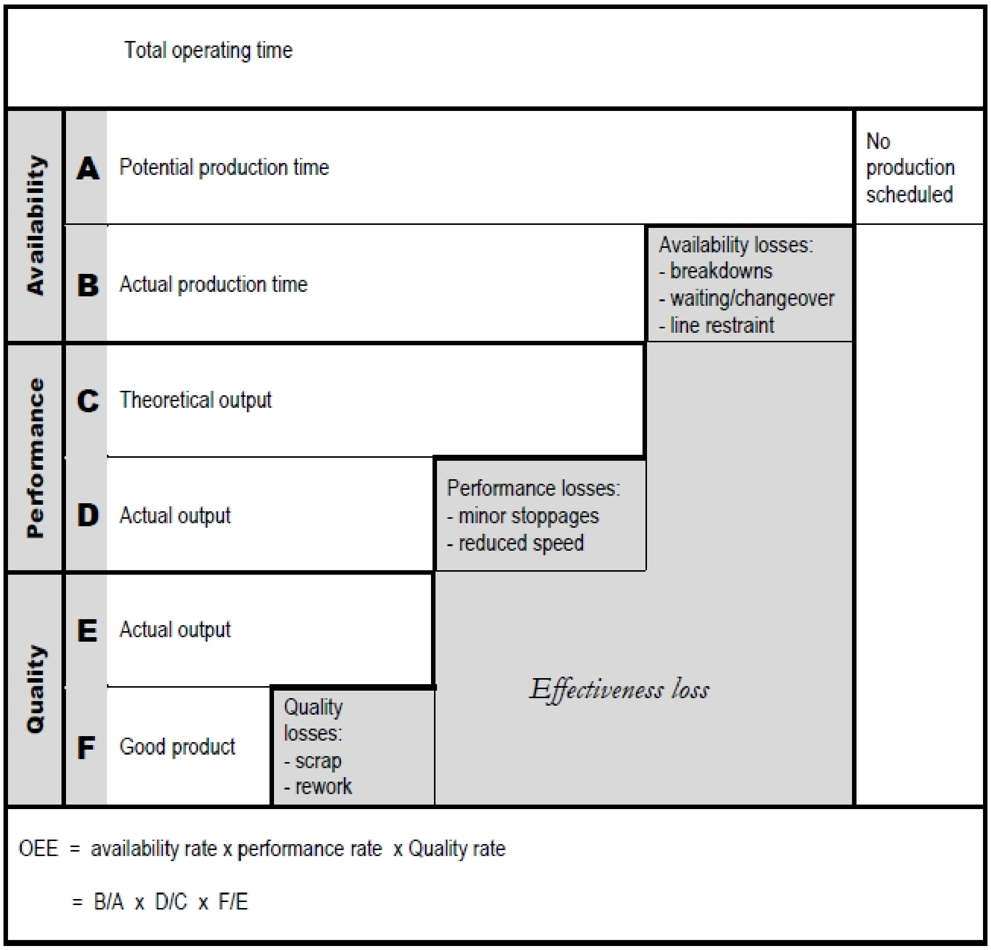


Image Source: "OEE for the Production Team" by Arno Koch

Here we'll demonstrate how this metric can be applied to a 3D printing manufacturing process that provides more variation among parts produced than traditional manufacturing processes.

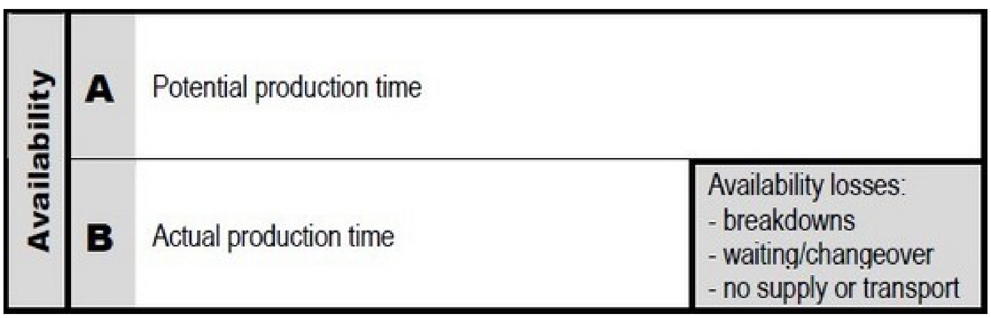
Before we can start we'll need a data-set that includes the number of parts per plate that has been printed, the estimated times, the actual times(elapse time), and the number of successful parts that pass inspection. This data-set needs to be comprised of all the plates that have been printed on the machine in a day. We'll use the data-set bellow for our example calculations:

Printer 1 Data-Set

bot_id	plate_printed_id	parts	est_time	state	created_at	finished_at	elapsed_time	successful_parts	failed_parts
Printer 1	2177	2	127	finished	2017-06-01 19:24:36	2017-06-01 21:00:18	95.53333	2	0

bot_id	plate_printed_id	parts	est_time	state	created_at	finished_at	elapsed_time	successful_parts	failed_parts
Printer 1	2173	4	177	canceled	2017-06-01 14:24:59	2017-06-01 14:25:04	0.10000	0	4
Printer 1	2176	1	64	finished	2017-06-01 14:25:19	2017-06-01 15:12:38	47.21667	1	0
Printer 1	2177	2	127	finished	2017-06-01 15:25:34	2017-06-01 17:01:11	95.50000	0	2
Printer 1	2178	1	245	finished	2017-06-01 21:28:24	2017-06-02 01:24:35	235.61667	1	0
Printer 1	2177	2	127	finished	2017-06-01 17:06:44	2017-06-01 18:42:21	95.41667	1	1

Availability



The availability metric is a measurement of how much time a machine is actually running to produce parts versus the potential amount of time the machine could be operated nonstop. The formula is $\text{Availibility} = \frac{ActualProductionTime}{PotentialProductionTime}$. To find the actual production time we need to add up all of the elapsed times in minutes of the printed plates. Using R code this is done by:

```
actual_time <- sum(printer_1$elapsed_time)
```

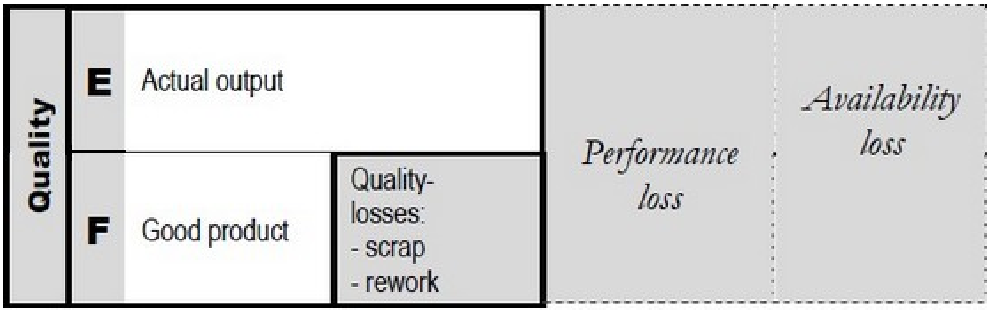
For this calculation we'll use a full 24 hours as the potential production time. If we were calculating Oee instead, we would use the time of a shift for the facility.

```
length_of_day <- 24 * 60
availability <- actual_time / length_of_day
```

569.3833333 / 1440 = 0.3954051

Availibility = 39.5405093%

Quality



Quality simply sees how many parts were good compared to all of the parts produces. It should be noted the a cancelled plate will deflate this metric. This gets balanced out for the TEEP metric by the inflation this causes when we calculate the performance metric later on.

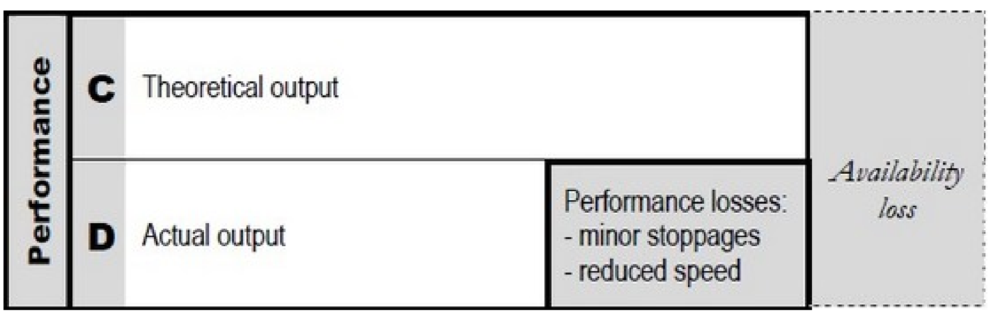
Our formula for quality is $\text{Quality} = \frac{TotalGoodParts}{TotalPartsProduced}$

```
total_parts <- sum(printer_1$parts)
good_parts <- sum(printer_1$successful_parts)
quality <- good_parts / total_parts
```

5 / 12 = 0.4166667

Quality = 41.6666667%

Performance



TEEP first started being used in the 1960's in conjunction with lean manufacturing processes. It's been used in manufacturing processes that are very standardized. The process of 3D printing though allows for a lot more variation of manufactured parts. We need to use averages in this case to center the data in order to calculate the performance metric.

To figure out the theoretical output we need to find the average time it takes to print a part per minute. First you calculate each plate's theoretical part per minute by dividing the number of parts on a plate with the estimated print times. Then you calculate the mean.

```
printer_1$parts_per_min <- printer_1$parts / printer_1$est_time
ave_parts_per_min <- mean(printer_1$parts_per_min)
```

Theoretical output is the product of the actual production time and average parts per minute.

```
theo_output <- actual_time * ave_parts_per_min
```

Performance is the total number of parts produced divided by the theoretical output.

```
performance <- total_parts / theo_output
```

12 / 8.498008 = 1.4120956

Performance = 141.209563%

TEEP

Finally TEEP is the product of availability, quality, and performance.

$$\text{TEEP} = \text{Availibilty} \cdot \text{Quality} \cdot \text{Performance} = 0.3954051 \cdot 0.4166667 \cdot 1.4120956 = 0.2326458$$

TEEP = 23.2645751%

Scaling for Use in 3D Printing Factory

To implement this for an entire factory of 3D printers you would need to calculate the TEEP for each 3D printer in a given day. Then you would calculate the average of all the TEEP metrics to get a measurement to gauge the whole factory's equipment effectiveness.

For more information on TEEP and OEE:

https://www.machinemetrics.com/blog/oee-ooe-teep (https://www.machinemetrics.com/blog/oee-ooe-teep)
http://oeecoach.com/ (http://oeecoach.com/)