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ORIGINAL ARTICLE

THE PREDICTION OF TIME TRENDING TECHNIQUES IN MANUFACTURING

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ABSTRACT – The paper writes about utilizing time trend predictive techniques to calculate an estimated prediction in machine setup application. The prediction is based on arithmetic equations to estimate a future time. With these techniques in place, time trend predictors are able to know an estimate time in setting up machine, which is a variable time factor, with known prediction limits. Based on actual data collected over a period of time, a time trend is perceivable. It is concluded that time trend techniques provide an estimate predictor, sufficient to know a rough value within a categorical limit. In comparison with probability and categorization techniques, this paper shows coherence findings. Machine setups are known of its variances due to human factors and other uncontrollable factors. These activities, mainly repetitive in nature during parts change or adjustment of parts, are done by trained personnel. The setups of the machine are difficult to perform due to the complexity of the machine. The tasks are able to be performed by skilled workers only. With the technical skills required to perform the tasks, it is unimaginable of the set time to setup the machine and the target achieved by the job performers over the years. The movements estimates, which is mentioned briefly in this paper, shows that it could estimate a time to reduce the work hours. Besides time trend techniques, estimating the number of movements can know the time to reduce the setup activities. The findings are reported as follows in this paper.

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INTRODUCTION

The search to find a suitable predictive equation, which can and could have helped in understanding the interpretation of data, requires research in various areas before it can be applied. An idea, thought and agreed upon by a group of researchers, remains th0061t it is falsifiable, which, if this happens, will mean that the data generated and the results published are in question. In making belief ideas that fail when it comes to actual implementation, a set of ideas is disproved to remove wrong thoughts that readers believe in. This would mean that the data collected or data analysis leading to a conclusion was wrong.

The machine, of Italian make, has gears, shafts, and a timing flange with oil as its lubricator and its cooling system. It runs on a single motor and multiple gear parts, timing shaft, vacuum erection, etc. Some of these are the same in the latest machine design. It is highly thought off with many considerations which look like the first generation machine, the use of limit switches instead of electronic cam timer. The machine is rigid and firm, with cast housing, polished shaft, etc. The gears are designed with proper thoughts of an absolute long life span. When machine setups are required to be performed, a team of skilled workers, with skills learned throughout its operation, performs the tasks with absolute certainty as the work is done completely - from initial start to the end; fit and run.

The work was done entirely well throughout the years of training and coaching by seniors. Although with hiccups and improper job tasks, the smooth workflow is fully paid-off with the co-operations of observant operators. The fitters and operators' work produced the results management was hoping for years of patience. Is that the record time? The paper writes with factual data on-time records achieved.

METHOD

In predicting a data set, the method utilised is critical to know whether it will accurately depict and consistently publish to determine its reliability. This paper calculates the possible prediction estimates from the observable trend. Time trending prediction technique based on moving averages or exponential smoothing, straightforward equations utilising two past data (moving average) or utilising a past and a current prediction (the first prediction value based on experience while the formula computes subsequent. See equations below) weighted (exponential smoothing), are utilised. This article compares two mathematical equations with probability and categorisation methods to determine whether the results are consistent. The curve shown here is close to a reducing exponential decay curve.

The two methods are simple to understand with the known errors to estimate a time. This paper discusses moving average or exponential smoothing techniques to calculate a prediction value compared with probability and categorisation

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techniques. This paper also discusses the possibility of *steep curves or step improvements* from the observed time trend. Two charts are developed to ease the understanding of this setup sub-routine.

Setup Time – The Actual Time Trend

What was unknown is that the time to set up the machine is taking too long, and there might be doubts about job performers attending to other tasks while the production is waiting for job performers to attend to the activity. The priority was set for the week and is critical to the team to meet the target to avoid a supply shortage. Production is nearly obsolete yet still in use, and the technology involved remains today. The new generation of the machine turns out to be another replicate of the traditionalist instead of a futurist view of change. The latest technology is included in the new packaging machine.

The old machine is firm and rigid, and the technology still applies today, with improvements brought into the new machine. Fig. 1 and 2 show the time achieved in this machine.

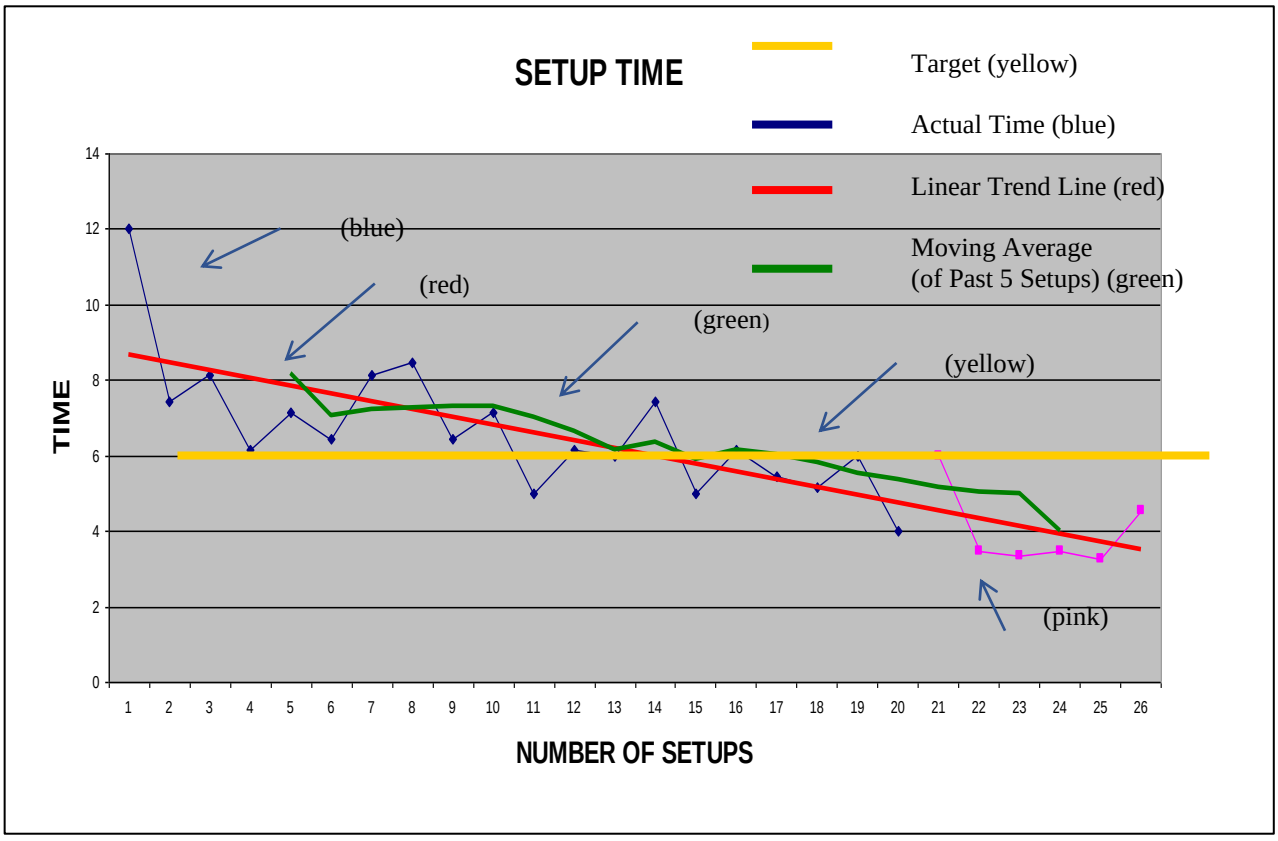

Figure 1. The Actual with a Predictive Technique

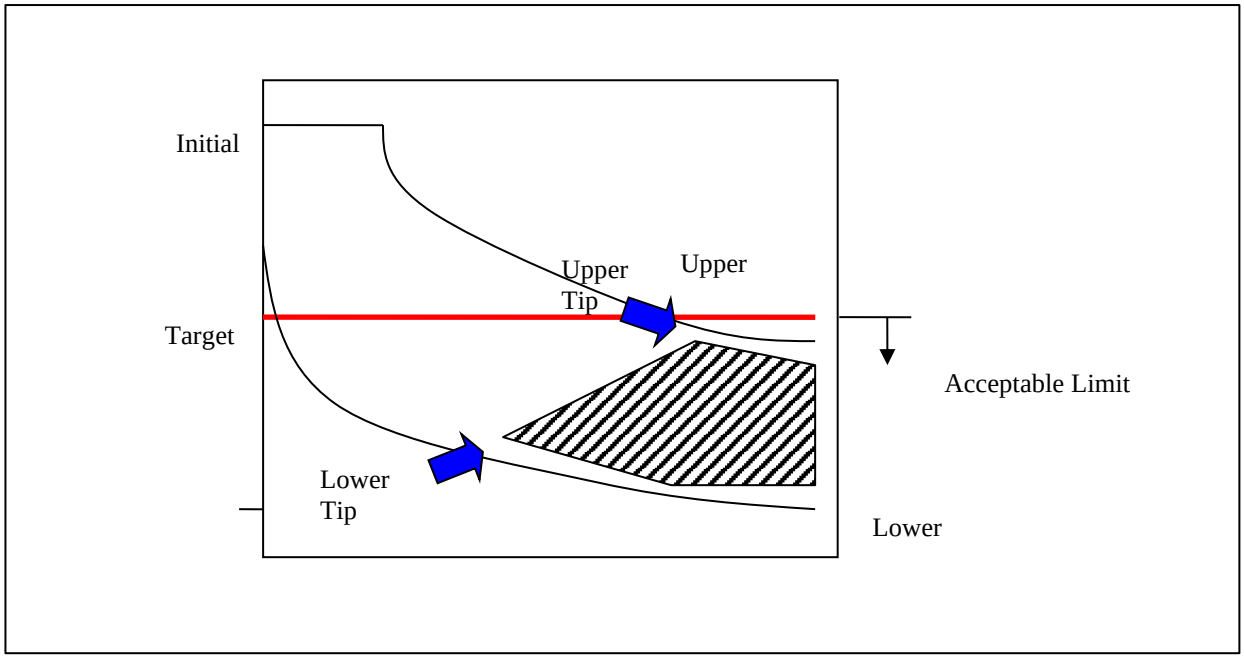

Figure 2. The Limits of Acceptance (Framework with hatches)

In Fig. 1, it can be depicted that the time reduces to a minimum, which cannot be reduced further. However, it is noticed that the target time is achieved. The setup time trends downward within the upper and lower limits. Fig. 2 shows the setup time behaviour of this machine as it reaches a firm setup time. This is as shown in the hatch lines. The gradient of the hatch line indicates that if setup time is reduced to the lower tip, then set up time is achieved on an earlier target than the upper tip. Ideally, the time to achieve is earlier for the upper tip. However, it is to be noted that this means exhaustion of the workers. This is discussed in the later section.

The Predictive Equations (Moving Average and Exponential Smoothing)

The following are two predictive methods to calculate the estimated prediction time. These methods are outlined and defined below.

Moving Average (MA) is the average of past facts. If there are two (2) observable times, then the average of the past two will be the next prediction value.

$T_{MA} = (T_N + \ldots + T_{-2} + T_{-1} + T_0) / (N + 1)$ - [1] ; where P_1 (the prediction value) is T_{MA}

Exponential Smoothing (ES) is the weighted factor of an actual past value and a future prediction value. An initial guess value of P_0 is required.

$T_{ES} = \alpha T_0 + (1-\alpha) P_0$ - [2] ; where P_1 (the prediction value) is T_{ES}

α Smoothing Constant

The prediction error is the difference between the actual and the predicted value. It is not possible to achieve a zero error.

Moving average technique estimated prediction time calculated as follows. The last actual recorded time is 4.55 hours. Therefore, the prediction estimate for this technique is 3.90 hours with a cumulative error limit of +/- 0.3 hours (approx. 20 minutes).

The exponential smoothing technique estimated prediction time calculated as follows. The last actual recorded time is 4.55 hours. Therefore, the prediction estimate for this technique is 4.84 hours with a cumulative error limit of +/- 0.2 hours (approx. 10 minutes).

A COMPARISON OF METHODS – A REDUCTION TREND BASED ON MACHINE SETUP TIME

Probability of Occurrence on The Time Trend

The result is shown in the graph below comparing the above techniques with the probability of occurrence in a defined range.

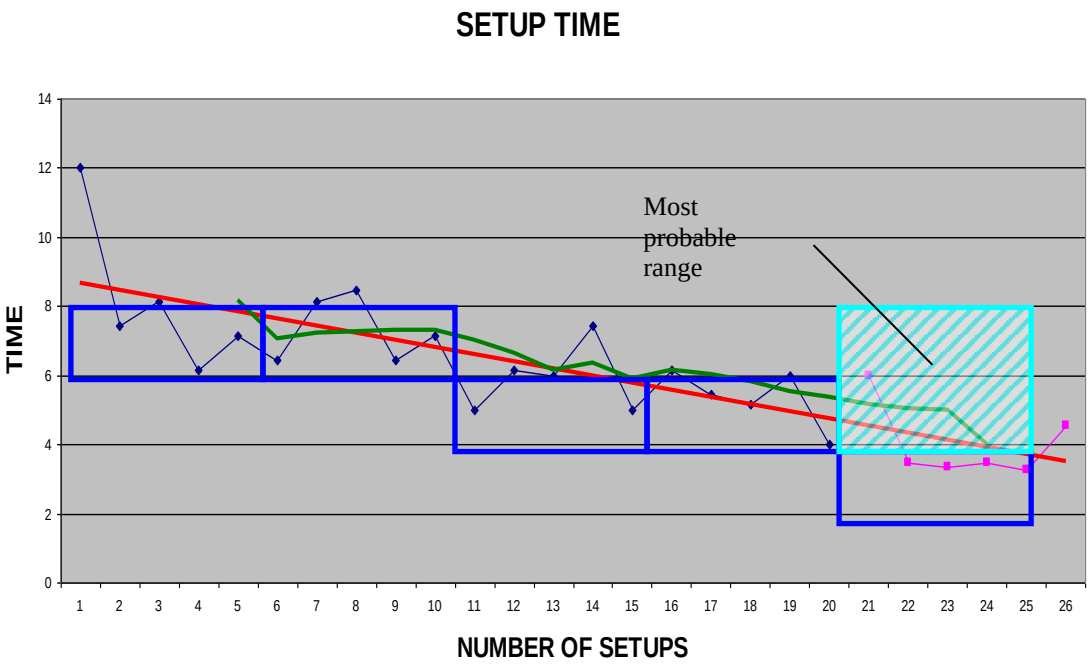

Figure 3. Most Probable Range

In the graph above, the most probable range is shown. The occurrences in each of the ranges are shown below.

Table 1. The Probable Range and Occurrences

Probable Range	Occurrence	
Between 6 – 8 hours	2	
Between 4 – 6 hours	2	
Between 2 – 4 hours	1	
---	---	
Probable Range	Occurrence	
Between 6 – 8 hours	2	mode occurrences 1
Between 4 – 6 hours	2	mode occurrences 2
Between 2 – 4 hours	1	
---	---	
Between 5 – 7 hours	1 (x4)	
Between 2 – 4 hours	1	
---	---	
Between 4.4 – 6.4 hours	1	see calculation below

Because most of the occurrences happened in the range 4 to 6 and 6 to 8 hours, with two occurrences in each range, the result in the most probable range is between 4 to 8 hours. A calculation of the average time shows that the average is between 4.4 to 6.4 hours. The calculation is as below:

Calculations:
Minimum Range: [(5hours x 4occurrences) + (2hours x 1 occurrence)] / 5occurrences
= (20 + 2) / 5
= 22 / 5
= 4.4 hours

Maximum Range: [(7hours x 4occurrences) + (4hours x 1 occurrence)] / 5occurrences
= (28 + 4) / 5
= 32 / 5
= 6.4 hours

The probability of a machine set up in this range is high.

Categorisation of Mode Occurrence on The Time Trend

In categorising the type of trend at an instantaneous time, straight lines are drawn across the actual time record to determine which category the setup activity is in. An average of equal division is applied here. This is shown in the graph below.

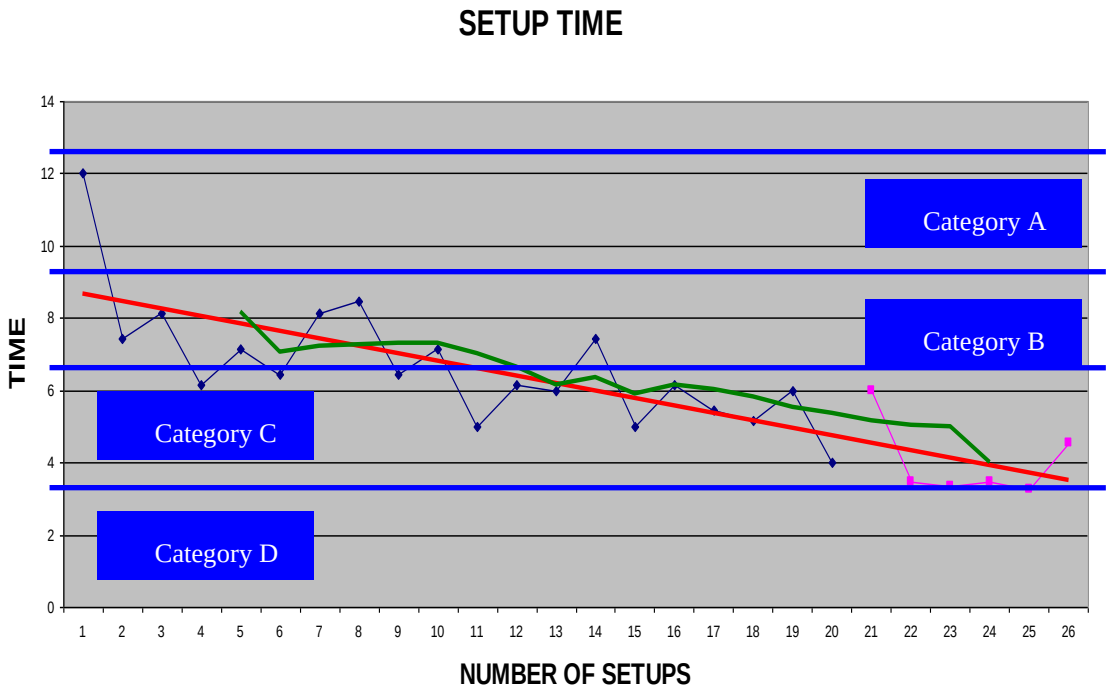

Figure 4. Categories of Setup Time

In this case, it is shown here that the behaviour of the time trend is reducing to Category C with the possibility that it will maintain within category C, as shown in Fig. 4. The mode occurrences in each of the categories are as follows:

Table 2. Occurrences in each of the categories

Category	Occurrence
A	1
B	9
C	16
D	0

Category A: 9 to 12 hours
Category B: 6 to 9 hours
Category C: 3 to 6 hours
Category D: Up to 3 hours

From the above Table 2, the mode occurrence based on the categories above is "Category C". The occurrence(s) percentage in each of the categories above is 3.9% for Category A, 34.6% for Category B, 61.5% for Category C, and nil for Category D. Category in access of fifty per cent shows a high number of occurrences.

RESULTS

Two arithmetic equations are utilised here to estimate a prediction. These two methods are straightforward with equations to refer to. The prediction error is simply the summation of the actual minus the prediction value. The other method of comparison is probability and categorical range. Probability is based on the number of occurrences in a defined box (or range, here defined as 2 hours time frame in every five setups). In this case, the most probable upper limit appears to be higher than the two-time trend technique mentioned here. The categorical range, here defined, is the mode occurrence, where the mode occurrence shows that the upper limit is within the target setting.

All three methods (time trend technique, probability and categorisation) show that the time has reduced to a certainty. Although there are instances where time increases after a reduction, the target time was met at the end of the project. This

results in functional modes. Repetitive tasks become a functional routine within the limit. The methods above show a consistent result of trend-setting. The overall achievement is accomplished.

Maximum and Minimum Time

The maximum time here is the maximum time taken to set up the machine. The minimum time is the minimum time taken to set up the machine. Based on graph Trend 1 above, the maximum time is 8.45 hours, and the minimum is 3.25 hours.

The maximum or minimum time is important to know because if the setups are achieved in a short duration, the job performer will be exhausted to perform subsequent setups. The quality of work is unimaginable because each time the machine is required to be set up, the job performers performing the work will not want to do the work again, considering the exhaustion involved. In addition, it will cause the job performer to raise the query of the unjustified change order. With regards to this observable trend, it is noted that there is a reduction in time as shown. The job performers cooperated with the operators and performed the tasks with considerable effort.

However, it is also noted that a maximum time is required to be known due to concerns about the unachievable target. The maximum time not to be exceeded is not seen in the trend due to a reducing trend. In the situation, as shown above, the reducing time trend shows the minimum achievable time not less than 3 hours. In case of sporadic occurrences, the target line is above to detect it. In the case of predicting the sporadic occurrence, it remains a factor that is not able to avoid, or an unknown, till it occurs. However, the three methods discussed confirm that the setup time is below the target line, assuring that subsequent setups will be within the target and under control. A gradual increasing trend is not noticed here. The target setting is discussed in the next section.

Target Setting

If the setup time is set too high, the machine will not be flexible. The number of machine setups will be less frequent. If a target is set too low, the job performers will be exhausted. What is a realistic target? Now that it is known that the trend is as shown, the target should be known.

It is known that two job performers will reduce the time by half. However, it is also required to know the path of the task. If it is a critical task, then ideally, two men will reduce the time by half. If two persons on two separate occasions can do two tasks, then two persons will reduce the time by half.

Studying the critical activities, the time can be reduced by a fraction of the total setup time. The time can be reduced after it is implemented to a certain extent, based on the number of movements.

The blue line in trend 1 shows the time before a minor modification along with the critical activity. The pink line shows the time after the change. For example, it is estimated that reducing four repetitive tasks to one in one of the sections will reduce setup time to 5 minutes of work simply by moving up the section using a chain block and slotting in a buckle pin.

The time recorded shows the trend before and after the modification. It is noticed that a target to reduce the time from 30 to 5 minutes resulted in the graph above. The actual time of an intended target setting of 25 minutes is recorded above. A time reduction is justified by an estimated time based on the number of movements, which concluded to an estimated reduction of 25 minutes of an actual approximate—the average time before the modification is 4.5 hours (approx. overall), based on x number of setups. The average time after the modification is 4 hours (approx. overall), based on y number of setups. A reduction of 1/2 hours.

The Possible Behaviors – Step Reduction or Steep Reduction

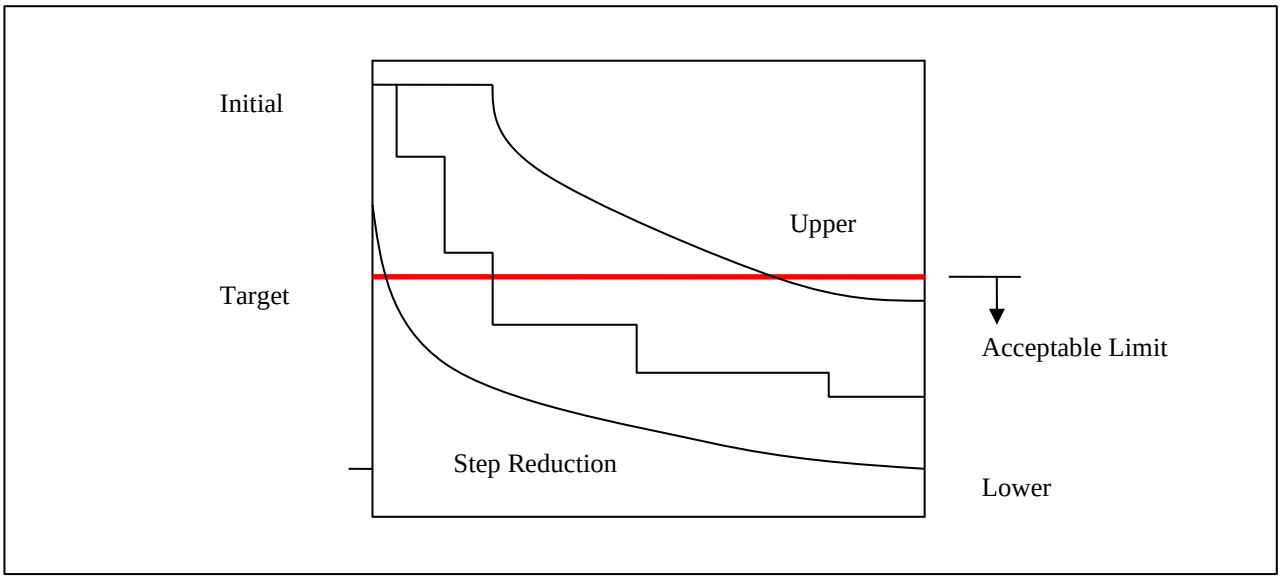

Figure 5. Step Improvements

Step Reduction - The above is a step reduction curve. Short vertical lines show a small reduction. Long vertical lines show huge step improvements. If there is an instance where an increment follows a step reduction, then it means that time has increased. Past improvements have countered reduction. The effort is lost due to work strain or fitters unable to attend to the activity. The step reduction above is charted within the upper and lower limits of a target time, representing the reduction.

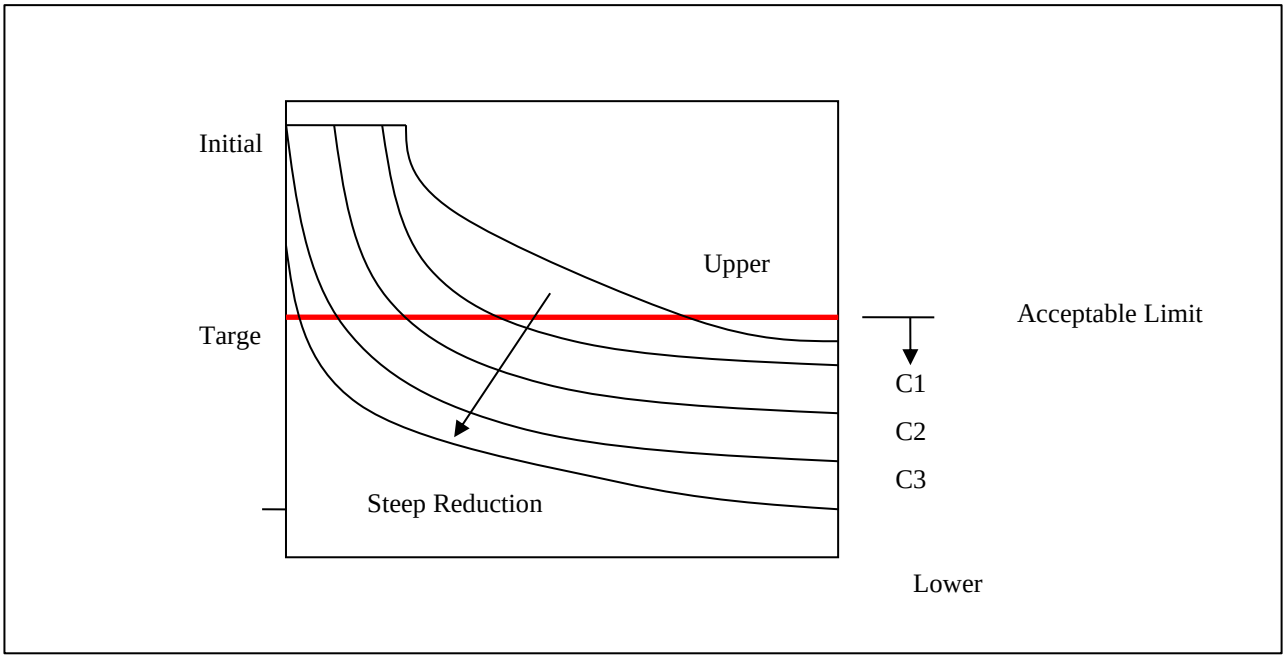

Figure 6. Steep Curves

Steep Reduction - The model above shows three possible types of reduction curves, C1, C2, and C3. All these curves show a gradual reduction, with C3 being the steepest. When a steep reduction is noticed, the time to achieve the set target is faster than a gradual reduction. C1 is the most gradual reduction curve in this case, whereas C3 is the steepest. All three are within the upper or the lower limits. All three characteristics are below the set target within a time frame.

The actual time is shown in Fig. 1. There is an overall reduction in time. At each time interval, the setup time sometimes reduces and sometimes increases. Overall, time reduces, and a reduction is observed. The curve shows a C2 type characteristic. Setup time is achieved below the target setting, within the upper and lower limits. The behaviour is considered to be gradual.

Movements Estimate - The number of movements can be listed on a sheet with the time to perform the work recorded besides the list of tasks. The critical path analysis method identifies the activity and hours of critical activities. By recording past work time, a time can be estimated for a new task. In this case, moving up or down a vertical section using a chain block and inserting a pin in a slot hole is estimated. The height to move up or down with precise accuracy can be known. Slotting in the pin or removing it if not required is only a relief job. Movement estimate is calculating the number of steps and estimating a time. So simple it is, the result is recorded and plotted in Fig. 1 above (blue and pink trend).

CONCLUSION

In conclusion, it is noticed that improvements along the machine are required to reduce the machine's setup. The intended reduction was reduced and achieved during the duration of the project. Remarkably, these changes have impacted the requirement to perform the calculated number of work tasks to estimate a reduction based on the number of movements. The actual is seen in the graph above.

In order to predict an estimated time, it is required to set a reasonable target and achieve the intended purpose by calculating the number of movements in a setup. As a result, as shown in the graphs above, the estimated time reduction of 25 minutes is shown by the difference between the blue trend and the pink trend.

Utilising time trending techniques and equations to predict returns at an estimated time. The number of tasks (movements estimate) will identify the items to reduce and to know the actual later. The estimated time as calculated is compared to other techniques, probability, and categorisation. The results show consistency within a range.

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CONFLICT OF INTEREST

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Author Professional Bio (not more than 150 words): I am a licensed engineer, registered with the Board of Engineers Malaysia. I worked in the general industry as well oil and gas industry – more than 16 years. As a contributor in this value economy, writing articles to magazines (e.g. Supply Chain Asia, Singapore), conduct talks in local institution (e.g. Malaysian Institute of Management MIM, Institute of Engineers Malaysia IEM), and publishing papers on Journal in NIOSH, Malaysia is unusual to me, with my experience in these few esteem areas. I obtained my degree in Mechanical Engineering in the University of Manchester, UK (BEng, 1996). Thereafter I complete my Master in Manchester School of Management, University of Manchester Institute of Science and Technology UMIST, UK (MSc, 1997). I have awards from this University linked to Ford Motor Company in Design subject, also a price winner in Fluid Mechanics throughout the undergraduate degree program, where my experiments are in aircraft industry.