Optimising the use of rolling plant capital equipment - Improving plant output

By Dan Miller, Senior Process Engineer, Innoval Technology Ltd.

In trying to maximise the output of a plant, most companies will collect requests for new equipment or upgrades and assess these in terms of the strategic and business objectives of a plant. One of the difficulties is how to decide between the conflicting demands of the different stakeholders and to ensure that the demands for new equipment can be fully justified. Strategic objectives might include responding to increased demand, the protection of existing markets, or the entry into a new market through the introduction of a new product. All these could require new or upgraded equipment. Business objectives which might necessitate similar action include the reduction of costs by minimising inventory (work in process) and minimising energy utilisation. This is frequently done by looking at likely increases in output that can be obtained without compromising product quality and without adding to the direct costs of production. The utilisation of the existing machinery is frequently used to decide whether to improve one piece of equipment or to purchase new equipment. If the utilisation is close to the engineering value and there is perceived growth then new equipment seems to be an obvious route forward. By definition, utilisation is the ratio of the number of hours used on a piece of equipment compared with the number of hours available. The number of available hours often excludes planned downtime such as scheduled maintenance time. This can be applied easily to a major piece of equipment, but how can this be extended to apply to the plant as a whole? One way, as will be illustrated later, is to recognise and understand the impact not only at the machine centre itself but also on the downstream processes.

Utilisation is used when calculating capacities. Capacity calculation for new equipment (and for any major upgrade) is often supplied by a manufacturer as part of their supporting documentation for the provision of equipment. Once supplied, the numbers tend either to become targets for production, or if the capacity never seems to be realised in practice, the capacity is adjusted pragmatically and this latter number becomes both the target and the limit for that machine.

However, all capacity calculations have inbuilt assumptions that should be explored. If the calculation comes from a supplier, it is bound to represent an extreme i.e. a calculation done to show that the original enquiry targets are met or perhaps to entice a customer with the prospect of more output from a machine centre. For this reason, they frequently use maximum speeds, minimum handling times and minimum planned downtime. Calculations are generally done for a select product range which, after a few years, may not be representative of the current product mix in the plant. When market conditions alter significantly (as has been seen recently during the recession) the capacity of the equipment should be recalculated. Improved circumstances seldom mean a return to the status quo, and so the product mix becomes permanently altered.

Table 1 below give some examples of how the capacity of a cold rolling mill producing industrial sheet products alters from a base case scenario when parameters partly within the plant's control deteriorate. As would be expected, a change in yield (more scrap produced), a reduction in mill speeds or an increase in handling time all reduce the machine's capacity. What is often forgotten is that the change in average exit thickness can be even more dramatic, and the exit thickness may simply be a response to market conditions.

When using such capacity values, the real plant performance must of course be assessed. The differences from the theoretical values need to be explored and explained, for they can often identify opportunities for increased output without the need for major capital expenditure. Plant audits and benchmark studies provide some objectivity, and carrying out such activities provides a structural approach to problem identification. These have the added advantage of checking that the data used in the calculations are robust and reliable, and are not found by ensuring the sum of components equals 100%! Comparing with what has been historically achieved may give some clues. It is important to identify the biggest gaps between the values that are achieved in practice, and those that could be calculated from the engineering-based values. Where external data or outside consultants are involved, additional questions about how this plant compares with similar ones and, in particular, what the gap is between current performance and world-class performers can also be addressed These answers need to be carefully examined because it is important to know how much of the differences seen relate to people, to automation or to the equipment itself. People are an important asset and their experience and knowledge is a big factor in achieving the best from equipment. Improving skills and methods can often achieve a significant improvement in output. If operations are not standardised and the people not properly trained in the procedures, there can be performance differences between shifts. Equipment automation may not always be optimised. In terms of equipment, the mill may not be running at its maximum speed. There may be reasons which prevent this, such as quality problems as a result of excessive vibration or a failure of handling equipment to 'keep up', and these all need to be investigated.

A typical arrangement for a modern cold mill is shown in Figure 1. There are several features that can be expected from a reputable supplier. The correct design of the mechanical and thermal actuators on the mill for the product range is expected so quality parameters such as gauge and flatness can be achieved not only in the body of the coil but also during speed changes. To ensure this and to cope with product changes, good set-up models are essential and are generally provided by all the major suppliers. Effective coil preparation (ensuring the head of the strip is correctly trimmed and there is no surface damage or buckling that both affect threading) and optimised coil handling minimises the time between rolling coils and this has a big impact in terms of the capability of equipment. It is therefore expected that rapid roll changing facilities, coil preparation and efficient spool and coil handling are included in the initial design, rather than considered after the mill itself is installed. These are often seen as supplier requirements, but the plant must ask the right questions when looking at new or upgraded equipment. With all this in place, not only will the plant output be maximised, but the soft factors that inhibit speeds being reached – vibration or fear of strip breaks – will be eliminated.

One factor that remains solely within the plant's control that is important in optimising the use of the equipment, is the way in which scheduling impacts on quality. There is a requirement to use process-based scheduling rules in order to minimise the detrimental effects the change of product has on the quality of the next coil. This can be most easily illustrated when looking at the strip profile (the thickness variation over the strip width, frequently characterised by the strip crown – the difference between the thickness near the centre and that near the strip edge). Strip profile is fixed by the end of hot rolling, but it has as profound an impact on the finishing operations, such as recovery of multi-slit coils or the generation of off-line flatness, as final gauge. Consistency of profile is a very important factor, but it is known that product changes during hot rolling will produce a transient change to the crown values. This can be seen in Figure 2. As this is predictable, it should be possible to include such effects into scheduling rules. However, to achieve this requires good measurement or model prediction of profile to allow profile based rules to be included with the other more common scheduling rules such as those for strip width. Figure 3 shows the measured crown errors during part of a shift, some of which are quite large and thus detrimental to final product quality. Figure 4 shows what could be achieved if the impact on crown is included. The same set of coils is still rolled by the hot mill, but by changing the sequence of coils the overall profile error is much smaller.

Profile is a quality dimension; the equipment itself is a capacity dimension. Techniques that combine such factors are extremely powerful in identifying where resources, including capital spend, should be concentrated. One such technique is overall equipment efficiency (OEE) which was developed through the 1970's at Nippon Denso as part of a Total Productive Maintenance approach. It combines availability, performance and quality through a series of parameters. In a rolling context these can be adapted and a set of parameters defined such as breakdowns, set-up times, mill stops, reduced production speeds, scrap at start-up or end of coil and in-process scrap.

The technique looks at how the available time for producing good material is reduced through the various stages, and seeks to reduce the amount of "lost" time. The contributions of each type of loss are illustrated in Figure 5.

The overall measure of OEE is a multiplication of availability, performance rate and quality rate. Availability measures the amount of time the machine is producing product (the 'up time'). Performance measures the output rate of the machine. Quality measures 'right first time'. All three measures are expressed as percentages, and so can be multiplied together. Availability is affected by scheduled and unscheduled down-time, by set-up time and by any calibration procedures. Performance is affected by minor stoppages, by any idle time and by not achieving maximum speed on the equipment. Quality is affected by defects in production, by reduced yield for a product and by any customer returns.

Though this seems a little theoretical, these approaches are not too difficult to implement. Innoval Technology, as a group of independent technical experts, is often asked to perform audits on rolling mills. As the following examples from their work illustrates, output improvements can be obtained without capital expenditure.

Figure 6 shows an example for a hot mill, where of course handling time is important. The initial study took three months, during which a detailed analysis of coil movements, mill set-up and general handling was made. From this the study identified the key points for improvement. It also estimated what the benefit might be. As can be seen in the graph, the expected benefits were exceeded. Moreover, the timescale to achieve the benefit was comparatively short, and in this case, the capital expenditure was relatively low.

Figure 7 shows an example for a cold mill operation. In this example, there were no changes in the normal solutions to increasing output: there were no changes in the equipment, in the product mix, in the pass speeds or the reductions taken. What was done in this case was to identify where the bottle-necks were occurring and to recognise that a great deal of the problem lay with the large process variability. Tackling this through improving operator skills and increasing the visibility of the mill performance led to an improvement in consistency. Once the performance was more consistent, then changes in procedures for coil handling led to the improvement in output.

What becomes clear in these types of audit is that no single measure should be considered the driving force for improvement. The standard metrics of productivity, utilisation and quality (both specification limits and the more intangible customer satisfaction) need to be combined. Coupled with these external measures is the need to keep costs down through efficient use of staff, minimising any re-working of products, and low energy usage. When equipment approaches optimal conditions, then the purchase of new equipment becomes self-evident, thus making best use of the capital employed. OEE or similar techniques combine the key plant performance indicators into quantifiable targets and these are extremely powerful in driving up output. In this it must not be forgotten that process knowledge enables the prediction of the impact of product changes. This can be embedded in other systems, especially in mill scheduling where there is a big impact on quality and hence in overall output. In this way significant performance enhancements are achievable without the need for major capital expenditure. Innoval Technology can work with plants to ensure that current equipment is optimised before a decision to invest is made.

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Innoval Technology Ltd provides high quality consultancy and technical support to investors, manufacturers and end-users of aluminium and other selected engineering materials, across a broad range of industry sectors. The company, based in Banbury, UK, and employing 26 people, holds ISO9001:2000 certification and ISO17025 accreditation.

Varying parameter	Base case	Average exit gauge	Product yield	Mill speed	Average handling time	Units
Av. exit gauge	0.59	0.49	0.59	0.59	0.59	[mm]
Yield	85	85	80	85	85	[%]
Mill speeds	100	100	100	90	100	[% of expected]
Handling time	5	5	5	5	7	[min]
Capacity	119	99	112	95	94	kt/year

Table 1. Sensitivity of capacity to key parameters

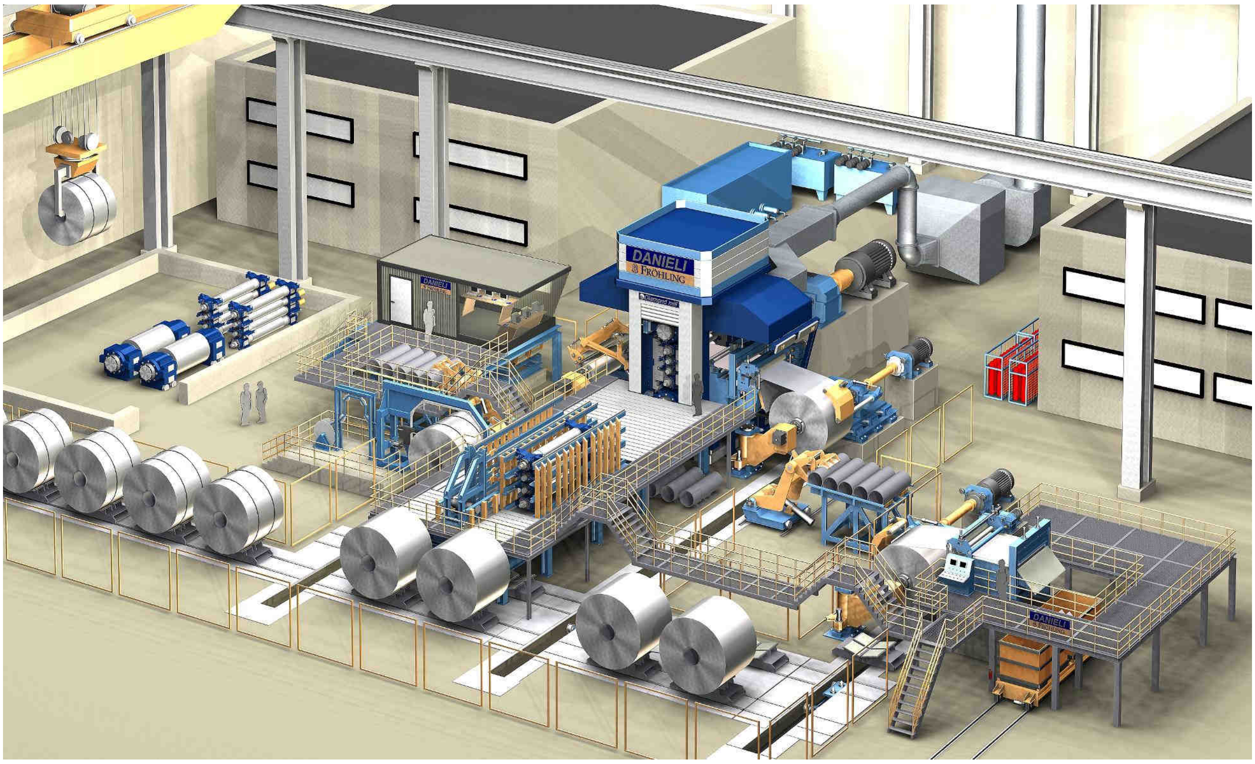

Figure 1. A typical mill design and layout from a good supplier

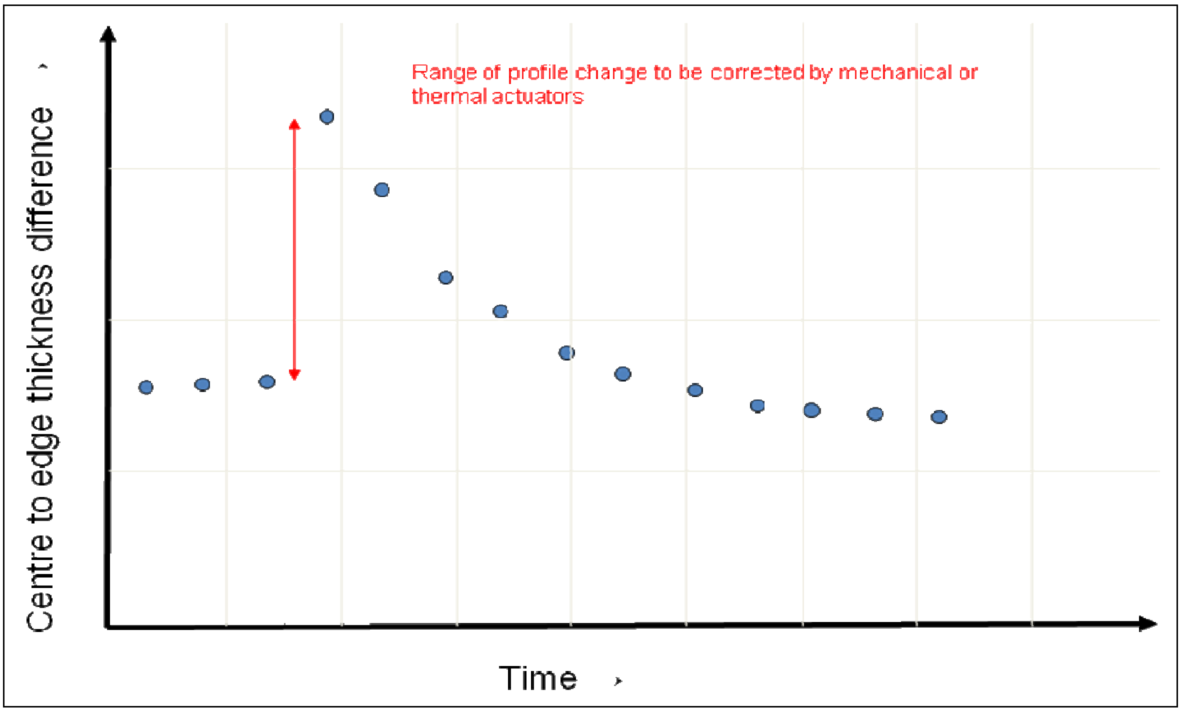

Figure 2. Predicted changes in crown due to a product change in width

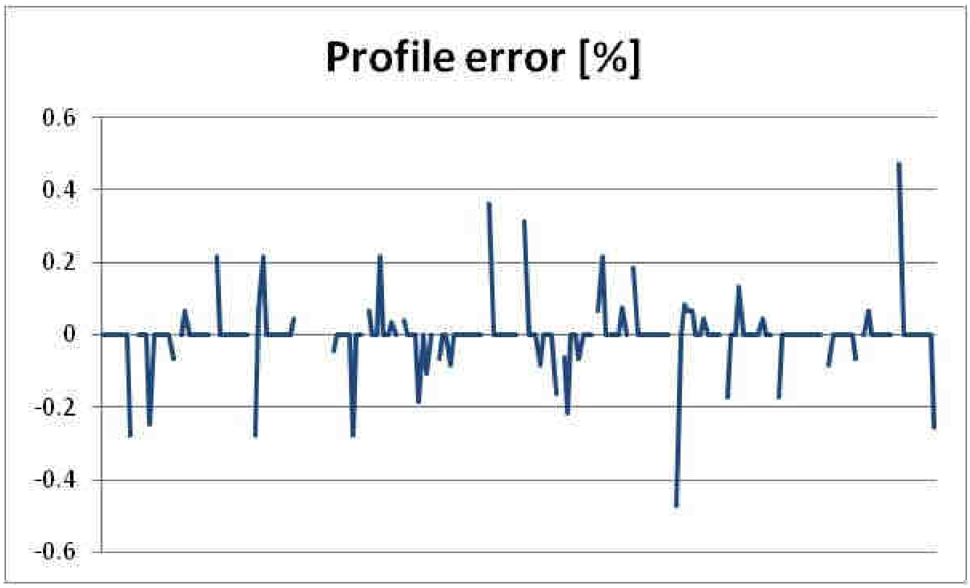

Figure 3. Profile errors (deviation from target) produced during a sequence of coils on a hot mill

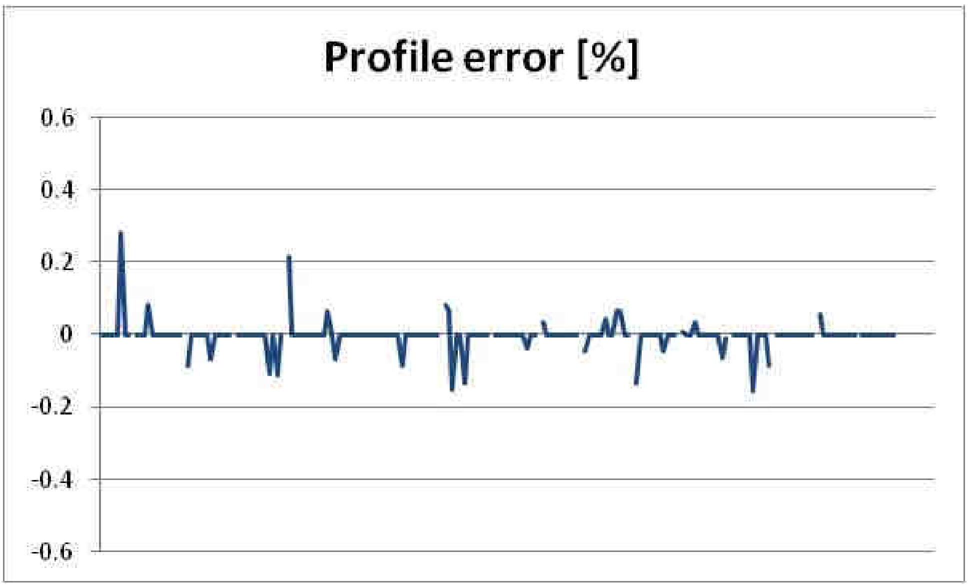

Figure 4 Simulated profile errors produced by re-arranging the sequencing of the same set of coils

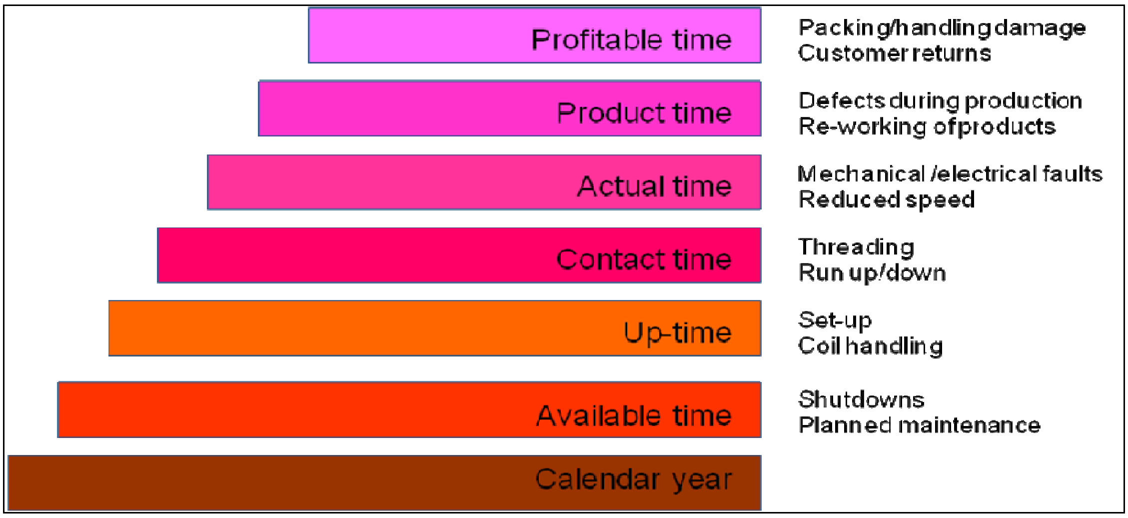

Figure 5. Attacking value through OEE mill studies

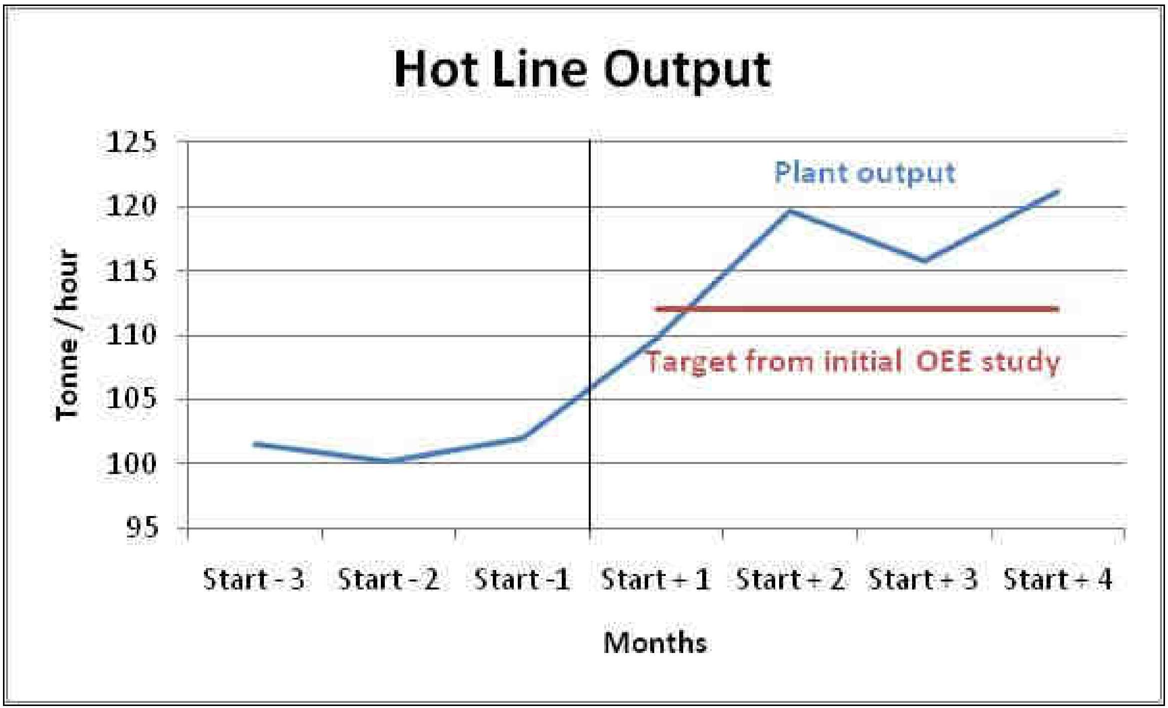

Figure 6. Implementation of a hot mill OEE improvement program

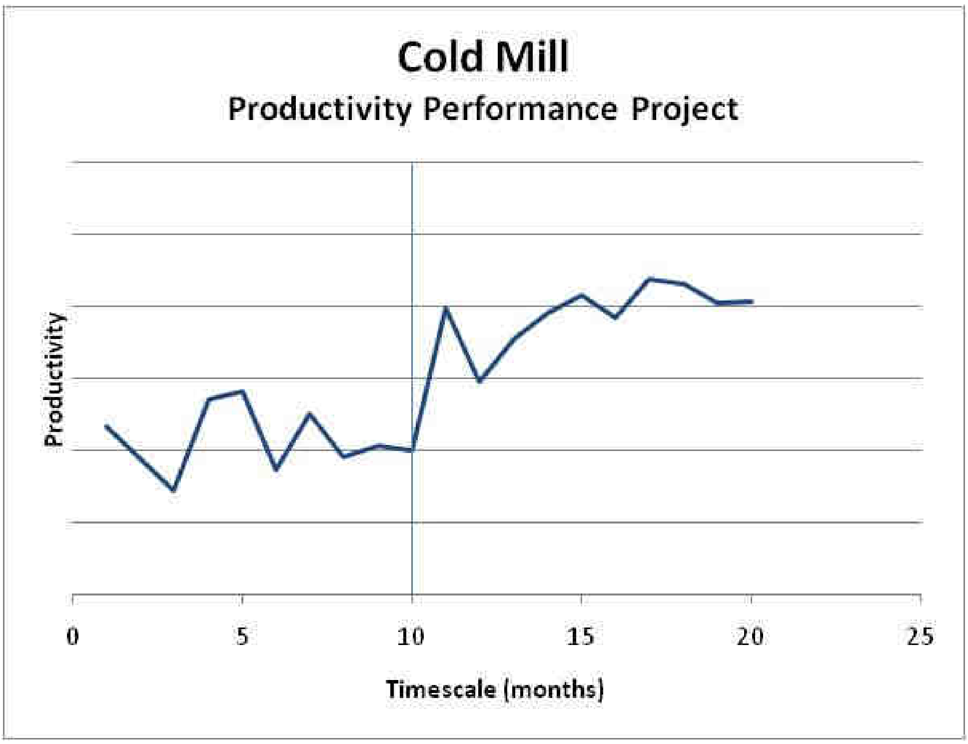

Figure 7. Example of productivity improvement through practices