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Trending Towards Continual Improvements in Manufacturing Operations

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ABSTRACT

In this ever-changing world, we perish if we do not change with changing times. In manufacturing also rapid changes are happening. Changing for better-"Improvement" is the keyword now. This paper deals with improvements in Manufacturing. We shall dwell on understanding the meaning of improvements- continuous/continual, shall learn the difference between these two terms and shall then demonstrate how continual improvements can be injected into major components of manufacturing operations. I hope the tips provided will go a long way to help entrepreneurs in improving the manufacturing operations of their business. Ready-made templates are also provided which would ease up their continual improvement efforts. I hope the paper serves its intended purpose of ushering in continual improvements in manufacturing sector, especially in entrepreneurially run traditional units.

Keywords: *Improvements, Continual And Continuous Improvements, Improving The Manufacturing Process, systems in manufacturing*

Change is universal! We live in a dynamic world where nothing is static. The whole world is changing from moment to moment, be it environment, time, or living species; transformations are visible everywhere; mother nature is continuously evolving.

Humans have come a long way from a primitive way of living in caves to residing in palatial comfortable cozy abodes! Gone are the days when humans survived only by preying on animals; the humans have evolved and survived because of their capacity of changing with times whereas the other species who could not adapt to changes have become extinct. Gone are Dinosaurs and in recent times sparrows have become extinct!! When we were kids, the sparrows would daily enter our houses and chirp but today they have become extinct—maybe they could not adapt to the changing environment due to emissions of rays from satellite towers. The will to survive has made humans to adapt and change with times and we are still throbbing with life. If we did not have the

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will and capacity to go for a needed change, we all would have succumbed to recent Corona pandemic and mankind would have vanished like other species. We had the will to fight it and this will made us discover vaccines and we made the needed changes in our way of life by going in for social distancing and made wearing masks a way of life. The work from home was another major change adopted by us. We have been adapting to the changes which mother nature springs before us and we continue to improve and evolve.

Change is the most vital aspect anchored for very existence of each of us and also for our businesses. The writing on the wall is clear that you will be washed away if you don't improve and adapt according to changes happening all around. And manufacturing operations are no exception!!

In the fierce age of cutthroat competitions, organizations die if their manufacturing operations do not keep on improving their processes by eliminating unnecessary wastes, improving productivity, and minimizing costs. Without improvements, the organization attains stagnancy and in course of time, others enter with improved methods and processes and the stiff competition from better competitors forces the traditional units to close down. If you have to keep alive and vibrant in the business, you must have systems in place which take you on a ***"Continual Improvement"*** path.

If you are a keen observer, you would have noticed that the topic of the paper and the above sentence talk of ***Continual Improvement*** and not ***Continuous Improvement.***

In this paper, we shall understand these terms and shall learn difference between these terms and shall discuss why Continual Improvement is preferred over Continuous Improvement and shall demonstrate how can we make traditional units converted to dynamically improved system-oriented professional units through installation of effective Continual Improvement Systems in the manufacturing operations of a company. We shall give a demo using the developments happening in a Rigid Plastic Package Manufacturing unit and the systems designed for them can be suitably modified and applied to other manufacturing operations as well.

I, once again, reiterate that if a business has to remain a leader it must have inbuilt continual improvement systems which go on adapting to changed situations, else, the monster -the competition would swallow the business and shall make it extinct.

Let us now understand the terms, "***Continual / Continuous Improvements"***
Continual Improvements vs Continuous Improvements"

William Pollard said, "Without change, there is no innovation, creativity, or incentive for improvement. Those who initiate change will have a better opportunity to manage the inevitable change.

Change, as we know is inevitable and when it is inevitable, why not we ourselves make it happen and be its guiding factor. Change we must and must for continual improvement! We may not achieve excellence but we must continually strive for improvement. Rightly said by Tom Peter, "Excellent firms don't believe in excellence - only in constant improvement and constant change."

Thus, we see that since nothing is constant in this continuously changing world, we must adapt ourselves and must keep pace with change. We can become leaders in our fields if we keep on changing by improving our processes. The improvements could be ***"Continuous"*** or could be ***"Continual".***

Let us now understand these terms:
ISO talks about Continual Improvements[1]: -

> *Continual Improvement is defined as a recurring activity to increase the ability to fulfil requirements.*

The standard requires the organization to continually improve the effectiveness of the quality management system through the use of Quality Policy, Quality Objectives, *Audit* Results, Analysis of Data, Corrective and Corrective actions, and Management Review. Let us see what do the management thinkers say about these terms.

Jon Miller[2] posits the following views: -
"*Most organizations implementing lean principles today do not in fact practice "continuous improvement". What they practice would be better termed "continual improvement". The distinction between continual improvement and continuous improvement is a fine but important one. Continuous means "without interruption" while continual means "frequent, repeated or seemingly without interruption". Continuous is "go go go…" while continual is "start-stop start stop start…" Continual improvement is far better than no improvement at all but it is far from world-class and not the aim of lean.*

I could not comprehend the real difference between "Continual" and "Continuous" because Miller is not able to clearly bring out the difference. Let us see what others say: -

Admin[2] gives a detailed account of the terms –
Continuous improvement *is a technique used for improving the efficiency of the process by eliminating waste and non-value-adding activities. This was practiced through various Japanese concepts like Lean, Kaizen, 5S, etc. Continuous improvement is an ongoing effort used in developing products, services, or processes.*

Continual improvement *is about identifying and making changes that would result in better outcomes which is a central concept to quality management theories. With regard to ISO 9001 framework, continual improvement must be an essential requirement of the organizations.*

Difference between Continuous Improvement and Continual Improvement: -
Although these two terms sound equal, there is a difference between continuous improvement and continual improvement.

- Continual improvement is a concept initially introduced by Dr. Edward Deming, to make changes and improvements in the existing systems to produce better outcomes either by adopting new technologies or methodologies.

- Continuous improvement is a subset of continual improvement, with more focus on linear, incremental improvement within the existing process. Kaizen, 5S, and Lean are some of the continuous improvement techniques.
- Both these concepts are concerned with improving the quality of the process and thereby increasing the productivity of the organizations."

Careful examination of what is said above makes us more confused about the real difference between the two terms. What it conveys to us is that both are attempting to improve the working of an organization and continuous improvement is a subset of continual improvement; meaning thereby that Continual Improvement is supreme and continuous improvement is only a fragment of continuous improvement. The author comments that Kaizen, 5S are examples of continuous improvement. But what is the difference between the two terms concerning improvement is not well laid out.

I do not agree that 5S is a continuous improvement technique—to me, it is a Continual improvement technique. I shall elaborate my views later; first, let us see what others thinkers have to say.

A paper published by Learn in Hub[3] gives the following views: -

> *"The words continual and continuous are like twins: they both come from continue, but they get mad if you get them confused. Continual means start and stop, while continuous means never-ending.*
> *Though when we talk concerning improvement…The adjective* ***continual*** *describes something recurring, that happens again and again.*
> *The adjective* ***continuous*** *describes something that occurs over space or time without interruption.*

A critic in Miller's paper counters Miller's views which is a counter to the above meanings of the two terms --Just because an improvement program is never-ending, it isn't continuous. The simple fact is, there is no such thing as "continuous" improvement, and I wish that the word "continual" (which is more appropriate) was used. Even so-called examples of "continuous improvement," in Miller's paper are in fact, continual. Continuing the discussions of the paper by Learn in Hub: -

Continual Improvement-- *A major premise of a* quality management *environment is based on continual improvement. Plan-do-study-act cycle, or the PDSA cycle, is an iterative approach to do the continual improvement. (Dr. W.E Deming's PDSA uses S-Study instead of C- Check of Shewart's model PDCA)*

> *Once we have achieved an improvement, we take steps to maintain and sustain the improvement and then we start to look forward to the next improvement milestone.*
> *This leads to a new PDSA iteration….and this way the PDSA goes on and on…that is why it is a way of continually improving.*
> *Meaning, improve, set better standards, do PDSA, improve again, set further better standards…and so on so forth.*
> ***Continuous Improvement***

We can comfortably say that continuous improvement is a subset of continual improvement. The term 'Continual improvement' also *includes room for discontinuous improvements (innovative or radical improvements, such as in the lean manufacturing movement). Continuous improvements are linear, incremental improvements to an existing process.*
Let's take the example of Lean six sigma. *It is a way of continuous improvement. We identify a problem area, apply Lean six sigma, make improvements and conclude the project."*

The above does make sense. Indeed, continuous improvements are linear, incremental improvements to an existing process. On the other hand, continual improvement is an iterative approach to Plan– do– study- act cycle. Once we have achieved an improvement,

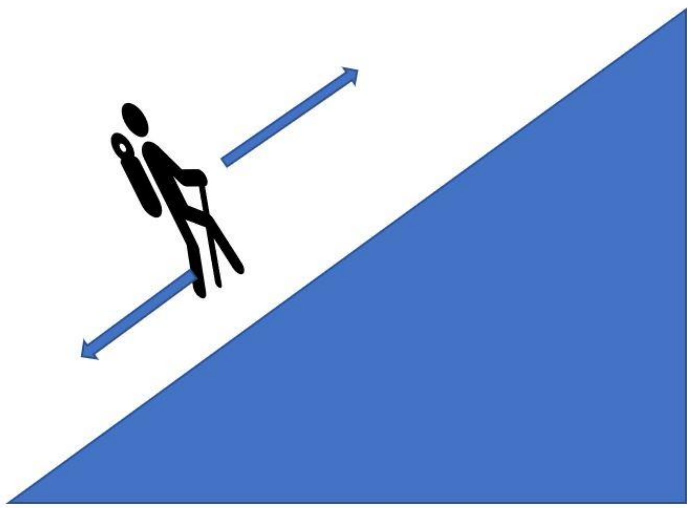


Figure 1: - Continuous improvement path

we take steps to maintain and sustain the improvement and then we start to look forward to the next improvement milestone. The above concepts will be clear by the pictures given above and below: -

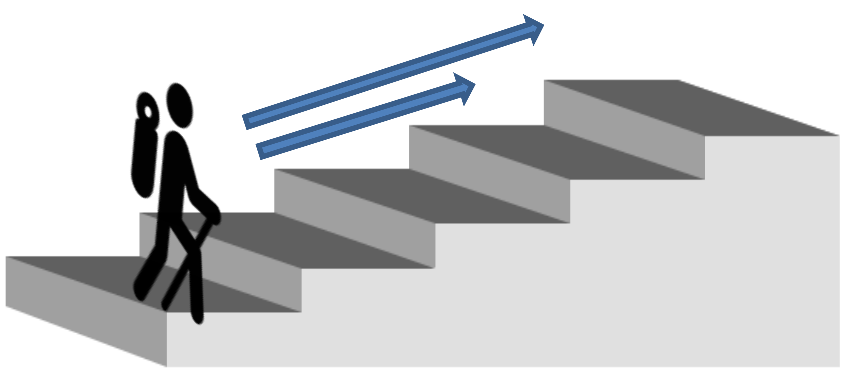


Figure 2—Continual Improvement Path

I hope the pictures bring out the conceptual difference clearly and prominently.

Continuous Improvement

Continuous improvement (see figure 1) is like climbing a slope, the position on the slope indicates the levels of improvement you have achieved. The picture shows that person is just starting to make improvements and with newer improvements, he goes up and up on the slope, and the higher he is on the slope, the higher are the achievements. His movement is upwards but there is always a fear that having climbed a height on the slope, he may slide down, and hence improvements achieved can be lost as he slides down the slope. This is because there is no anchor to hold him to the level he has reached, so he can move forward as well as can slide down. One more thing is evident that at any level, he cannot be stationary, he will be constantly on move (either forward or backward) because of the gradient of the sloping path. Thus, in continuous improvement, we can never say that having reached a higher level we shall maintain or improve the level, we may suffer a downfall and our performance level can decline. It is like we achieved an improvement by fluke and in future, we may not, again, achieve the higher level. Take the example of kaizen we go on doing small improvements but since there is no mechanism to sustain the achieved improvements we may slide down and lose the benefits of improvements. Another example would be setting up the machine by randomly adjusting parameters; and combination of parameters may lead to a cycle time which takes you to a record production but since the combination was a random permutation of process parameters, we may not achieve the same combination in future and shall slide down in productivity.

I remember a real-life incident in a glass factory where I happened to work. American visitors were, once likely to visit the factory and we worked hard to make the factory presentable for the visitors. No oil on the floor (normally the floor area near the machine was full of oil which got accumulated as process needed that mould oil be swabbed regularly on moulds to provide the needed lubrication). Cleaning efforts made the whole shop floor neat and clean and gave it a lovely look.

You will be amazed to note that on the day of the visit and till 3-4 days after the visit, the production efficiency of the plant increased by around 5%. But as the days went by and we reached our normal working with the shabby shop floor, the production efficiency slid back to the normal level.

The above is an accurate befitting example of ***Continuous Improvement***, where the improvement achieved could not be sustained.

As the arrows indicate in figure 1, the improvements can move in a positive direction but there is always a fear that the movement can be downwards and improvement achieved gets lost. Truly said by Miller, Continuous improvement is “go go go…” because on a slope you cannot be stationary, you have to be continuously on the move so "go go go…" either up or down!!

Continual Improvement

While continuous improvement is to go, go, go…; the continual improvement is to start, stop, start, stop, start…

The climbing on the improvement path is not similar to climbing on a slope but is similar to stepping up on stairs.

In PDSA cycle we plan, do, study and act. The Continual Improvement is done by ***planning*** for improvement and then we ***do*** take a step to climb the improvement ladder, then ***the study*** is done to assess where we have reached and anchor the improvement on the achieved step of a ladder so that there is no sliding back. We analyse and ***act*** to anchor ourselves on the improved stage, thus, ensuring that no sliding back occurs as was in case of continuous improvement. This completes the cycle of PDSA and iteration of this cycle begins when we ***plan*** the next improvement and ***go*** for the do stage and climb another step on the improvement ladder. Having landed on the next step, we ***study***, analyse and find out a way to anchor ourselves on the second ladder and ***act*** with actions for anchoring which prevents us from sliding back from the second step of the improvement ladder to lower steps. Having completed the second iteration of PDSA cycle we have reached the second step of the improvement ladder firmly anchored there preventing backward slide. The next iteration will take us to the third step and then to the fourth and so on…

Reaching a step makes us stop there and take actions for anchoring there with only forward movement possible and no sliding back and 'start' for next step. So, we start, stop, start, stop …and the iterations of PSDA keep up the continual process which has only forward movement and no downward slide!!

Consider the example from continuous improvement where we randomly reached a combination of parameters which resulted in high productivity but we could not sustain the high level because we could not replicate the same combination in the future because the combination was got randomly. We could have avoided a continuous improvement approach and go in for continual improvement; here is how: -

We may have, say, five parameters for setting up the machine- A, B, C, D, and E. Continual improvement in productivity will be done in a systematic structured way. First, we note existing parameter values at which the machine is operating. As the first step of continual improvements, we keep parameters B. C, D, E constant (at existing levels) and make changes only in A and watch its effect on production quantity and vary it and see an impact on production quantity and reach a level which yields high production and if any further change is done in the level of A it results in lower production. Thus, we reach a value of A which gives the highest production. We freeze this level of A as the final setting level of parameter A.

Next, we take on parameter B for making changes while keeping the A parameter at the above-frozen level and all others C D, E all at old levels. At this stage, we have climbed the first step on the continual improvement ladder and PDSA first cycle has anchored us on the first step. We do the second iteration by changing B only and reach a further improved level higher than the one achieved earlier and we note down the parameter values of A and B which with other constant parameter values of C D and E. This will anchor us on step 2 of the continual improvement ladder. Now following same process, we shall go for optimizing C D E in the same manner. We continue PDSA iteration by keeping new A and B fixed and make changes in C and reach a combination that takes on a higher level of production and then for anchoring we note down changed A B and C keeping D and E constant. The same steps are repeated for D and E and we reach the best combination of changed A, B, C, D, and E which maximizes the production. The combinations which were taking us on higher levels were noted at each stage and the final combination of the parameter is frozen for future use and we shall be maintaining the highest level of production if we set the machine at the newly arrived combination of parameters. There will be no sliding back. In normal situations reaching the most optimal combination of parameter levels of A B C D E, parameters are not so simple due to interaction effects between the parameters and we may have to use the complicated design of experiment techniques to arrive at the optimal combination of parameter levels.

The crux of the issue is that the optimal parameters are reached in a systematic way and if at any time these parameter levels are used for setting the machine, the production yield will be highest and we shall never be sliding back to lower production. Thus, we would have done a continual improvement. The continual improvement, in this case, is achieved through a systematic process of reaching an optimal combination of parameter values instead of reaching high production by fluke.

Continual improvement is preferred in business for obvious reasons.

I hope we, now, have clarity on the difference between Continuous and Continual Improvements and why Continual Improvement is preferred over Continuous Improvement.

In the next section, we shall see how continual improvement systems can be adopted in manufacturing operations: -

Continual Improvements in Manufacturing

Let us begin with understanding what we mean by Manufacturing. ***Manufacturing*** is the vital constituent of the overall business cycle.

On manufacturing systems, William K. Holstein and Morris Tanerbaum[4] suggest that *"All manufacturing systems, when viewed at the most abstract level might be said to be "Transformation Process"—processes that transform resources into useful goods and services. The transformation processes typically use common resources such as labour, capital (for machines and equipment, materials, etc.) to effect a change. Economists call these resources "factors of production" and usually refer to them as capital, labour, and land. The production managers refer to them as "five M's"— machines, materials, money, men and methods".*

It is, indeed true that the strength of a manufacturing unit is inherent in the five "M" pillars on which it stands. As stated above also, the five pillars are:

1. Machines
2. Materials
3. Money
4. Men
5. Methods

The first four pillars are materialistic and they go on to determine the size and scale of operations but do not reflect much on the efficient way of working. We may pump in a lot of money to buy sophisticated machines and procure the best material and have good competent people to run the operations but if the methods adopted are not robust and efficient, the result will be mediocre or poor. In this competitive era where it is survival for fittest, we cannot afford to be poor or mediocre; we have to be the best. The manufacturing units which stand out are the ones that have the best methods (Systems) in place, which put them on track of "Continual improvement". I used the word "Continual" and not "Continuous". The difference has been well explained in above section and it lies in improvements with sustenance mechanism—In "Continual" improvement, you cannot slide back to a lower level once you have reached a higher level through improvement efforts; thus, the movement is only upwards. In "Continuous" improvement you may do improvement and take the organization on a higher level but since there are no anchors to keep you fastened, you slide back to the original level. The "anchors" which prevent the slide are the ***Systems*** that you have put in place.

More about the Systems as we go along our journey of continual improvement in manufacturing.

Steps involved in continual improvements in manufacturing

As is in every aspect of working, for manufacturing also the first step would be setting the house in order.

Setting house in order: - Many factories in the small and lower middle size sector where I worked or happened to visit were found to look clumsy, disorderly, and dirty. The reason given was lack of space. My argument against this reason has been whether we keep our homes this way. Even if our home is just 1BHK, do we live in a dirty clumsy environment because there is a shortage of space? The answer is a big NO!! We do away with unnecessary items that block space and arrange the needed things in an orderly manner. In our home even when the light goes off and we have to find the torch, the wife can get it easily in darkness because of the orderliness maintained by her in the house. Not only place for the torch is fixed, but it is, also, for everything; shoes will be at the entry of the house, the books will be on the bookshelf, the clothes will be in the cloth cabinet, and so on… i.e., there is a place for everything and everything is in its place. We manage our house not only by keeping things in an orderly fashion but also do sweeping and mopping the floor on daily basis. There is an un-written SOP (standard operating procedure) that all family members follow to make our houses our cherished homes.

On similar lines, our factories must follow a system and corresponding SOPs to make them a cherished place to work in. Need is much more for the workplace compared to our homes because more than 3/4th of our waking time is spent at the workplace. One of the aspects of improvement is ensuring that all processes of manufacturing are arranged in a logical sequence that regulates material flow in a way that ensures minimum efforts in material movement. I give an example of a unit where the processes were not having proper material flow. In this unit when you enter the shop floor you first came across WIP (work in process) goods storage and then came machines and in next area, the raw materials were stored and next in line was printing department which got goods for printing from WIP area which was at the start position of the plant. After printing department was Finished Goods store as given in figure 3 below: -

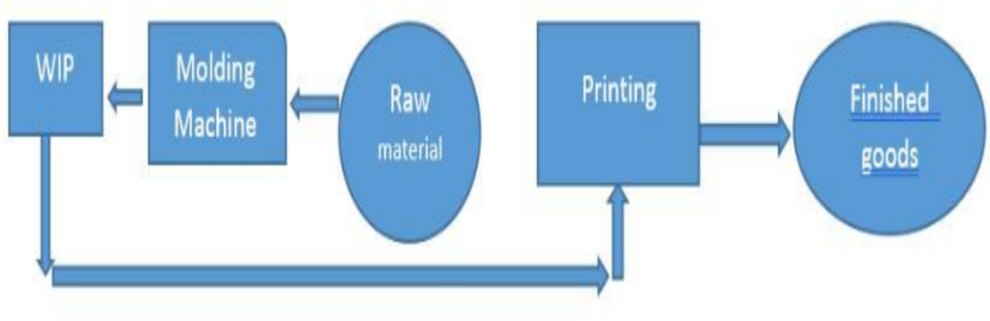


Figure 3: Improper flow of materials

The material flow was corrected by interchanging positions of the raw material store and WIP store and then the flow became a single line flow which eased up the material flow. This was an improvement that was permanent in nature and could be considered as continual improvement.

I talked about systems that provide the needed anchors for continual improvement, for setting the house in order one such system is 5S. In discussions in the above paragraphs, some thinkers had commented about 5S and had made its reference as a continuous improvement system but I beg to differ because it is not so. It is very much a continual improvement program with a built-in anchor arrangement that prevents it from sliding down in improvements which is the characteristic of continuous improvements. This will be clear when I briefly describe this Japanese System.

5S-The Japanese system for setting the house in order- 5S is a *Japanese system* for factories and workplaces which brings orderliness in working. As per Brian Mcfadden[5], the 5S system is a lean manufacturing tool that improves workplace efficiency and eliminates waste (Muda in Japanese). There are five steps in the system, each starting with the letter S:

1S - SEIRI - ***Segregation***
2S - SEITON - ***Systematic Arrangement***
3S - SEISO - ***Spick and Span***
4S - SEIKETSU - ***Standardizing***
5S - SHITSUKE - ***Self Discipline***

5S takes us on a continual improvement path. The objectives of 5s are:

- Creating a neat and clean workplace.
- Systematize day-to-day working.
- Improve work efficiency.
- Standardize work practices.
- Improve work discipline.
- Improve productivity.
- Improve quality.

1S-Seiri means to distinguish between what is necessary and what is not necessary by following specific rules and principles and getting rid of what is not needed. When practiced at the units I worked on, we could create extra space in the range of 20-30%. Not only that but, also, the sale of unwanted things brought cash to the company.

2S-Seiton means having things in the right place or the right location. It is for the most efficient and effective retrieval. Make a system that enables anyone to take out things promptly.

Seiton believes in "Place for everything and everything in its place".
With boundaries marked for each machine, work station, and pathway; the shop-floor becomes orderly and there is the ease of work. The storage and arrangement should be done so that:
Things that are used once or twice a year --- to be stored in a remote place.
Things that are used about once a month --- to be placed collectively in the workplace.
Things that are used daily --- to be placed within the work area.

While arranging the things, make sure that a single line flow of materials is maintained to ease the flow of materials—this was discussed in the above paragraphs. In one unit where I worked the material flow was incorrect and was corrected by changing the sequence of processes.

While arranging materials in the store, we must be careful not to store similar-looking items near each other. This is a frequent cause of complaints about material mixing. If similar-looking raw materials are stored near each other, wrong material may get issued to molding resulting in a loss due to the wrong production and if similar-looking items are stored in the finished goods store, customer complaints on wrong supplies may result.

***3S*-Seiso-** *Spick & Span- Seiso* means getting rid of waste and foreign matter and making things clean. Make a system that eliminates the cause of dirtiness. SEISO (Cleaning) is a philosophy and commitment to be responsible for all aspects of the things you use and to ensure that they are in tip-top condition. The dust, dirt, and foreign matter, etc. are looked upon as the prime causes of an unexpected failure of equipment, unhygienic environment, and even accidents.

Therefore, SEISO should be viewed as a way to eliminate these problems one by one. We must take measures to eliminate the cause of uncleanliness viz.,

1. Prevention of leakage
2. Prevention of scattering
3. Prevention of falling

Seiso must be performed using checklists so that no aspect is left out.
Make checkpoints:

- Checkpoints for floor and machine cleaning.
- Checkpoints for oil leakage and control
- Checkpoints for additional tightening
- Checkpoints for temperature control
- Checkpoints for dealing with breakage.

If checkpoints are followed systematically, a part of preventive maintenance gets taken care of, and not only the whole set up looks tidy but also, these actions contribute to improvements in productivity.

As was shared earlier in the paper, in one company, preceding a visit of foreign experts, we did perfect cleaning and made the shop floor look impressive. After their visit, our production efficiency remained high by 5% for more than a week! A clean and tidy work environment does impact productivity.

We observed that in the same glass bottle making unit, the production was highest in winter. The reason was that the heat of the furnace created a warm environment which prevented workers moving away from their machines and they attended the machines in a better way.

Thus, the environment does have an impact on productivity. The above 3S's build up a pleasant working environment.

4S - Seiketsu – Standardising means continually maintaining achieved 1S, 2S & 3S standards. We need to make and maintain a system that enables quick detection of a disordered condition/ state. It must be made possible for anyone to see the actual situation at a glance through "the visual control".'

- Make clear what should be done.
- Do it every day with the participation and practice of everyone.
- Train employees until they become capable of complying with the standard.

Standardization is a condition where the segregation, systematic arrangement, and cleaning have been repeated and maintained. The extensive visual controls must be implemented so that abnormalities show up by themselves.

Possible tools for visual control could be:

- Labels - lubrication label, accuracy label, inspection label, a label showing the person-in-charge, equipment number, and category.
- Limit marking - meter zone, stop line, place marking for machines, layout marking Danger alerting signals.
- Visualization - A status indication, direction indication, maintenance display board, instructions, color code for pipes, picture of safety gadgets to be used in the area, direction sign for emergency points & fire extinguisher, caution, and operation reminders.

5S - Shitsuke – Self- Discipline means having the ability to do things the way they are supposed to be done. The emphasis is on creating a workplace with good habits and discipline. This self-discipline will result in doing the right things as routine by injecting healthy work culture in the organization.

Discipline means getting accustomed to the operation in compliance with standards. It is the discipline to honour faithfully the promises agreed upon by the fellow people.

The purpose of "*Shitsuke*" is to support the four "S" (Segregation, Systematic arrangement, Spick & Span, and Standardizing) as the means to satisfy such fundamental things. We should keep practicing the activities through those procedures until they become our work culture.

Discipline means thinking about the many problems that occur from day to day and resolving to do better. People sometimes make the most unbelievable mistakes because they let their guard down because they forget their discipline.

When you assume that something is easy just because you have done it many times, you are most likely to get it wrong.
To instil self-discipline, the following will have to be done:

- Cultivation of habits
- Conduct training

Make workers responsible for the action and not for the results.
It is very important to practice and more practice because practice reinforces correct habits.

The disciplined workplace is the most important thing to ensure "Product Quality" and the traditional working units must work in this direction.

The implementation of 5S can be done easily while all activities of the organization are going on. Only a little extra effort is required which results in recurring benefits continually.

Some benefits expected on the implementation of 5S are as follows:

- Increase in production efficiency.
- Reducing wastage (Muda in Japanese) of all kinds. Material wastage reduces, machine breakdowns reduce, rejections reduce and Labor efficiency improves.
- Low production cost.
- More space and storage are obtained.

The Organization tends towards becoming world class-company and the improvements achieved are made permanent through the 4S and 5S stages of 5S and this is the reason 5S is a continual improvement tool that is a must for all professional manufacturing operations.

Needless to say, that every organization must implement 5S as the first step towards continual improvement in its manufacturing operations. Having put this system in place we can take up optimization of each process involved in the manufacturing activity of an organization.

<u>Optimizing manufacturing processes through a continual improvement approach</u>

Manufacturing is the core part of a business. Productivity being the keyword, attempts are made to keep it at the highest level. Kanthi Muthiah and Samuel H Huang[9] say, "Productivity measurement and improvement go hand in hand because one cannot improve what one cannot measure." We talked about systems which serve as anchors in the Continual Improvement process. The structured manufacturing system which has inbuilt anchors for continual improvement will need

- Identifying processes involved in manufacturing operations, decide how the process will be carried out, develop and implement a monitoring system
- Defining the characteristic which will reflect the level of its working. Evolve measurable index for each of the above characteristics
- Developing suitable formats for collecting data which will help in arriving at the above indices. We need to develop the working sheets for calculating the indices
- Collecting data and measure the indices
- Comparing the indices over a period to learn the trend of progress/decline and do brainstorming to learn the reasons for declining trends, if found, and take needed actions
- Taking corrective and preventive actions (CAPA) for sustaining the efficiencies of different processes at high levels
- While sustaining high levels, take improvement projects to improve operational excellence

Manufacturing involves several processes. Some typical processes in manufacturing are

- Production Planning
- Production
- Quality assurance and,
- Storage and despatch

We shall take on each of the above processes and shall explore how can a culture of continual improvements be cultivated for each process.

Before we take up the processes one by one, I wish to recall an important quote by H. James Harrington *"Measurement is the first step that leads to control and eventually to improvement. If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it."*

So, to understand and improve a process we have to organize to measure its performance. Hence, we shall be developing a Key Performance Index for each process and shall take continual improvement measures to improve the index to achieve continual improvements in each process. Let us now begin our journey: -

Production Planning, its KPIs and Continual Improvements: -

Production planning is an important process and it can make or break the organization—poor planning can result in missed delivery dates making customers unhappy leading to lost future business or it could lead to excessive blockage of funds and spoilage of materials in storage due to overstocking and keeping idle inventories for excessive periods. On the positive side, an efficient production planner could never miss deliveries and would keep minimum inventories -the best would be "Just in time" which adds to the bottom line of business and leads to customer delight, and would bring in more business with words spreading about customer delights at reduced costs. All these can happen if production planning is efficiently done. I happened to lead such an organization where the customer was so delighted with our "Just in time deliveries" that they never did incoming inspection of our material and did not keep any stocks, our despatched materials reached their premise, and goods were unloaded and straight away taken to their production lines. They were damned sure about the quality as well as timely delivery of our supplies. We worked on a precise time schedule and never failed them. They were delighted to pay us premium prices when compared to their other suppliers. All this was not achieved overnight, we had to toil hard and had to take a long continual improvement journey and even now the culture of continual improvement pushes us to take continual improvement projects to cut down our production costs and improve production efficiencies besides doing excellent production planning.

As rightly pointed out in the above paragraph, Planning is the most critical of all processes. Planning, per se, is critical and it can make or break the unit for which it is being done. Evident examples in pandemic times are poor planning in the USA, Britain, and Italy; whereas we, in India, are fortunate to proceed with proper planning. The results are obvious. We could control the pandemic in better way and the vaccination also has gone at speeds better than most of the countries.

In manufacturing also, it plays a very critical role. Poor planning viz., allocating a job on a bigger machine will result in higher power consumption and hence increased cost when compared to run it on an appropriate smaller machine if it is available. Even preceding jobs on the machine is important and can result in a higher cost. For example, if the previous job on Extrusion Blow Moulding Machine (in plastic bottle manufacturing) was of a single cavity and we are planning double cavity job on this machine, we shall be spending avoidable time on job change and set up time, which will increase because we shall have to make changes from single head to double head, which is very time-consuming. In this case, we should have planned the job only on the available double head machine. Needless to say, if the planner plans a job on a machine that is not capable of producing it, the organization will be incurring a loss that could be avoided by proper planning. It is not wrong to say that Planning can make or break an organization. In short, the planner has to utilize available resources optimally.

I worked in an organization that did not have a planning department, Job allocation on machines was done in an ad-hoc way; the jobs were loaded on a machine on instructions from salespeople sitting in Head Quarters. The benefits of proper planning as discussed above could not be taken but there was a more adverse impact on productivity. Many a time, the intimation for making a job change came after 4 p.m, and immediately the running job was unloaded and the job change crew got busy in doing the job change. In unplanned job change, normally, the job change took more than three hours. At 6 p.m the shift was over and the job change crew left leaving the job change half done. The machine remained stopped for the remaining part of the day and only the next day morning, the job change was completed and the next job started. Needless to say, productivity took a backseat, and production efficiency was lower than 55%.

Faber [6] suggests six basic principles while doing production planning. The six principles to be considered concern the following: -

- Customer Demand
- Materials
- Equipment
- Manpower
- Processes
- Control

***Customer Demand**:* Before you can plan to assign resources, you have to know how much to produce. The beginning of manufacturing is based on sales order confirmation (SOC) forwarded by the sales department. Production planning has to ensure producing on time for meeting the delivery schedule, not only that, but planning has, also, to ensure optimal utilization of available resources.

Even in the traditional run units, this is the starting point in the manufacturing operation but not much care is taken to optimize the available resources.

Materials: To fulfil the production target, the availability of materials needed to produce should be ensured. The most efficient production planning keeps the minimum materials as standard inventory. Planners should evaluate how much material the company needs and when; the lead times for supplies and the reliability of the supply and accordingly decide on EOQ (economic order quantity) and MSL (minimum Stock Level) to be kept. The professional-run units develop a system of ordering in such a way that minimizes the inventories and at the same time ensures that no stock-out situation appears. Standard inventory models are available for this.

Equipment: The production planner takes into account the capabilities of the equipment used to produce the output. As mentioned in the above paragraph, the machine which is most optimal for the item must be chosen so that moulding cost does not go up.

We must make a machine allocation sheet where we allocate jobs on each machine in a sequential manner against time. A sample template sheet for moulding machine allocation is given in ***Appendix A.***

The machine allocation sheet must be periodically updated by changing the dates based on actual performance to date and also when new orders are received.

Manpower: Manpower planning requires accurately estimating the number of employees required to do the work. The capacity of the workforce has to match the capabilities of the equipment to plan for the highest efficiency. In one of the units where I worked, we had arrived at standard manpower needed for each activity by employing time and motion study and had fixed a standard number of people to do the job activity and this data was used by the planner to do labour planning for each process involved in manufacturing and labour was managed by the HR department based on labour planning given by the planner.

Such a system will not be found in traditional run units and labour management will be poor in those units.

Processes: An effective planning makes sure that the processes used for the output continue to operate efficiently and safely. If there is some problem resulting due to downtime of machines, the plans have to be modified accordingly.

Also, the secondary processes have to be planned in a way that the products needed for them from primary processes are produced in time and are available in adequate quantity for secondary processes. For example, bottles for printing must be produced in quantities sufficient for printing machine requirements; if the quantity of moulded bottles is less than the printing capacity of the printing machine for a day, the printing machine will get stopped for bottles.

Controls: A final production planning principle puts in place controls that detect problems as soon as they occur. Verification of inventory, use of qualified suppliers and personnel, standardization where possible are needed for better control. When controls are in place, it enables us to take possible preventive actions to eliminate the causes of factors that could adversely affect production and would return the production to the required levels. In the unit where I worked, we had developed a production plan control tracker (PPC tracker) for helping control over production planning.

A production planning & control tracker is necessary to monitor and know the status of jobs under manufacturing. The PPC tracker must be shared on daily basis with salespeople so that they know the current position of their items and if the tracker shows that items will get delayed, they can, accordingly, inform the customers. The salespeople can also suggest a change of priorities after seeing the progress n PPC tracker so that the planner makes the corresponding change in machine allocations.

Sample PPC tracker for moulding process is given in ***Appendix B;*** for other manufacturing operations, it can be developed on similar lines.

The controls on any process need performance evaluation of the process and must be compared with the set target and if the performance is much below the target, reasons must be studied and actions are taken. ***The planning process, thus, has inbuilt controls which would anchor the performance at high levels and ensure that we are on a continual improvement path. The achieved performance index of planning can be improved through the analysis of causes that affected it adversely and through actions to eliminate those causes.***

The performance Index for the planning process in a unit where I worked was developed by me. The performance index with minor modifications can be applied in different manufacturing units; the details are given below:

Key Performance Indicators for the planning process

Performance measurement is defined as the process of quantifying the efficiency and effectiveness of action. Tangen[7, 8] mentioned that performance measure criteria must be driven by strategic objectives and the measures must provide timely feedback.

The objective of planning is to ensure that deliveries to customers are done before the due delivery date and also the planning must achieve the lowest possible lead times from the dates of receipt of confirmed orders and also maximum lead time in the worst case, also, must not be very long.
The performances indices developed and used effectively by me were as follows: -

Suppose A= No of trucks dispatched before due delivery date during the month
B = Total number of trucks dispatched during the month

Monthly Delivery Index (D) = A / B x 100; Delivery Index calculation demo template is given in

Appendix C

We fixed the Target for Delivery index (TD) = 100%
Suppose Target for mean lead time =TM
The target for maximum lead time=TX
Actual achieved mean lead time=ML
Actual achieved max lead time=AL

Then ***Production Planning Control Index*** is calculated as: -
PPCI=0.6xD+10x((1-((ML-TM)/TM)))+30x((1-((AL-TX)/TX)))
Please note that the performance index for PPC gives 60% weightage to timely delivery, 10% to average lead time and 30% to max lead time.
The target for PPC index is normally kept at 97%.

On monthly basis, we must calculate the Delivery index and PPC index and if the Delivery index is below 95% or PPC index is below 90%, we must analyze the reasons and take corrective actions to ensure ***continual improvements***

Demo calculations for this index are given in ***Appendix D***
The performance evaluation for planning is never done in traditional entrepreneurial units. The planning is an ad-hoc activity in these units and it is aimed to somehow meet the delivery commitments to customers. We never know how bad it is being done and to what extent it is harming the organization.

Structured systematic planning and performance measurement, if adopted by traditional units will help them to get benefitted by reducing the lead times and serving customers in a better way.

Continual improvements in production planning must be attempted to improve the PPC index – we fixed the target as 97% -- we must identify the blockades and must strive ways to remove the blockades and strive to reach 100%. It is certainly possible, we could cut down on lead times by taking needed actions in planning as well as in production, quality and stores processes (improve cycle times, reduce downtime of machines, assure production right at first time, go for speedy transportation etc.). We did this in one of our units and could meet customer expectation of "Just in time" with zero inventory at customer end through the continual improvement initiatives in planning supported by such improvements in production, quality and store processes.

Production Process, its KPIs and continual improvements

I would like to continue with the real-life example of a plastic bottle manufacturing unit that was producing bottles at an efficiency of 55% when I joined it as manufacturing operations head. Continual improvement initiatives were started by analysing the reasons for the poor level of production efficiency. We developed a KPI for the manufacturing process which gave information on production efficiency (it was 55%), rejections at the production stage (it was 20%), and downtime of machines (it was 25%).

The formula for Molding efficiency was developed in the following manner: -
Machine available hours per day =24

Machine hours lost due to factors beyond the control of production constituted the sum of the following aspects:

Time lost due to power cut=p
Time lost due to no orders from marketing= m
Time lost due to shortage of raw materials=r
Thus, ***machine hours lost due to factors beyond the control of the production department***=p+m+r

Time available for production =24-p-m-r

Cycle time= c (time taken in seconds to produce one unit)
Target production per day=T= 1/c*60*60*(24-p-m-r)
Actual Production in a day= P (say)

Then ***Production performance index*** i.e.,
Production efficiency = P/T x 100---- It maps the real efficiency of the production department for which they are accountable

The detailed working and the formats developed are given in ***Appendix E*** which maps even the Overall Equipment Utilization %

Continual Improvement in Production Efficiency
The continual improvements are done by analysing the reasons which have resulted in high levels of downtime of machines and high rejections and then taking permanent actions for eliminating the major causes of the high levels of downtime losses and losses due to high rejections.

In the example of the above unit where downtime loss was 25% and rejections were 20%, it was found that the major reason for the downtime was an abrupt stoppage of machine for making a job change on demand of sales department and since job change could not be completed during the general shift, the job change crew left without completing the job change and machine remained in idle condition for next two shifts and only next day the job change was completed and thus downtime of the machine was at a high level. Another reason was that if a breakdown occurred towards the end of the general shift, the maintenance crew would not be able to complete the repairs during the general shift and they will leave for the day, and the machine, again, would be idle till next day when it will be repaired and production resumed.

These factors were not acceptable to me. Improvements in efficiency were not possible if this state of affairs continued.

I took up the matter with the sales department and could convince them that they did not gain anything by insisting to stop the machine as per their demands and they did not get supplies in urgent manner as the machine was unnecessary remaining idle. The job changes must be done in a planned way and must be completed in the shortest possible time. If the customer could wait till the time the loaded job is completed, the machine should not be disturbed; and even if the customer wanted it urgently, the running job could be unloaded halfway only at the beginning of the next day so that the job change crew could do the job change within their shift and machine does not remain idle for two shifts. Job change crew were also advised that they must do advance preparations by having all tools etc. ready before they stop the machine. Time should not be lost doing the activities of job change which could be done while the machine was running. Sales people could understand the logic and reasoning and job change did do advance preparations and downtime of machines could be substantially avoided. On the other hand, the repair problem for machine breakdown was tackled differently. I took up with higher authorities and explained to them that machine breakdowns could happen in any shift and it was illogical to have maintenance crew only in the general shift. The general shift could do the periodic preventive maintenance of the machines but for breakdowns, we must have maintenance engineers deployed in each shift. It was not difficult to convince the top management and we recruited maintenance engineers and put them in each shift. Now if there was machine breakdown occurred, the repair work continued uninterruptedly till the machine was repaired; if shift time was over, the maintenance crew of the next shift continued the work, and the machine was repaired in the shortest time.

These actions brought down the downtime % from 25% to less than 10%, thus, improving the production efficiency by over 15%. ***This was a remarkable improvement and it was continual because the actions taken were of permanent nature which will anchor downtime loss at lower levels and would not let production efficiency slide down to lower levels.***

Next, we attacked the problem of rejections which were high at 20%. We did a rejection analysis and found the defect which contributed to more than 80% of rejections. We found that the defect was a rough surface at the inner neck walls of the bottles which were prone to result in leakage of the filled liquid as the liquid was likely to seep through the furrows created at the neck inner wall surface due to the roughness of the surface. Our production engineers could find the reason for this defect which was due to faulty design of the tool which formed the neck inner walls. The tool design was modified and this defect was permanently eliminated. The rejection percentage fell from 20% to hardly 5%.

Another ***continual improvement*** in production efficiency happened when efficiency rose by another 15 %. In the first stage of continual improvement had happened with a reduction in downtime of machines when efficiency had improved from 55% to 70% and now with rejections controlled in permanent way efficiency further rose from 70% to 85%.

The continual improvements were done in less than six months and production efficiency has been maintained above 85 % in that unit.

Further Continual improvement measures are being planned to improve the level to over 90%. ***Continual improvements can be achieved following a simple rule, study and look for blockages in the way and find permanent ways to remove the blockades.***

We did this in the above cases where we permanently removed the blockades leading to higher downtimes and rejections.

Another example of continual productivity improvement is being shared below. Production quantity depends on the cycle time or speed of the machine. If by some measures we could reduce the cycle time of machines the production quantity would increase. In the above paragraphs, we had talked about reaching an optimal combination of process parameters that would give maximum production quantity.

In one of the units where I worked, we were producing plastic bottles. Mould cooling time is one of the process parameters in the production of plastic bottles using blow moulding machines. If somehow, we could cool moulds faster the cooling times could reduce, and thereby cycle time would reduce thereby increasing the production quantity of caps. We were using cool water from cooling towers for doing mould cooling, we decided to replace it with chilled water from chillers. This will cool moulds faster and required cooling will be achieved with lower cooling time, thereby cycle time will be reduced. We installed chillers and used chilled water to cool the moulds.

The bottle was being moulded at a cycle time of 12 seconds (i.e., 2bottle in 12 seconds) using double cavity mould was producing 14400 bottles per day ((2/12)*60*60*24). We found that the same cooling was achieved with reduced cooling time which brought down cycle time to 9 seconds (i.e, 2 bottles in 9 seconds); we could produce 19200 bottles per day ((2/9)*60*60*24), i.e., a productivity rise of over 33%!!

Such a phenomenal rise in production is possible and that too for all future times to come. This is one of the outstanding examples of ***Continual Improvement.***

Continual improvements in manufacturing operations is not only by increasing production quantities, we could also achieve this by other means like cost-saving initiatives or by saving on raw materials which directly contributed to increasing the bottom line of the business. We take the latter for discussion first: -

Continual Improvement through raw material saving tools

Most often we find that the customer specifies the weight of the product with tolerances that are quite wide; much wider than the process capability of manufacturing machines. The machines are capable of producing the product in a range much narrower than the specified tolerance width. In such cases, we can set machines at weights lower than the standard weight and still produce the product meeting all specification requirements even that of weight. In such situations, we tend to save on raw materials compared to other competitors who are ignorant about this aspect. Employing process capability studies for manufacturing machines and process control tools of X bar R charts we can design a system which if implemented will yield a saving of a few grammes of raw material per piece of product produced on the machine.

I developed the system and the tool for a plastic bottle manufacturing unit which was successfully implemented and we could save tons of raw materials per month on a continuous basis. This excellent continual improvement is still going on that unit and the unit is adding a substantial boost to the bottom line of their business through this continual improvement initiative which is ever going till the machine keeps on running.

Appendix 1 provides the details about demo templates of Xbar Rchart and the SOP for constructing and operating the charts for reaping the benefits of raw material savings. The improvements are ever going upwards and there cannot be any decline—the beauty of continual improvements!!

Having covered an important aspect of manufacturing let us now move to an equally important aspect – Quality

Quality Assurance Process, its KPIs, and continual improvements in QA

High levels of quality are essential to achieve the company's business objectives. Quality, a source of competitive advantage, should remain a hallmark of company products and services. High quality is not an added value; it is an essential basic requirement. Quality does not only relate solely to the end products and services a company provides but also relates to the way the company employees do their job and the work processes they follow to produce products or services. Kishu Manghani[10] rightly says, “Quality control and quality assurance systems together constitute the key quality systems. Quality control and quality assurance are parts of quality management. Quality control is focused on fulfilling quality requirements, whereas quality assurance is focused on providing confidence that quality requirements are fulfilled.”

Quality assurance, in reality, encompasses quality control because without fulfilling quality requirements (i.e., without QC implementation) one can never instil confidence in customers that the product would meet their requirements.

Quality Assurance in manufacturing does not manifest by itself, a lot of effort is needed to build this and through these efforts, the quality gets built into the product to delight the customers. The words of William A Foster keep ringing in my mind, ***“Quality is never an accident; it is always the result of high intention, sincere effort, intelligent direction, and skillful execution; it represents the wise choice of many alternatives.”***

Needless to say, a lot of effort is needed to build Quality Assurance systems that help the organization to anchor itself on a continual improvement path.

Quality Assurance Systems:

Before we build QA systems, let us first examine the factors which may result in the quality deficiency in the produced lot:

Incomplete knowledge about customer requirements; inferior raw materials/ masterbatches / contaminated grinding material/ malfunctioning in machine working/ poor calibration of testing equipment/ and weak QA systems are major factors that degrade the quality.

Care is to be taken at each stage of manufacturing by all concerned so that the ultimate product comes out good. Good QA systems provide the basic framework at each stage of manufacturing. The starting point is making a Quality plan. The quality plan is a roadmap for quality steps to be carried out at different stages of manufacturing processes. The plan makes it clear what checks should be carried out at each stage of manufacturing; how these have to be carried out (i.e., the methodologies) and what formats are to be used and what actions are to be taken based on results of testing

A model quality plan is given in ***Appendix F***

The plan is to be strictly implemented, monitored, and controlled.

Some steps in QA systems could be:

- Incoming inspection of incoming materials,
- First piece approval at the start of production,
- In-process checks to monitor the process at the proper level
- Periodic finished Goods inspection checks to ensure that good quality is being packed.
- Laboratory testing during processing
- Pre-despatch inspection.

In all above checking, the samples should be collected based on scientific principles of acceptance sampling – usually IS 2500

Key Performance index (KPI) for QA system—
In the units, I worked, I used the following quality index:

Quality Index (QI) = (10 x (10-(80R+20N)/T)
R=no of invoices where lots got rejected by the customer during the month
N= no of invoices to which complaint was made but the lot was not rejected
T= total no of invoices in the month
In the index, 80% weightage is given to external rejections and 20% to complaints without rejections.

The *quality index below 99%* must be considered as a poor-quality index
A good and robust quality system is needed for sustaining the business by retaining the customers and not only that but the business, also, expands when quality reputation reaches other prospective buyers.

Most traditional manufacturing units have weak QA systems that make them struggle for existence with virtually negligible growth. In the organization where I worked, we built good and robust QA systems and took pains to build a quality culture across the organization.

Continual improvements in Quality
As we saw in production, continual improvements are possible in the quality of products as well as in quality systems.

Product quality improvements happen mostly through research and development into the product characteristics and innovative ways are researched which could add more value to the quality of a product. The researchers in the particular fields can come out with innovative improvements which if implemented will yield a better product. Needless to say, the improvements are continual in the sense that the improvements do not get retracted.

On the other hand, continual improvements in quality systems happen mostly through preventive actions that are arrived at while analyzing customer complaints and we arrive at correction; corrective actions, and Preventive actions. Preventive actions are the actions that correct a flaw in the existing quality assurance system which led to the complaint. The preventive actions install more actions which go on to continually improve the quality assurance system and goes on to make them more and more robust and permanently prevent customer complaints.

The tool used for the continual improvement of Quality Assurance systems is CAPA – which is a universal tool for continual improvement.

We shall discuss this tool later; let us first take on the last important aspect of the manufacturing process—Stores Management

Stores Process, its KPIs, and continual improvements in stores management
The store is considered the custodian of materials. As mentioned in this paper earlier, normally expenses on materials constitute 55% of the total expenses. Hence store is an important process and it must work efficiently to maintain the health of the organization.

Basic functions which are done by the store are Receipt, Stocking, and Issue of materials,
While taking ***Receipt*** of goods, care is to be taken to accurately tally the physical quantity received against the quantity mentioned in the receipt document i.e., challan. After receipts, the store person must get ***QA Approval for the quality*** of the material received. This is to be followed with receipt documentation.

Stocking of goods has to be done so that no goods are spoiled while in storage and also quantities remain intact and there is no shortage. While stacking the goods in store, care must be taken not to stack similar items near each other. This eliminates chances of mixing that may have serious consequences. Physical stocks must always tally with book stocks.

Issues can be for issuing material to production or stocks could be liquidated by selling or grinding if these are no longer needed. Samples also can be shipped for promoting the business. Dispatch to customers is the main component of Issues.

Stock-taking is a very important and vital activity of Stores. Normally companies close down all factory operations for a day or 2 once in a quarter and take physical stocks of all items and compare them with book stocks. Deviations found are investigated, reasons are found and stocks are reconciled.

These are the normal activities of stores of all companies, be it traditional or professional.
In traditional organizations, stock taking, often when confronted with unexplainable shortages does not get its reason as many transactions must have taken place after the shortage happened.

Key Performance indicators for stores function
The performance of stores is evaluated by their ability to prevent stock-out situations for materials needed for production. The KPI for this aspect is the Number of stock-outs per month- the target obviously is zero for this KPI.

Stores must also take action so that no product becomes obsolete while in storage. Thus, it must take up with appropriate levels in management to ensure that goods move quickly from stores and there are no dead stocks generated which will have to be disposed of without getting its sale executed. The relevant KPI is deadstock %: -
Say, at end of month the dead stock quantity is = D and
Closing stock quantity = C

Then KPI will be

Dead stock %= (D/C) x 100

This is % of stocks that have become dead at the end of the month. The target % obviously should be the minimum% possible.

Another aspect is arranging despatches timely in order to adhere to customers' delivery schedules. The respective KPI is calculated as follows: -
Say, number of trucks despatched on or before the committed delivery date during the month = N and
Total trucks despatched during the month= T Then the KPI – ***Delivery index*** is = (N/T) x 100
Obviously, we should target it at 100%

Stores have to maintain stocks accurately so that book stocks and physical stocks of each item always tallies.
KPI for this aspect could be calculated as follows:
Say, Number of items for which physical stock tallied with physical stock at the time of monthly stock-taking = C

And the total number of items at the end of the month = N
Then KPI will be ***Stock Accuracy Index*** =(C/N) x100
The target for this KPI, naturally, must be 100 %
These are a few parameters on which store performance can be evaluated. Improvements in store functions can be done by devising ways and means to improve these KPIs.
One such continual improvement system which was devised by me is given below.

Continual Improvements in Store activity

We discussed the KPI of stock accuracy in the above paragraph. Discrepancies in stocks are frequent because of several reasons and seldom the KPI achieved is 100 %.
Mistakes happen due to the wrong item despatched which affects stock of the correct item as well as the item wrongly despatched and their book stocks and physical stocks would not tally at the time of next stock-taking.
The discrepancy can also happen due to human error of bringing goods from the shop floor and stacking in the wrong stack of a different similar item.
A mistake can also happen if the stock register is wrongly updated due to human errors.
The sources of errors are many.

We developed a system that could be taken as an example of continual improvement- the system was called the ***Perpetual stock-taking system.***

In ***the Perpetual stock-taking system***, all goods brought in the store are stacked in different lots and we put a stock card on each lot. For lots in which there are additions of items or items have moved out (i.e whenever there is a movement of materials from a lot); the physical stock-taking is done for that particular lot immediately and stock reconciled on daily basis. Getting to the mistake is easy and most often mistakes are found and stocks get reconciled. Stock-taking is to be done on daily basis for each lot in which there is a movement. Since the lots having no movement are not needed to be counted on a daily basis, this system is feasible and practical and serves as a strong tool to maintain the accuracy of stocks i.e, book stocks and physical stocks always tally. This ensures accurate stocks at all times and this coupled with quarterly physical stock-taking for all lots, doubly, ensures that stocks are accurate at all times. This was an improvement over the prevailing system of stock accounting only monthly, the improvement done in the system is irreversible and, hence, continual.

We have, now, covered all important aspects of manufacturing and observed how continual improvements are possible in each process. I hope that all manufacturing units will get benefitted from this awareness and shall strive to make continual improvements in their operations.

I shall conclude the paper by discussing the most powerful universal problem-solving tool which is effectively used for ***Continual Improvement*** universally in any field of manufacturing.

CAPA- The tool which leads to continual improvement in the manufacturing process

The tool CAPA- corrective and preventive actions is a tool that uses a fishbone diagram to find a solution to problems encountered by the customer while using the despatched product. We saw its usage in customer complaints analysis in the above paragraphs. This tool leads to continual improvement in the manufacturing system through the preventive actions taken for each complaint. To demonstrate the steps involved and the approach taken will be clear from a real-life root-cause analysis and CAPA done using the Fish-bone diagram technique for a rigid plastic manufacturing process. This involves defining the problem, then listing down probable causes which could relate to any of the following five factors viz., Man, Machines, Method, Mould, Material, and Environment. By process of elimination, we rule out from the probable cause, the causes which may not have happened in the present case, and then arrive at the most probable cause.

Then the why-why analysis is done till we reach s situation which indicates some flaw in the prevailing manufacturing process. The last why gives us the root cause. The root cause always points to some deficiency in our manufacturing system and throws up scope for continual improvement. By taking a preventive action- the action which will ensure that the problem encountered now will never ever happen again goes on to do a continual improvement in the manufacturing system by making it more robust. Each customer complaint makes us reach a root cause pinpointing still remaining loopholes in the manufacturing systems and pushes for continual improvement.

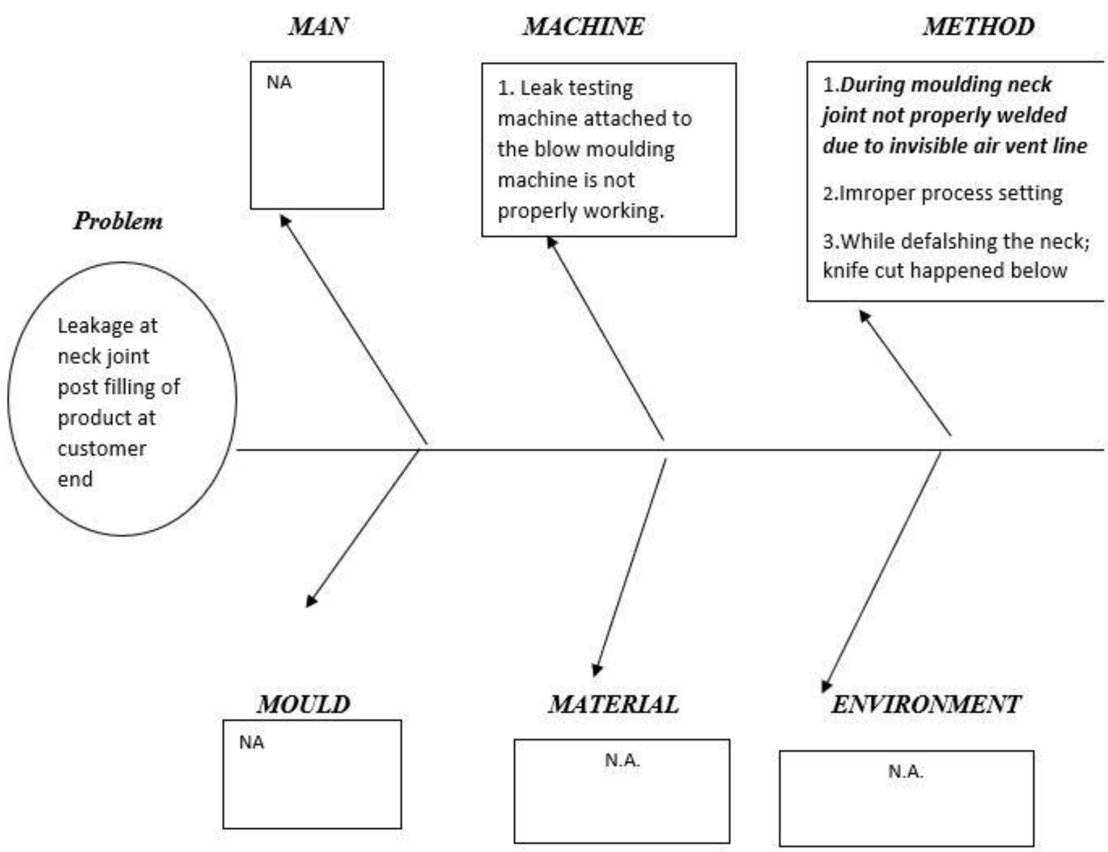
We can create opportunities in adversities. A distressing feature in business -the customer complaint can be used for improving our manufacturing system—true silver lining in a cloud

We shall take on a real-life customer complaint and do CAPA to demonstrate how preventive actions emerged which led to continual improvement in the manufacturing system. We shall observe that having found the root cause, how we decide on immediate action needed to solve the issue that happened at customer end and then take corrective measures at our machine and finally improve our working system by installing a preventive measure in our working which will ensure that the complaint will never get repeated in future. The CAPA will be true and effective only when it is done by joint Cross-Functional Teams.

Real-life Customer complaint analysis using CAPA tool

All the steps are clear from the CAPA done for a customer complaint of leakage found from the handle of a 5 litre jerry can after filling liquid it in. Just study the CAPA: -

CAPA No: - ***Complaint Date –***
Product: - 5 litre plastic container ***CAPA Done Date: -***
<u>Customer name:</u>



N.A means not applicable

MAIN REASON: - Neck joint not properly welded due to invisible air vent line

Why (1): - Some invisible gap [minor hole] created inside the neck joint/weld.
***Why** (2): - It may have happened due to blow pin improper positioning at higher levels, it would not have come down fully in the neck of container. Blow pin should be fully pressed down in the neck to melt polymer material for better welding strength.*
***Why** (3): - This happened because Hydraulic Valve did not work properly.*
***Why** (4): - it happened because Valve may be partially choked due to dust/contamination in the oil.*

Why (5):- It happened because the machine maintenance checklist did not have periodic hydraulic valve cleaning and oil changing schedule

ROOT CAUSE: - Hydraulic valve got partially choked, resulting in malfunction of movement of blow pin which caused gap inside neck joint/weld because the periodic maintenance checklist did not have its cleaning schedule and did not have schedule for changing the contaminated hydraulic oil

***CORRECTION*: -** *Visited at customer end and replaced all defective containers.*

CORRECTIVE ACTION*: - Cleaned the hydraulic valve of the machine and changed the oil which was found contaminated*

PREVENTIVE ACTION

Introduced hydraulic valve cleaning schedule in the machine maintenance plan and introduced oil filter cleaning schedule on weekly basis.

DH – QA
VERIFIED BY: PLANT MANAGER ***APPROVED BY: GM (OPERATIONS)***

Rev No: 0 *Rev No date :- 1-1-2014*

If we observe the root cause reached and the preventive actions taken, we shall immediately realize that the area for improvement in the manufacturing system was identified and continual improvement was done through preventive action and now in future the hydraulic valve will never get choked and will never result in a malfunction of blow pin and hole creation at the neck joint will never happen. This is an improvement that cannot be reversed and hence is a continual improvement in the manufacturing system.

The example was taken from the manufacturing of plastic containers but it is applicable to any manufacturing system which will get improved by CAPA.

This improvement is only when we end up in customer complaints but the same tool could also be used without ending up in customer complaints. The tool is a problem-solving tool and instead of identifying the problem as a customer complaint, we could take the problem as a factor causing blockade to improvement and follow the whole CAPA procedure and come out with preventive actions which will yield continual improvement by throwing up preventive action which will permanently eliminate the blockade.

I end the paper here and I hope that we have brought out in detail the meaning of continual/continuous improvements and understood clearly the distinction between two types of improvements and also seen why Continual improvement is most preferred. We have also seen how continual improvements happen in all important stages of manufacturing. I have given demo using examples from rigid plastic package manufacturing unit, but the tools and systems are generic and can be suitably modified for any manufacturing organization.

I am sure that entrepreneurs, especially owning small and medium size manufacturing units will get greatly benefitted from the systems and tools given in the paper.

In this age of cut-throat competition where our survival is at stake, continual improvements, alone, can be our saviour and each unit must strive for it!!
Please do take the first step by using this paper effectively !

Appendix 1— SOP for construction of X Bar R Charts

SOP for Construction of the charts: -

- ***Step 1***Set the machine in perfect condition by removing all technical faults which can lead to variation in weight e.g parison lengths, mould in-out timings, pre-blow settings, etc………
- ***Step 2*** Take out samples from each cavity on ½ hourly basis; measure weight and record in the prescribed format (in case of single station, single cavity ----take 2 consecutive samples and measure and record weight). Collect at least 50 samples i.e., it will be done in 25 hours
- ***Step 3*** Input the data in the Xbar R chart tool
- ***Step 4*** It will calculate process width and UCL and LCL
- ***Step 5*** Compare each Xbar with the limits and if a particular Xbar reading is outside limit –it is an O ***Outlier*** and may be due to some assignable cause --- delete that row from the table
- ***Step 6*** The tool will recalculate the UCL and LCL
- ***Step 7*** Repeat step 5 and if all readings ar within the limit ---homogenisation is complete and now data pertains to " in state of control" situation i.e machine is working under chance cause
- ***Step 8*** If still some Xbar reading is beyond the limits , delete the row and repeat step 6 and 7
- ***Step 9*** If more than 3 rows get deleted by following steps 5 to 8 then it is concluded that machine is not in '' STATE OF CONTROL" and needs to be attended to remove technical fault and control charts cannot be constructed. Machine must be technically corrected and then all steps 1-9 should be followed
- Step 10: Once we have a homogenized tool, check Cp---if it is less than 1, then the machine is not capable of meeting the specification, and the control chart technique cannot be used
- Step 11: If Cp ≥ 1.33, Cpk will get calculated at end of the tool and revised Xbar R bar control Limits i.e., UCL and LCL will get calculated ------Use these in the graphs of Xbar and Rbar charts

USE OF THESE CHARTS WILL RESULT IN RAW MATERIAL SAVING AS WE SHALL BE RUNNING THE CONTAINER AT REDUCED WEIGHT AND STILL WILL BE ENSURING THAT ALL CONTAINERS ARE PRODUCED WITHIN CUSTOMER SPECIFICATIONS

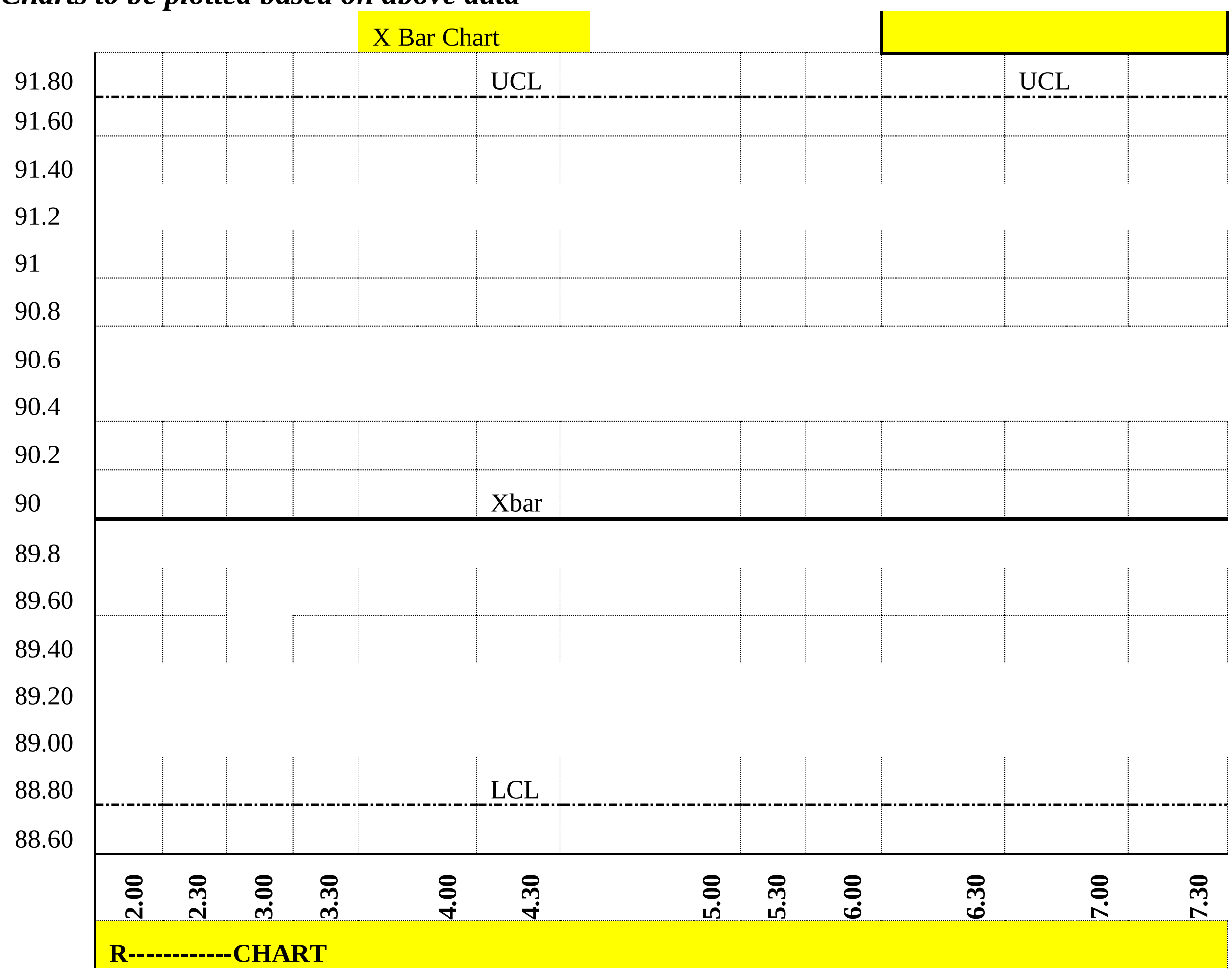
NOTE: - THERE IS A DISCIPLINED WAY OF OPERATING THE CHARTS AND NO ATTEMPT SHOULD BE MADE TO VIOLATE THE DISCIPLINE. THIS IS GIVEN IN NEXT SOP

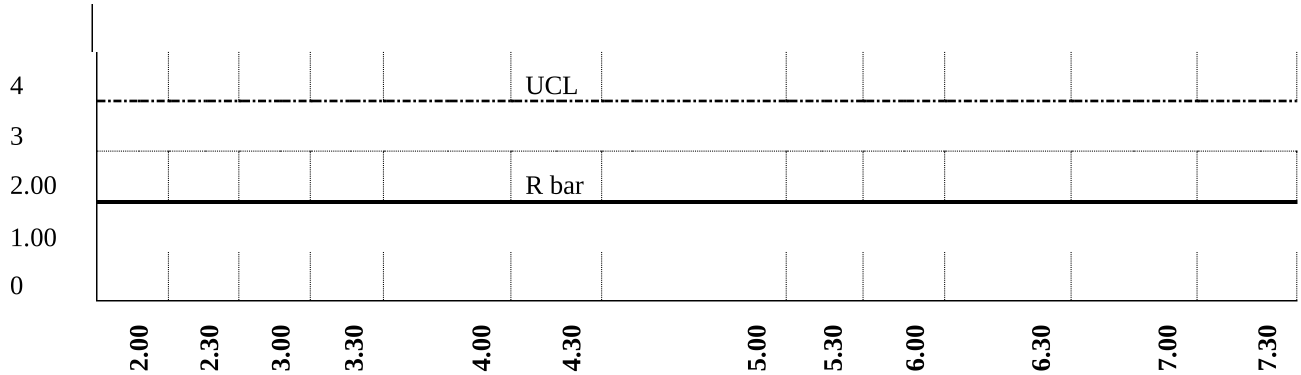
1/2 HOURLY WEIGHT MEASUREMENT—Xbar R calculation
DATE :- **Shift :-**

Cavity nos

Time	1	2	3	4	Average	Range
2.00						
2.30						
3.00						
3.30						
4.00						
4.30						

Charts to be plotted based on above data





SOP for operating above X Bar R Charts

take 1 cavity bottle sample on 1/2 hourly basis and record weights
calculate average and range in aa the above data sheet and the above Data sheet
And plot the average (Xbar and Range R) in the above chart

	DECISION MAKING
1	Xbar R charts are to be developed nad used for combination of machine and item i.e for same item if run at different machines, different charts will have to be used
2	If any individual reading is outside specification limit in the data table, put the earlier 1/2 hour lot and production in tray on hold and measure weight of cavity outside limits and reject the ones outside limit . No change in setting is required at machine
3	If weight is uniformly distributed around the average line and the readings are within the control limits ---- do not change machine setting and pass the produced lots
4	If at any time any point goes outside limits in R chart --it means the process is out of control. The use of charts is to be stopped; action to be taken on machine to remove assignable causes and when problems are resolved then only X bar R chart to be started again
5	if Xbar falls above control limit --- ask operator to reduce weight as setting has gone up --reduce setting to average. put the earlier 1/2 hour lot and production in tray on hold and measure weight of cavity outside limits and reject the ones outside limit
6	If Xbar falls below control limit --- ask operator to increase weight as setting has reduced --increase setting to average. put the earlier 1/2 hour lot and production in tray on hold and measure weight of cavity outside limits and reject the ones outside limit
7	In cases 2 & 3 , bottles lying in cutting tray and bag being filled and packed bags of last 1/2 hour to be put on hold and each bottle to be weighed and then passed if falling with in limits , else , bottles should be rejected ---records to be maintained at backside of chart for qty put on hold , qty rejected after sorting
8	If seven consecutive readings fall above the average line; then reduce the weight setting at machine to average of Xbar cart
9	If seven consecutive readings fall below the average line then increase the weight setting at mchine to average as per Xbar chart
10	In cases 3& 4 , only weights are to be reset at machine , the produced lots are to be passed
11	if less than 7 consecutive readings fall above the central line or less than seven consecutive readings fall below the central line --then do not disturb the machine setting

Demo of tool for X bar R chart

M/C NO.: - **Item: -**

DATE :

SR.NO.	TIME	1	2	3	4	AVG.	max.	min.	Range
1	9.00	283.6	285			284.3	285	283.6	1.4
2	9.30	279.3	283			281.2	283	279.3	3.7
3	10.00	282.2	284			283.1	284	282.2	1.8
4	10.30	279	285			282.0	285	279	6
5	11.00	282	285			283.5	285	282	3
6	11.30	283.4	282.2			282.8	283.4	282.2	1.2
7	12.00	281.3	280			280.7	281.3	280	1.3
8	12.30	281	282			281.5	282	281	1
9	1.00	285	284			284.5	285	284	1
10	1.30	280	282			281.0	282	280	2
11	2.00	285	283			284.0	285	283	2
12	2.30	280	285			282.5	285	280	5
13	3.00	277	281			279.0	281	277	4
14	3.30	278.2	281			279.6	281	278.2	2.8
15	4.00	282.2	281			281.6	282.2	281	1.2
16	4.30	281	289			285.0	289	281	8
17	5.00	280	280.6			280.3	280.6	280	0.6
18	5.30	283.3	283.2			283.3	283.3	283.2	0.1
19	6.00	281.4	285			283.2	285	281.4	3.6
20	6.30	283.3	285			284.2	285	283.3	1.7
21	7.00	284.4	285			284.7	285	284.4	0.6
22	7.30	285.2	289			287.1	289	285.2	3.8
23	8.00	289.6	282			285.8	289.6	282	7.6
24	8.30	282.2	283			282.6	283	282.2	0.8
25	9.00	283.1	280.1			281.6	283.1	280.1	3
26	9.30	278.1	283.1			280.6	283.1	278.1	5
27	10.00	277.1	281.6			279.4	281.6	277.1	4.5
28	10.30	284.2	282.1			283.2	284.2	282.1	2.1
29	11.00	283.1	279.1			281.1	283.1	279.1	4
30	11.30	281.2	279.2			280.2	281.2	279.2	2
31	12.00	277.1	282.1			279.6	282.1	277.1	5
32	12.30	283.1	278.2			280.7	283.1	278.2	4.9
33	1.00	280.1	277.1			278.6	280.1	277.1	3
34	1.30	283.1	280.2			281.7	283.1	280.2	2.9
35	2.00	279.1	281.1			280.1	281.1	279.1	2
36	2.30	278.2	280.2			279.2	280.2	278.2	2
37	3.00	279	280			279.5	280	279	1
38	3.30	278.1	281.2			279.7	281.2	278.1	3.1
39	4.00	277.2	279.2			278.2	279.2	277.2	2
40	4.30	283.1	279			281.1	283.1	279	4.1
41	5.00	280	282.1			281.1	282.1	280	2.1
42	5.30	283.1	279			281.1	283.1	279	4.1
43	6.00	283.1	280.2			281.7	283.1	280.2	2.9
44	6.30	281.2	279.2			280.2	281.2	279.2	2
45	7.00	283.1	279.1			281.1	283.1	279.1	4
46	7.30	279.2	280.2			279.7	280.2	279.2	1
47	8.00	277.1	279.2			278.2	279.2	277.1	2.1

48	8.30	279.1	283.1			281.1	283.1	279.1	4
49	9.00	278.1	280.1			279.1	280.1	278.1	2
50	9.30	278.2	281			279.6	281	278.2	2.8
						281.5			2.8
			specification	min.	max.	sp.width			

specification		280	275	285	10	
	d.centre	280				
	A2	1.88				
	R_	2.8				
	A2R_	5.33				
	D3	0				
	D3R_	0				
	D4	3.27				
	D4R_	9.27				
	X_CHART			**R_CHART**		
	UCLX_	286.82		LCL	0	
	LCLX_	276.15		R_	2.8	
	X_	281.5		UCL	9.27	
	Proce.width	10.7				
	spe.width	10				
			max.	281.5		
	cp	0.9	min	280.0		
	cpK	0.66	k=	0.30		
	revised X_ =		**280.33**			
	revised LCL=		**275.00**			
	revised UCL =		**285.66**			
	recalculate K =		0.07		max.	280.33
	cpk		0.88		min	280.00

Table of Appendices

Appendix Ref	Description	Link *(Please right click to open the link)*
Appendix - A	Planning --Job allocation on machine	https://rb.gy/kch43w
Appendix - B	Production planning and control Tracker	https://rb.gy/xu4qwf
Appendix – C	Planning – Delivery Index Calculation Template	https://rb.gy/t0mmea
Appendix – D	Planning ---PPC index calculation template	https://rb.gy/vvjzh8
Appendix – E	Production Efficiency and Overall Equipment Efficiency Template	https://rb.gy/ps7wrc
Appendix – F	Quality Plan	https://rb.gy/pve3er
Appendix – G	Customer complaint Analysis for a complaint in rigid bottle manufacturing –Fish Bone diagram template	https://rb.gy/z8hts3

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Conflict of Interest

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