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Impact Assessment of SPC Tools on Quality Improvement in Pakistani Industrial Environment: A Dynamic Case Study

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Abstract
Whether one belongs to service or production industry, Quality is always a big issue for business persons and the customers. If we do not have any means of measuring the performance of manufacturing Unit in trouble, how can we improve it? As W. Edwards Deming said "If you cannot measure it, you cannot improve it". Everybody in the field of TQM is familiar with control charts and statistical process improvement for Quality. A number of tools, including the Six Sigma tool box, are made up of seven simple tools: flow chart, check list, histogram, Pareto chart, cause and effect diagram, scatter diagram, control chart. The Japanese call them "seven QC (quality control) tools, which have been used for decades to support quality improvement efforts to solve the problem.
Usually variation is the only main reason for varying or low quality of their product/service, increasing dissatisfaction among customers and decreasing business credibility as a result. For that purpose, we chosen a business organization "Silver Lake Foods Pvt. Ltd." as a study object, as management of SLFL was highly willing to cooperate. SLFL is a Food Manufacturing organization which produces food items like Biscuits, toffees, candies and chocolates, drinks etc. Management of SLFL has found that the process average for critical characteristics i.e. weight, taste etc. were out of control and causing big losses. In some cases, they have some ideas about possible causes. However, in most cases, they do not want or lack of knowledge and resources restrict them to carry out experimental design to find out the reasons for the change or decline quality.We have decided to use statistical process control (SPC) procedures for quality control, quality improvement and then ultimately towards total quality management.There were some ideas about possible causes but, as in most cases, they were reluctant or lacking the knowledge and resources to perform experimental design to find out the causes of variation or the causes of decreased (/ing) quality. We decided to use statistical process control (SPC) program to make the steps towards quality control and from quality control to quality improvement and then ultimately towards TQM. The Proposed study intends to find out impact of SPC tools in Quality improvement in Pakistani Industrial environment by studying Silver Lake Foods Pvt. Ltd. This research also identify the main sources of variations and bottlenecks through dynamic use of SPC tools and suggest recommendations regarding higher quality improvement and customer satisfaction levels in future.
Keywords: Six Sigma tool box, TQM, Customer satisfaction, SPC tools, SLFP (Silver Lake Foods Pvt. Limited), Food industry, Quality improvement

1. Introduction

Whether one belongs to service or production industry, Quality is always a big issue for business persons and the customers. If we do not have any means of measuring the performance of manufacturing Unit in trouble, how can we improve it? As W. Edwards Deming said "If you cannot measure it, you cannot improve it". Usually variation is the only main reason for varying or low quality of their product/service, increasing dissatisfaction among customers and decreasing business credibility as a result. For effective business approach, one has to watch over quality of service/Product and control variation, this is Quality Control. Everybody in the field of Quality Control is familiar with control charts and statistical process improvement for Quality control. For that purpose, we had chosen a business organization "Silver Lake Foods Pvt. Ltd." as a study object, as management of SLFL was highly willing to cooperate**.** Under study business organization is a Food Industry which produces food items like Biscuits, toffees, candies and chocolates, drinks etc. Management of SLFL has found that the process average for critical characteristics i.e. weight, taste etc. were out of control.

In some cases, they have some ideas about possible causes. However, in most cases, they do not want or lack of knowledge and resources restrict them to carry out experimental design to find out the reasons for the change or decline quality. We have decided to use statistical process control (SPC) procedures for quality control, quality improvement and then ultimately towards total quality management. The Proposed study intends to find out impact of SPC tools in Quality improvement in Pakistani Industrial environment by studying Silver Lake Foods Pvt. Ltd. This research also identify the main sources of variations and bottlenecks through dynamic use of SPC tools and suggest recommendations regarding higher quality improvement and customer satisfaction levels in future

Silver Lake Foods Pvt. Limited (SLFP) is operating in Hattar Industrial State, Haripur, NWFP since 1995. Being HACCP (Hazard Analysis of Critical Control Points) and ISO certified, the company produces various types of food products. The company had strong business standing in early years, having good share in domestic and international market as they were third in the Production of biscuits, candies, toffees, chew gums, chocolate and drinks. They exported their product to about 25 countries including Middle East and south eastern countries.

1.1. SLFL Vision Statement
Be the most respected and successful enterprise, delighting customer with innovative food products and continuous improvement in technology and people.

1.2. SLFL Mission Statement
We are striving to produce safe and quality food at appropriate value while meeting all legal and other requirements regarding quality, environment, and food safety management systems. Management committed to prevent pollution and make all efforts for continual Process Improvement.

1.3. The SLFL Market
The products of SLFL are marketed throughout the country through a strong marketing network. There are also exported to over 25 countries throughout the globe including: Canada, USA, New Zealand, Australia, UK, African countries, Middle eastern countries, Korea Sri Lanka, Bangladesh, Afghanistan etc.

1.4. Brief History of SLFL:
1995 Started with Biscuit, Toffee, bubble gum Manufacturing
1998 New Block including Candies, Chocolate and Wafers
2000 Biscuit 2nd Plant and Ink manufacturing
2000 ISO 9000-1994 certification
2002 HACCP Certification
2003 ISO 9001-2000 Re certification
2004 ISO 14000 implementation
2006 ISO 9001, HACCP Re certification
2007 TQM Implementation
2008 TQM Sessions and Quality Assurance department closed and 50% Downsizing of the whole company.

1.5. The Management Systems at SLFL:
SLFL has implemented three internationally recognized management systems namely;

- **Quality Management System:** QMS as adopted by SLFL is designed to be aligned with International Standard, ISO 9000; 2000, and Quality Systems Model for Quality Assurance in Installation, Production and Servicing.
- **Environmental Management System**: EMS conforms to ISO 14001 - 2004 Standards; it covers all internal/ external environmental issues and legal matters.
- **Food Safety Management System:** FSMS takes care of potential physical, chemical and micro biological hazards associated with the product and /or services. HACCP concepts of food safety conform to Codex Alementarious standards.

2. Background of the Study
Things changed few years back when cost of input (utility charges, labor charges, material, regulatory charges etc.) rose gradually, whereas the relevant rates of the produced items could not be increased accordingly due to tough competition. In the meanwhile, working capacity utilization decreased gradually due to stress introduced by tough environment, improper defined procedures and processes and maintenance processes, lack of communication between administration and workers. There were many issues affecting the productivity and consumption. Even when asked, researcher came to know that there is no annual production report formulated and printed during previous years.

In round estimates, company is producing about 18 tons of biscuits per day, which is just 50% of their production capacity, with the wastage of 1 ton per day i.e. 5.55% of production. Candy Section is more critically addressable as wastage rate and defective rate are being increase for last six months and quality is getting lower since then.

Among all other units, candy section is more critical as during last two years, productivity is deceased from 95% (that used to be ideal) to 70-75%, scrap generation increased from 1.5% to about 5.7%, and wrapper wastage increased 3% to 5% per day. Earlier the candy section at KIMS had third highly Candy producing unit in Pakistan, however, its production is under critical circumstances for last two years. Quality and Production Philosophies are being practiced much enthusiastically and employees are being trained for last year but theirs is not such improvement in production rate and Product quality. “wastage and rework on the other hand has increased critically as from 0.05% defect rate per package to 1.0% per package during last two years” stated by a

Quality Assurance worker at KIMS Foods. Candy Section should produce 14 batches (i.e. single cooked ingredients) per day; however, it is producing 10 batches in average.

Company's financial standing is also addressable as the Price per share has decreased from 301Rs to 176Rs per share during last 4 years.

3. Research Problem

"Candy Unit is producing 10 batches per day in average, with 1.0 defect rate. Scrap generation is 5.7% while wastage of material is 3-5% per day. Previously, Company had been achieving the production of 14 batches of candies per day, with 0.05% defect rate and 1.5% Scrap generation with very low rejection rate (no authenticated data available). Considering First state ideal and achievable, researcher intends to design and improve the system towards best performance again".

4. Purpose of the Study

Find out the causes of variation & wastage and suggest remedial measures.

In general the purpose of the study is to quantifying process capability. cost reduction, reduced variation around targeted values and compensation of process deviations to ensure product conformity indicating how the process is likely to behave if improved in the future.

More precisely; To define and refine processes to reduce variation in the product quality, workplace output, work methods, inspection criteria, and materials, and to train workers to get best production rate and product quality and least wastage.

5. Literature Review

5.1. Why Total Quality Management needs SPC tools?

Total quality management (TQM) is a set of continuous process improvement activities that involves all people in the organization i.e. Managers and workers work in a fully integrated manner to improve performance at each level. It is done with the team concept. Managers and workers are members of the quality team (often referred to as quality circles), focusing on continuous process improvement. The definition of quality as well as degree of excellence are two critical points which need to be agreed by management and team members of any organization participating in TQM implementation (Matsoso and Benedict 2015).The principle of SPC is almost the same as that of total quality. It should not be surprising that both exist in parallel, because it is Walter Shewhart's works which inspired Japan to invite W. Deming and later Edwards Joseph Juran to help them to start their quality program in 1045-1950. SPC is the seed from which Japanese grew total quality concept.

In order to understand how SPC concurrently help in Product Quality improvement, cost reduction and product image improvement in world's market, it is necessary to study five key points and get understanding about working of SPC in each one: These five key points are Control of Variation, Elimination of waste, Continuous Improvement, Predictability of Processes, and Product inspection(Goetsch and Davis 1997).

Total Quality Management (TQM) is the concept of combining teamwork with Deming and Juran's philosophies of quality management and statistical process control (SPC) to achieve process control as a means of achieving process improvement. Total quality management, as a concept, has been interpreted differently by different quality leaders, but there are some common principles. Business management and engagement team must have technical knowledge of customer needs / requirements and processes to meet these needs as well as to develop innovative solutions. Private organizations and federal agencies must development and adapt such internal organizational culture that help in effective implementation of TQM (Romeu 1997).

Total quality management is a management philosophy that aims to integrate all organizational functions (marketing, finance, production, customer service, design, engineering, etc.) to meet customer needs and organizational goals. In the sight of TQM, an organization is a collection of processes. It also argues that organizations must strive to continuously improve these processes through the knowledge and experience of workers. The ultimate goal of total quality management is "**Do the right things, right the first time, every time**".

TQM provide base for activities, which include: senior management and staff commitment , meeting customer needs, reduction in development cycle time, Just-in-time / demand flow manufacturing, improvement teams, reduction in costs of products and services, system to facilitate improvement,, line management system, employee involvement and empowerment, recognize and celebration, benchmarking and challenging quantitative objectives, focus on process improvement plans and specified incorporation in strategic planning (Hackman and Wageman 1995, Chileshe 2007).Martin defines key principles of TQM as following, which shows need of SPC tools in every major area of TQM (DeLaney 1993):

Table 5.1: key principles of TQM, which shows need of SPC tools in every major area of TQM adopted from (DeLaney 1993)

Management Commitment	Employees empowerment	Fact-based Decision making	Continuous Improvement	Customer-focus
Plan (drive & direct)	Training	SPC (Statistical Process Control)	Systematic measurement and focus on CONQ	Supplier partnership
Do (deploy, support, and participate)	Suggestion Scheme	DOE, FMEA	Excellence Teams	Service relationship
Check (review)	Measurement and recognition	The 7 statistical tools	Cross Functional Process Management	Never Compromise quality
Act (recognize, communication, revise)	Excellence teams	TOPS (FORD 8D – Team Oriented Problem Solving)	Attain, Maintain, improve standards	Customer driven standards

The TQM tools help organization identify, analyze and evaluate the qualitative and quantitative data that are relevant to their business. These tools can identify programs, ideas, statistical cause and effect concerns and other related issues of their organization. Each can be checked and used to improve efficiency, effectiveness, standardization, and overall quality of the programs, products and working environment in accordance with ISO 9000 standards (Sun 2000, Duffy 2013).

TQM tools illustrate and helps in the integration of complex information such as: Identification of your marked audience, Evaluation of customer requirements, Productivity variations, Market analysis, Staff responsibilities and work flow analysis, Business configuration, Positive and Negative forces disturbing business, Various statistics, Competition analysis, Model creation, Brainstorming ideas, Statement of Purpose and Logistic Analysis. There is a long list, however fundamental TQM tools can be used in any circumstances for a number of reasons and happened to be very effective if used in proper way (Payne 2004).

5.2. Why SPC is needed anyway?

Change is a fact of life. It is everywhere, it is inevitable. Even with a brand new, state-of-the-art machine, there are always some fluctuations around the target and it can't maintain the perfect target setting (Leavengood and Reeb 1999). Variation is the only reason for varying or low quality (Hitoshi 2006). To control variation in System and Processes, Statistical Process Control (SPC or The 7 Quality Improvement) tools are used. Achieving consistent product quality needs to understand, monitor and control changes. Achieving optimal product quality requires a never-ending commitment to reduce variation. Where does the change come from? Walter Shewhart, who worked to lay the base for SPC, recognized that the variation has two main reasons:

- **Common** (also known as random, chance, noise or unidentified) reasons and
- **Special** (also known as assignable, signal) reasons.

Common causes of variation can be considered as the process of natural rhythms". Real quality improvement needs to continue to focus on reducing common causes. Special reasons of variation are a signal that some changes have taken place in the process. It results in unpredictable performance of the process, so it must be identified and removed before taking other steps to improve the quality. It is important to distinguish between these two types of variation because the treatments are quite different (Leavengood and Reeb 1999).

ISO 9000:2000 puts great stress on the use of statistical methods compared with previous versions. For example, the standard requirements "applicable methods, including statistical techniques" were identified and used for monitoring and measurement of product and process, and through the monitoring and measurement, the organization can meet the requirements of the verification process and product ability to meet the requirements for new ISO standard, 11462-1, provides directions for organizations wishing to use SPC to meet these requirements. SPC is a useful method for the process that run at a low sigma level, for example, 3 Sigma or less. At 4-signma or high, the cumulative count (CCC) chart is constructed to monitor the total number of fit items until found a defective item (Hitoshi 2006).

5.3. SPC in a Nutshell:

Montgomery (Montgomery 2007) defines SPC as "a powerful collection of problem-solving tools useful in achieving process stability and improving capability through the reduction of variability". Control chart and process capability analysis are two main tools of SPC. Other tool such as flow charts, histograms, cause-and-effect diagrams, check sheets, and Pareto diagrams are useful in quality and process improvement.

SPC tools describe:

- The estimation of the process distribution under normal conditions
- Determine whether the process is stable
- Continued monitoring and control process

- Comparison of process performance and specifications
- Identify how to continuously improve the process

Evans and Lindsey (Evans and Lindsay 2002) define SPC tools as Basic tools for process improvement.

According to them, Six Sigma has created a new emphasis on process improvement. Among many tools which are included in the Six Sigma tool box, there are seven simple tools: Flowcharts, histogram, check sheets, cause and effect diagram, scatter diagram, Pareto diagram and control charts. The Japanese call it "the seven QC (quality control) tools that has been used for decades to support quality improvement efforts to solve the problems.

Table 5.2: Application of the 7 Quality Control tools in Six Sigma adopted from (Ghobadian and Gallear 2001)

Tool	DMAIC Application	CPS Application (Creative Problem Solving)
Flow charts	Define, Control	Mess-Finding
Check sheets	Measure, Analyze	Fact-finding
Histograms	Measure, Analyze	Problem-Finding
Cause-and Effect Diagram	Analyze	Idea-Finding
Pareto Diagram	Analyze	Problem-Finding
Scatter Diagram	Analyze, Improve	Solution-Finding
Control Charts	Control	Implementation

Although SPC is usually thought of as an industrial application, it can be applied to almost all processes. Everything that is done at workplace is a process. All processes are affected by many factors. For example, in the workplace, the process may be affected by the environment and the machine, the material used, the method of measurement (work instructions) and the man (human) (Five M's). If these are the only factors that effects the process output and all of these are perfect - this means that the working environment is conducive to the quality of work; no disturbance in the machine; material without defects; completely accurate tracking of work instructions, accurate and repeatable measurements and meticulous work by workers according to the work instructions and are concentrated on the completion of the work - if all these factors are consistent then the process is under statistical control. This means that there is no particular reason to adversely affect the output of the process. Special reasons (temporarily, anyway) are to be eliminated. Does this mean that 100% of the output will be perfect? No, it does not. Natural variability is inherent in any process that affects yield. Natural changes are expected to account for about 3 out of limit parts per 1000 manufactured (the $\pm 3\sigma$ variation). Thus "**Statistical Process Control (SPC) is a statistical method of separating variation resulting from special causes from natural variation, to eliminate the special causes and to establish and maintain consistency in the process and to enable process improvement"** (Goetsch and Davis 1997)**.**

5.4. Effective use of SPC:

Statistical methods are effective tools to improve production process and reduce defects. However, it must be kept in mind that statistical tools are just tools: they would not work, if used inadequately.

Statistical tools require fairness and accuracy to observation. The maxims of statistical mode of thinking are:

- Give more importance to facts than theoretical concepts
- Do not interpret facts in terms of sense or idea. Use figures resulted from precise observational result.
- Observational results, along with their errors and variation, are part of a hidden whole. Discovering the hidden whole is the ultimate goal of observation.
- Accept consistent tendency which appears in a large number of observational outcomes as reliable information.

"One must understand imperfection of human recognition. One must then understand that knowledge presently held is nothing more than grounds for further hypotheses. After gaining that understanding, the above mentioned methods of thinking can be used for further deepen our understanding of the production process and the ways to improve it" (Hitoshi 2006).

6. Hypotheses

Following Questions are responded during this study:

1. What is the Defined Ideal situation for Candy Section Production/ Wastage/scrap/ Rework, Breakdowns, Maintenance, Performance rate?
2. What are major problem areas and major causes to be focused on?
3. What will be refined processes in the floor ideally?

7. The Design- Methods and Procedures

7.1. Process improvement methodologies:

There are following methodologies for Process improvement. The Deming Cycle, **PDSA (**Plan, Do, Study, Act to satisfy customer), that emphasizes on the short-term continuous process improvement and long-term organizational learning), another approach is **FADE** (Focus, analyze, develop and execute), Juran's breakthrough sequence, and use of **innovative problem solving** as and when required. Researcher intends to improve processes by using FADE and creative problem solving.

7.2. Process improvement Tools/ Data Analysis Tools:

Process mapping, Charts, Histograms, Check sheets, Pareto diagrams, Scatter diagrams , cause-and-effect diagrams, Stratification, Control Charts, Additivity of variances, and Use of Statistical inference as and when required. (Choice is open ended; researcher may use any appropriate tool if needed).

7.3. Data Gathering and Collection:

Required data and information will be collected through interviews of the company management, relevant officers & employees, historical record of the M/S Silver Lake Food Limited (SLFL), surveys of internal customers and recording the production data etc.

Table 7.1: Data Collection Sources in SLSF Case Study

Interviews	**Meetings**	**Surveys**	**Use of Existing Data collection system (Manual reports and charts)**
General Manager KIMS	General Manager KIMS	Workers at Candy Department (Cooking, packing, wrapping sections)	Use of Daily Produced Run Charts, other charts.
General Manager Production	General Manager Production	Quality Assurance Inspectors	Use of Manually produced Reports: Production Repot, Breakdown Reports, Sanitation report, Wrapper wastage report
Quality Managers	Quality Managers		General information gathering
Supervisors at Candy			

8. The Application of Process improvement tools and techniques:

The use of quality management tools and improvement techniques initially relied on the involvement of the quality assurance department to facilitate its application. The reason for this is that the initial training of SPC was wrongly focused on complex statistical techniques. It was also delivered prematurely as well as to wrong group of people. Specific training lead a group of senior managers to be able to construct a control chart (or mostly the run-chart), but do not have the knowledge to interpret or use the information and results, or how to select the business area for technique application.

Now researcher intends to create interest in use of the techniques of process improvement and to reduce the resistance for using SPC to improve business processing and working output on the floor as well as to reduce the understanding deficiency in the team about how SPC, simple process improvement techniques and Kaizen's tools can improve throughout business standing of the organization.

Table8.1: Identification of Major, core and support processes at SLSF

Major Processes		**Core Processes**	**Support Processes:**	
Accounting	Shareholder Relations	Accounting	MIS	Store Management
MIS	Human Resource	Finance	Legal	Human Resource
Procurement	Production	Procurement	Printing	Shareholder Relations
Legal	Store Management	Production	Quality Assurance	Product Design
Research and Development	Customer Complaint Handling	Research and Development	Maintenance Works (Complaint Handling)	Scrap and Waste Consumption
Mechanical Works (Local Manufacturing (Plant and Equip.))	Maintenance Works (Complaint handling)	Customer Complaint Handling	Mechanical Works (Local Manufacturing (Plant and Equip.))	
Marketing	Quality Assurance	Sales and Distribution		
Sales and Distribution	Printing	Marketing		
Finance	Scrape and Waste Consumption			
Product Design	Shareholder Relations			

9. Limitations and Delimitations:

- Candy Section is taken as a sample unit for all the running units in the organization due to less time available for study. Already collected data is being used, subject to its authenticity. New data is also being collected (under supervision) to check the results and findings as optimal and true. Floor data is not 100% precise and accurate; researcher needs to extract accurate readings herself.
- Lack of understanding and use of accurate terminology for TQM and SPC implementation.
- System understanding for researcher might not be too realistic.
- 100% Accurate, in-time and Authenticated data provision is not possible
- Limited number of visits.
- Less Time available to study the matter.
- No (Proper) data available for Shift C.
- Access to the whole organizational data is possible due to cooperative management of the organization.
- Good environment and comparatively unstressed and cooperative workers

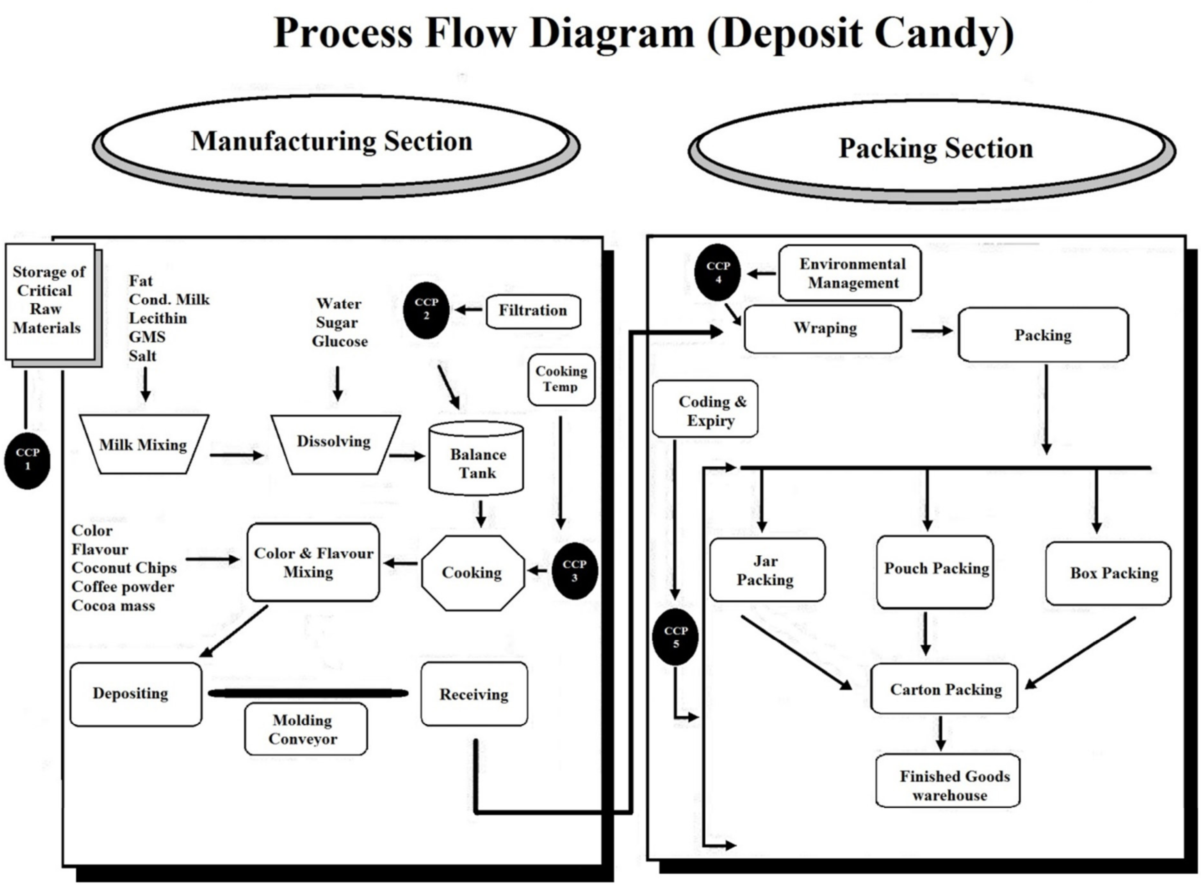


Figure 9.1: Process Flow Diagram (Deposit Candy)

10. Sampling:

Floor data is collected from the day to day taken samples (run charts (reading taken every half an hour by operator) and other tabular data by supervisors). So subject to only provision, that data is being used for processing and analysis right now.

Data Sample is taken from 2 shifts, Shift A and B and data of a complete Month of May, 7 is taken. For comparisons, Manual reports of past six months ae also used.

Table 10.1: Summary of Defect in Candy Deposit at SLFL

Percentage Defects in Candy Manufacturing (Both Shifts)					
s#	**Defectives List**	**Total %age of defects in 5 months (both shifts) (%)**	**Average defects per month per shift**	**Percentage of total defects (%)**	**Cumulative percentage (%)**
1.	Empty Wrapper	58.75	5.88	27.12	27.14
2.	More Bisc./PCS	35.68	3.57	16.47	43.61
3.	Registration Out	35.38	3.54	16.33	59.93
4.	Broken	29.54	2.95	13.63	73.56
5.	Double Candy	25.51	2.55	11.77	85.34
6.	Less Bisc./PCS	19.54	1.95	9.02	94.35
7.	Weak Sealing	12.24	1.22	5.65	100.00
	Total	216.65	21.67		

11. Methodology

Following SPC tools will be used to identify the problem areas and find their solutions.

- Pareto analysis
- Cause and Effect Diagram
- Histograms, frequency polygons and ogives
- X-bar and R-bar charts

11.1. Pareto Analysis

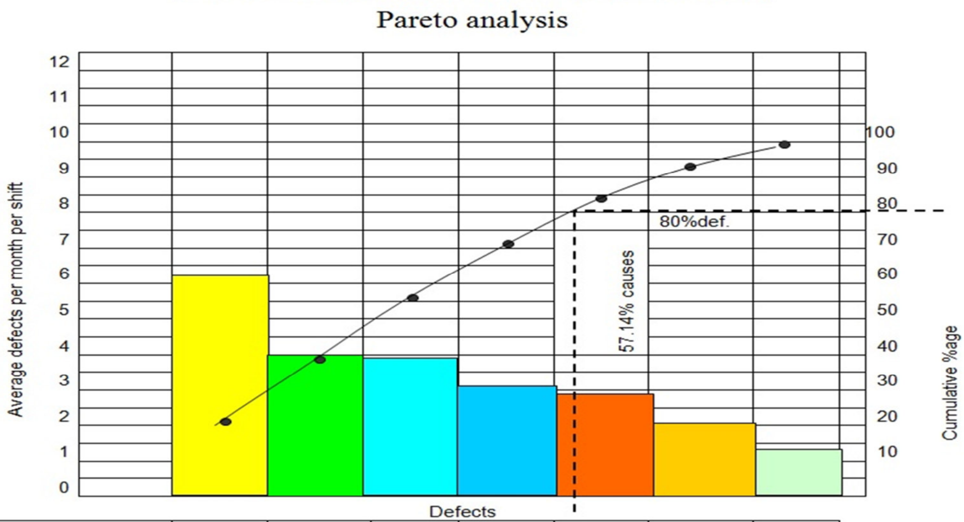
Quality problems arise in the form of loss (defective items and their incurred cost). Clarification of the loss distribution pattern is very significant. Most of the losses are due to very small types of defects, which can be attributed to a very small number of reasons. Thus, if causes of these few important defects are identified then we can eliminate almost all of the losses through concentration on these specific causes, leaving aside other insignificant defects for time being..

By using Pareto diagram, we can solve this type of problems efficiently (Hitoshi 2006). "80% defects are caused by 20% reasons"(Frank 2012).

Therefore analyses of only manufacturing section will be carried out in following categories:

1. Month wise combined data of both the shifts
2. Separated month wise data of both the shifts to differentiate the performance of shifts. Pareto charts and its data is placed below at Annex-A. Observations of the analysis are as under:

Defects in candy deposit (Both shifts combined)



Defects	Empty wrapper	More Bisc./PCS	Reg. out	Broken	Double candy	Less Bisc./PCS	Weak sealing
Average defects per month per shift	5.876	3.57	3.54	2.954	2.551	1.954	1.224
Cumulative %age	27.14%	43.61%	59.93%	73.56%	85.34%	94.35%	100%

Figure 11.1: Pareto Analysis of percentage defectives in Deposit Candy

11.2. Cause and Effect Diagram

Six parameters (Machinery, Men,, Material , Packing machines, Environment, Process) are used for the wastage and rework problem in candy factory.

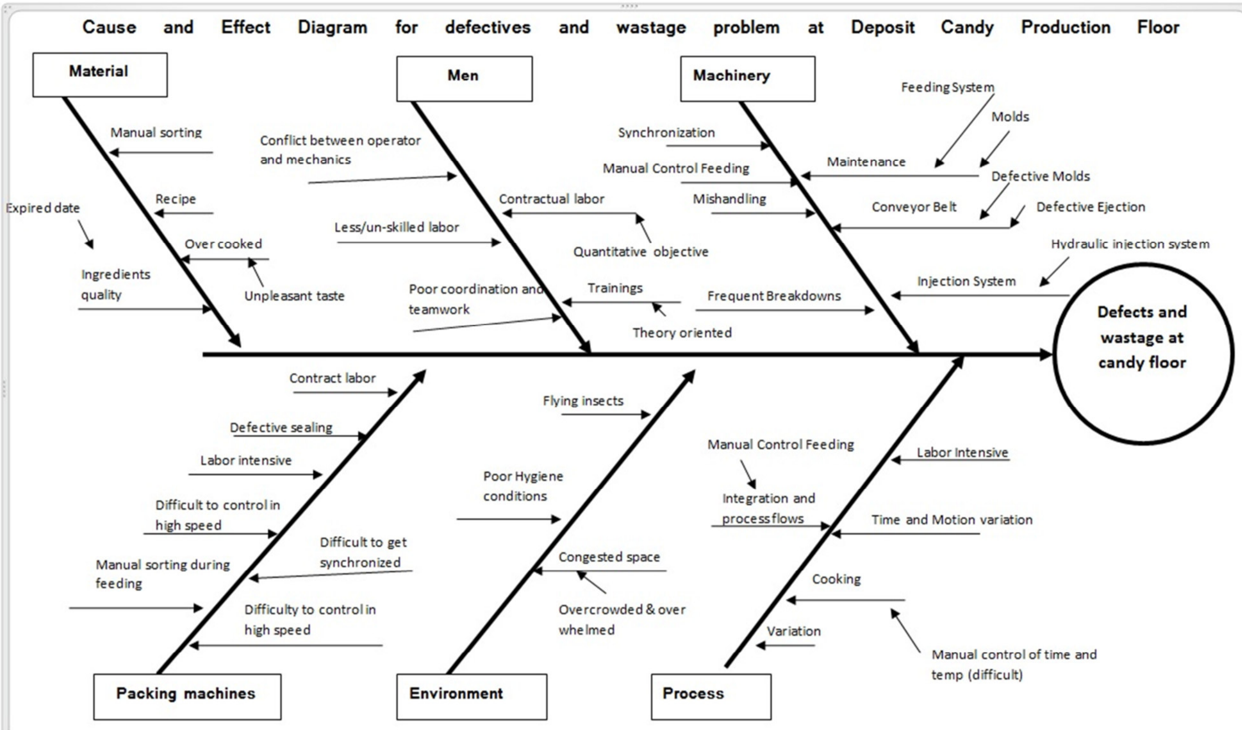


Figure 11.2: Cause and Effect Diagram for defectives and wastage problem at deposit Candy Production Floor

11.3. Histograms, frequency polygons and ogives

These charts are prepared, on the basis of data obtained. Control charts data of deposit candy is used.

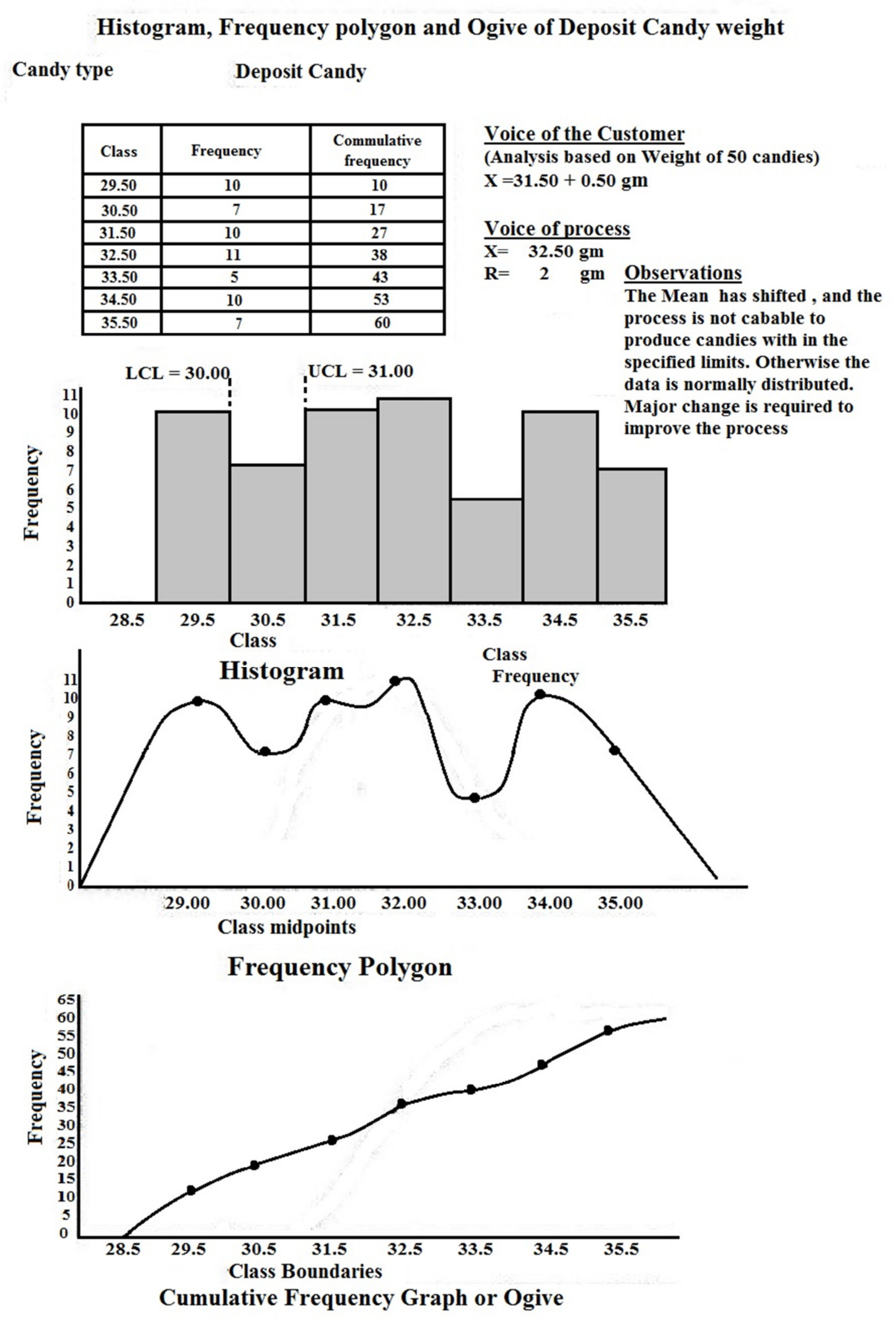


Figure11.3: Histograms, frequency polygons and ogives charts of deposit candy

11.4. X-bar bar and R-bar Charts

These charts are constructed on the basis of data values obtained on different machines

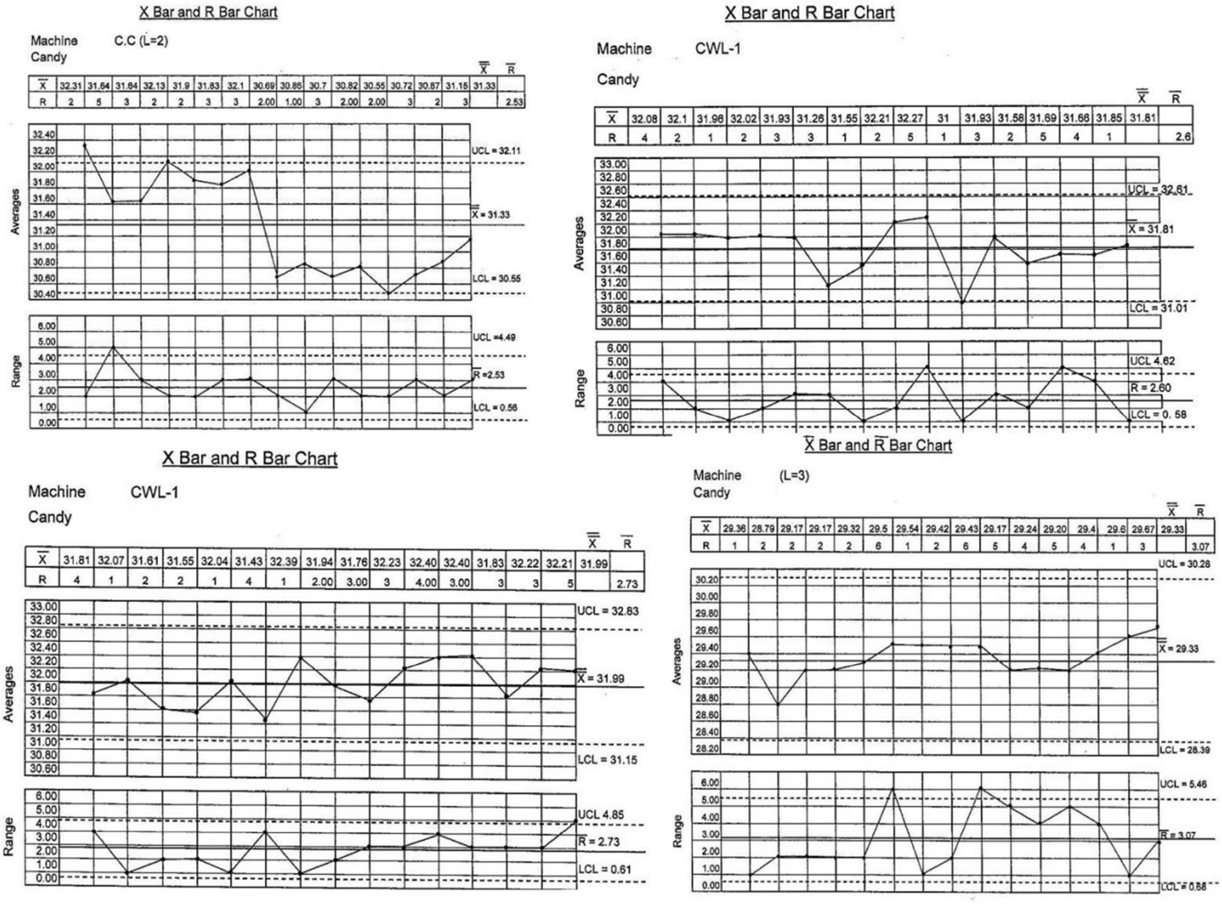


Figure 11.4: X- bar and R- bar charts showing readings on different machines

12. Summarized Findings:

12.1. Pareto Analysis

- The Pareto analysis does not hold well (80% defects are caused by 20% reasons) as per given data, for the 7 number of defects identified.
- Top three defects have a share of about 58% to 60%.
- Three top defects are listed as under:
  1. Empty wrapper
  2. More material per piece
  3. Registration out
- Therefore by resolving top three problems, about 60% of the problems can be resolved.
- There is another major defect “wastage due to over cooking of candy recipe” which has not been included the list of defects by the company, due to unknown reasons. It also is a main source of wastage.
- Two defects pertain to packing process, i-e packing candies in large envelops/packets for supplying into the market. The two defects are:
  1. Packing more No of candies in the packets,
  2. And packing less No of candies in the packets.

  The packing is carried out on weight basis, instead of counting. Therefore, variation in average weight of candies affects the number of candies packed in the packets. Adding more number of candies is a loss to the Company and on the other hand, packing less number of candies due to higher average weight, makes an adverse impression on the customers, especially on shopkeepers, who sell candies on numbers basis.
- Although the control charts were used to monitor the production and process control, but it did not cause a significant effect due to ineffective use.

12.2. Cause and Effect Diagram

The critical causes are listed as under:

- Improper Feeding/injection system in the molds.

- Defective ejection system of candies from the molds.
- Conflict between the operators and mechanics, who instead of resolving the problem, blame each other for the defective production.
- Quantitative objectives of contract labor.
- Uncontrolled cooking of recipe, which results in wastage of overcooked material.
- Time and motion conflict/synchronization of high speed semi-automatic wrapping machines with manual handling.

12.3. Histograms, frequency polygons and ogives

Conclusions drawn from above charts for different candies are as under;

Shift A

- The process is off center for all the samples analyzed; mean has shifted and out of specified limits.
- Whereas for later three samples the process is well centered with normal distribution and average well within limits.
- Considerable production is outside the specified limits and in rejection region. Range is very high, ranging from 2 to 5.
- Major effort is required to bring the process in the specified limits or specifications/limits need to be redefined.

Shift B

- The process is off center in all the samples analyzed. The mean has shifted however it is still with in specified limits.
- The process is not very consistent and stable; range is very high, ranging from 3 to 5.
- Specified limits are too tight i-e 32 ± 0.50 gm.
- Considerable production is out of specified limits and is in rejection zone.
- Major effort is required to align the process with in specified limits.

12.4. X and R bar charts

Observations and conclusions drawn from all the charts are as under:

Sample 1:

X- Chart:

- Average of X-bar value is 31.33 gm against required 30.50 ± 0.50 gm. It is outside the specified limits.
- Since the observations are based on weight of 50 candies, therefore limits of X bar charts have been fixed for A2 value [55] (0.308) against Subgroup (n) = 50.
- Reading First 7 consecutive points are above the average line with 2 signals, which means that the mean has shifted up words but the second 8 consecutive points are below the average line with one signal which shifts the mean value below average line. The trend of graph line is up words and it seems that the mean is trying to match the average line once again.
- The adjustment/tempering has been made in the process after first 7 observations or due to assignable causes, the mean value has shifted below the average line.
- The system seems to be out of control. There is variation due to assignable causes. Process is unable to produce candies with in specified limits.

R-Bar chart:

- Average R value is 2.53 gm. The limits of R bar chart have been fixed [55] for Subgroup (N) = 50 i.e. D3 = 0.223 and D4 = 1.777.
- The trend of graph line seems to be normal, with the exception of one signal.
- The data point's distribution shows presence of continues tempering/adjustments in the process and an effort on the part of operator to reduce the variation.

Sample2:

X- Chart:

- Average of X-bar value is 31.81 gm against required 32.50 ± 0.50 gm. It is outside the specified limits and is on lesser side.
- Since the observations are based on weight of 50 candies, therefore limits of X bar charts have been fixed against Subgroup (n) = 50 with A2 = 0.308.
- First 5 consecutive points are above the average line after that the data points are rotating around average line, there is also a signal. The trend of graph line is to maintain the average line.
- The system seems to be consistent and stable with a shifted mean. The process is unable to produce candies with in specified limits.

R-Bar chart:

- Average R value is 2.60 gm. The limits of R bar chart have been fixed for Subgroup (N) = 50 i.e. D3 = 0.223 and D4 = 1.777.
- The trend of graph line is to cross the mean/average line after every two three data points. There are two signals also, with some assignable causes.
- The data point distribution shows presence of continues tempering with the process.

Sample 3:

X- Chart:

- Average of X-bar value is 31.99 gm against required 32.50 ± 0.50 gm. It is slightly out side the specified limits and is on lesser side.
- Since the observations are based on weight of 50 candies, therefore limits of X bar charts have been fixed against Subgroup (n) = 50 with A2 = 0.308.
- There is a central tendency and data points are rotating around the average/mean line. The graph line shows presence of continuous tempering with the process.
- The system seems to be consistent with a shifted mean. The process is unable to produce candies with in specified limits.

R-Bar chart:

- Average R value is 2.73 gm. The limits of R bar chart have been fixed for Subgroup (N) = 10 i.e. D3 = 0.223 and D4 = 1.777.
- 4 consecutive data points are on lower side of the average line and 7 consecutive points are on upper side, which show a shifted in the mean. There is one signal also, with some assignable causes.
- The data point distribution shows presence of continues tempering with the process.

Sample 4:

X- Chart:

- Average of X-bar value is 29.33 gm against required 29.50 ± 0.50 gm. It is within the specified limits and is on lesser side.
- Since the observations are based on weight of 50 candies, therefore limits of X bar charts have been fixed against Subgroup (n) = 50 with A2 = 0.308.
- There is no rapid change, 4 consecutive points are below the average line, and 2nd 4 consecutive points are above then again 3 below and 3 above. The trend of graph line is to maintain the average line.
- The system seems to be consistent with a shifted mean. The process is producing candies with in specified limits.

R-Bar chart:

- Average R value is 3.07 gm. The limits of R bar chart have been fixed for Subgroup (N) = 10 i.e. D3 = 0.223 and D4 = 1.777.
- The trend of graph line is very erratic. 1^{st} 5 consecutive points are below the average line then process could not remain stable and data points are rotating around the mean line with high range resulting in two signals with some assignable causes.
- Due to high average range value, the specifications fixed for both the charts have very wider limits
- The process is not stable, data point distribution shows presence of continues and abnormal tempering with the process.

13. Conclusion and Recommendations

- Attention may be focused to rectify the top three defects, which are causing 60% problems.
- The cooking process of candy recipe requires to be improved, with better temperature and time control. It is recommended to install, thermostat for temperature control and timer switch/devise to shut down steam when cooking time is over.
- Injection molding system of candy material may be improved, which is the main cause of variation in average weight of candies. It would make the process controlled and aligned with in the specified limits.
- Ejection system of candies from the molds may be kept in functional condition, which is also a source of over/less weight of candies including double candies. It is recommended that a vibrator be installed near the offloading position of conveyor belt, to facilitate the candies ejection. The molds get lubricated with cooking oil, which is part of candy recipe; the vibration would help the candy to fall off the mold.
- Conflict between the operators and mechanics may be resolved amicably.
- Contract labor may also be made accountable for poor quality. They should have some sort of fine for the defective output.
- High speed semi-automatic packing/wrapping machines may be synchronized with manual

feeding/handling.

- It is recommended that an independent section be created to record and monitor data for control charts.
- The operating staff has a nominal education; most of them are under metric. Training of operating and monitoring staff may be arranged to create awareness about the quality and use control charts to control the product quality.

Some Other Recommendations

- The candy shop area may be made fly proof, and general cleanliness may also be improved.
- Candy shop floor has worn out on some spots; it may be repaired/ replaced.
- Environment in the cooking and injection molding area is not comfortable and convenient for movement, which also affects the efficiency of workers. It may be significantly improved.

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