Quality Function Deployment

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Introduction to PTC

Pakistan Tobacco Company (PTC) is a subsidy of British American Tobacco (BAT), which is the world's most international tobacco group, with brands sold in 180 markets around the world. PTC, with annual sales of 27 billion sticks, is the 6th largest BAT companies based on volume. PTC produces high-quality tobacco products to meet the diverse preferences of millions of consumers, and work in all areas of the business - 'from seed to smoke' and is committed to providing consumers with pleasure through excellent products.

Pakistan Tobacco Company (PTC) has achieved one of the most remarkable transformations ever seen inside British American Tobacco through an extraordinary team effort.

In line with its long-term vision of becoming the "*First choice for Everyone*", PTC continued to relentlessly pursue its medium-term mission of "*Transforming PTC to perform with speed, flexibility and enterprising spirit of an innovative, consumer-focused company*".

PTC has achieved a score of 30 (from 15) in the 'Winning in Our World' (WOW) Change Management Model and a rating of 'Class A' in Manufacturing Resource Planning (MRPII – Oliver Wight version 5 checklist) in 2001 is just additional supportive evidence of our winning corporate culture. PTC has also achieved ISO 9000 -2000, ISO 14000, SA 8000 certifications and reaccreditation of MRPII 'Class A' in 2002

"*It's all about people***"** explained PTC's Chairman, Gottfried Thoma. **"***They are the most important asset of any organization. A winning culture enables ordinary people to achieve the extraordinary by willingly performing to the best of their abilities*."

Why QFD

Achieving customer satisfaction and superior product quality is a prime objective of Pakistan Tobacco Company. Therefore, product physical testing is one of the fundamental tools to ensure that our products meet customer expectations. For PTC to remain competitive in the market place and to be and be seen as a proactive company, it is very essential to get regular consumer feedback, "***Voice of the customer"*** about its products. PTC firmly beliefs the fact that ***"To know your customer is to know your Future".***

Finished Product Inspection system

Finished Product Inspection is the measurement of finished product quality. In this system, three quality indices, based upon measurements of physical, visual and tactile properties of the product and smoke yields, are used to determine ex-factory quality (MQI and PQI) and retail quality (RQI).

MQI – Manufacturing Quality Index
PQI – Product Quality Index
RQI – Retail Quality Index

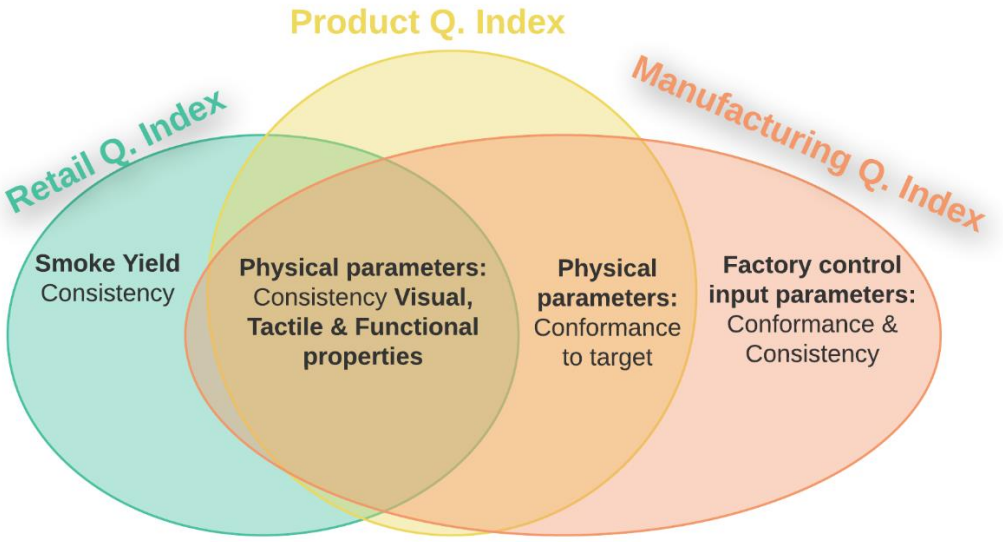


Figure 1: Measurements within the FPI indices

Manufacturing-led definitions of product physical quality represent the basis of commitment to quality, by ensuring the consistency of the manufactured item. This is the clear objective of MQI & PQI. However, RQI is the measure of how stable is the product in the market over a certain period.

Changing marketing scenarios demand that manufacturing quality systems must be extended to fully address consumer needs. PTC has a well-defined method of

getting the of Customer feedback known as Consumer Physical Quality Evaluation (CPQE). This system is designed to analyse the consumer's perceived physical quality performance, assessing the relative frequency of occurrence of product quality defects and the annoyance that they may cause.

Historically this information was limited to mainly PTC Product Department, which used to do the product designs/specifications changes accordingly and manufacturing department involvement at the design stage was very low. What lagging was ***a structured approach towards total integration of the all product development and improvement processes to examine the overall company's response to the customer voice in-order to achieve PTC's long term vision of 'The first choice for Everyone'.***

PTC Product Development and Improvement Process

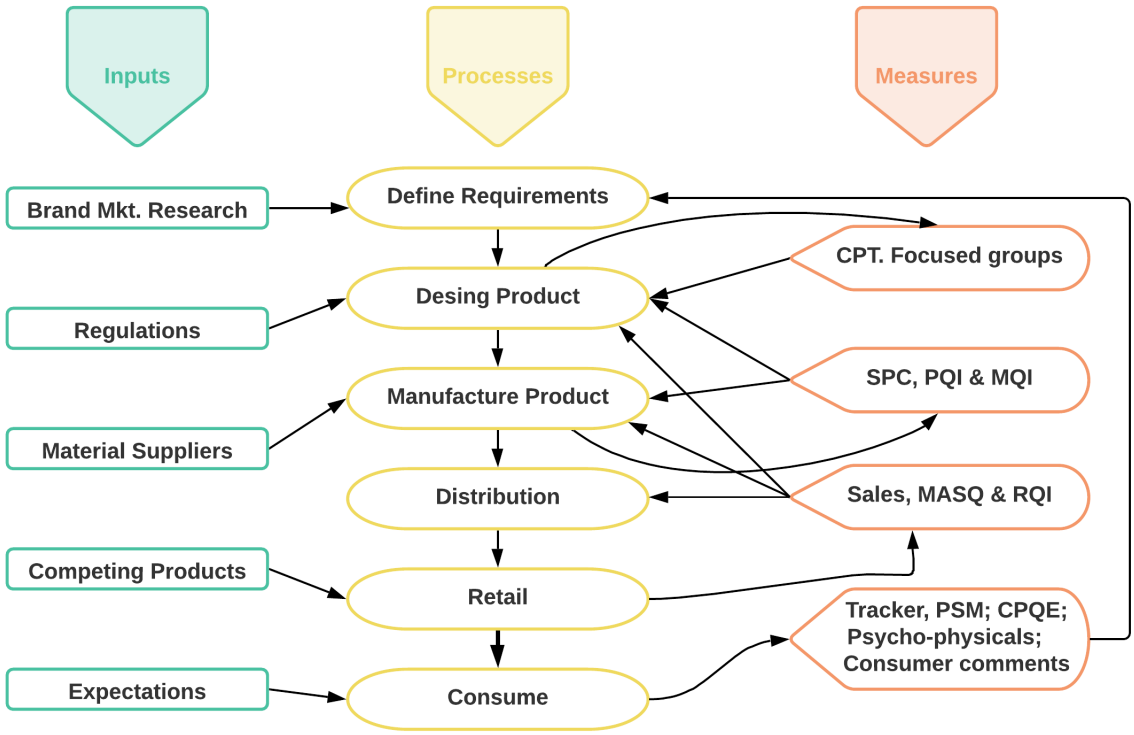


Figure 2: PTC product development/improvement process

On its journey towards ***'beyond Class A'*** in MRPII, PTC selected QFD to further recuperate the process of new product introduction and product improvement.
QFD is a process – a methodology, for planning products and services. It starts with the voice of customers – "the input". Customer's wants and needs become the driver for the development of requirements for the new or revised products or services. QFD process requires a number of inputs and decisions that are best done through teamwork and this process tends to remove many of the functional barriers that develop in large organizations.

QFD process is a pointed way of listening to customers to learn exactly what they want, and then using a logical system to determine how best to fulfil those needs with available resources. It translates customer requirements into company requirements at each stage of product development and improvement process: research, product development, engineering, manufacturing, marketing, sales and distribution.

Continuous improvement was driven by insights into customer perceptions, and active cross-functional participation of many employees reduces cost and improves quality. QFD is also a powerful tool in shifting the entire range of consumer price/performance option to a higher level, it is, therefore, necessary to complement product development process with information on consumer requirements and sensitivities in relation to the product, in order to avoid the costs involved in over or under-controlling product attributes.

QFD at PTC

In-order to integrate customer needs with the company's response to achieve total customer satisfaction, PTC embarked upon QFD initiative, by holding first-ever in-house 3 days extensive QFD workshop at Jhelum Factory in collaboration with Toyota Motors and National University of Science and Technology (NUST), Pakistan in Nov-01. Top management gave full support to this new initiative, reiterating its slogan of "Daring to be different".

Among attendees were the participants from various functions/departments:

- Marketing Research
- Product Development
- Leaf Department
- GLT (Green Leaf Threshing Plant)
- Primary Manufacturing Department
- Secondary Manufacturing Department
- Material Management / Shipping
- Production Engineering

Objectives & Deliverables of Workshop

- Thorough understanding of QFD concept, steps and resources involved
- Determining attributes related to consumer judgment of product quality and thus developing a consumer-driven product quality attribute set.
- Translate customer voice into process areas and technical requirements
- Develop a House of Quality for PTC product
- Develop consensus on the areas that need to be focused to address the customer needs

- Formation of sub-teams to facilitate / cascade training downward and to further work on this project

Step 1: Voice of Customer (whats)

Using existing CPQE information, a comprehensive set of customer comments on the frequency of occurrence of product quality defects and the annoyance caused by these problems were formulated.

Voice of Customer

Customer comments about product

- Bad taste
- Dries the throat
- Firmness of tobacco
- Firmness of filter
- Filter going soggy
- Filter falling off
- Cigarette burns fast / slow
- Ash flaking
- Loose tobacco falling off
- Filter falls down
- Logs & sticks in cigarette
- Dry tobacco
- Wrong cigarette in pack
- Taste variation
- Missing cigarettes
- Cigarette sparks
- Problem with the packs
- Cigarettes stained / spotted
- Cigarette difficult to lit
- Cigarette/filter not joint properly
- Difficult to get cigarette from the pack
- Broken cigarette
- Bad printing of brand name
- Tobacco drops in the packs
- Loose tobacco in the packs
- Cigarettes missing from the pack
- Improper shape of pack

s
Using concept of Affinity diagram, natural grouping of these defects was done in following 15 categories as follows:

1. Dries throat / dry tobacco
2. Loose filling / tobacco falling off
3. Loose filter
4. Rate of cigarette burning
5. Taste variation
6. Filter firmness / soggy filter
7. Ash flaking
8. Logs in cigarette
9. Wrong brands in packs
10. Pack problems
11. Cigarette stained / spotted
12. Different to lit
13. Broken cigarette
14. Bad printing on cigarette
15. Missing cigarette

CPQE Introduction – Customer Voice

The method is divided in two stages:

- Qualitative Stage

Based on focus groups, it determines which attributes relate to consumer judgement of product quality and thus develops a comprehensive consumer driven product quality attribute set to be subsequently used in the Quantitative Stage.

- Quantitative Stage

Based on the Problem Detection Analysis (PDA) method, it quantifies from the consumer's perspective the frequency of occurrence and the annoyance caused by product quality defects.

1. Methodology

1.1. Qualitative Stage

Approximately 8-12 qualitative group discussions with each group consisting of 8 smokers of a variety of brands. The groups should be split by age, sex and socio-economic classification and should cover a range of locations/distribution areas.

The objective is to understand what are the main attributes that drive consumers' perception of product quality and to build a comprehensive list of attributes, divided in three areas: Pack, Cigarettes (physical) and Cigarettes (while smoking).

1.1.1. Group Moderation Protocol

- Individual quality definitions(2)

Beginning with the broadest frame of reference, every consumer should be given a sheet of paper with the following heading:

> Please write down your definition of what 'quality' means to you and describe a typical situation where quality would be

- Quality definitions used to stimulate quality discussion

Each consumer should read what s/he has written to the group and the group should be then led into a general discussion on what quality means and how such a concept bears on everyday life.

- Quality as applied to cigarettes

The possible relevance of the idea of quality to the purchase/evaluation and use of cigarettes should be probed in order to determine whether quality per se is actually relevant to the cigarette as a commodity relative to other commodities.

- Quality vocabulary: Salient attributes relating to product and packaging quality; definitions and relative rankings(3)

On the assumption that quality is seen as relevant to the cigarette commodity, a detailed probe of those attributes considered important to the judgement of quality should be made. Once a vocabulary set has been elicited, the group should be required to define each attribute clearly. Finally the list of attributes should be subjected to consensus listing, placing items in order of importance of contribution to the judgement of cigarette quality.

- Causal quality relationships

The group should then be probed to elicit any subjective 'theories' regarding causal relationships between attributes relating to product quality.

- Historical trends in cigarette quality and pricing

This section should focus on an open probe on consumer perception of any shifts in product quality with the passage of time (i.e. from as far back as subjects can reliable recall). In addition it should include an open probe on consumer perception of the relative cost of cigarette usage with the passage of time

- Quality relationship to price

This section should be based on an open probe on whether consumers perceive cigarette product quality to be directly related to price paid (i.e. in the sense of a direct / linear correlation).

- Price / quality trade-off

This section should include an individual probe on the extent to which each consumer is prepared to trade level of product quality against pricing level.

- Quality image in relation to quality reality

This section should be based on an open probe on consumers beliefs regarding the extent to which quality promises implied by imagery are generally reflected in the reality of the product (in the case of cigarettes compared with other commodities).

- Examples of high and low quality

This section should focus on a detailed probe on cigarette brands considered to exemplify good and bad quality, including extended discussion justifying reasons and amplifying disagreements.

- Open letter to the manufacturer

At the end of the qualitative group, each respondent should be invited to write to the manufacturer of his/her own brand and suggest product quality improvements. Each respondent is given a sheet of paper with the following heading:

> Dear Sir,
> I am a smoker of your products and I think you should...

1.2.Quantitative Stage

This Stage will be based on individual interviews. The objective is to quantify the level of occurrence and annoyance of quality defects, based on the relevant list produced in the Qualitative Stage.

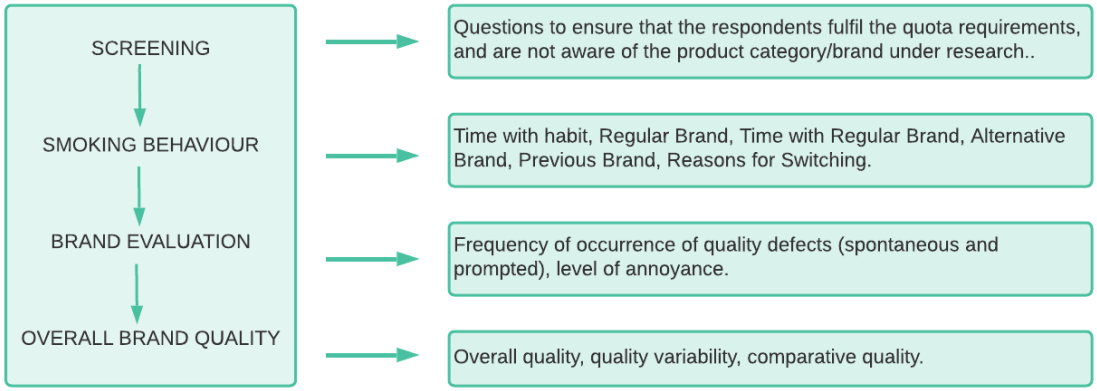


Figure 3: Quantitative Stages

Each main product quality attribute/problem generated from the pre-qualitative research is rated in the following manner:

For example: Filter Collapse

I would like you to think back over your recent experience of smoking (own brand) How frequently do you experience a problem with Filter Collapse. By Filter Collapse I mean (definition).

FREQUENCY	CODE
It Always occurs	4
It Often occurs	3
It Seldom occurs	2
It Never occurs	1

When you experience a problem with Filter Collapse, how annoying is it to you.

FREQUENCY	CODE
Extremely annoying	4
Fairly annoying	3
Slightly annoying	2
Not at all annoying	1

At the analysis stage it will be possible to cross-check the frequency of occurrence and the level of annoyance of each quality defect.

- Attributes

The prompted attributes to be used in the quantitative stage will be derived from the Qualitative stage. The following list of attributes shows a typical set.

ATTRIBUTES		
PACK	CIGARETTES (Physical)	CIGARETTES (While Smoking)
Tear strip malfunction	Tobacco Firmness	Burn Rate (too low/fast)
Pack damaged (crushed)	Filter Firmness	Ash fall out
Pack dirty	Filter Collapse	Hot collapse
Opening/closing malfunction	Stem Inclusions	Cigarette stops burning by itself
Pack Print damaged	Cigarette Paper wrinkled	Off aroma
Cigarette misplaced	Cigarette not filled up to the tip	Difference in taste
Other Brand inside pack	Cigarette perforated / torn	Things popping/crackling while smoking
Cigarettes missing in pack	Cigarette stained / spotted	
Cigarettes upside down in pack	Die print damaged	
Loose tobacco at bottom of pack	Filter tip not glued	
Cellophane torn	Old/Dry tobacco appearance	
Aluminium foil damaged (HL)		

2. Sampling

CPQE should be conducted with a minimum of 100 smokers of each of the brands of interest (i.e. key volume own and competitor brands).

Sample composition must reflect typical brand profile in terms of demographic classification (age, sex, S.E.L., geographic location, etc.) and buying behaviour (pack/stick, daily/less often, usual outlet, etc.) derived from GCS.

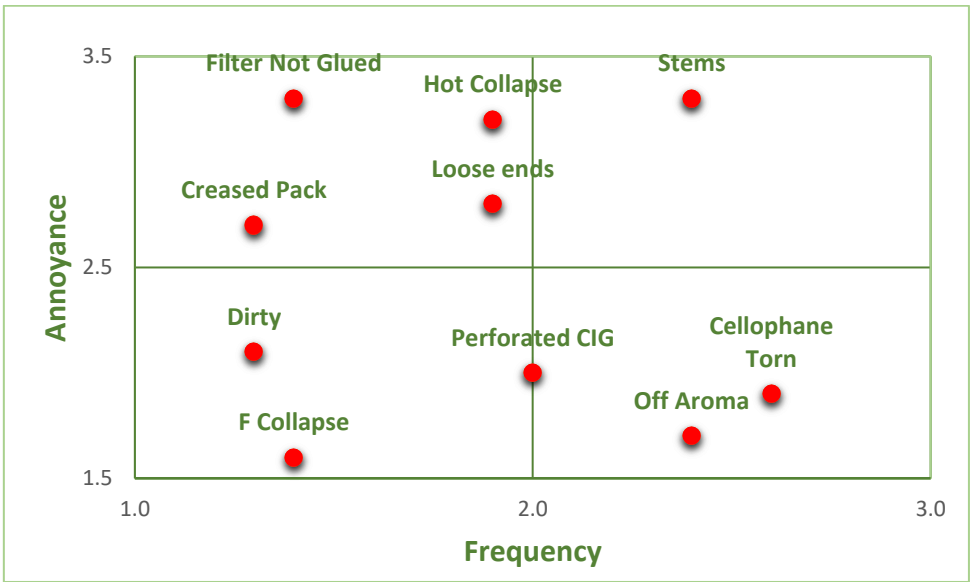
If further breakdown analysis (e.g. by age group) has to be performed, the absolute minimum sub-sample is 100 respondents. This means that if, for example, a brand is to be evaluated analysing two age groups (18-24 and 25-34) the sample composition will be 200 respondents (i.e. 100 18-24 and 100 25-34).

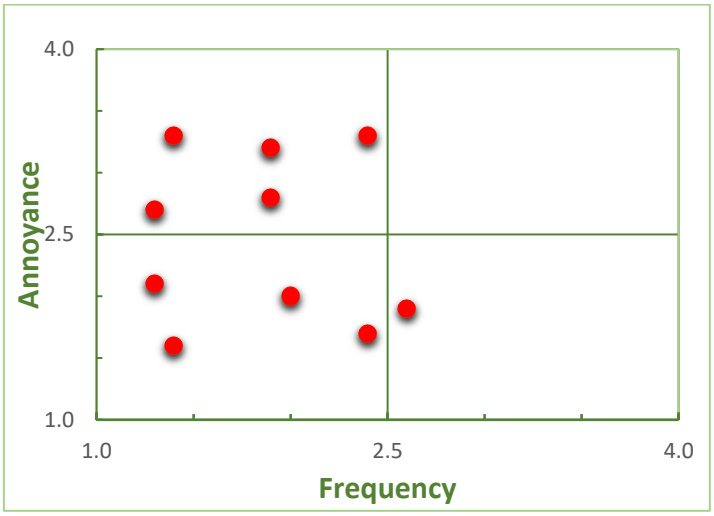
3. Analysis

For each group of smokers simple mean scores should be calculated per attribute for the frequency and the annoyance rating on each attribute. These scores should then be used to construct a problem detection matrix for each brand.

Taking an hypothetical example, the problem detection matrix below represents smokers ratings of quality problems experienced with their own brand.

Quality Defects	Frequency (Mean scores)	Annoyance (Mean scores)
Dirty	1.3	2.1
Creased pack	1.3	2.7
Filter collapse	1.4	1.6
Filter Not Glued	1.4	3.3
Loose ends	1.9	2.8
Hot collapse	1.9	3.2
Perforated cigarette	2.0	2.0
Off aroma	2.4	1.7
Stems	2.4	3.3
Cellophane torn	2.6	1.9





The charts above represent the performance of the attributes for a given brand. The left bottom corner represents the lower ratings and the right and top corners the higher ratings. The small chart (Right) shows the absolute performance, i.e. using the full scale (1-4 for Frequency and Annoyance). The large chart (Left) reduces the scale to magnify the spread of results.

The matrix can be divided in four quadrants that will be ranked by priority level.

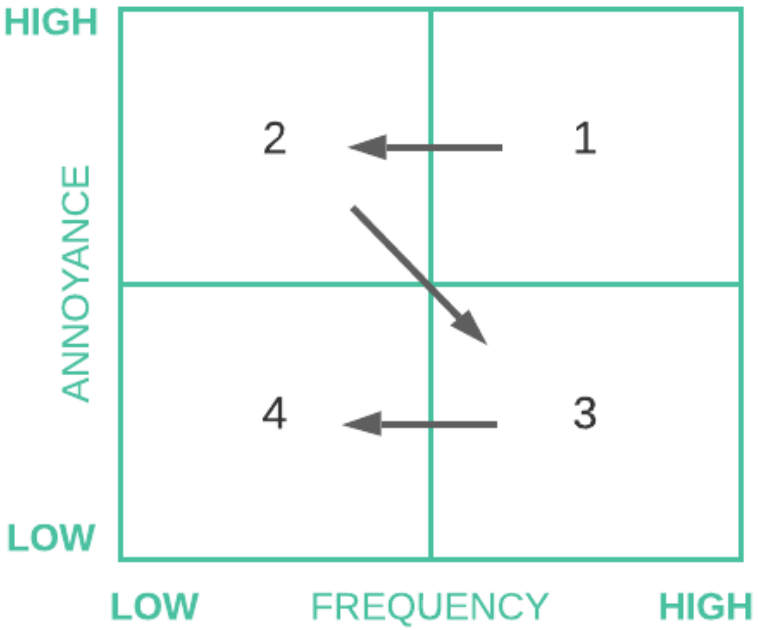
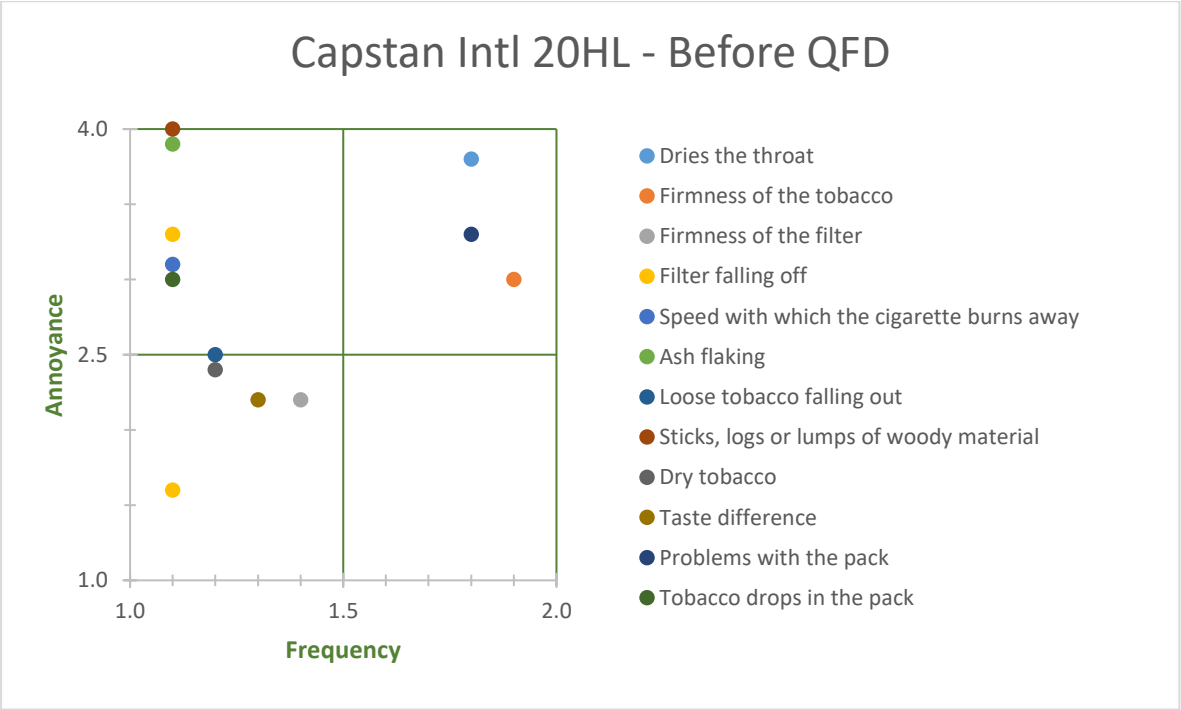


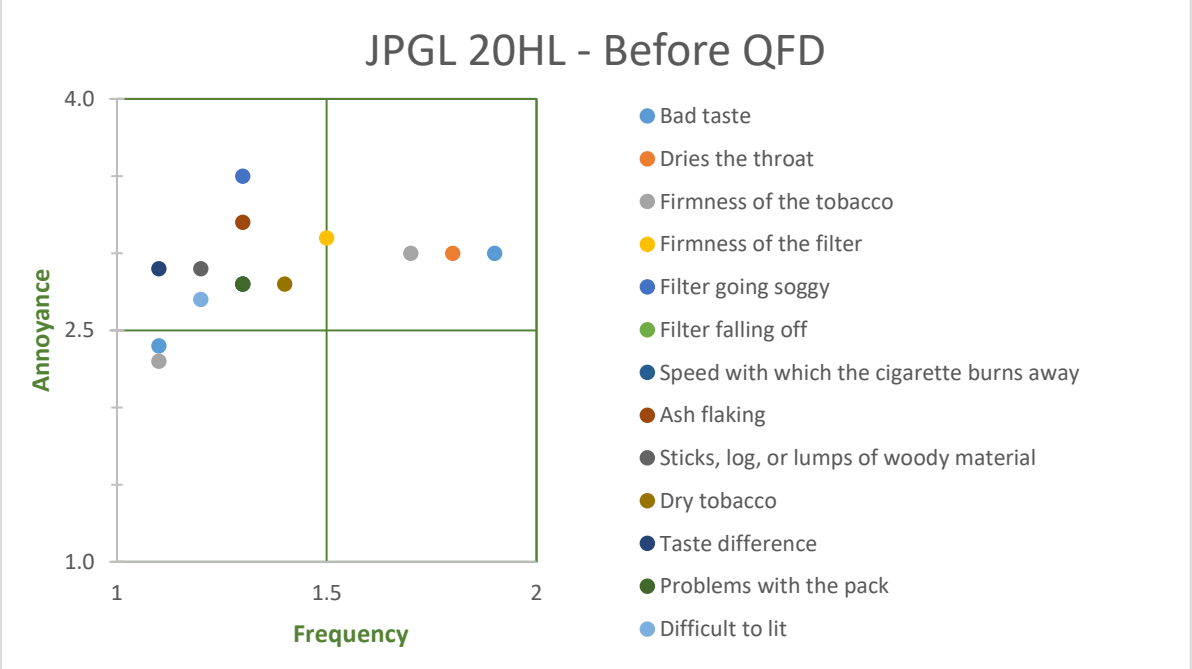
Figure 4: Frequency and Annoyance matrix

Attributes lying in quadrant 1 (i.e. High Frequency and Annoyance) are the highest priority for inhouse quality control, as they imply both high frequency of defects and risk of losing franchise loyalty.

Attributes in quadrant 4 (i.e. Low Frequency and Annoyance), however, are unlikely to require remedial in-house quality control action.

CPQE Results of Capstan Int'l and Gold Leaf:





Step 2: Translating voice of customer technical methods/requirements (Hows)

Following are the parameters that are should be taken care off in order to meet / exceede the customers needs

**(Targets are not written for confidentiality)

Brand : Capstans International RS 20 HL		
	Parameters	**Targets**
1	Cigarette circumference	mm
2	Cigarette tobacco weight	mg/cig
3	Cigarette pressure drop	mm WG
4	Filter pressure drop	mm WG
5	Cigarette firmness	%
6	Ends fall outs	mg/cig
7	Cigarette moisture	%
8	Pack seal	%
9	Outer visual	DW
10	Pack visual	DW
11	Cigarette visual	DW
12	Puff No	Nos
13	NFDPM	mg
14	Tobacco blend	As per recipe
15	Plasticizer percentage	%
16	Stems in cut tobacco	%
17	Orientation of cigarette paper	wire side inside

Step 3: Building House of Quality for PTC

Step approach was applied in making the house of quality for PTC.

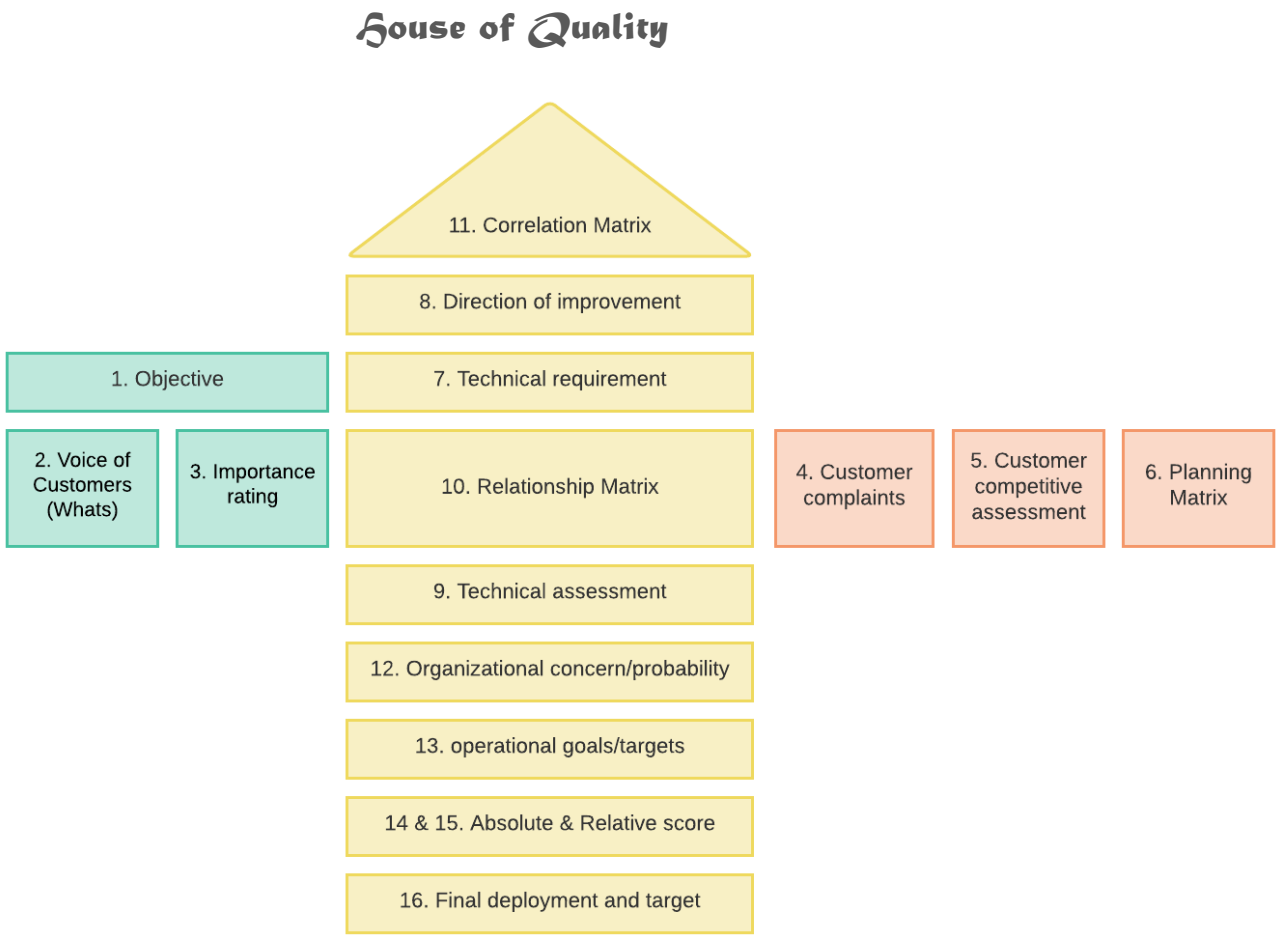


Figure 5 House of quality

After in depth analysis of voice of customer, each customer need was assigned an importance rating on a scale of (1-5). Results from CPQE were on a scale of 1-4 (annoyance level), these were prorated accordingly.

Voice of Customer	Importance Rating
Dries Throat/Dry Tobacco	4.4
Loose Filling/Tobacco Falling off	3.8
Loose Filter	4.4
Rate of Cig. burning	3.6
Taste variation	4.7
Filter Firmness / Soggy Filter	3.8
Ash Flaking	3.4
Logs in cigs.	4.3
Wrong Brands in pack	4.7
Pack problems	3.3
Cig. Stained/ Spotting	3.6
Difficult to lit	3.5
Broken cig.	4.6
Bad Printing on cig.	3.4
Missing cig.	4.7

Customer complaints regarding Capstan International brand were:

	Nos
Loose Filling/Tobacco Falling off	5
Loose Filter	7
Wrong Brands in pack	6
Pack problems	3
Broken cig.	15
Bad Printing on cig.	3
Missing cig.	47

Customer competitive assessment:

OUR

A

B

OUR = RA; A = PG; B = R&W (Competitor)

	1	2	3	4	5	RA	PG	R&W
Dries Throat/Dry Tobacco						3.13	3.31	3.51
Loose Filling/Tobacco Falling off						4.18	3.94	3.88
Loose Filter						4.16	4.25	4.06
Rate of Cig. burning						3.93	3.93	4.03
Taste variation						3.66	3.73	3.80
Filter Firmness / Soggy Filter						3.73	4.07	4.00
Ash Flaking						3.83	3.93	3.97
Logs in cigs.						3.88	3.64	3.85
Wrong Brands in pack						4.25	4.28	4.66
Pack problems						5.00	4.16	5.00
Cig. Stained/ Spotting						5.00	5.00	5.00
Difficult to lit						4.50	4.21	4.07
Broken cig.						4.14	4.03	4.38
Bad Printing on cig.						3.87	3.93	3.69
Missing cig.						3.75	4.25	3.75

Central part of House of Quality:

		Cig. Circum	Cig. Tob Wt.	Cig. PD	Filter PD	Firmness	EFO	Moisture	Pack Seal	Outer Vis.	Pack Vis.	Cig. Vis.	Puff No	NFDPM	Tob Blend	Plasticized %age	Stem in cut Tob.	Orientation of vig paper
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Dries Throat/Dry Tobacco								9	9						9			
Loose Filling/Tobacco Falling off		1	9			5	9	9							9			
Loose Filter		9													5		5	9
Rate of Cig. burning			9	1		5		9										
Taste variation				9				9							9			
Filter Firmness / Soggy Filter																9		
Ash Flaking			5												5			9
Logs in cigs.																	9	
Wrong Brands in pack											9	5						
Pack problems											9							
Cig. Stained/ Spotting								9				9			5			
Difficult to lit						9											5	
Broken cig.												9						
Bad Printing on cig.												9						
Missing cig.											9							

Step 4: Internal Actions / Areas to be focused:

Stemming out of team discussions and Customer House, following were the areas to be focused to improve the product quality in order meet the consumer needs.

1. Pack visual
2. Cigarette visual
3. Cigarette moisture consistency
4. Cigarette pressure drop consistency
5. Reduction of Stems / log in cut tobacco

Sub-teams were formed to make individual "Process house" for each identified area in detail.

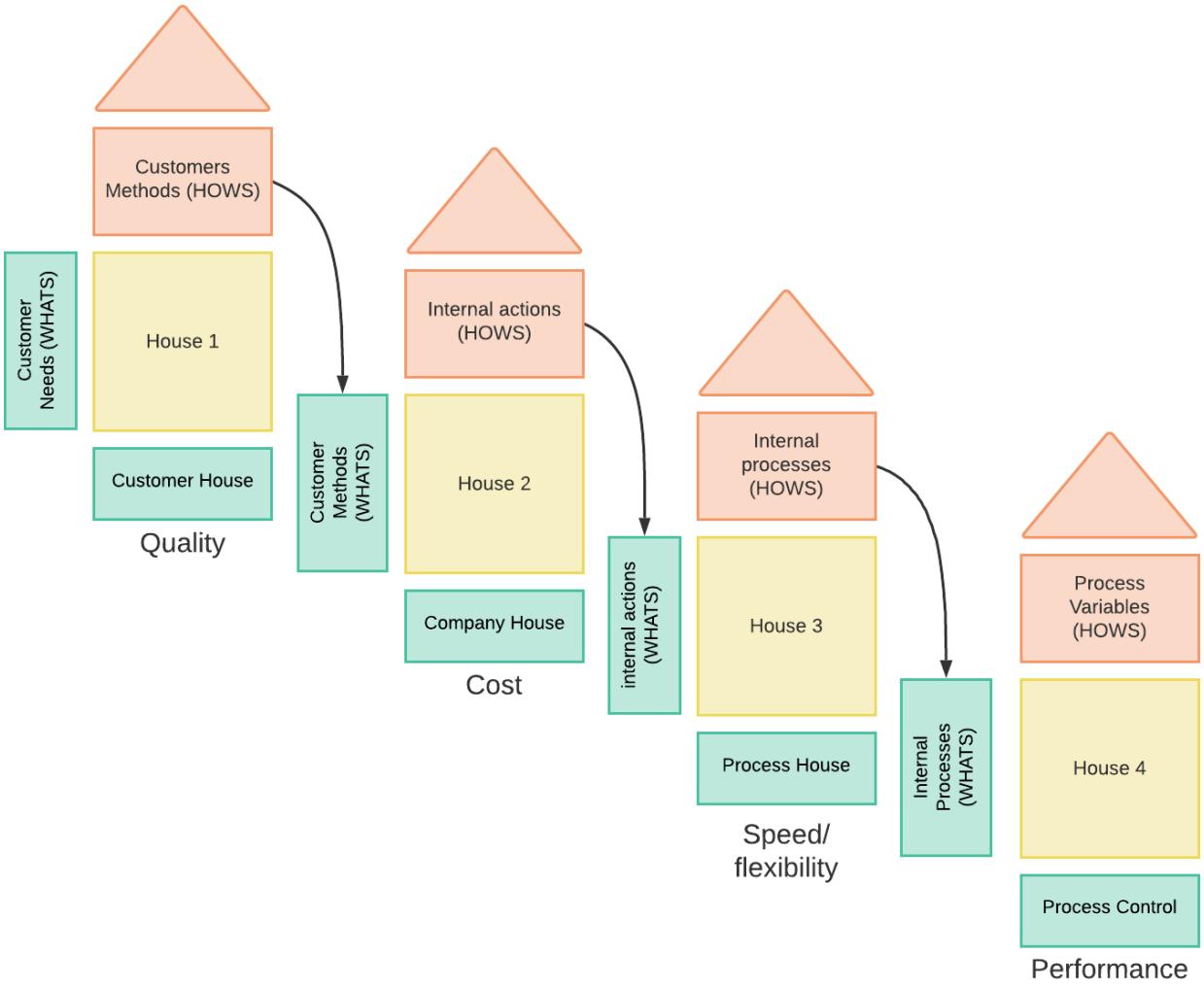


Figure 6 Process house

1. Pack Visual:

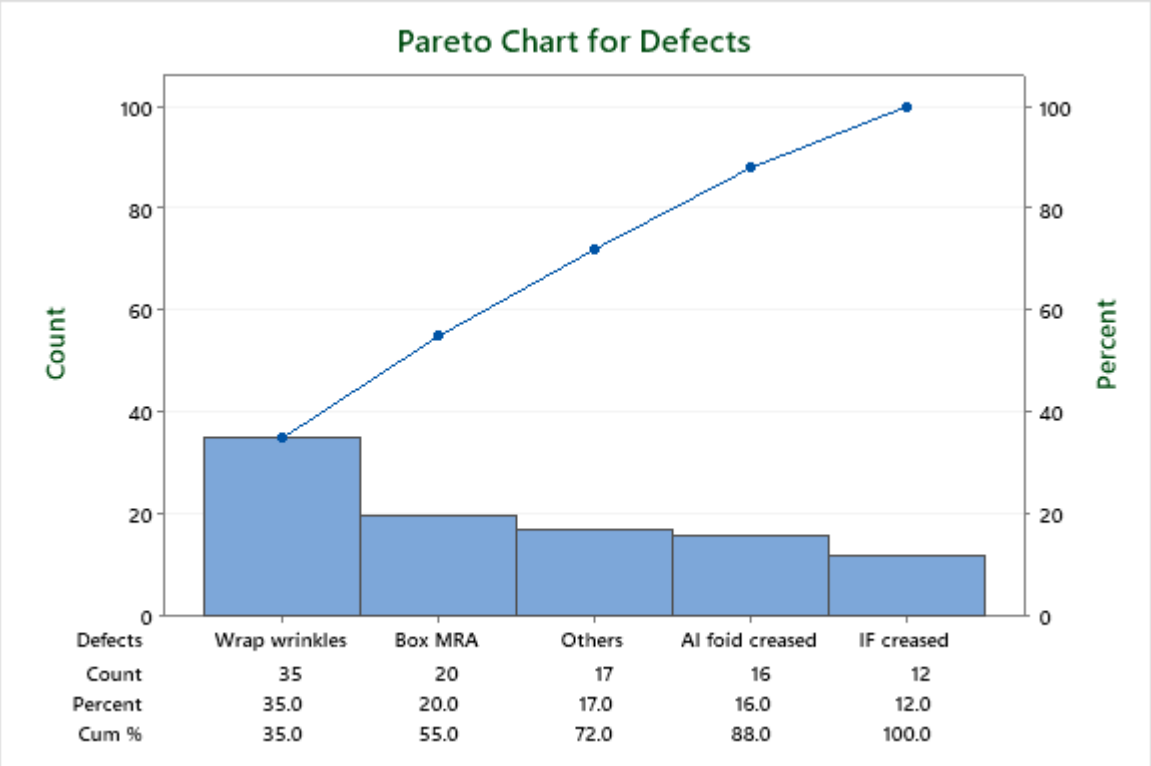


Figure 7: Pareto chart for defects-1

2. Cigarette Visual:

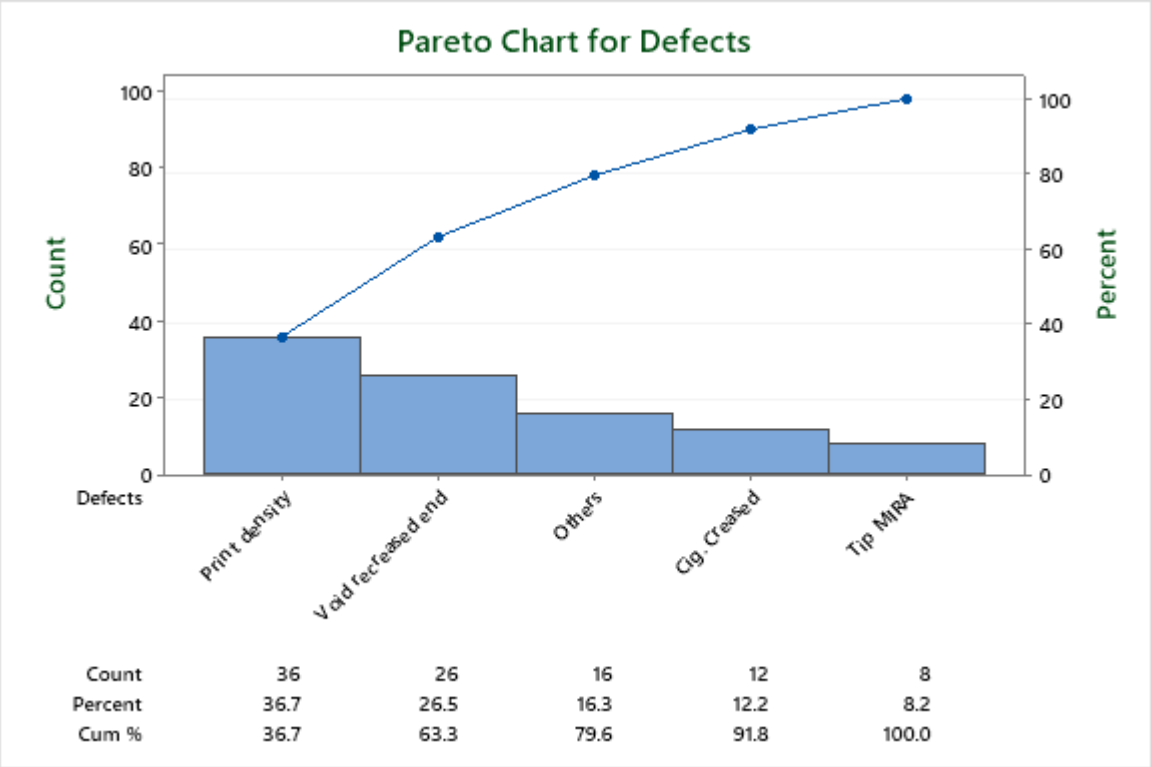
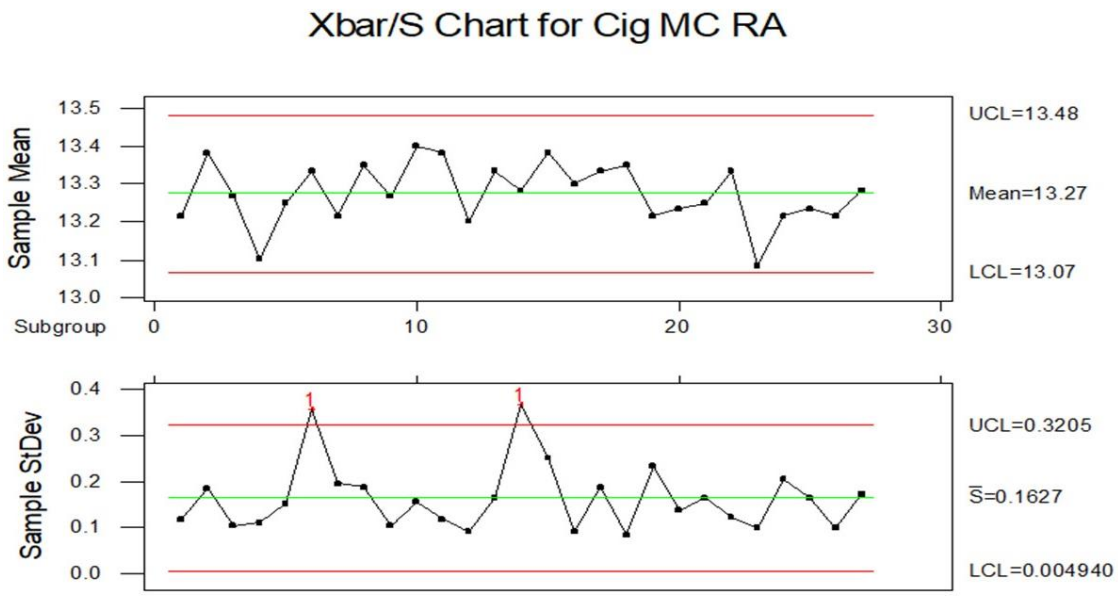
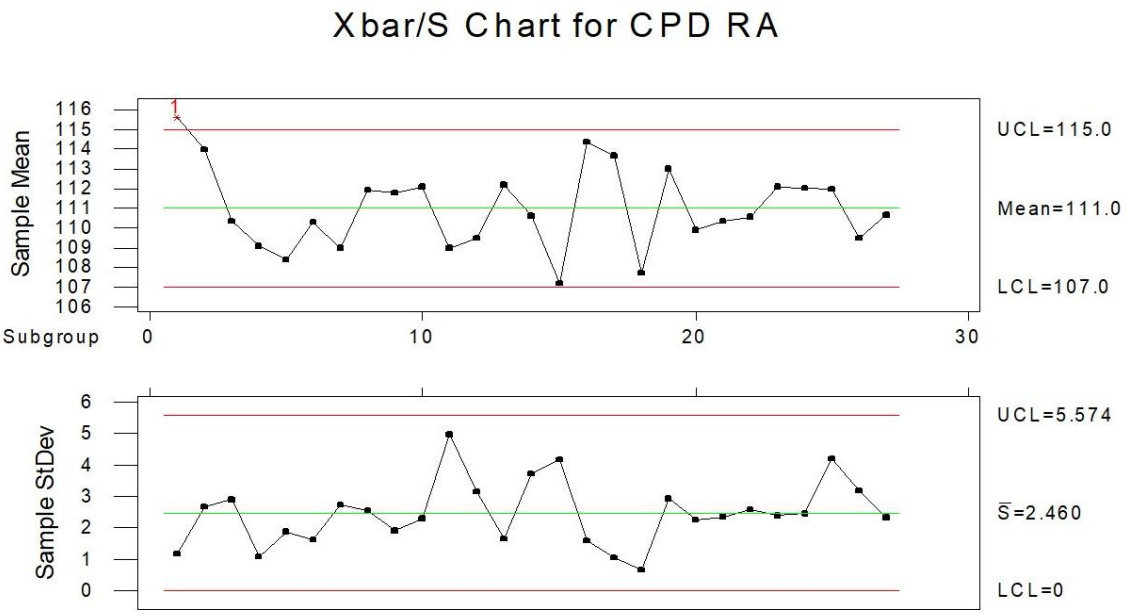


Figure 8: Pareto chart for defects-2

3. Cigarette Moisture Consistency:



4. Cigarette Pressure Drop Consistency:



5. Reduction of stem / logs in cut tobacco:

Following factors are reasons of stems / logs in cut tobacco:

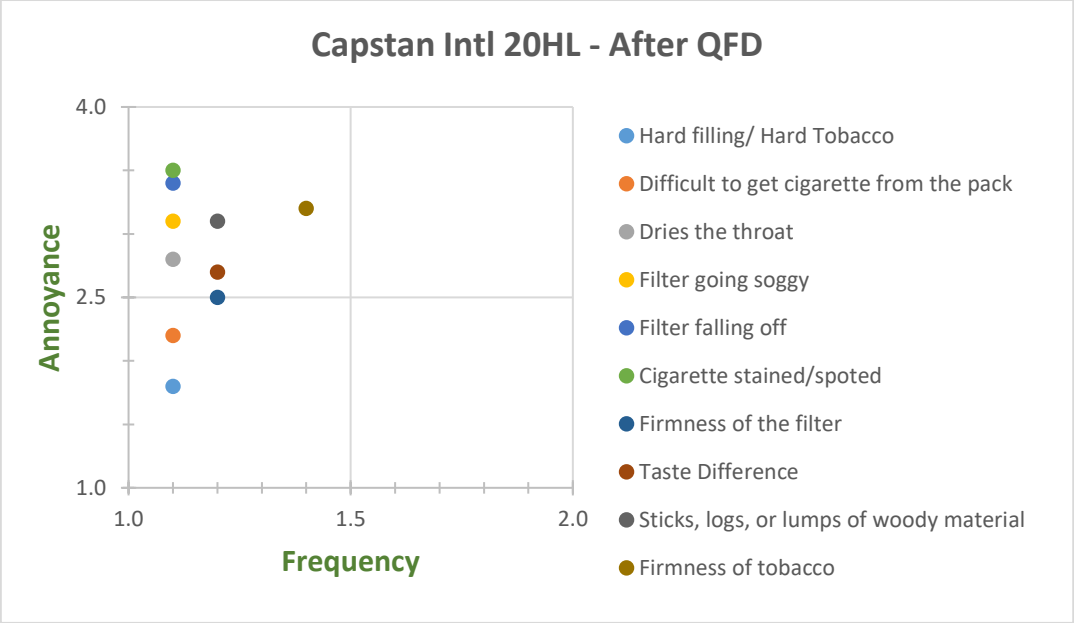
- Total objectionable stem in lamina from GLT
- Stem conditioning in PMD
- Cuts per inch (CPI) for lamina and stems
- Cutters settings:
  - ✓ Zero gap between knives and the bottom bar
  - ✓ Conditions of cutter knives
  - ✓ Setting of grinder and diamond
  - ✓ Cheese formation & pressure
- Setting of Air particle separators

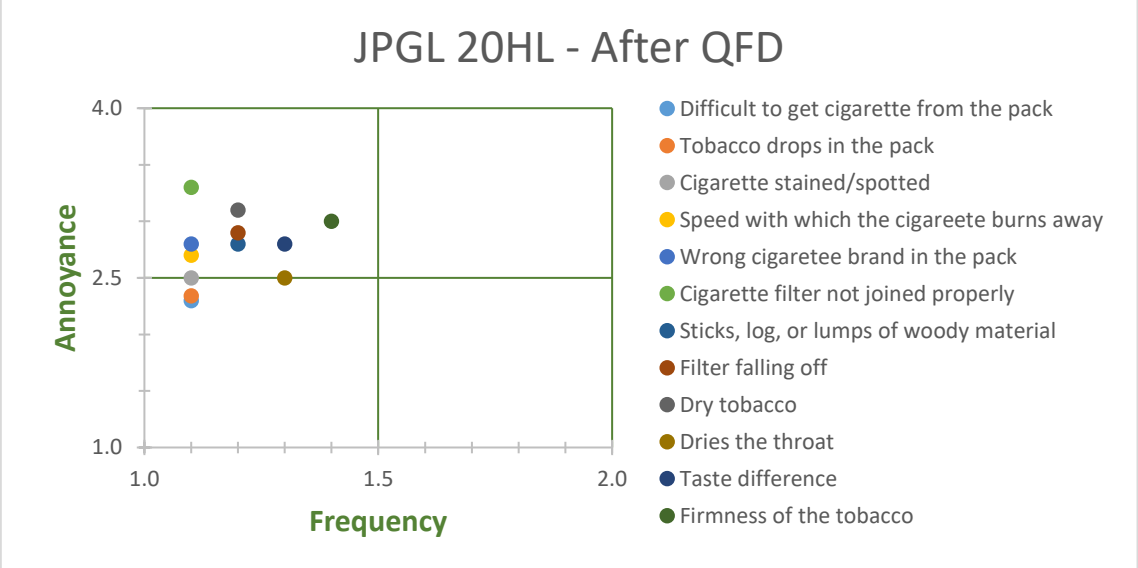
Internal actions agreed:

Areas	Actionable items	Areas	Actionable items
Pack Visual	Quality Awareness / attitude	Stem in Tobacco	Operator's Motivation
	Tech. Training		Equipment maintenance
	Machine Setting		Operator's Skills
	On-line checks		Control Systems
	Maintenance		Machine settings
	Machine cleaning		Stem Cutting
Cigarette Visuals /EFO	Machine setting	Cigarette pressure drop consistency	Tobacco CPI
	Training		Tobacco PSD
	Maintenance		Tobacco Fill Value
	Tobacco/Spares Quality		Cig. Weight SD
	Attitude		Tobacco Moisture
	Shop floor Control		Filter PD SD
Moisture Consistency	M/c / equip. setting		CTS & Floor environ.
	Calibration of Control Equip.		
	Process / SPC training		
	Calibration of Lab Equip.		
	RH control system		
	FIFO in CTS / SMD		

CPQE Results:

Both frequency and annoyance related to the customer defects highlighted in Voice of customer has reduced and product quality improved.





DESIGN OF EXPERIMENT:

Different studies carried out the QFD projects revealed that the main parameter affecting the MQI & PQI indices is the cigarette pressure drop variation with a lowest Quality numbers (Q_Nos) in range of 70-75. In-order to reduce the variation in cigarette pressure drop (CPD) design of experiment (DoE) was carried out on Gold leaf.

Designed experiments is the simultaneous evaluation of two or more factors (Parameters) for their ability to affect the resultant average or variability of particular product or process characteristics.

The key parameters that control cigarette pressure drop are Tobacco moisture, Tobacco particle size, Cigarette weight, Cigarette circumference, Filter pressure drop and Tobacco filling. Typically these factors are susceptible to variation from operation to operation and machine to machine.

Factors:

- Individual weight of cigarette
- Cigarette circumference
- Cigarette moisture
- Filter plug pressure drop
- Particle size distribution of cut tobacco
- Fill value of the blend

Response:

- Cigarette pressure drop

Factorial Design:

StdOrder	RunOredr	CenterPt	Blocks	Ind Wt	Cig Cir	Cig MC	Plug MD	PSD	Fill Value
				A	B	C	D	E	F
4	1	1	1	0.983	24.63	13.2	65	78	45
6	2	1	1	0.983	24.57	13.8	55	86	45
3	3	1	1	0.959	24.63	13.2	55	86	45
1	4	1	1	0.959	24.57	13.2	65	86	48
2	5	1	1	0.983	24.57	13.2	55	78	48
7	6	1	1	0.959	24.63	13.8	55	78	48
5	7	1	1	0.959	24.57	13.8	65	78	45
8	8	1	1	0.983	24.63	13.8	65	86	48

Fractional Factorial Design

Factors: 6 Base Design: 6, 8 Resolution: III

Runs: 8 Replicates: 1 Fraction: 1/8

Blocks: none Center pts (total): 0

*** NOTE *** Some main effects are confounded with two-way interactions

Design Generators: D = AB E = AC F = BC

Defining Relation: I = ABD = ACE = BCF = BCDE = ACDF = ABEF = DEF

Alias Structure (up to order 3)

I + ABD + ACE + BCF + DEF

A + BD + CE + BEF + CDF + ABCF + ADEF + ABCDE
B + AD + CF + AEF + CDE + ABCE + BDEF + ABCDF
C + AE + BF + ADF + BDE + ABCD + CDEF + ABCEF
D + AB + EF + ACF + BCE + ACDE + BCDF + ABDEF
E + AC + DF + ABF + BCD + ABDE + BCEF + ACDEF
F + BC + DE + ABE + ACD + ABDF + ACEF + BCDEF
AF + BE + CD + ABC + ADE + BDF + CEF + ABCDEF
ABEF + ACDF + BCDE

Data Matrix (randomized)

Run	A	B	C	D	E	F
1	+	+	-	+	-	-
2	+	-	+	-	+	-
3	-	+	-	-	+	-
4	-	-	-	+	+	+
5	+	-	-	-	-	+
6	-	+	+	-	-	+
7	-	-	+	+	-	-
8	+	+	+	+	+	+

After conducting the trails on Gold Leaf the data was analysed using Minitab software

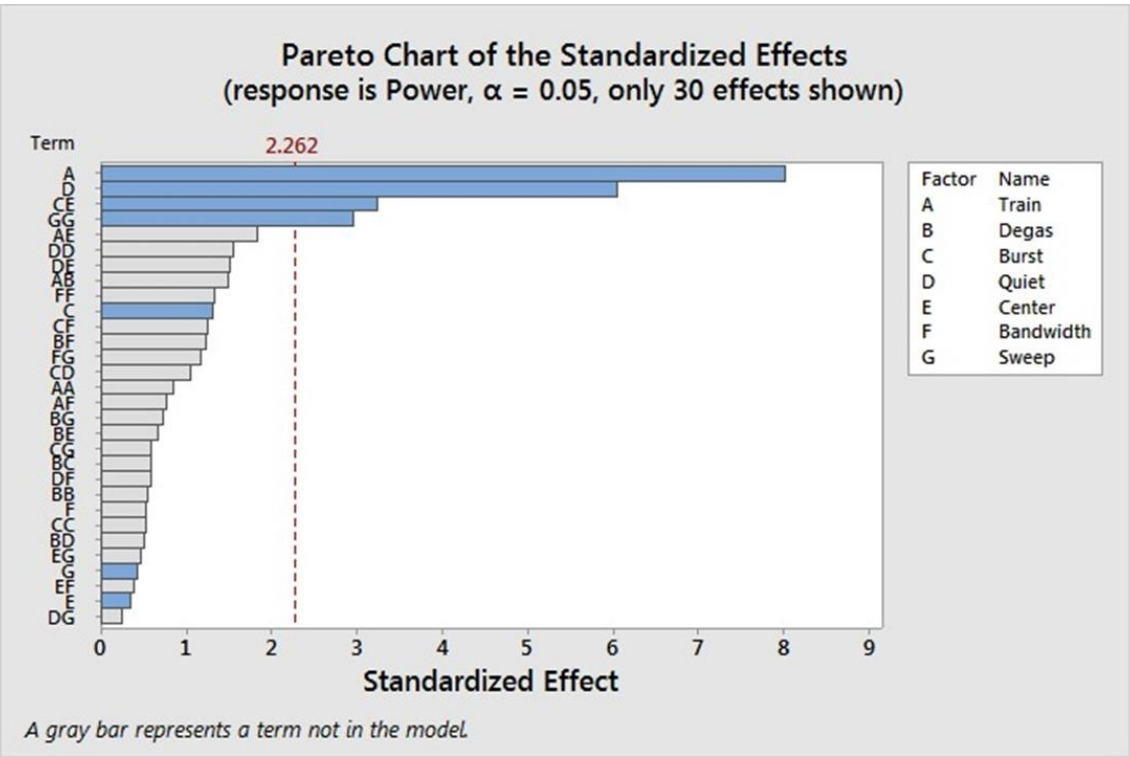


Figure 9: Pareto chart for standardized effext

- Strengthening employee's knowledge about statistical process control.
- Reinforcing process capability index evaluation of manufacturing processes.
- Integrating SPC tools and preventive maintenance systems thus keeping the machines and processes statistically in control resulting in minimizing the non-conforming product
- Further improve process capability by optimization of process parameters through QFD and Design-of-Experiments techniques in-order to meet / exceed customer expectations
- Moving towards 6-sigma change management model.