Chapter 13

Cause-and-Effect Matrix and Quality Function Deployment

Introduction

- Processes have inputs (operators, machines, process temperatures, time of day, and raw material characteristics) and outputs (product or service).
- The performance of these key output variables can be affected by process input variables. But not all input variables affect the outputs equally.
- To improve a process we need to determine what the key process inputs are, how do they affect key process outputs, and what can be done differently with them.

Introduction

Topics
- Tools to assess the relationships between key process inputs and key process outputs.
- Quality Function Deployment (QFD)
- Cause-and-effect matrix

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13.1 S^4/IEE Application Examples: Cause-and-Effect Matrix

- Satellite-level metric: S^4/IEE projects were to be created to improve the company's ROI. A cause-and-effect diagram was created to generate ideas for improvement. A cause-and-effect matrix was created to prioritize the importance of these items.
- Satellite-level metric: S^4/IEE projects were to be created that improve the company's customer satisfaction. A cause-and-effect diagram was created to generate ideas for improving customer satisfaction. A cause-and-effect matrix was used to prioritize the importance of these items.

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13.1 S^4/IEE Application Examples: Cause-and-Effect Matrix

- Transactional 30,000-foot-level metric: DSO reduction was chosen as an S^4/IEE project. The team used a cause-and-effect matrix to prioritize items from a cause-and-effect diagram.
- Manufacturing 30,000-foot-level metric (KPOV): An S^4/IEE project was to improve the capability/performance of the diameter of a manufactured product (i.e., reduce the number of parts beyond the specification limits). The team used a cause-and-effect matrix to prioritize items from a cause-and-effect diagram.

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13.1 S^4/IEE Application Examples: Cause-and-Effect Matrix

- Transactional and manufacturing 30,000-foot-level cycle time metric (a lean metric): An S^4/IEE project that was to improve the time from order entry to fulfillment was measured. The team used a cause-and-effect matrix to prioritize items from a cause-and-effect diagram.
- Transactional and manufacturing 30,000-foot-level inventory metric or satellite-level TOC metric (a lean metric): An S^4/IEE project was to reduce inventory. The team used a cause-and-effect matrix to prioritize items from a cause-and-effect diagram.

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13.1 S⁴/IEE Application Examples: Cause-and-Effect Matrix

- Manufacturing 30,000-foot-level quality metric: An S^4/IEE project was to reduce the number of defect in a printed circuit board manufacturing process. The team used a cause-and-effect matrix to prioritize items from a cause-and-effect diagram.
- Product DFSS: An S^4/IEE product DPSS project was to reduce the 30,000-foot-level metric of the number of product phone calls generated for newly developed products. The team used a cause-and-effect matrix to prioritize items from a cause-and-effect diagram.
- S^4/IEE infrastructure: A steering committee uses a cause-and-effect matrix as part of their black belt selection process.

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13.1 S⁴/IEE Application Examples: Cause-and-Effect Matrix

- Process DFSS: A team was to create a new call center. A process flow-chart of the planned call center process was created. The team used a cause-and-effect matrix to prioritize items from cause-and-effect diagrams on what should be included within the call center.

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13.2 Quality Function Deployment (QFD)

- QFD is a tool that can aid in meeting the needs of the customer and in translating customer requirements into basic requirements.
- It is a communication tool that uses a team concept, and breaks down organizational barriers.
- A QFD chart can be used to organize, preserve, and transfer knowledge.

13.2 Quality Function Deployment (QFD)

- An overall product QFD implementation strategy involves fit listing the customer expectations (VOC). These "whats" can be compiled into primary, secondary, and even tertiary requirements.
- The "whats" are then tabulated along with the list of design requirements ("hows").
- The important "hows" can then be transferred to "whats" of another QFD matrix.

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13.2 Quality Function Deployment (QFD)

QFD Matrix	Example Matrix Output
Customer requirement	Years of durability
Design requirement	No visible exterior rust in 3 years
Part characteristics	Paint weight: 2-2.5 g/m^2
	Crystal size: 3 max.
Manufacturing operations	Dip tank
	3 coats
Production requirements	Time: 2.0-min. minimum
	Acidity: 15-20
	Temperature: 48 - 55°C

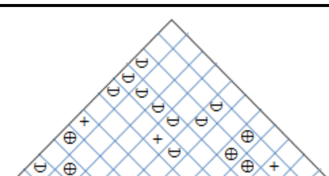
13.2 Quality Function Deployment (QFD)

- The "whats" for other matrices may be determined from internal inputs in addition to pass-down information from higher-state matrices.
- Begin with tertiary "whats" and then summarizes into a shorter list of secondary "whats" , then primary "whats".

- Example for the development of a design requirement matrix, but basic procedural flow is similar for others.
- With this procedure, equations, weights, specific parameters, and step sequence may be altered to better identify important items.

13.2 Quality Function Deployment (QFD)

- The "whats" for other matrices may be determined from internal inputs in addition to pass-down information from higher-state matrices.



			Open-closed effort						Sealing-insulation					Customer ratings				
			↓	↑	↑	↓	↓		↑	↑	↑	↑						
			Torque to close door	Closing force level grounc	Closing force 10° slope	Torque to open door	Peak closing force	…	Door seal resistance	Acoustic tram., window	Road noise reduction	Water resistance	…	1	2	3	4	5
Easy to open and close door	Easy to close from outside	5	⊙				⊙		⊙						●		■▲	
	Stays open	3		⊙	⊙										■●▲			
	Easy to open from outside	2				⊙			○								●	■▲
	Doesn't kick back	2		○	○	○	△		⊙							▲■	●	
	⋮																	
Isolation	Doesn't leak in rain	2							⊙			⊙				▲■	●	
	No road noise	1							○	○	⊙					■	▲	●
	⋮																	
Technical difficulty			4	5	1	1	3		1	3	3	5						
Objective target values			7.5 ft-lb	9 lb	6 lb	7.5 ft-lb	12 lb		3 lb/ft	.10	9 db	70 psi						
Objective measures	Our car door		11	12	6	10	18		3	.1	9	70						
	A's car door		9	12	6	9	13		2	.1	5	60						
	B's car door		9.5	11	7	11	14		2	.1	6	60						
Technical importance	Absolute		45	33	33	24	47		90	1	9	18						
	Relative		3	4.5	4.5	6	2		1	9	8	7						

13.2 Quality Function Deployment (QFD)

Step 1

- A list of customer requirements ("whats"), including applicable government regulations, is made in primary, secondary, and tertiary sequence.

Easy to open and close door		Easy to close from outside	5
		Stays open	3
		Easy to open from outside	2
		Doesn't kick back	2
		⋮	
Isolation		Doesn't leak in rain	2
		No road noise	1
		⋮	

Step 2

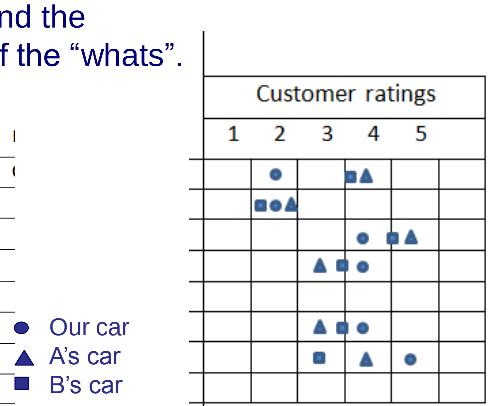
- The importance of each "what" can be determined from a survey using a rating scale (e.g., 1-5 (most important)).

13.2 Quality Function Deployment (QFD)

Step 3

- Customer ratings should be obtained for both the competition and the existing design for each of the "whats".

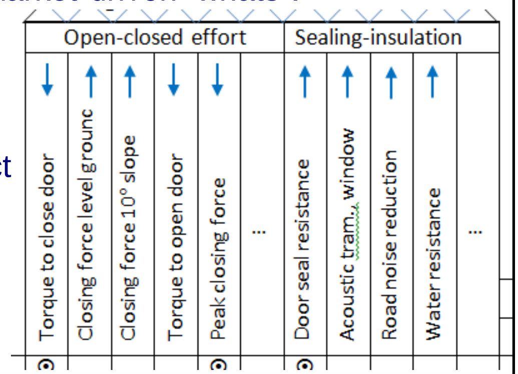
Easy to open and close door		Easy to close from outside	5
		Stays open	3
		Easy to open from outside	2
		Doesn't kick back	2
		⋮	
Isolation		Doesn't leak in rain	2
		No road noise	1
		⋮	



13.2 Quality Function Deployment (QFD)

Step 4

- Engineering first compile a list of design requirements necessary to achieve the market-driven "whats".
- The design requirements ("hows") were listed across the top of the matrix.
- Each design requirement should describe the product in measurable terms and should directly affect customer perceptions.
- The arrow indicates the direction for improvement.



13.2 Quality Function Deployment (QFD)

Step 5

- Cell strength within the matrix are determined to quantify the importance of each "hows" relative to each "whats".
- If a current control measurement does not affect any customer attribute, either it is not necessary or a "what" is missing.
- "Hows" may be added (at least 1 "how" for each "what").

Easy to open and close door	Easy to close from outside	5	⊙				⊙		⊙			
	Stays open	3		⊙	⊙							
	Easy to open from outside	2				⊙			○			
	Doesn't kick back	2		○	○	○	△		⊙			
	⋮											
Isolation	Doesn't leak in rain	2							⊙			⊙
	No road noise	1							○	○	⊙	
	⋮											

⊙ Much importance /strong rel. (9)
○ Some importance /rel. (3)
△ Little importance / rel. (1)
Blank: no rel. (0)

13.2 Quality Function Deployment (QFD)

Step 6

- From technical tests of both competitive products and existing product design, objective measurements are added to the bottom.

		Open-closed effort						Sealing-insulation				
		↓	↑	↑	↓	↓		↑	↑	↑	↑	
		Torque to close door	Closing force level ground	Closing force 10° slope	Torque to open door	Peak closing force	…	Door seal resistance	Acoustic tram., window	Road noise reduction	Water resistance	…
		⊙				⊙		⊙				
Objective target values		7.5 ft-lb	9 lb	6 lb	7.5 ft-lb	12 lb		3 lb/ft	.10	9 db	70 psi	
Objective measures	Our car door	11	12	6	10	18		3	.1	9	70	
	A's car door	9	12	6	9	13		2	.1	5	60	
	B's car door	9.5	11	7	11	14		2	.1	6	60	

13.2 Quality Function Deployment (QFD)

Step 7

- The absolute technical importance of each design requirement is determined by:

$$\sum Imp. \times Rel.$$

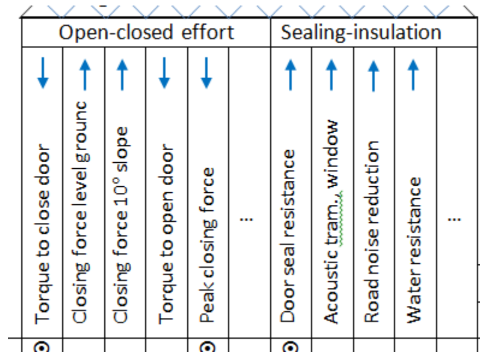
- Rank the absolute importance to obtain the relative number.

Easy to open and close door	Easy to close from outside	5	⊙				⊙		⊙			
	Stays open	3		⊙	⊙							
	Easy to open from outside	2				⊙			○			
	Doesn't kick back	2		○	○	○	△		⊙			
	⋮											
Isolation	Doesn't leak in rain	2							⊙			⊙
	No road noise	1							○	○	⊙	
	⋮											
Technical importance	Absolute		45	33	33	24	47		90	1	9	18
	Relative		3	4.5	4.5	6	2		1	9	8	7

13.2 Quality Function Deployment (QFD)

Step 8

- The technical difficulty of each "how" is documented so focus can be given to important "hows" that may be difficult to achieve.

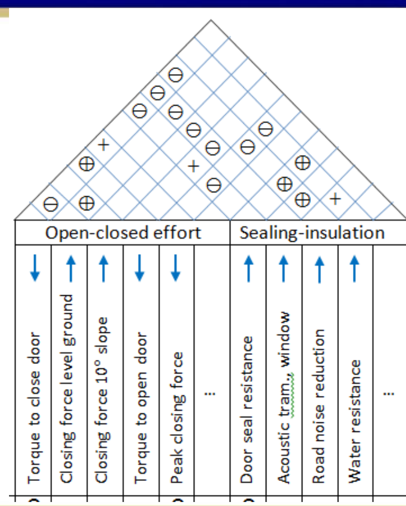


	Torque to close door	Closing force level ground	Closing force 10° slope	Torque to open door	Peak closing force	...	Door seal resistance	Acoustic tram., window	Road noise reduction	Water resistance
Technical difficulty	4	5	1	1	3		1	3	3	5

13.2 Quality Function Deployment (QFD)

Step 9

- The correlation matrix is established to determine the technical interrelationship among the "hows".



⊕ High positive
\+ Positive
⊖ High negative
– Negative

13.2 Quality Function Deployment (QFD)

Step 10
- The target values are determined from the customer ratings and information within the correlation matrix. Trend charts and snapshots are very useful tools. DOE techniques are useful to determine targets that need to be compromised between the “hows”.

Step 11
- Areas need concentrated effort are selected. Key elements are identified from the technical importance and technical difficulty for follow-up matrix activity.

13.4 Cause-and-Effect Matrix

- The cause-and-effect matrix (or characteristic selection matrix) is a tool that can aid with the prioritization of importance of process input variables.
- The results of a cause-and-effect matrix can lead to other activities, such as FMEA, multi-vari charts, vorrelation analysis, and DOE.

13.4 Cause-and-Effect Matrix

To construct a cause-and-effect matrix:

1. List horizontally the key process output variables (KPOV).
2. Assign a prioritization number for each KPOV. (AHP)
3. List vertically all key process input variables (KPIV).
4. Reach by consensus the amount of effect each KPIV has on each KPOV. Rather than use values from 1 to 10, consider a scale using levels 0, 1, 3, 5 or 0, 1, 3, 9.
5. Determine the result for each KPIV by the sum of the products of KPOV priority and the effect.
6. The KPIV can then be prioritized,

13.4 Cause-and-Effect Matrix: Example

	KPOV							
	A	B	C	D	E	F		
KPIV	5	3	10	8	7	6	Results	Rel.
1	4	3		3			53	5.31%
2	10		4	6		6	174	17.42%
3		4					12	1.20%
4			9	5	9	8	241	24.12%
5	4				6		62	6.21%
6		6		5		2	70	7.01%
7	5		4		5		100	10.01%
8		3		4		5	71	7.11%
9	6		3		2		74	7.41%
10		2	4				46	4.60%
11	4			4	2	5	96	9.61%

13.5 Data Relationship Matrix

KPIV can be affected by:

- Temporal variation (over time): shift-to-shift, day-to-day, week-to-week.
- Positional variation (on the same part): within-part variation, variation between departments, operators.
- Cycling variation (between parts): part-to-part variation, lot-to-lot variation.

- KPIV can be discrete (attribute) or continuous.

13.5 Data Relationship Matrix: Example

Within piece variation:

- Position on part (attribute)

Piece-to-piece variation:

- Inspector (attribute)
- Pressure (continuous)
- Operator (attribute)

Time-to-time variation:

- Shift-to-shift (attribute)

13.5 Data Relationship Matrix: Example

Measure ment	Position	Inspector	Pressure	Operator	Shift	Flatness
1	1	1	1148	1	1	.005
2	2	2	1125	1	1	.007
3	3	1	1102	2	2	.009
4	1	2	1175	2	2	.008
5	2	1	1128	1	3	.010
6	3	2	1193	1	3	.003

- Data are collected under normal process operation.
- At least 30 data points should be collected.

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