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Six Sigma:
Converting Real Life Problem in to a Statistical Problem

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One of the major differences between Six Sigma and other improvement approaches is its significant dependence on data based approach using statistical methods. In Six Sigma, we first **convert a real life practical problem in to a statistical problem**. This is like modeling a process. The process response is usually called "**Key Process Output Variable**" (KPOV). Examples of KPOVs could be:

- Yield of a process
- Quality Level such as customer acceptance
- Market Share
- Cycle Time
- Productivity
- Health Index
- Customer Satisfaction Index
- Repair Time
- Reliability
- Down Time
- Inventory Turns

As we may observe, our objective will be to maximize some of these KPOVs such as Yield, Market Share, Customer Satisfaction Index, Productivity, Inventory Turns. On the other hand, we would like to minimize some of the KPOVs. For example, Cycle Time, Repair Time, Down Time, Rejections.

Thus our first task is to decide the objective of our Six Sigma Project, its current level and our target. While Six Sigma Level of achievement corresponds to 3.4 defects per million opportunities (DPMO), we cannot reach this level without a series of Six Sigma Projects in the same direction. The target level of KPOV should be decided by expectation of your customers and industry benchmarks. Thus if the current yield of a process is 85%, we may strive for 90% as a next target. Later, we may take projects to achieve next levels of achievements. Usually, the difficulty levels increase in geometric proportion.

We now need to understand the process so that we can improve. First step for this is to map the process for KPOVs and **Key Process Input Variables** (KPIVs).

Developing the Process Map:

Process Map is one of the most crucial steps in Six Sigma Project. Using process map, we develop a model in a form that is similar to a mathematical function

Y = f (X1, X2, X3,….,Xn)

where Y is the KPOV and X1, X2,..,Xn are KPIVs. There can be more than one KPOV.

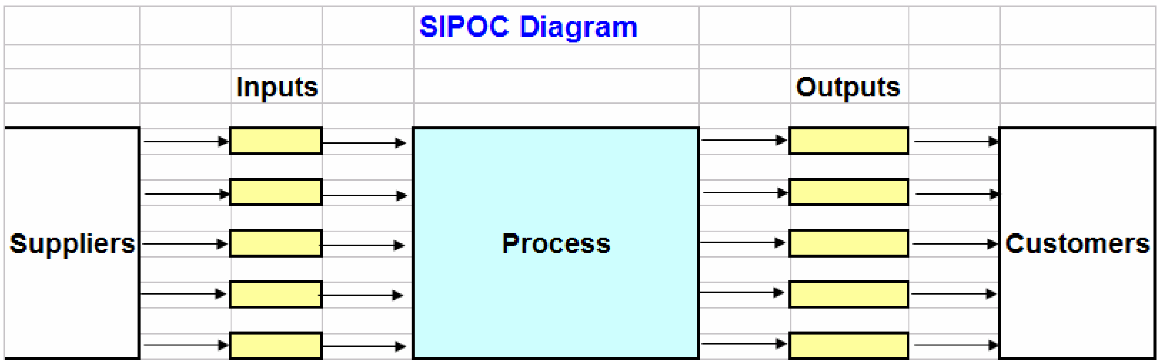
Typical format of a process map is shown in the example below. We need to classify the KPIVx (Xs) as controllable or not controllable. This is shows in column "C/U". Let us consider an example of car painting process to understand how we can develop a process map (PM). PM needs to be developed by the team that is knowledgeable about the process. Thus for a painting process, we should involve the painters, paint supervisor and or technologist, paint supplier's expert or representative etc. Six Sigma tools help us reducing the "unknown" portion of the process. If we have initial knowledge about the process, we should use it so that project is completed in minimum possible time. If we have less initial knowledge, more efforts will be required to screen the KPOVs.

For a painting process, the KPOVs could be Coating thickness T and Shine or

	KPIVs (Xs)	C/U	Process	KPOVs (Ys)	
X1	Type of paint gun	C	Painting	Coating thickness T	Y1
X2	Type of Paint	C		Gloss G	Y2
X3	Surface cleanliness	C		Adhession	Y3
X4	Paint viscosity	C			
X5	Distance of gun	C			
X6	Time of Painting	C			
X7	Painter skill	C			
X8	Drying Oven temperature	C			
X9	Drying Time	C			
X10	Ambient temperature	U			

Gloss G. Various KPIVs may be Type of painting gun, air pressure, type of paint, paint viscosity, distance of the gun from surface, time of painting, painter skill, drying oven temperature and time, Cleanliness of the surface before cleaning. These are all controllable KPIVs. We may also consider that some of the KPOVs may depend upon ambient temperature which is not controllable. The process map is shown here. In the KPOVs, we should note that painting thickness should be sufficient to protect the surface during useful life of the car. Excess thickness will add to cost. Gloss or shine of the paint will add to customer preference as the car may look better. Inconsistent gloss over the surface will make car appearance inferior. Poor adhesion can cause corrosion of the car. Our objective could be to improve consistency of the paint thickness, improve gloss and ensure good adhesion. We can also add ambient humidity as KPIV. This may affect adhesion and drying time as well as gloss.

Process map is usually supported with other types of process documentation such **Flow Chart** and **SIPOC diagrams**. SIPOC stands for Supplier-Input-Process-Output-Customer. SIPOC diagrams and flow charts are useful to understand overall perspective of the process.



In case of Lean Six Sigma Projects such as cycle time reduction, "**Value Stream Maps**" (VSM) are used. VSM is used to separate "Value Added" (VA) and "Non-Value Added" (NVA) activities. The NVA activities should be eliminated or minimized. Value Added Activities are of two types:

1. **Customer Value Added** (CVA) where form or feature that is useful to the customer is added.
2. **Business Value Added** (BVA) activities include those required by law, regulations, business needs and without which we cannot run business.

VSM lead to "Process Cycle Efficiency" which is defined as:

$$\text{Process Cycle Efficiency} = \frac{\text{Value Added Time}}{\text{Total Time}}$$

Process Cycle Efficiency at the beginning of lean six sigma projects may be very low. Michael George in his book "Lean Six Sigma" has given some world class benchmarks for cycle efficiencies.

Application	Typical Cycle Efficiency	World Class Cycle Efficiency
Machining	1	20
Fabrication	10	25
Assembly	15	35
Continuous Manufacturing	30	80
Business Process Transactional	10	50

However, these other tools such as Flow Charting VSM are not substitutes for Process Maps in Six Sigma Projects. Process Maps are usually at two level: Macro Level and Micro Level. Macro Level Maps are top level process maps and KPOVs considered are the customer critical characteristics sometimes called "Critical to Quality" (CTQ) characteristics. Lower level process maps consider interim KPOVs and KPIVs.

Prioritizing KPIVs using Cause and Effects Matrix:

Having Developed the process Maps, we can consider "quantifying" our current knowledge using **Cause and Effects (C&E) Matrix**. A C&E Matrix is a simple tool for "Quality Function Deployment" that helps us separating more important KPIVs from less important ones. We consider the same example of painting process. Softwares such as SigmaXL have standard templates for C&E Matrix.

In the C&E Matrix we first rate the KPOVs by importance on a scale of 1 to 10. We then rate strength of "known" relationship between each of the KPIV and KPOV. This rating is done on a scale of 0 to 10. However, most practitioners use ratings of 0, 1, 3 and 9 only. This is done to distinguish between most important and less important. Weighted score for each KPIV is calculated by multiplying and adding KPIV and

	Output Variables (Y's):	Coating thickness T	Gloss G	Adhession	Weighted Score
	Importance Score (1-10):	5	7	8	
X1	Type of paint gun	3	9	1	86
X2	Type of Paint	3	9	3	102
X3	Surface cleanliness	1	1	9	84
X4	Paint viscosity	9	9	1	116
X5	Distance of gun	9	3	3	90
X6	Time of Painting	9	3	1	74
X7	Painter skill	3	9	3	102
X8	Drying Oven temperature	0	9	9	135
X9	Drying Time	0	9	0	63
X10	Ambient temperature	0	3	3	45
X11	Ambient Humidity	0	3	3	45

KPOV ratings. Higher number shows more importance. Thus we can rank the KPIVs by weighted scores. As we can see from the matrix below, we can rank KPIVs by weighted scores. Remember that the scores are as accurate as the process knowledge of the team. These are useful but need subsequent validation with data.

Having defined the process, we need to **validate our measurement system** for KPOVs and some of the KPIVs as well. We frequently underestimate the inaccuracies in our measurement system. Dr. Dean Ornish in his famous book ”Reversing Heart Disease” has mentioned the difficulties he faced in establishing an appropriate and accurate measure of heart disease. He finally came up with “% blockage of main coronary artery” as the measure of heart disease, KPOV for his research. It was quite difficult to find equipment that would help him distinguish between the “real difference” between the patients before and after the treatment. In other words, we must assess the measurement system that is capable of distinguishing between the process variation and improvement. Thus if we wish to reduce average repair time, we should be able to measure it accurately enough so that we do not get confused or misled. Type of **Measurement Systems Analysis** (MSA) that we should use depends upon type of data. If we are using continuous data, which is a preferred type, we can use MSA for variables data. Examples are length, weight, time, pressure, force etc. We will discuss more about these methods later.

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