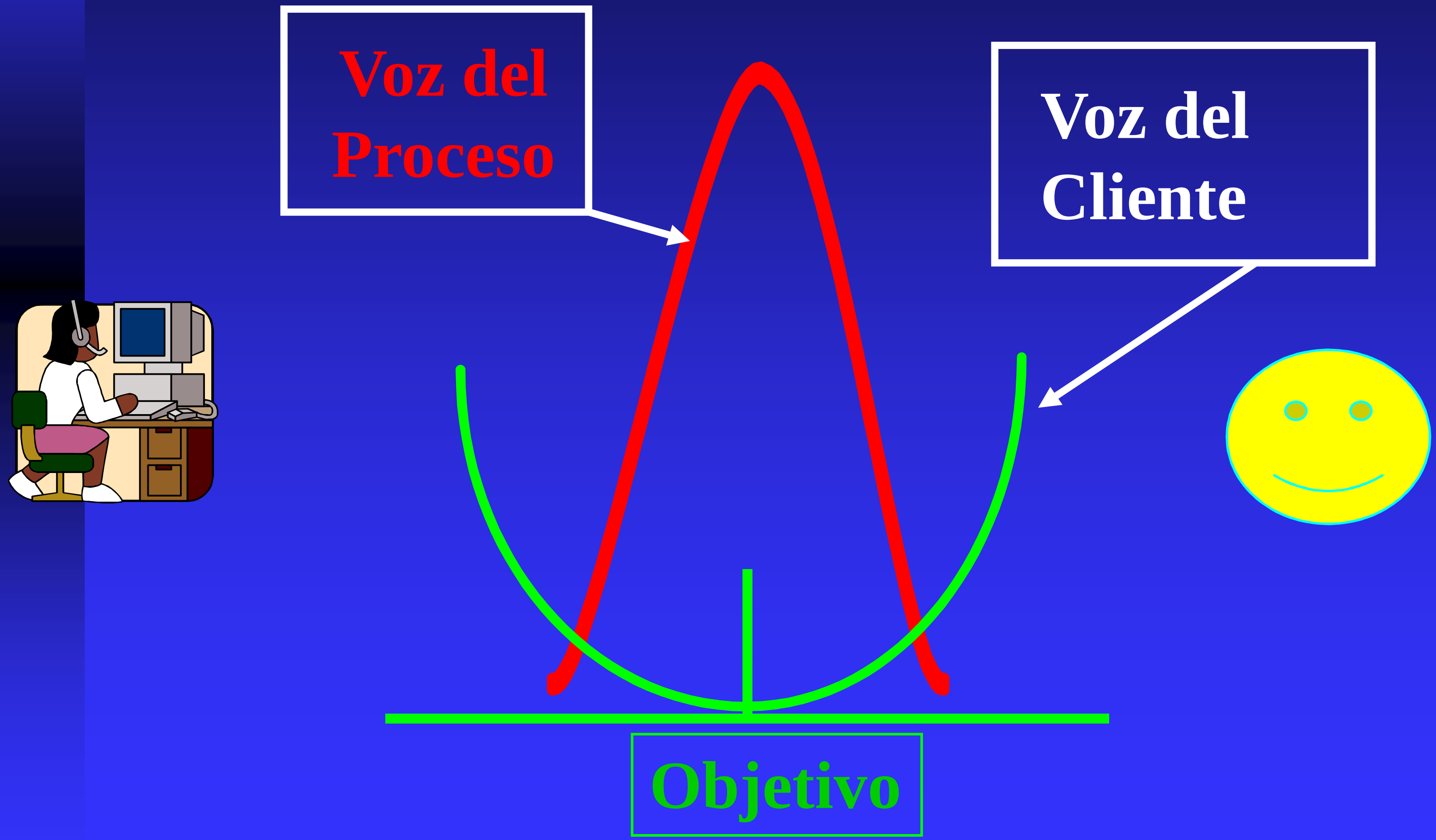
LEAN SIX SIGMA

Luis Arimany de Pablos, Ph.D.

Reducida variabilidad alrededor de la media y proceso centrado en el objetivo (ASQ)



I. QUÉ ES LEAN MANUFACTURING

II. QUÉ ES SIX SIGMA

III. QUÉ ES LEAN SIX SIGMA

I. QUÉ ES LEAN MANUFACTURING

(LEAN)

UNA DISCIPLINA QUE UTILIZA UN CONJUNTO DE HERRAMIENTAS PARA:

ACORTAR EL CICLO DEL PROCESO

REDUCIR LOS ALMACENAMIENTOS

ELIMINAR EL DESPERDICIO

INCREMENTAR EL VOLUMEN DE TRABAJO QUE FLUYE A TRAVÉS DE UN SISTEMA

Lean Production es una metodología desarrollada originalmente por Toyota (Toyota Production System - TPS)

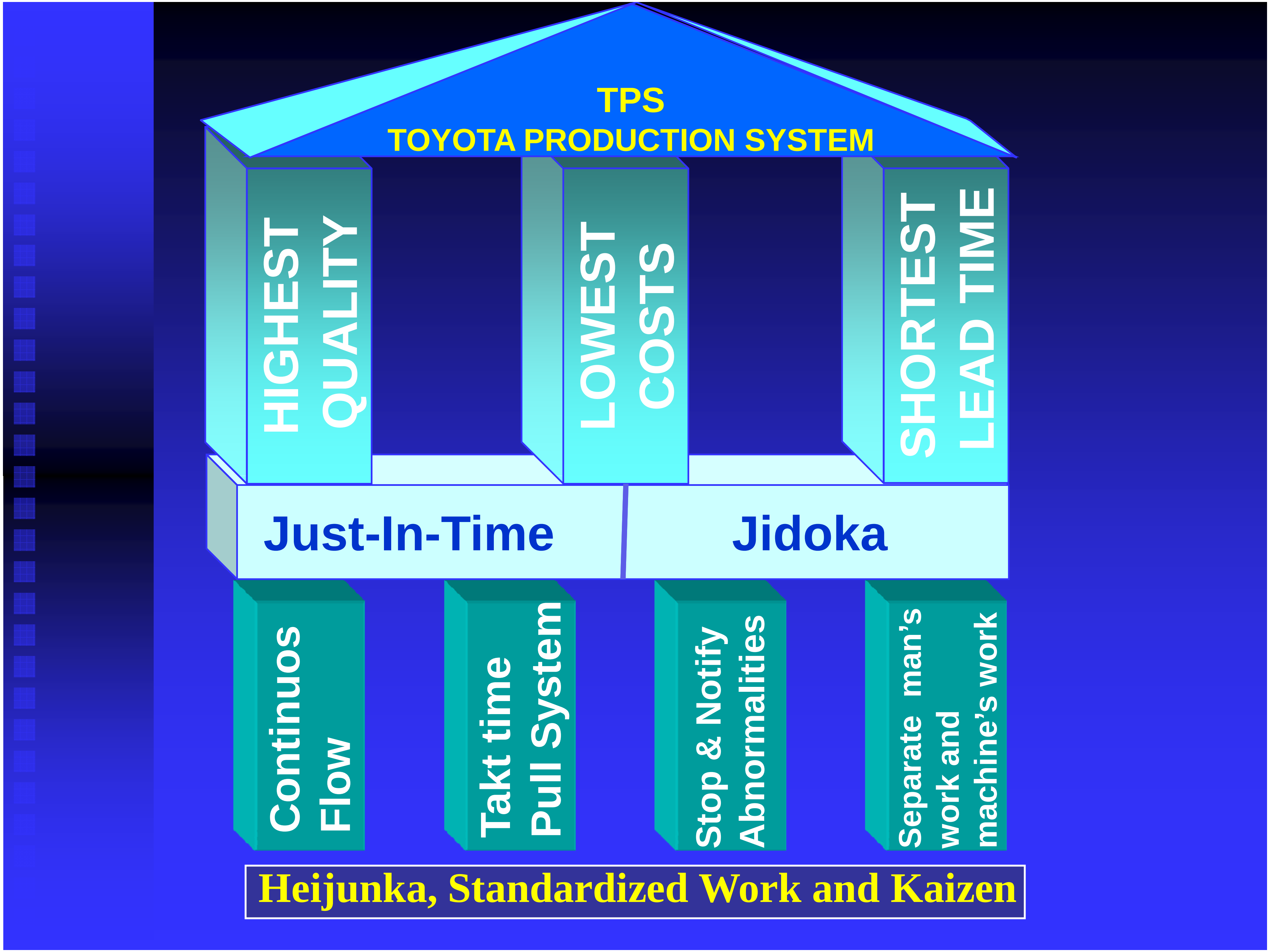
El objetivo de "Lean" se describe como:

"to get the right things to the right place at the rigth time, the first time, while minimizing waste and being open to change"

Sakichi Toyoda (1902) Automatic loom

Kiichiro Toyoda (1930`s) Just in Time (JIT)

Taiichi Ono (1956) Pull System


TPS
TOYOTA PRODUCTION SYSTEM
HIGHEST QUALITY
LOWEST COSTS
SHORTEST LEAD TIME
Just-In-Time
Jidoka
Continuos Flow
Takt time Pull System
Stop & Notify Abnormalities
Separate man's work and machine's work
Heijunka, Standardized Work and Kaizen

JUST IN TIME

(JIT)

La fabricación y movimiento de sólo "what is needed, when is needed, and in the amount needed".

JIDOKA

(Defect Detection System)

This defect detection system automatically or manually stops the production operation, or the supply of a service, whenever an abnormal or defective condition arises. Any improvements can then be made by analyzing and improving the stopped equipment or service and it is done by the worker who stopped the operation.

TAKT TIME

Takt Time is customarily defined as the pace of production to meet customer demand. That is, the quotien between "available time" and "customer demand".

Aircraft Engine Assembly line:

Available time: 7 hr. x 2 shifts x 250 days/year= 3500 hrs.

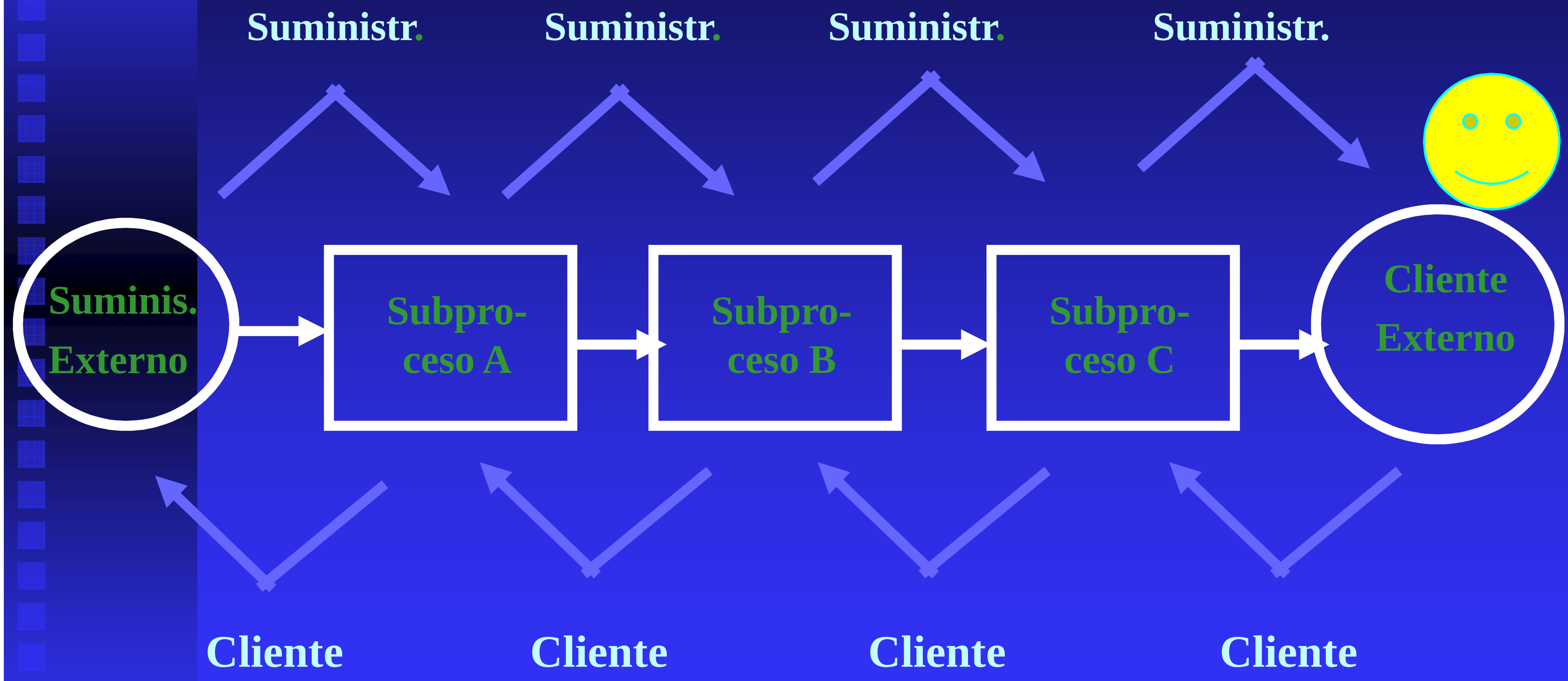
Demand: 500 engines per year

Takt time: 7 hrs. per engine

PULL SYSTEM

Each line became the customer for the preceding line. And each line became a supermarket for following line. The former line would produce only the replacement items for the ones that the following line has selected. This scheme, then, was a "Pull System", driven by the needs of the following lines. It contrasted with the traditional "Push Systems", which were driven by the output of the preceding lines.

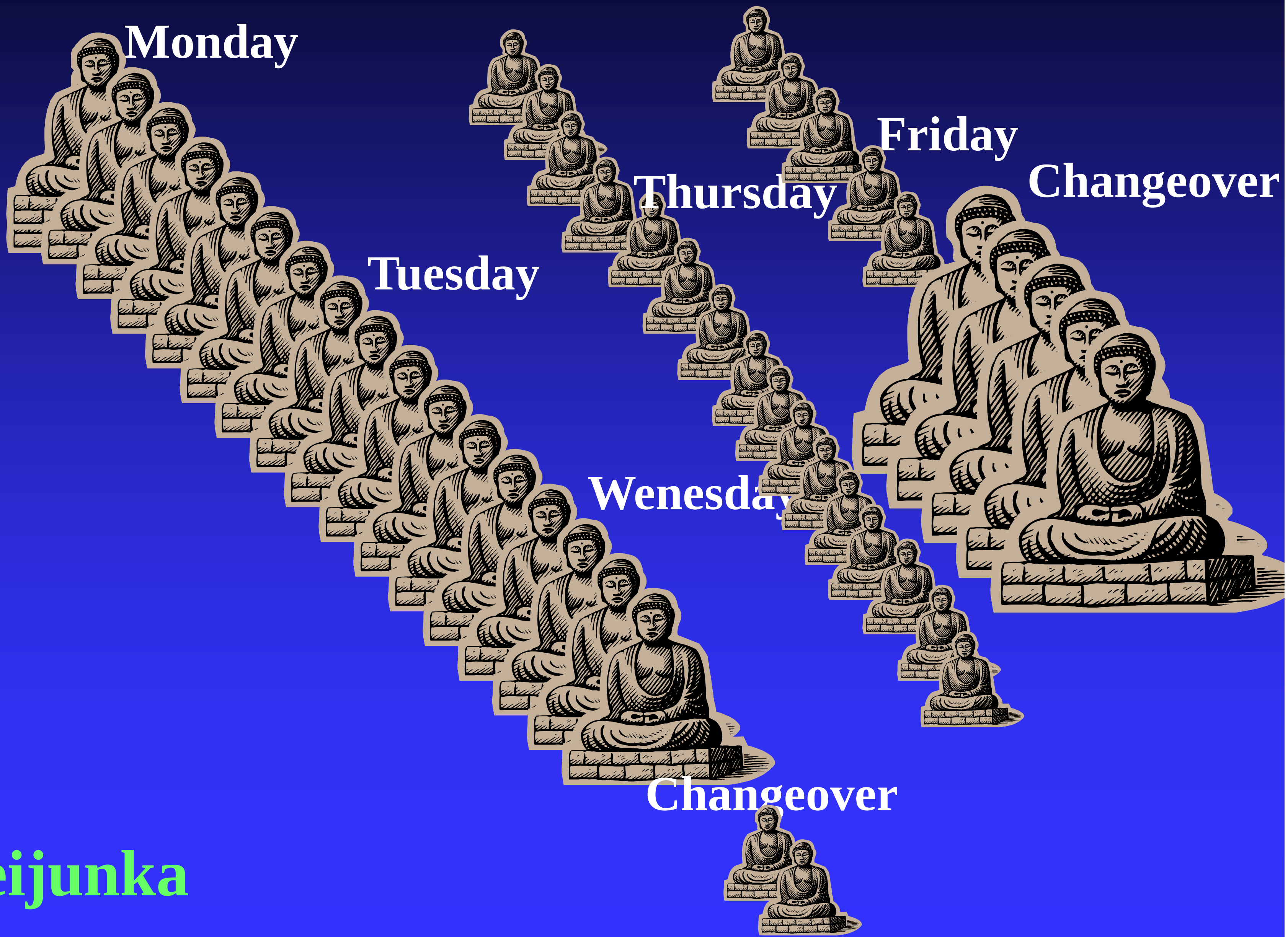
Procesos y subprocesos



HEIJUNKA

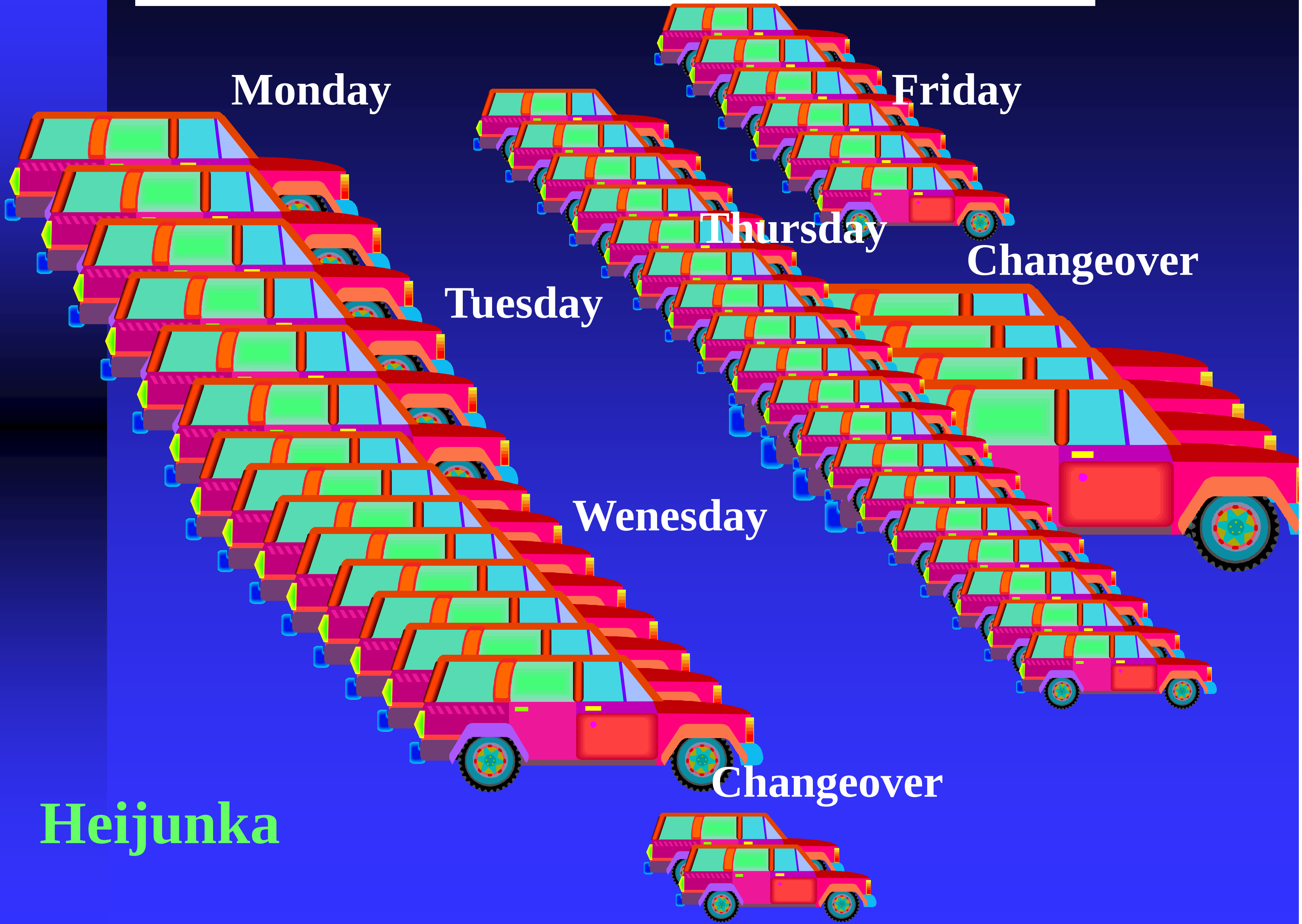
This Method of levelling production on the line makes Just-In-Time production possible. This involves averaging both the volume and the sequence of different model types (or services) on a mixed model production line. Heijunka takes the total volume of orders in a period, say a week, and levels them out so the same amount and mix are being made each day.

TRADITIONAL PRODUCTION



Heijunka

TRADITIONAL PRODUCTION



Heijunka

LEVELED PRODUCTION

Monday Tuesday Wenesday Thursday Friday

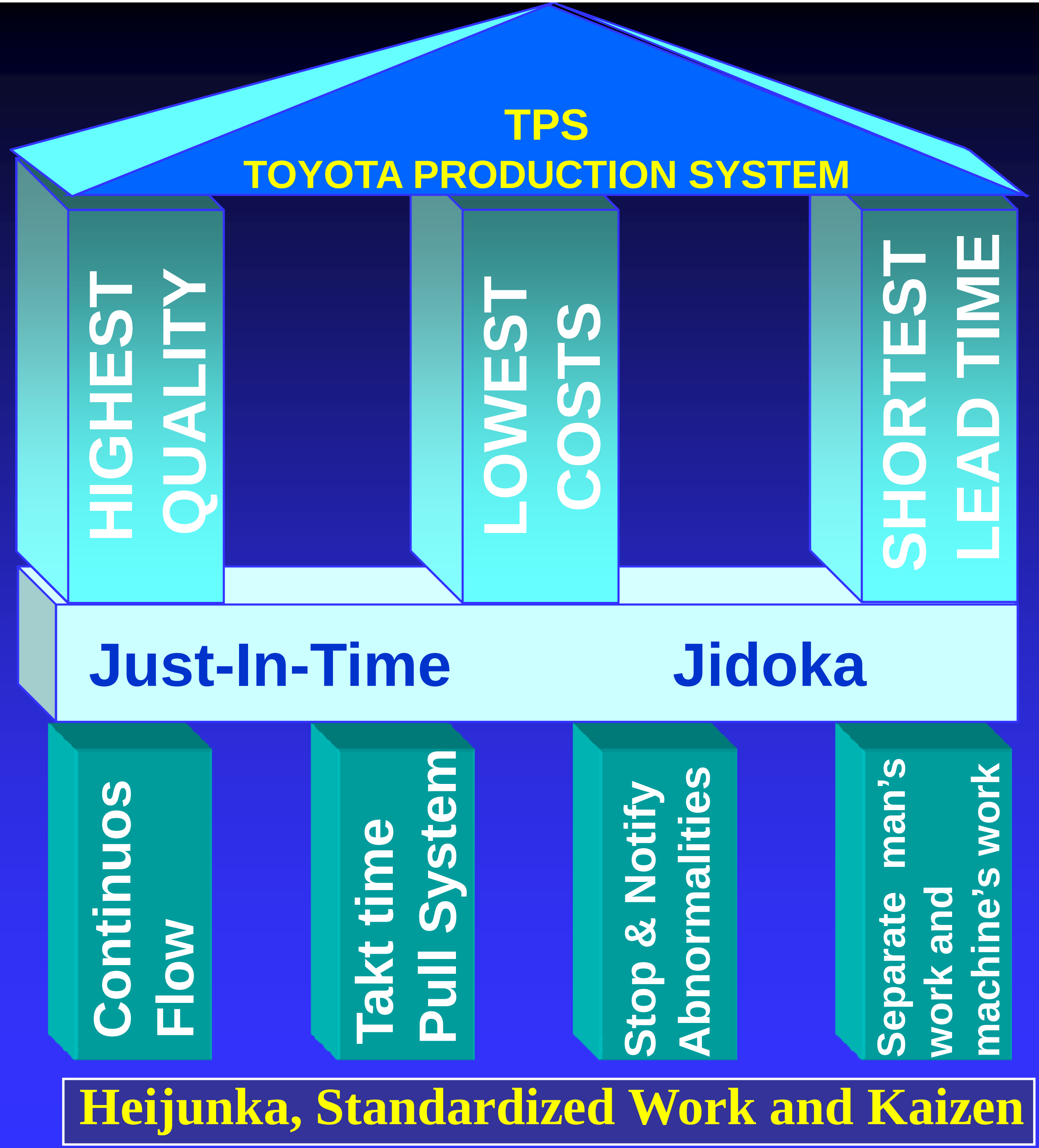
Heijunka

LEVELED PRODUCTION

Monday Tuesday Wenesday Thursday Friday

Heijunka

By reducing changeover time and other Lean methods (e.g.: SMED), the producer is able to make his products or supply his services in any order he wants to on the mix model assembly line. The four benefits of leveling production are: a) Flexibility to produce the customers want when they want, b) Reduced risk of unsold goods, c) Balanced used of labor and machines, and d) Smoothed demand on upstream.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LEAN TEN RULES

1. Eliminate waste (Muda)
2. Minimize inventory
3. Maximize Flow
4. Pull production from customer demand
5. Meet Customer requirements
6. Do it right the firs time
7. Design for rapid cangeovers
8. Partnership with suppliers
9. Create a culture of continuous improvement
10. Worker’s Empowerment

LEAN TOOLS

1. The five S's (Seiri, Seiton, Seiso, Seiketsu, Shitsuke: Sort, Straighten, Srub, Systematize and Standardize)
2. The seven wastes (see below)
3. Changeover reduction (Single Minute Exchange of Dices - SMED)
4. Kanban (Pull Signalling System)
5. Poka Yoke (Fool Proofing or failsafe mechanisms)
6. Lean Communications (Team briefings)
7. TPS
8. Takt-Time

THE SEVEN WASTES

1. Overproduction
2. Idle Time (time when no value is added to the product or service). Here, SMED will help to reduce setup & adjustment times from HOURS to MINUTES
3. Unnecessary moving or handling
4. Unnecessary raw material in stores, work in process (WIP), and finished stock
5. Movement of equipment or people that add no value to to the product or service
6. Overprocesing, work carried out on the P/S which add no value
7. Defective unit production or reworking scrap

II. QUÉ ES SIX SIGMA

Definición

La forma de pensar estadistica (Statistical Thinking) es una filosofía de aprendizaje y acción basada en los siguientes principioas fundamentales:

- ***Todo trabajo se realiza dentro de un sistema de procesos interconetctados***
- ***La variabilidad está presente en todos los procesos***
- ***Entender y reducir la variabilidad es la clave del éxito.***

Glossary of Statistical Terms - Quality Press, 1996

Todo trabajo se realiza dentro de un sistema de procesos interrelacionados

Proceso

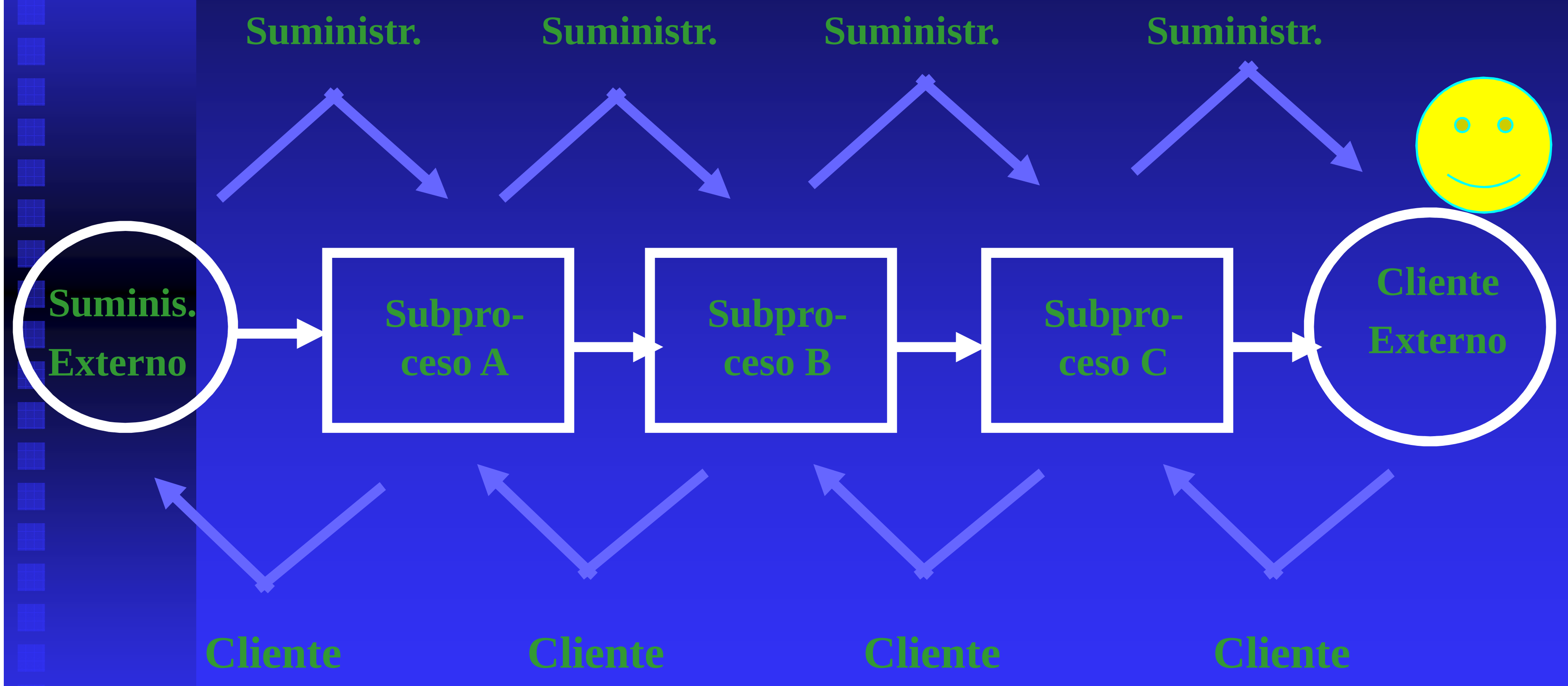
Transforma Inputs en Outputs

Inputs	Transformación	Outputs
Suministradores Información Datos Historicos	Cuentas a pagar Reparación de coches Blending Aprobaciones	Productos terminados or Servicios

Factores Externos

- Materiales
- Personas
- Métodos
- Máquinas
- M. Ambiente
- Medidas

Procesos y subprocesos



La variabilidad está presente en todos los procesos

Tipos de variabilidad:

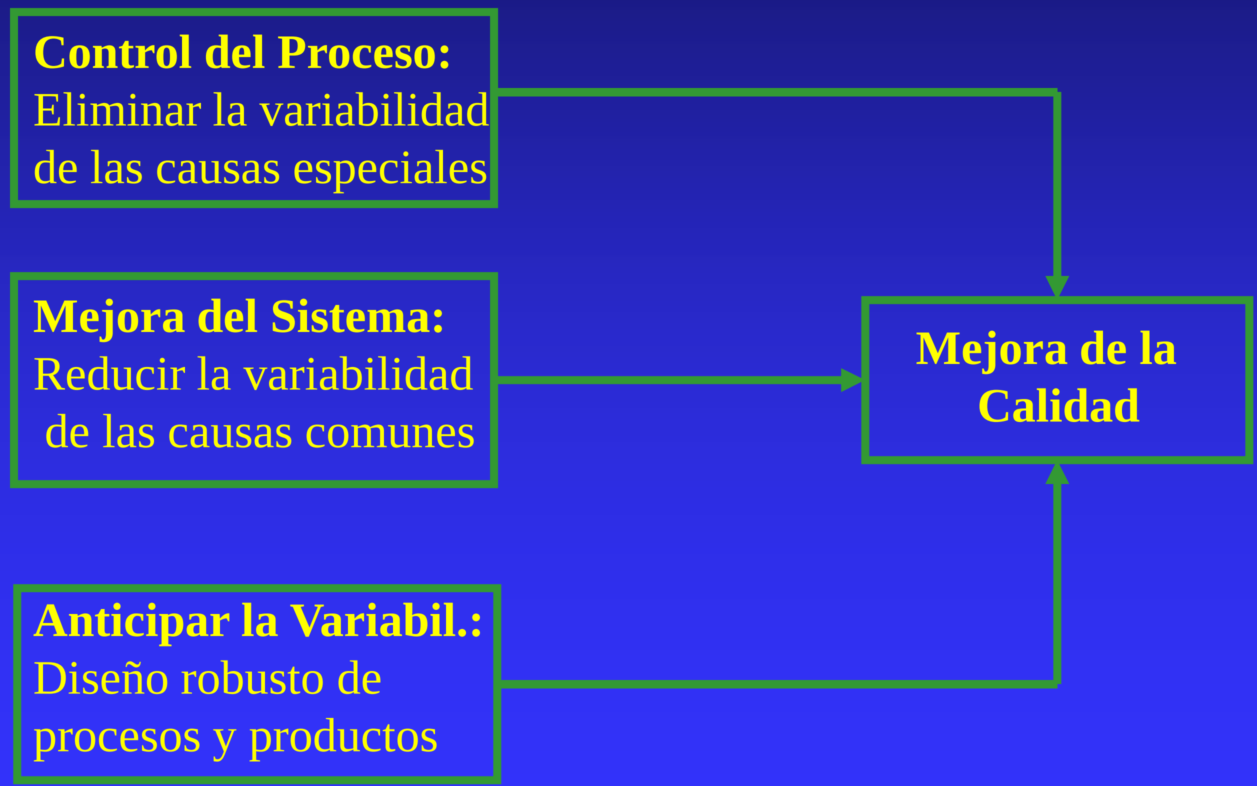
- Debida al Sesgo
- Debida a causas comunes
- Debida a causas especiales
- Debida a causas estructurales

Entender y reducir la variabilidad es la clave del éxito

Deming dijo una vez:

"Si tuviera que simplificar mi mensaje para la dirección en unas pocas palabras diría que todo se reduce a reducir la variabilidad."

Tres caminos para reducir la variabilidad y mejorar la calidad



PARA CUALQUIER DISTRIBUCIÓN

outside the mean $\pm 2\sigma$ <u>a maximum</u> 25% of the values

outside the mean $\pm 3\sigma$ <u>a maximum</u> 11.11% of the values

outside the mean $\pm 4\sigma$ <u>a maximum</u> 6.25% of the values

outside the mean $\pm 5\sigma$ <u>a maximum</u> 4% of the values

outside the mean $\pm 6\sigma$ <u>a maximum</u> 2.77% of the values

PARA LA DISTRIBUCIÓN NORMAL

outside the mean $\pm 2\sigma$ there are 4.55% of the values

outside the mean $\pm 3\sigma$ there are 0.27% of the values

outside the mean $\pm 4\sigma$ there are 0.006% of the values

outside the mean $\pm 5\sigma$ there are $5.74 \cdot 10^{-5}$% of the values

outside the mean $\pm 6\sigma$ there are $19.8 \cdot 10^{-8}$ % of the values

(two tails)

Una de las contribuciones más significativas de Motorola fue cambiar la discusión de la calidad, de niveles de calidad medidos en % (partes-por-cien), a unos, medidos en partes por millón, o, inclusive, partes por mil millones

PARA LA DISTRIBUCIÓN NORMAL

to the right of the mean + 2σ there are 22,750 per million

to the right of the mean +3σ there are 1,349.96 per million

to the right the mean + 4σ there are 31.686 per million

to the right of the mean + 5σ there are 0.28715 per million

to the right of the mean + 6σ there are 0.001 per million

(one tail)

PRODUCTOS O SERVICIOS DEFECTUOSOS

$X < LSL$ $X > USL$

Si fijamos los Límites de las Epecificaciones a

$m \pm 3\,\sigma$

En media 0.27 % defectuosos

2.7 por mil

2,700 por millón

1,350 per millón
(one tail)

Deberíamos tener un proceso con tan pequeña variabilidad que los Límites de las Especificacione estén en:

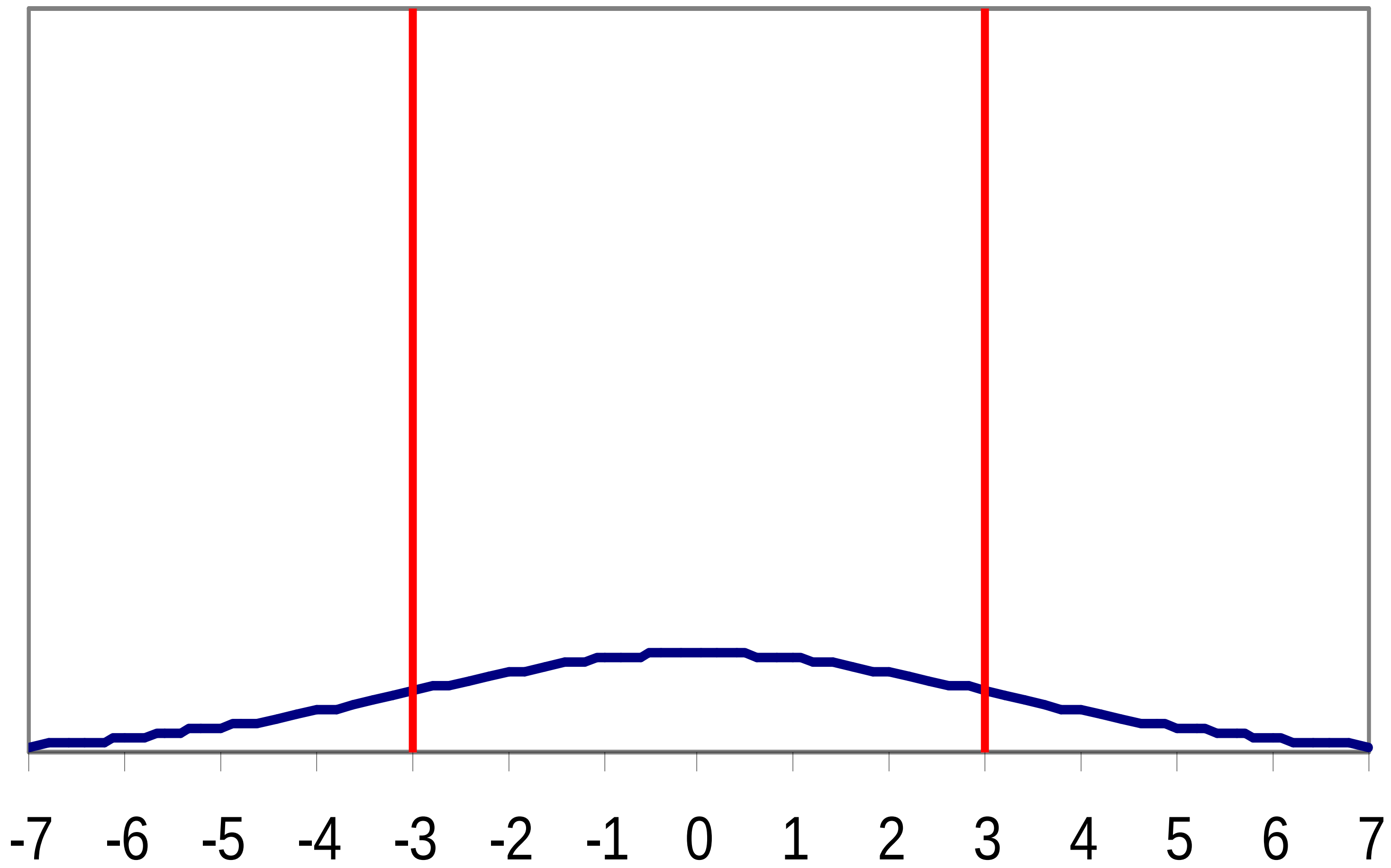
$$m \pm 6\,\sigma$$

0.00198 defectuosos por millón

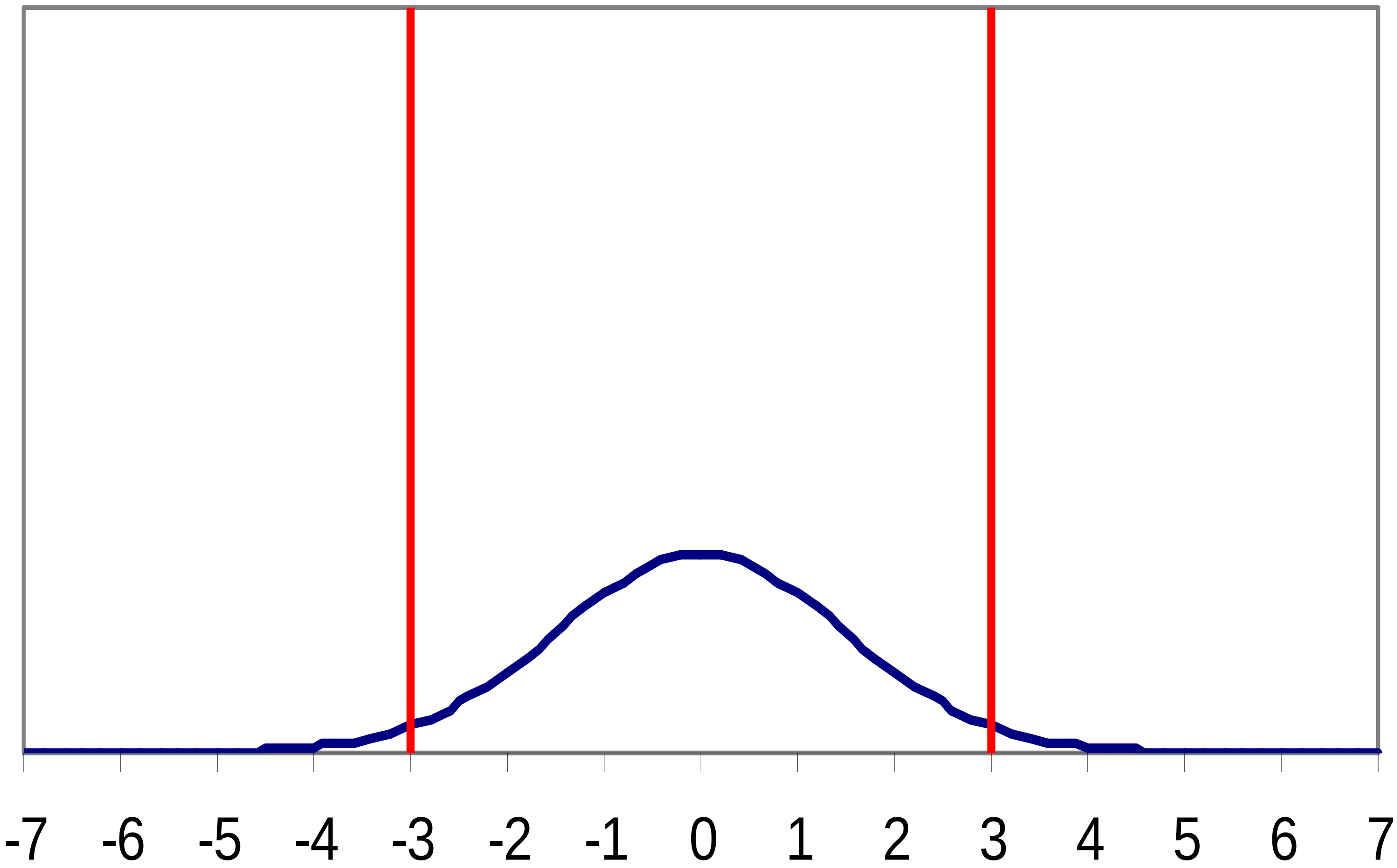
0.002 por millón

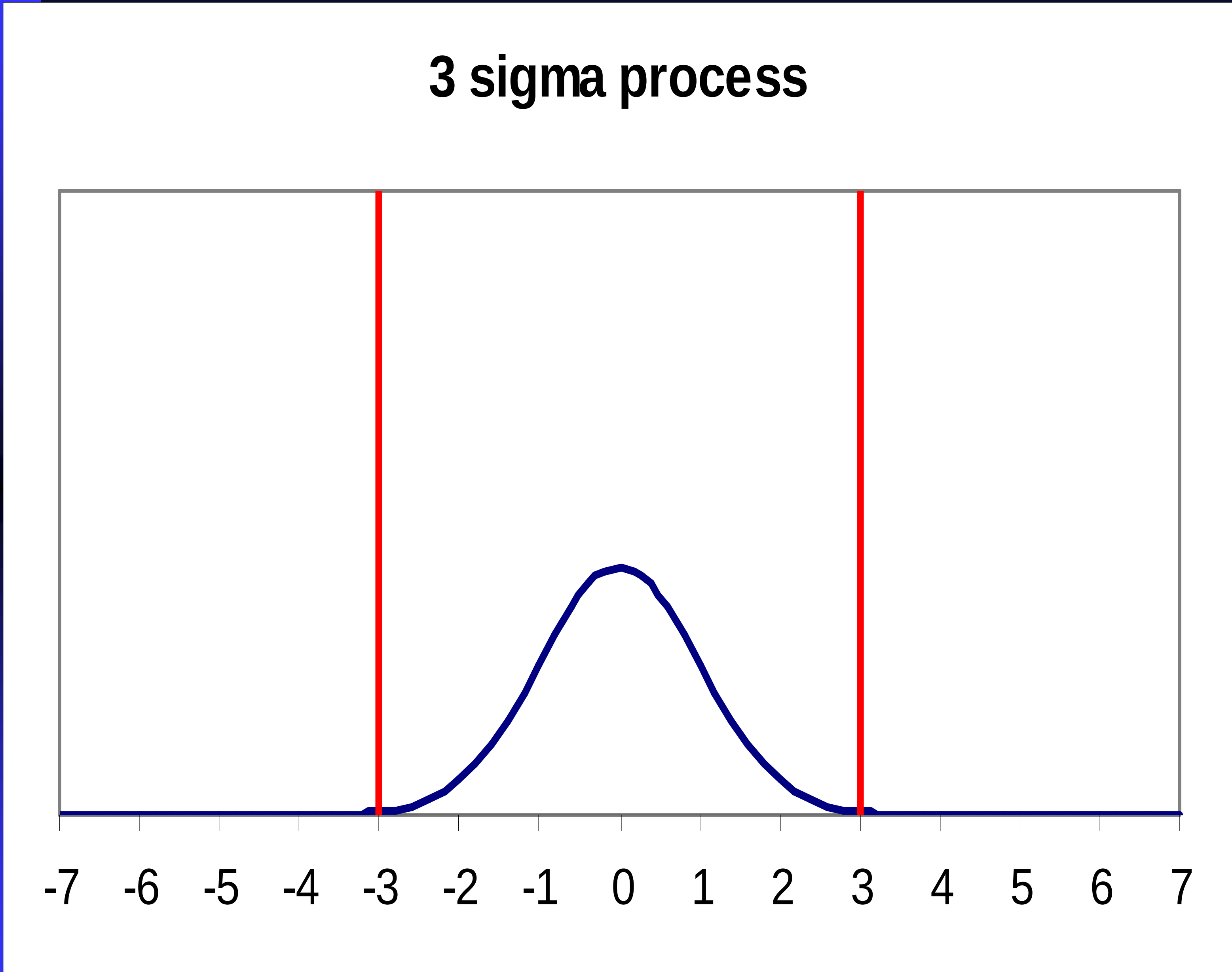
0.001 por millón en una cola

1 sigma process

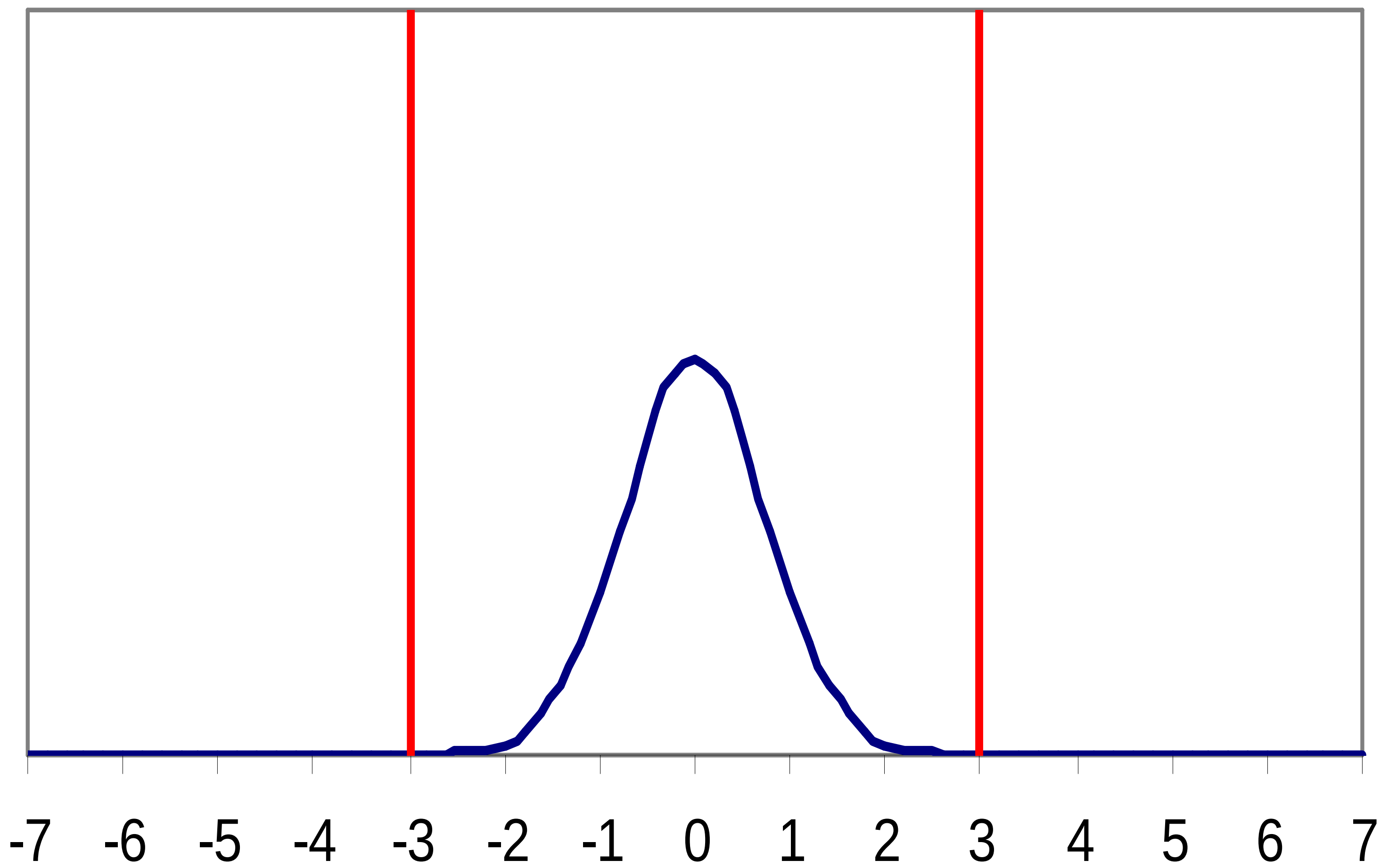


2 sigma process

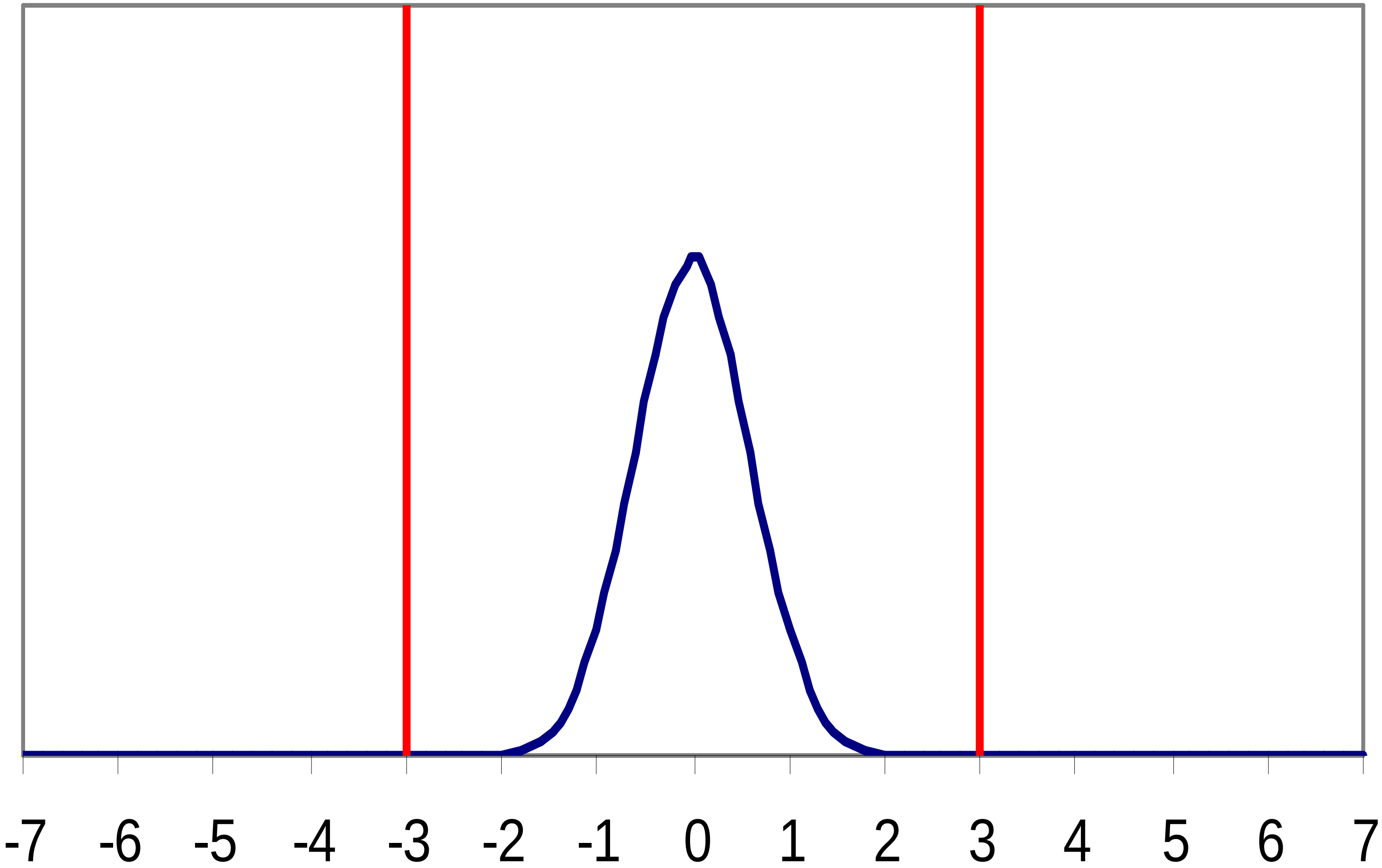


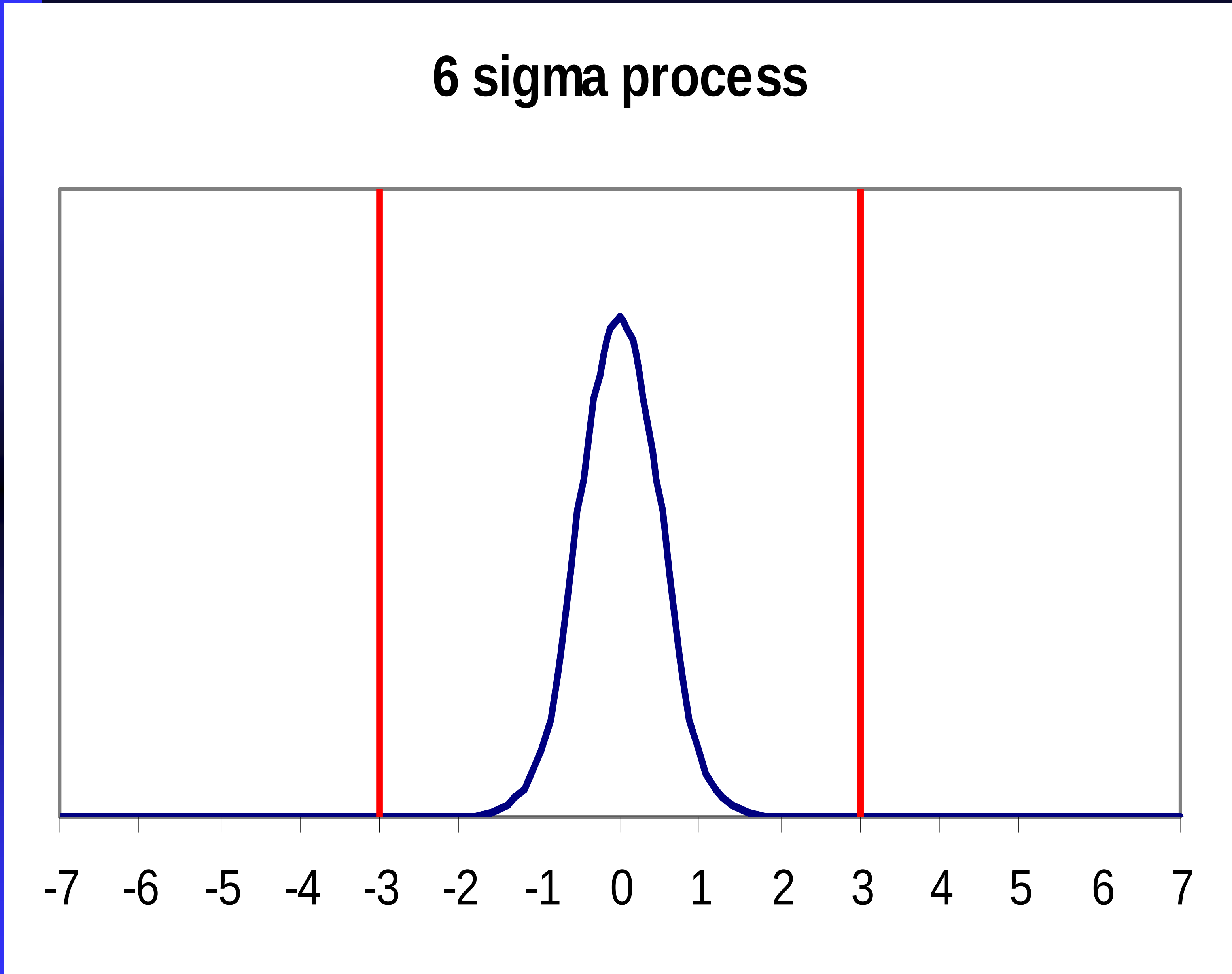

3 sigma process
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7

4 sigma process



5 sigma process




6 sigma process
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7

Índice de Capacidad de Proceso, Cp

(Capacidad Potencial)

$$Cp = (USL-LSL)/6\sigma$$

USL-LSL = Specification interval

6σ = Process Capability

Process Centred at Target				
Process	Cp	LSL	USL	Right hand ppm defective
1σ	0.33	$m-\sigma_1$	$m+\sigma_1$	158,655
2σ	0.66	$m-2\sigma_2$	$m+2\sigma_2$	22,750
3σ	1	$m-3\sigma$	$m+3\sigma$	1,350
4σ	1.33	$m-4\sigma_4$	$m+4\sigma_4$	31.686
5σ	1.66	$m-5\sigma_5$	$m+5\sigma_5$	0.287
6σ	2	$m-6\sigma_6$	$m+6\sigma_6$	0.001

Debemos conseguir un proceso con una variablilidad tan pequeña que los límites de la especificación

se sitúen en:

$$m \pm 6\sigma$$

0.00198 defectuosos por millón

0.002 por millón

0.001 por millón en una cola

Trabajando con la metodología 6 σ se obtiene

3.4 defectuosos por millón

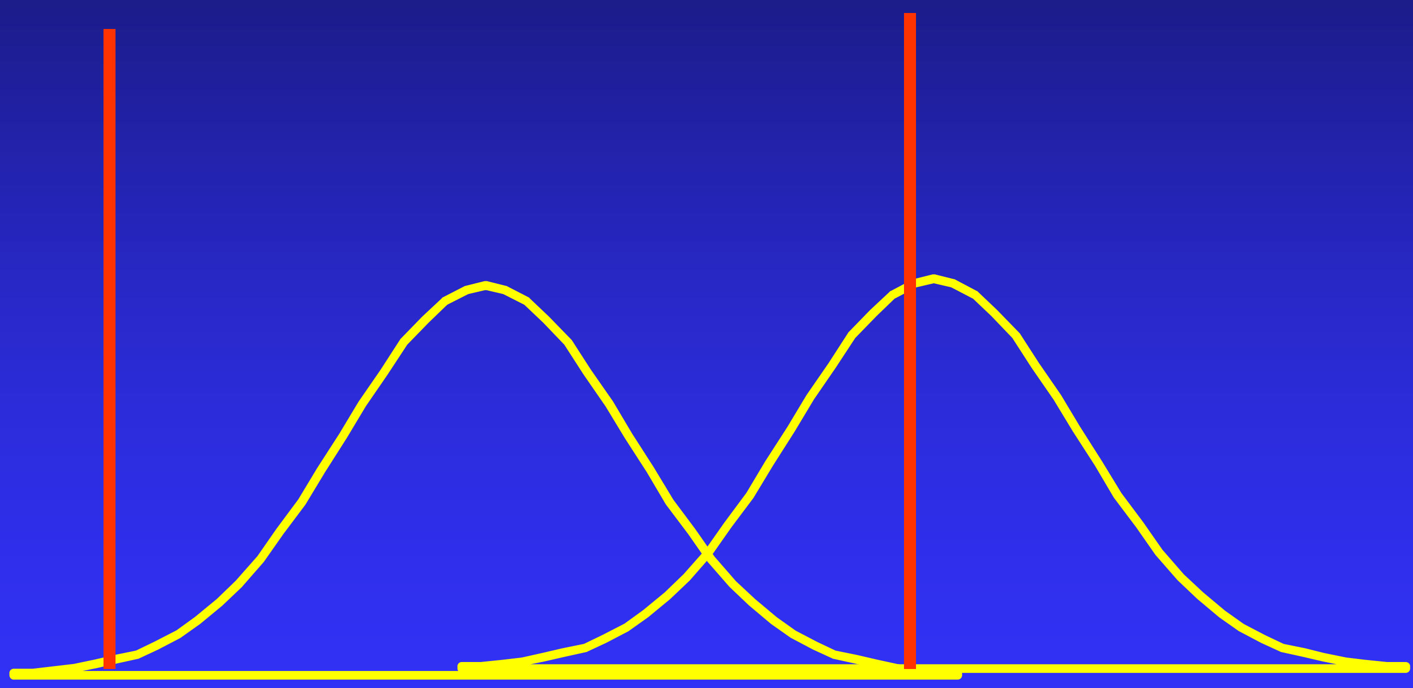
¿Cómo puede ser si la cifra exacta es 0.002 ppm

(o 0.001 ppm si consideramos sólo una cola)?

Aún si un proceso está bajo control no es infrecuente ver que la media del proceso se mueve arriba (o abajo) hasta media objetivo (target mean) más (menos) 1.5 σ.

Si éste es el caso, el peor caso, trabajando con la filosofía 6 σ nos garantizamos que no obtendremos más de 3.4 defectuosos por million de productos o servicios

Supongamos que la media del proceso no está en el punto medio del intervalo de las especificaciones, el valor objetivo m, sino a $m+1.5\sigma$



Índice de Capacidad de Proceso, Cpk

$$Cpk = (USL - mp)/3\sigma$$

USL = Upper Specification Limit

mp = process mean

3σ = Half Process Capability

Process Centred at m + 1.5 σ

Process	Cpk	USL	Z score	Right hand ppm defective
1σ	-0.166	$m+\sigma_1$	-0.51	691,464
2σ	0.166	$m+2\sigma_2$	0.5	308,536
3σ	0.5	$m+3\sigma$	1.5	66,807
4σ	0.83	$m+4\sigma_4$	2.5	6,209.66
5σ	1.166	$m+5\sigma_5$	3.5	232.67
6σ	1.5	$m+6\sigma_6$	4.5	3.4

	Process Centred at m		Process Centred at m + 1.5 σ	
Process	Cp	Right hand ppm defective	Cpk	Right hand ppm defective
1σ	0.33	158,655	-0.166	691,464
2σ	0.66	22,750	0.166	308,536
3σ	1	1,350	0.5	66,807
4σ	1.33	31.69	0.83	6,209.66
5σ	1.66	0.287	1.166	232.67
6σ	2	0.001	1.5	3.4

CALIDAD

La pérdida que un producto o servicio infringe a la Sociedad, en su producción, transporte, consumo o uso y sus residuos

(Dr. Genichi Taguchi)

$$L=k(x_i-m)^2$$

$$E(L)=k\sigma^2$$

Loss Function
(Process Centred at Target)

Six Sigma Metric	Standard Deviation	Cp	R H ppm defective	Loss Function
1σ	3σ	0.33	158,655	$9k\sigma^2$
2σ	1.5σ	0.66	22,750	$2.25k\sigma^2$
3σ	σ	1	1,350	$1k\sigma^2$
4σ	0.75σ	1.33	31.686	$0.56k\sigma^2$
5σ	0.6σ	1.66	0.287	$0.36k\sigma^2$
6σ	0.5σ	2	0.001	$0.25k\sigma^2$

Loss Function

(Process Centred at m+1.5σ)

Six Sigma Metric	Standard Deviation	Cpk	R H ppm defective	Loss Function
1σ	3σ	-0.16	691,464	$29.25k\sigma^2$
2σ	1.5σ	0.16	308,536	$7.3125k\sigma^2$
3σ	σ	0.5	66,807	$3.25k\sigma^2$
4σ	0.75σ	0.83	6,209.66	$1.8281k\sigma^2$
5σ	0.6σ	1.16	232.67	$1.17k\sigma^2$
6σ	0.5σ	1.5	3.4	$0.8125k\sigma^2$

			Loss Function (Process Centred at m)	Loss Function (Process Centred at m+1.5σ)
Six Sigma Metric	Cp	Cpk		
1σ	0.33	-0.16	$9k\sigma^2$	$29.25k\sigma^2$
2σ	0.66	0.16	$2.25k\sigma^2$	$7.3125k\sigma^2$
3σ	1	0.5	$1k\sigma^2$	$3.25k\sigma^2$
4σ	1.33	0.83	$0.56k\sigma^2$	$1.8281k\sigma^2$
5σ	1.66	1.16	$0.36k\sigma^2$	$1.17k\sigma^2$
6σ	2	1.5	$0.25k\sigma^2$	$0.8125k\sigma^2$

			R H ppm defective (Process Centred at m)	R H ppm defective (Process Centred at m+1.5σ)
Six Sigma Metric	Cp	Cpk		
1σ	0.33	-0.16	158,655	691,464
2σ	0.66	0.16	22,750	308,536
3σ	1	0.5	1,350	66,807
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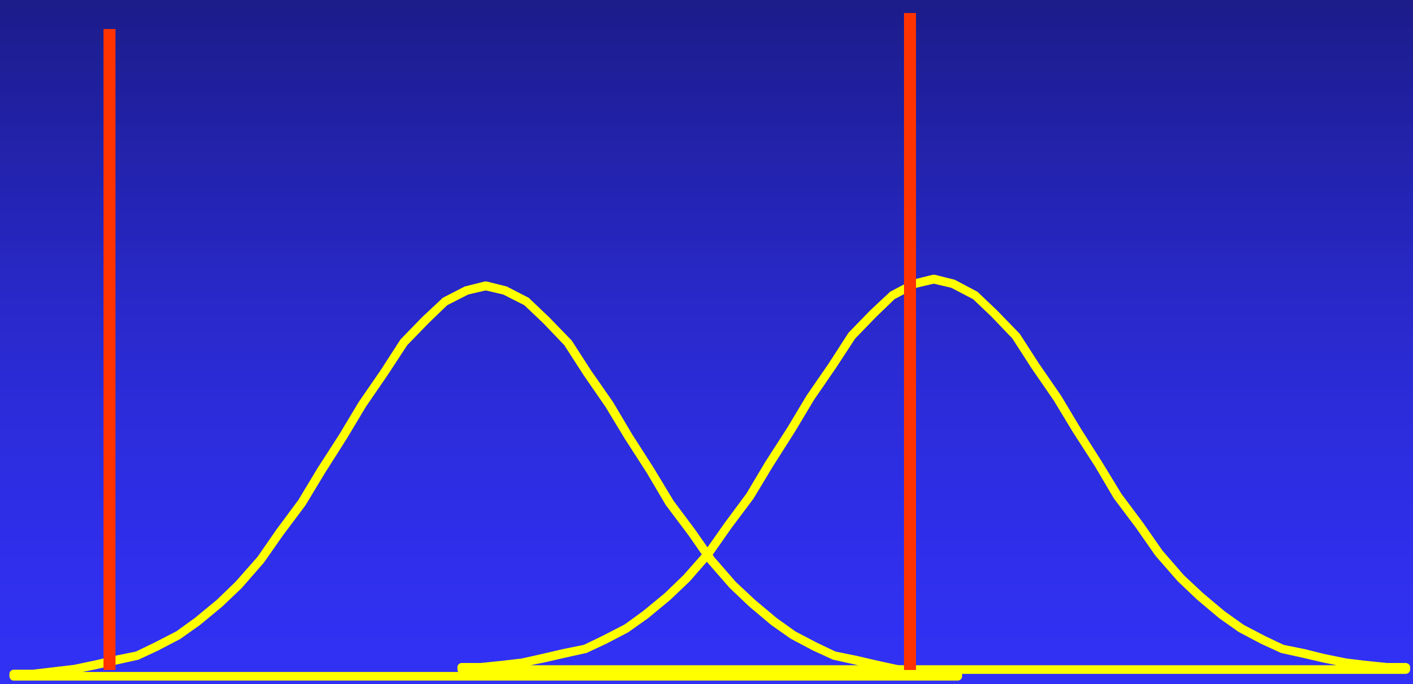


AVERAGE RUN LENGTH

6 Sigma process

Probability to detect the change

0.001349

Average Run Length

740.76

Average Run Length

Six Sigma Metric	Standard Deviation	USL	Probability of Defectives after the Shift	Expected Number of samples to detect the Shift
3σ	σ_3	$m+3\sigma_3/\sqrt{n}=m+3\sigma_3/\sqrt{n}$	0.5	2
4σ	$0.75\sigma_3$	$m+4\sigma_4/\sqrt{n}=m+3\sigma_3/\sqrt{n}$	0.158655	6.42
5σ	$0.6\sigma_3$	$m+5\sigma_5/\sqrt{n}=m+3\sigma_3/\sqrt{n}$	0.02275	43.45
6σ	$0.5\sigma_3$	$m+6\sigma_6/\sqrt{n}=m+3\sigma_3/\sqrt{n}$	0.001349	740.76

Average Run Length

Six Sigma Metric	Standard Deviation	Probability of Defectives after the Shift	Expected Number of samples to detect the Shift
3σ	σ_3	0.5	2
4σ	$0.75\sigma_3$	0.158655	6.42
5σ	$0.6\sigma_3$	0.02275	43.45
6σ	$0.5\sigma_3$	0.00134996	740.76

¿Compensa el coste y el esfuerzo de ir de un proceso 4 σ a uno de 6 σ ?

¿por qué la metodología 6 σ sostiene la “inevitabilidad” de un desplazamiento de la media del proceso de 1.5 σ si se puede detectar ese desplazamiento en 6 o 7 muestras, para un proceso 4 σ ?

Desde el punto de vista de la Sociedad un proceso centrado 4 σ puede muy bien ser preferible a un proceso 6 σ descentrado

III. QUÉ ES LEAN SIX SIGMA

LEAN SIX SIGMA es una combinación robusta de un *<u>Sistema de Produción</u>* y un *<u>método estructurado de reducción de la variabilidad (error)</u>*.

Tradicionalmente "Six Sigma" se enfoca más en la calidad que en la velocidad.

El método que se conoce como "Lean" es más apropiado para mejorar el flujo del proceso y su velocidad que para mejorar la calidad.

Al combinar los dos obtenemos una herramienta de mejora robusta y poderosa.

James Bossert

Vice-president. Bank of America

"I have found Six Sigma and Lean methodologies synergistic.

It was inevitable people would start to merge (both) approaches. Results were complementary when the Champion and Six Sigma team worked to find the best combinations of techniques to create a robust solution. GE Capital used this approach successfully time and time again.

Kevin Grayson

M. Specialist & Sis Sigma Coordinator

North Carolina State University

“Regardless of the terminology, more and more nonmanufacturing companies are using both concepts to improve their business processes, such as order entry, customer servises or material procurement”

Jane Heyward

Process improvement manager

Invensys Powerware

"Six Sigma and Lean tools are definitely synergistic. If you truly want a continuous improvement culture in your organization, then you need to be able to use both tool kits together or you'll ht a brick wall."

Randy Kesterton

Senior Vice-president operations

Curtiss-Wright Flight Systems

"Lean and Six Sigma work best when used together, with one person responsible for coordinating both tools. Try the recipe when starting out. Turn some business double plays. Win the game. "

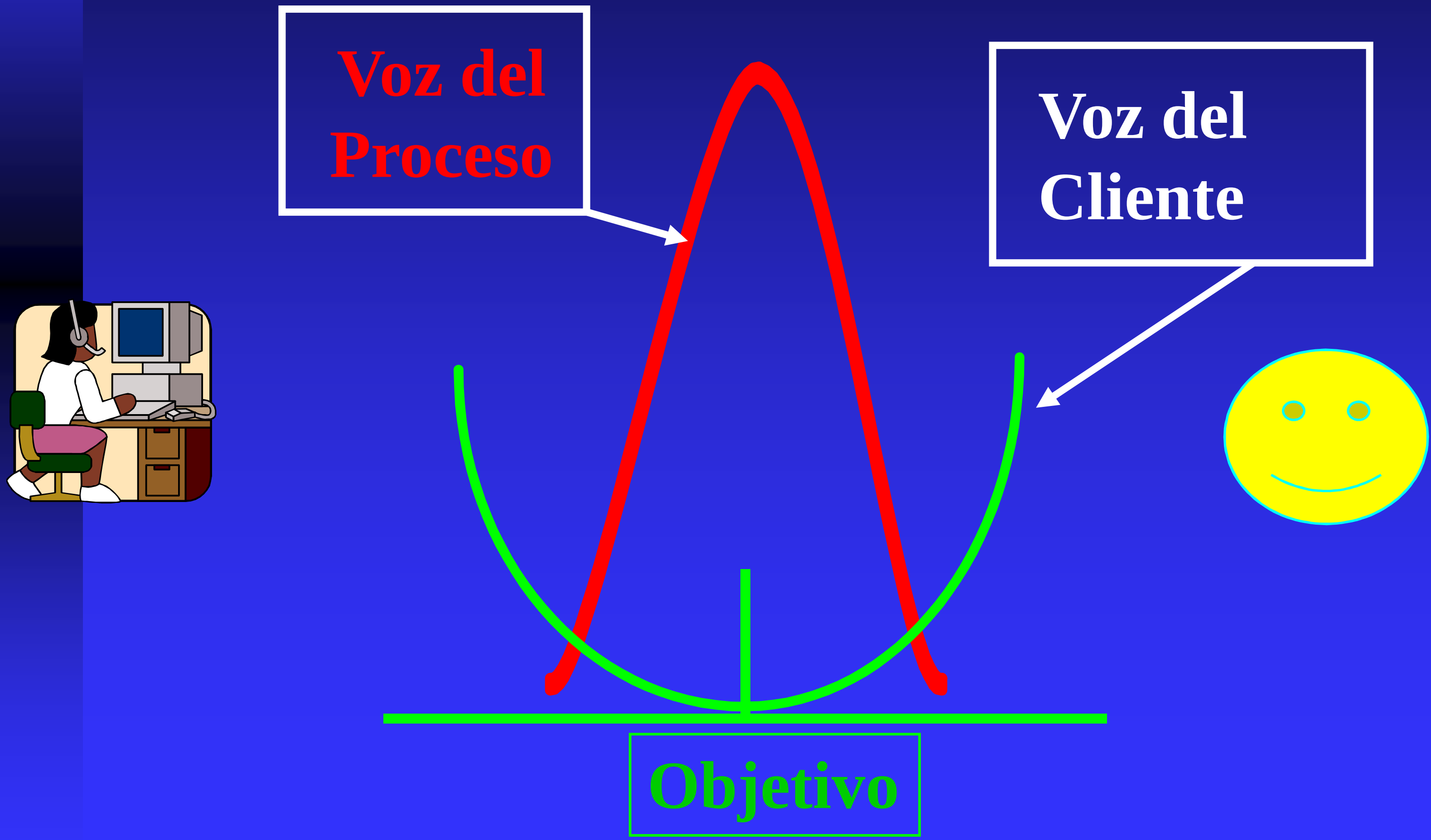
Sam Windsor

Change program manager

Filtronic Comtek

"Attempting to separate Lean and Sis Sigma into programs is really a mistake.This would be like saying a wrench and a ruler could not exist in the same toolbox… In Lean, we speak (for instance) of value stream mapping, and in Six Sigma we call it process mapping. Value stream mapping focusses on how the individual process steps conteribute to the overall process as it relates to optimization lead time and tack. Six Sigma process mapping loohs at process steps requiring certain critical inputs, then producing a desired outcome.   "

Reducida variabilidad alrededor de la media y proceso centrado en el objetivo (ASQ)



VALUE STREAM MAPPING: BEFORE

Product A,B, C

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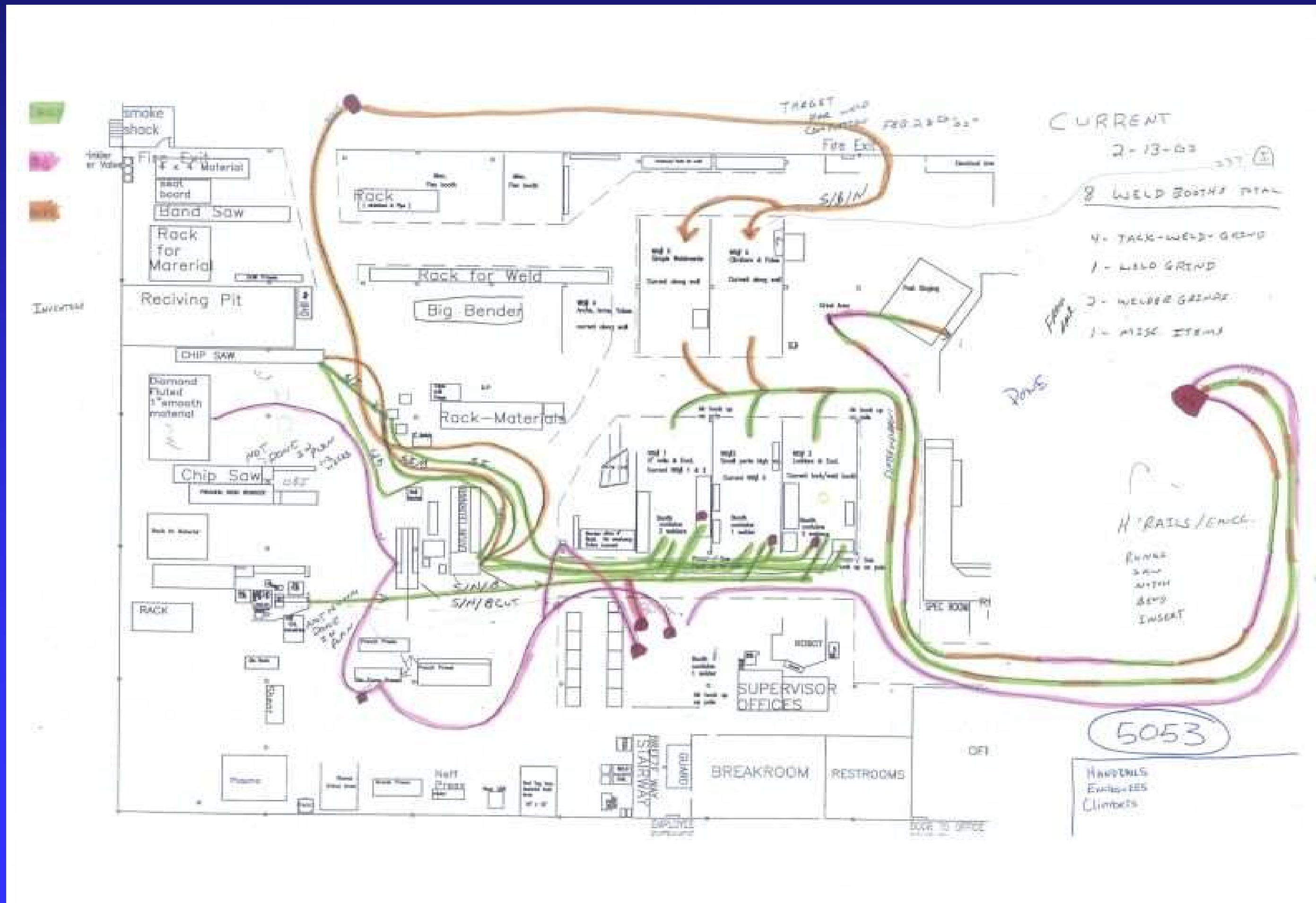

IMPROVEMENTS: SPEED & CAPACITY

Before: Total travel 6.2 Miles

After: Total travel 4.3 Miles

30 % Decrease

Before: Capacity. Operation A: 69/day

After: Capacity. Operation A: 115/day

71 % Decrease

Before: Capacity. Operation A: 69/day

After: Capacity. Operation A: 115/day

40 % Decrease

IMPROVEMENTS: SPEED & CAPACITY

Before: Capacity. Operation B: 27.6/day
After: Capacity. Operation B: 39.4/day

40 % Decrease

Before: Travel in cells Changed: 13,885 ft
After: Travel in cells Changed: 3,974 ft :

71 % Decrease

Before: Lead Times: 15 days 13 hrs
After: Lead Times: 4 days 12 hrs

71 % Decrease

IMPROVEMENTS: SPEED

Before: Cicle Times. Operation A: 91.4 Min.
After: Cicle Times. Operation A: 17.73 Min.

→ **17 % Decrease**

Before: Cicle Times. Operation B: 50.22 Min.
After: Cicle Times. Operation B: 40.33 Min.

→ **20 % Decrease**

Before: Cicle Times. Operation C: 57.47 Min.
After: Cicle Times. Operation C: 49.88 Min.

→ **13 % Decrease**

IMPROVEMENTS: COST

Before: Product A: 8 people x 3 = 24

After: Product A: 6 people x 3 = 18

25 % Decrease

Before: Product A: 8 people x 3 = 24

After: Product A: 6 people x 3 = 18

25 % Decrease

Before: Product A: 8 people x 3 = 24

After: Product A: 6 people x 3 = 21

13 % Decrease

VALUE STREAM MAPPING: AFTER

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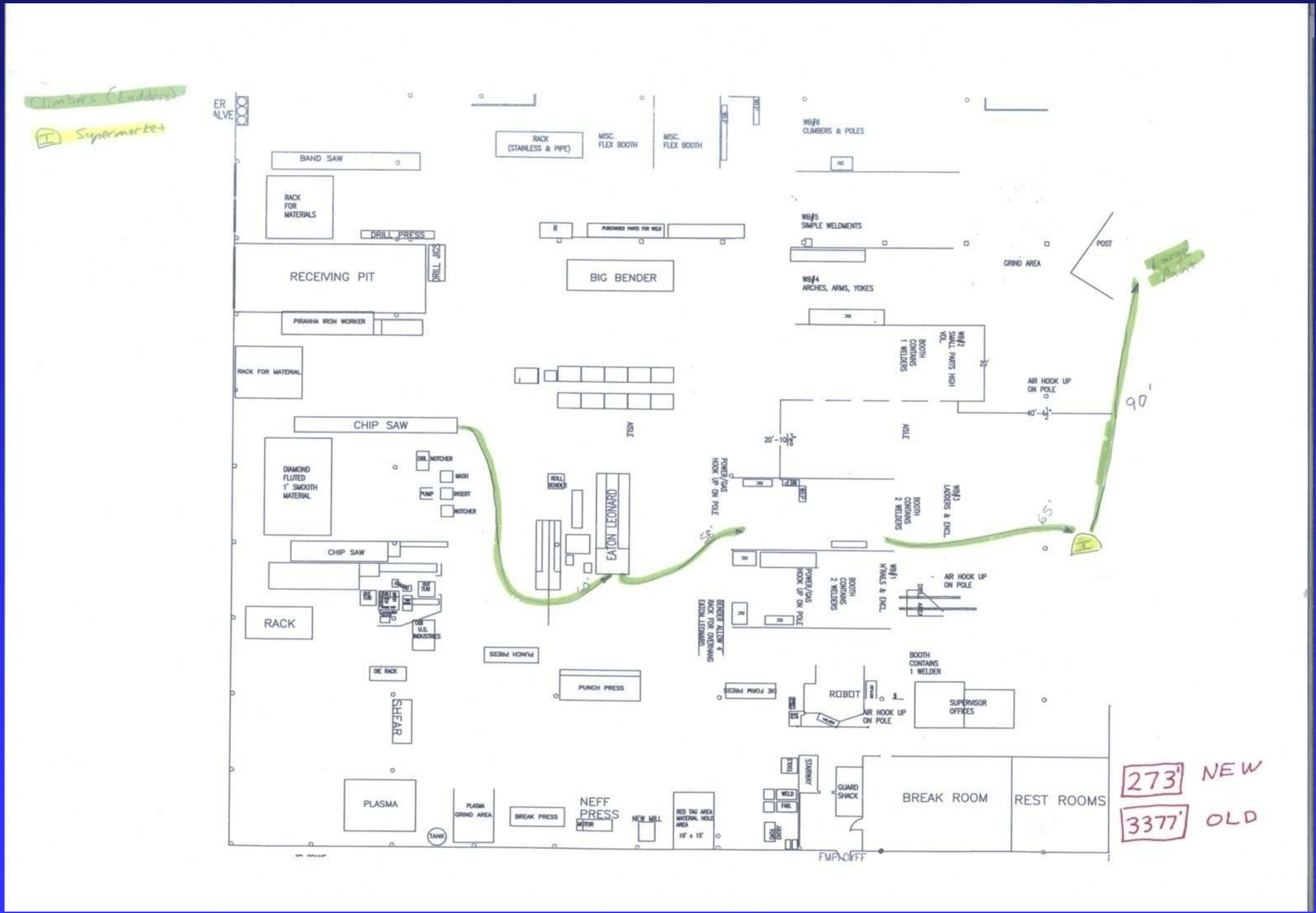
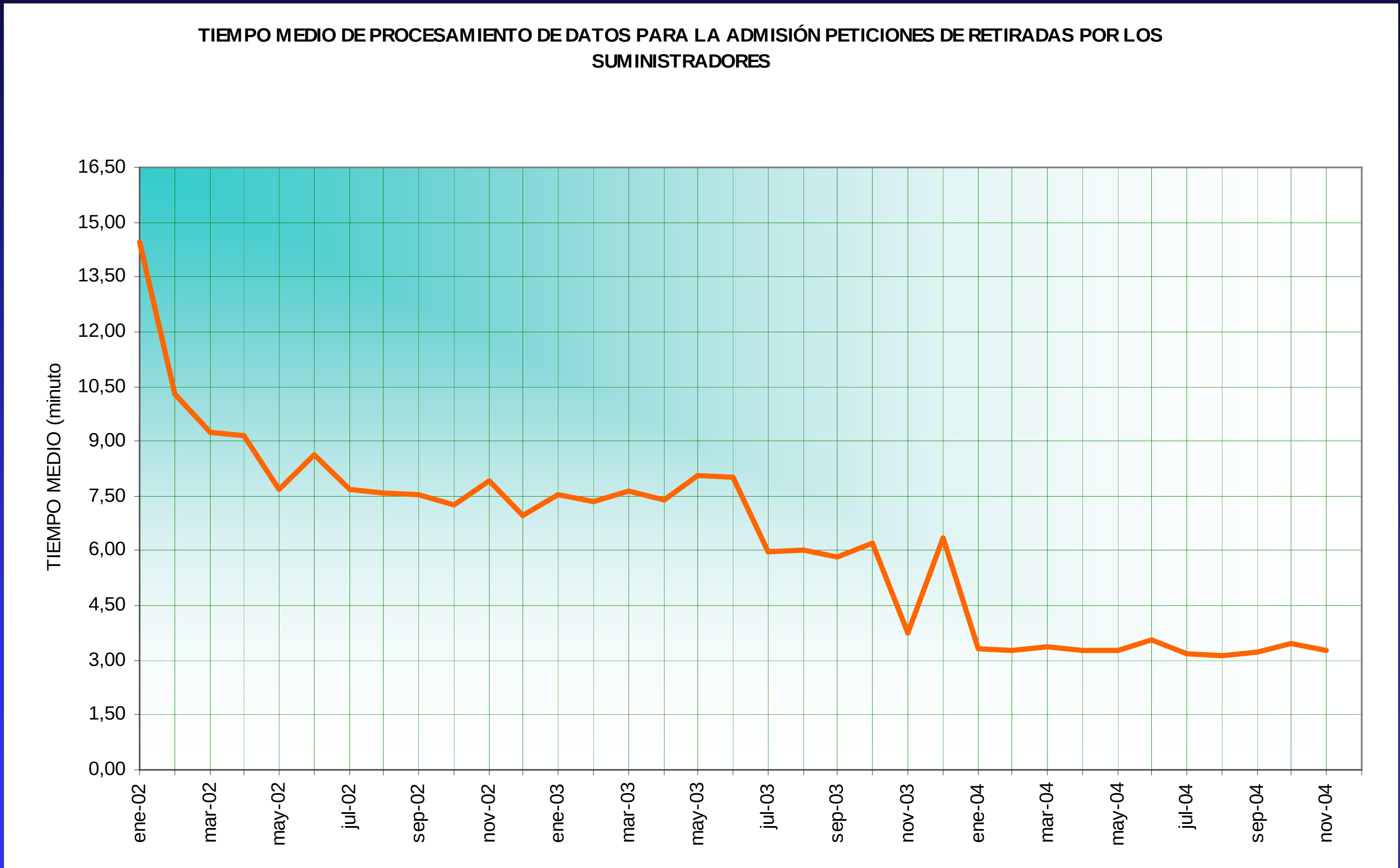


Average process time



¡¡That’all folks !!