Lecture #15

ERDM

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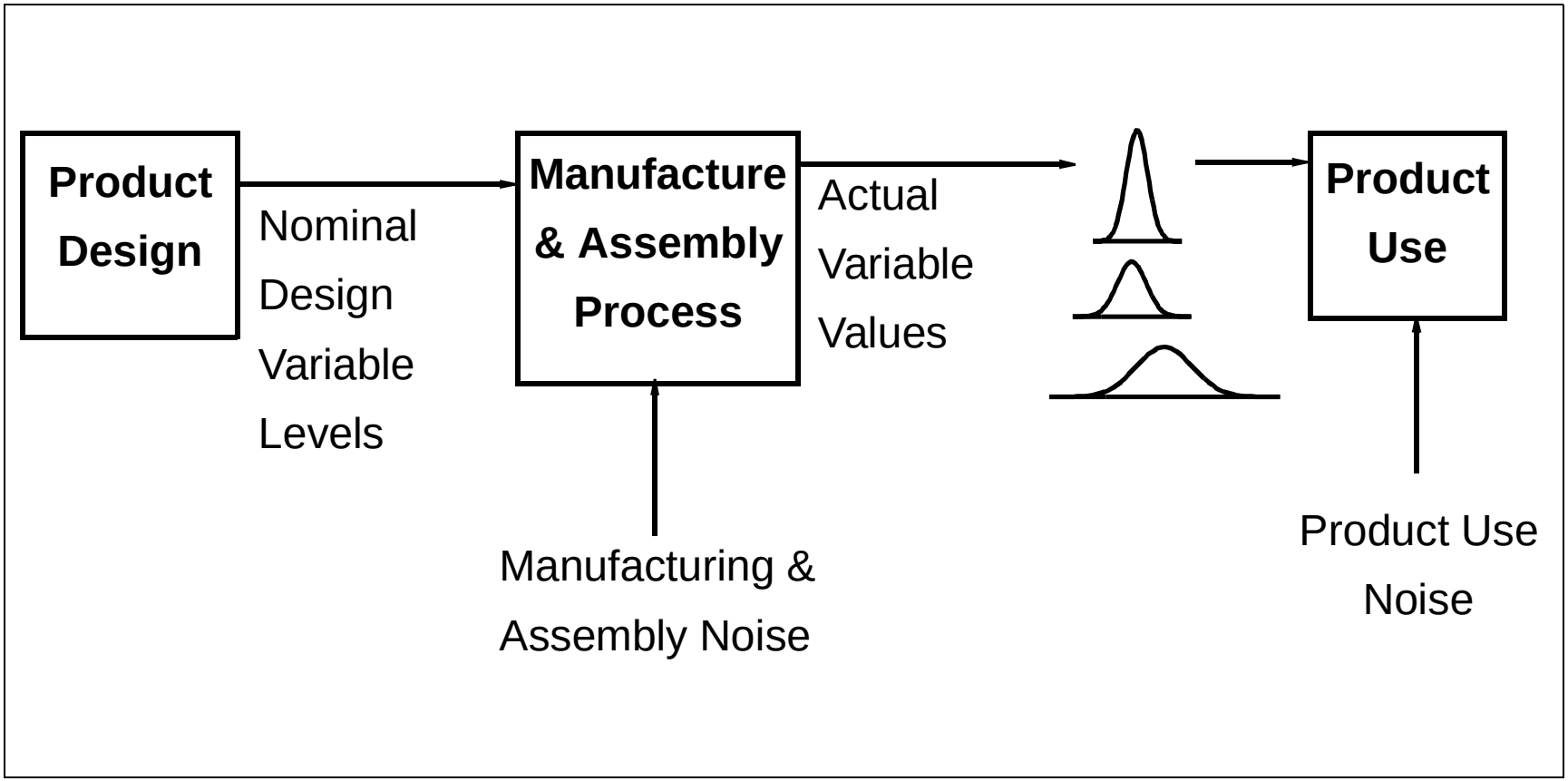
Introduction

Objective: Present recent work that links variation, quality, and post use options.

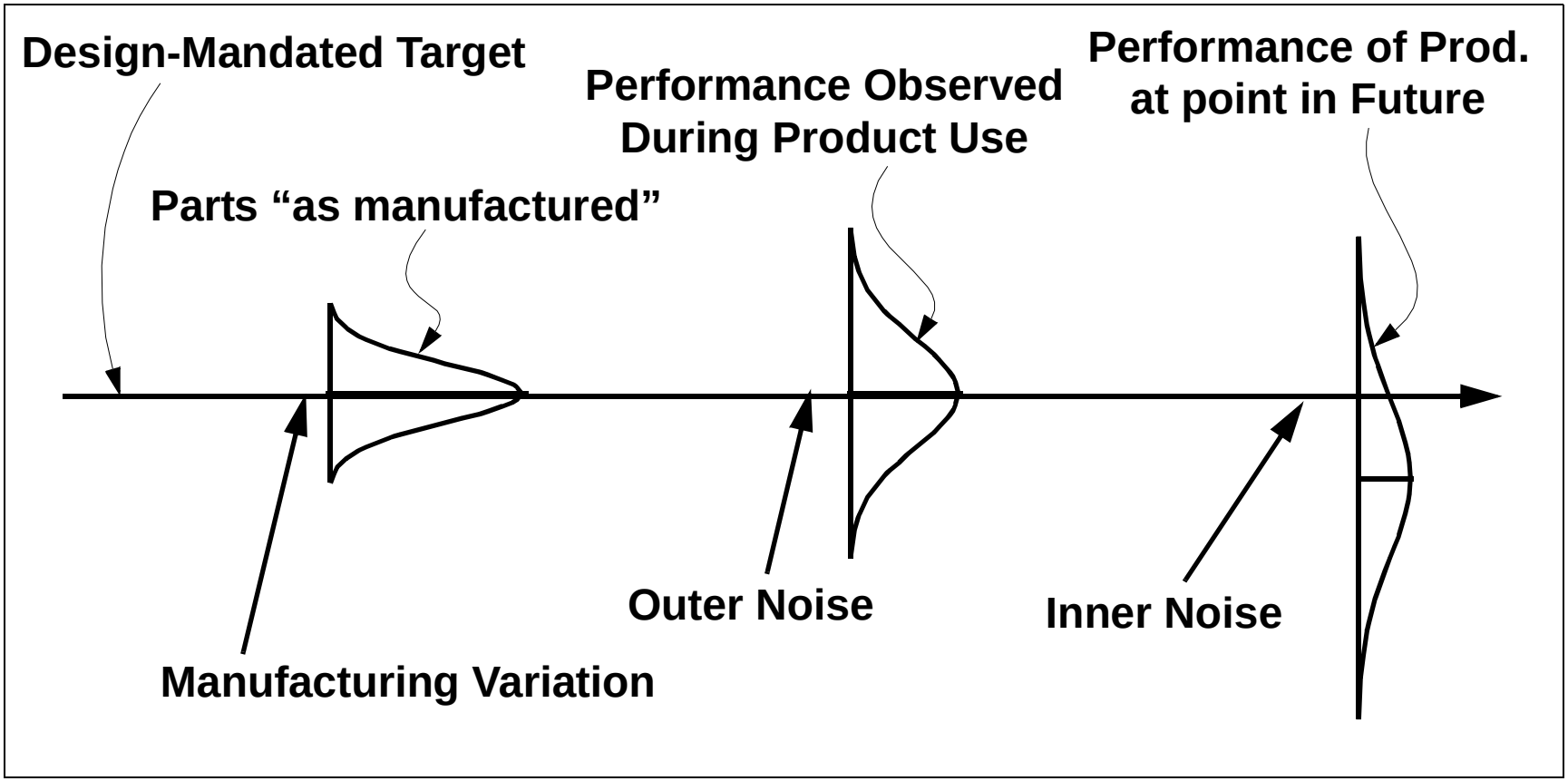
- **Product performance variation**
- **Effect of Wear & Aging**
- **Loss and Benefit Models**
- **Product Value**

Create economic model that supports the environment.

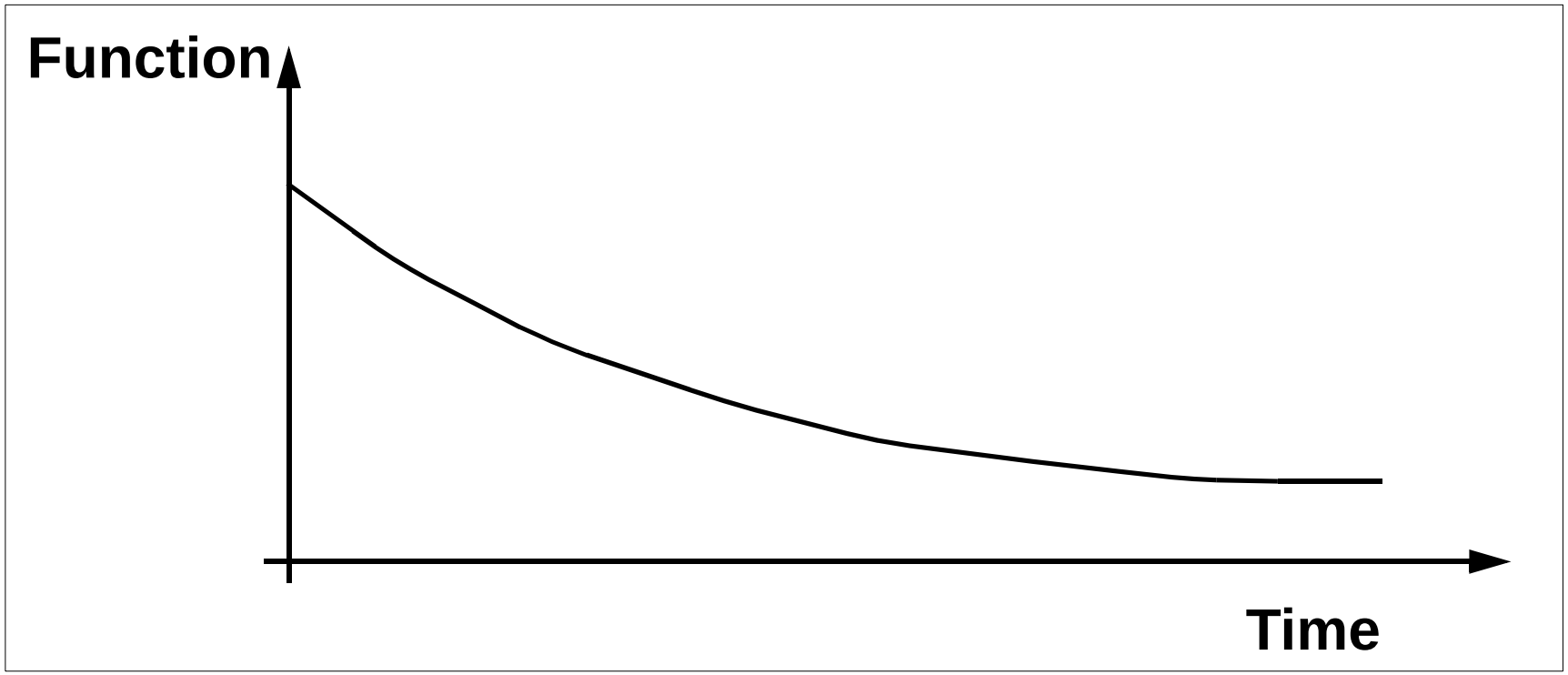
Product Performance Variation



Product Performance Variation (cont.)

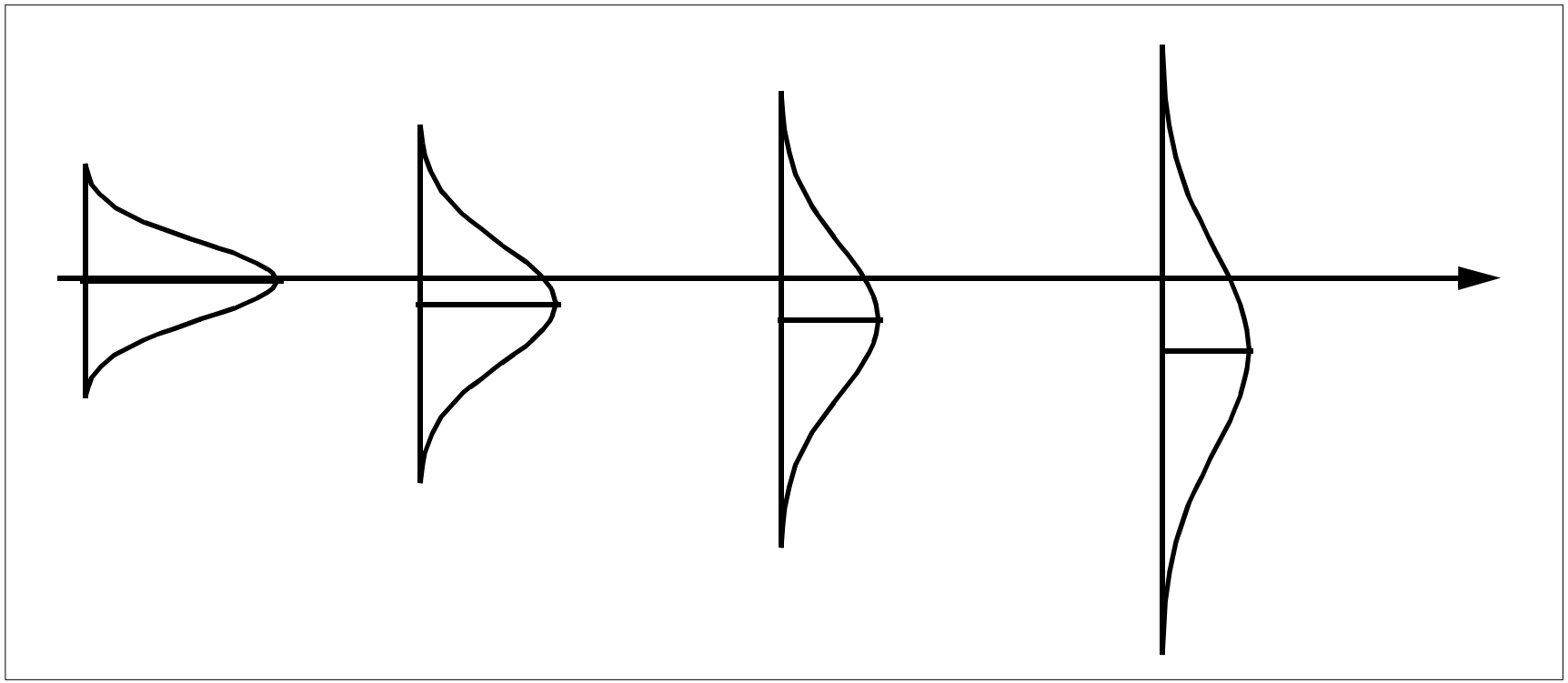


Product Function



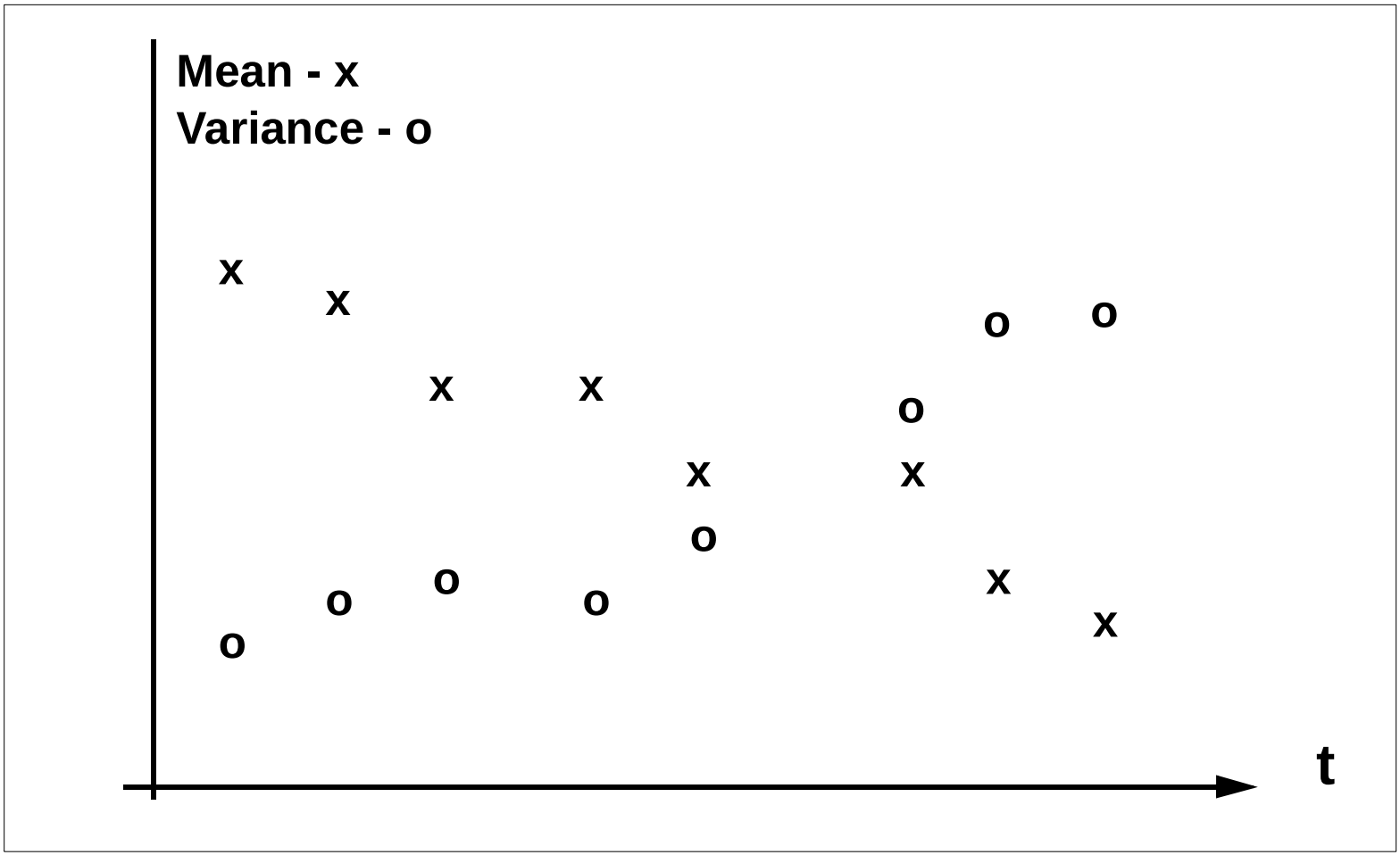
Function deteriorates because of wear and aging.

Function Behavior -- Distribution



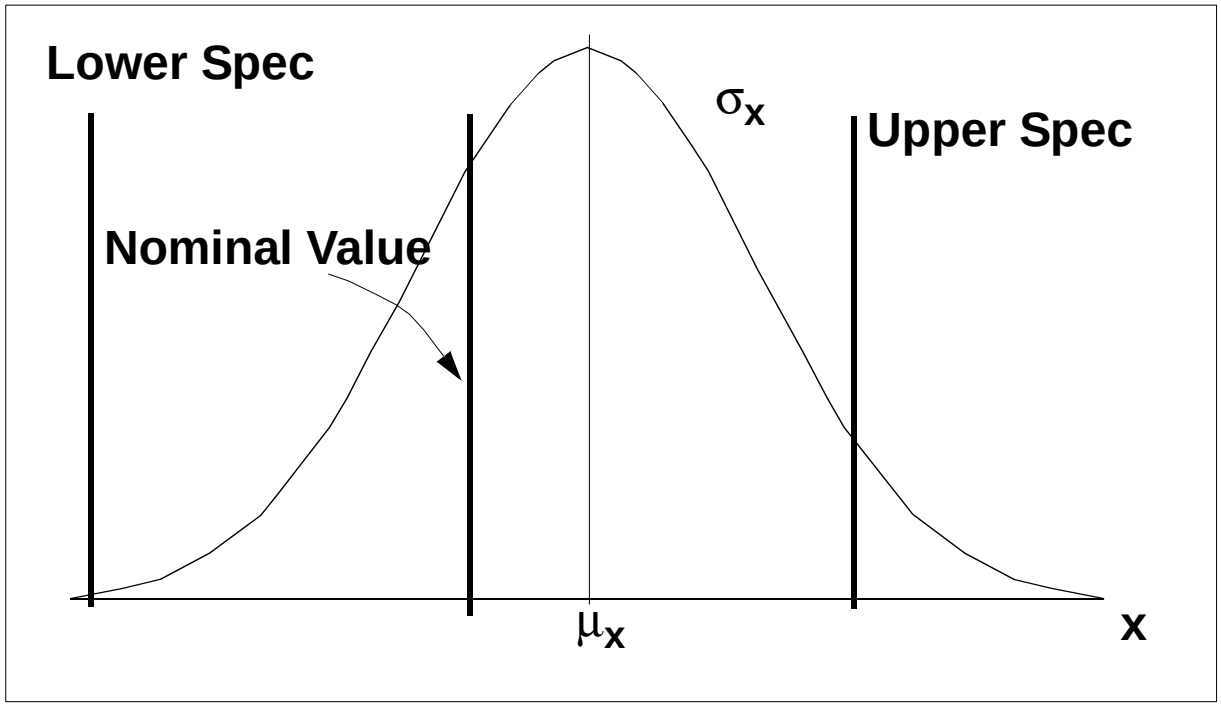
Process mean and variability change over time. True?

Toner Cartridge Data



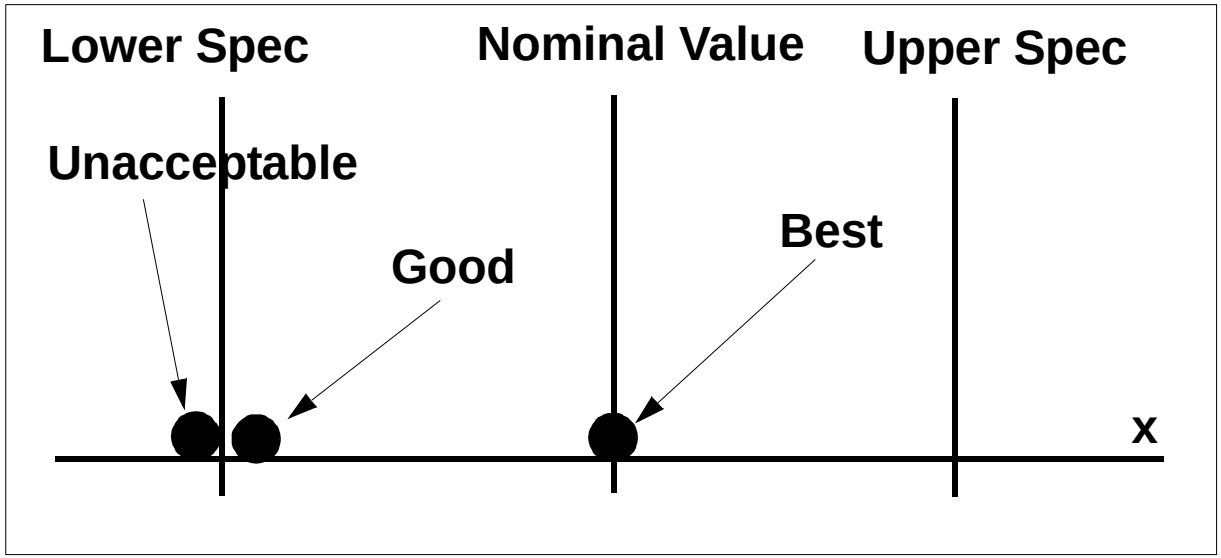
Quality

Traditionally defined as conformance to engineering specifications.



Quality (cont.)

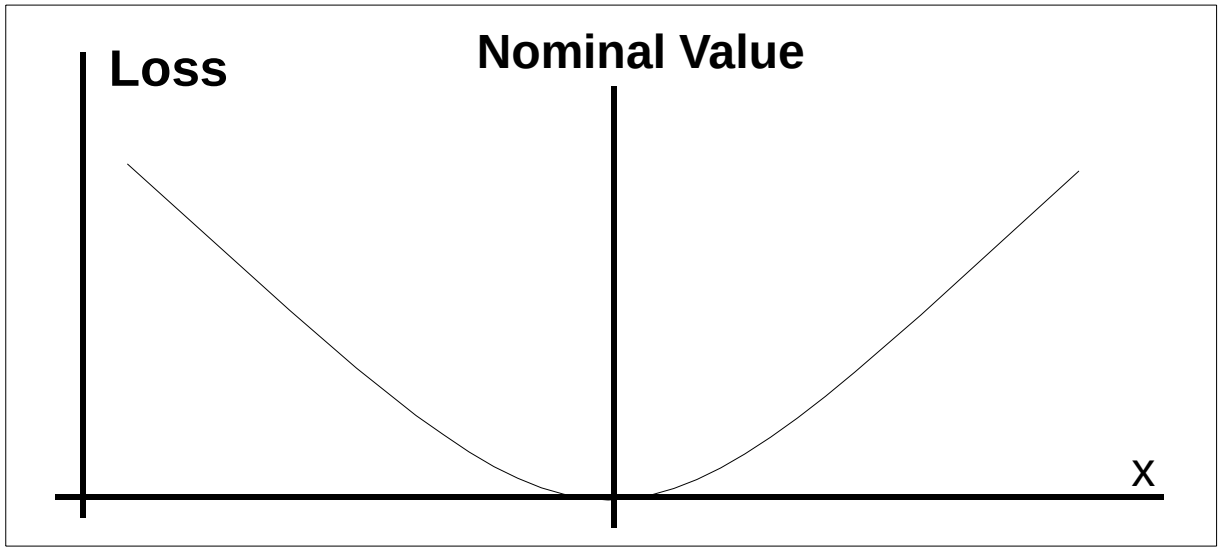
Traditional definition of quality does not promote notion of never-ending improvement.



We need some definition of quality that promotes being on target and penalizes variation.

Loss Function

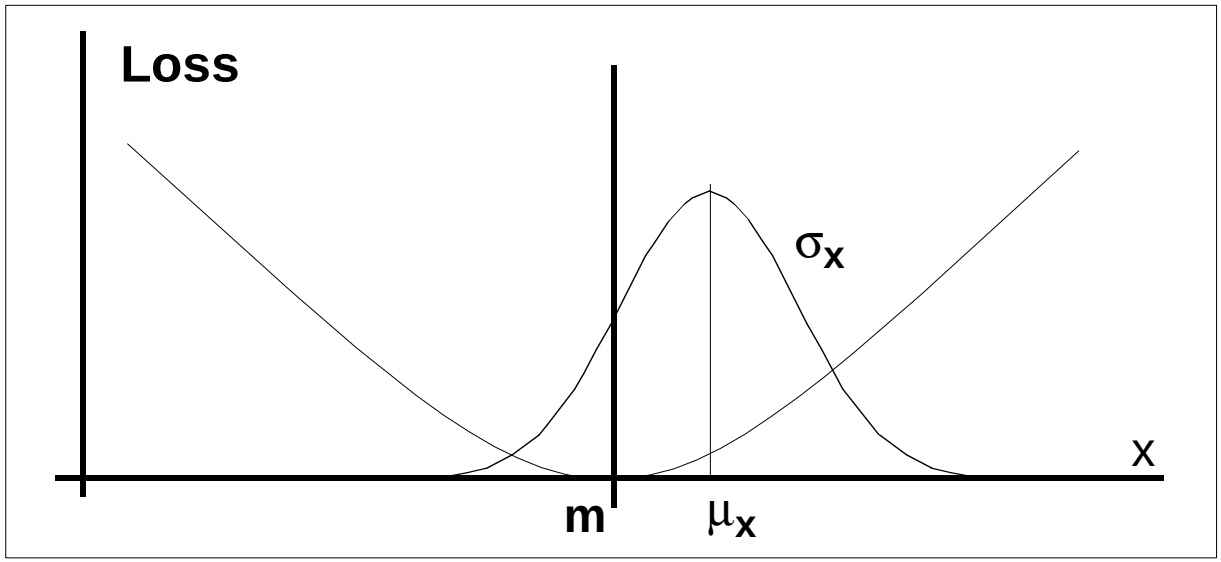
The loss function meets our need and we will use to characterize quality. Quadratic form:



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

Loss increases as we move away from the target

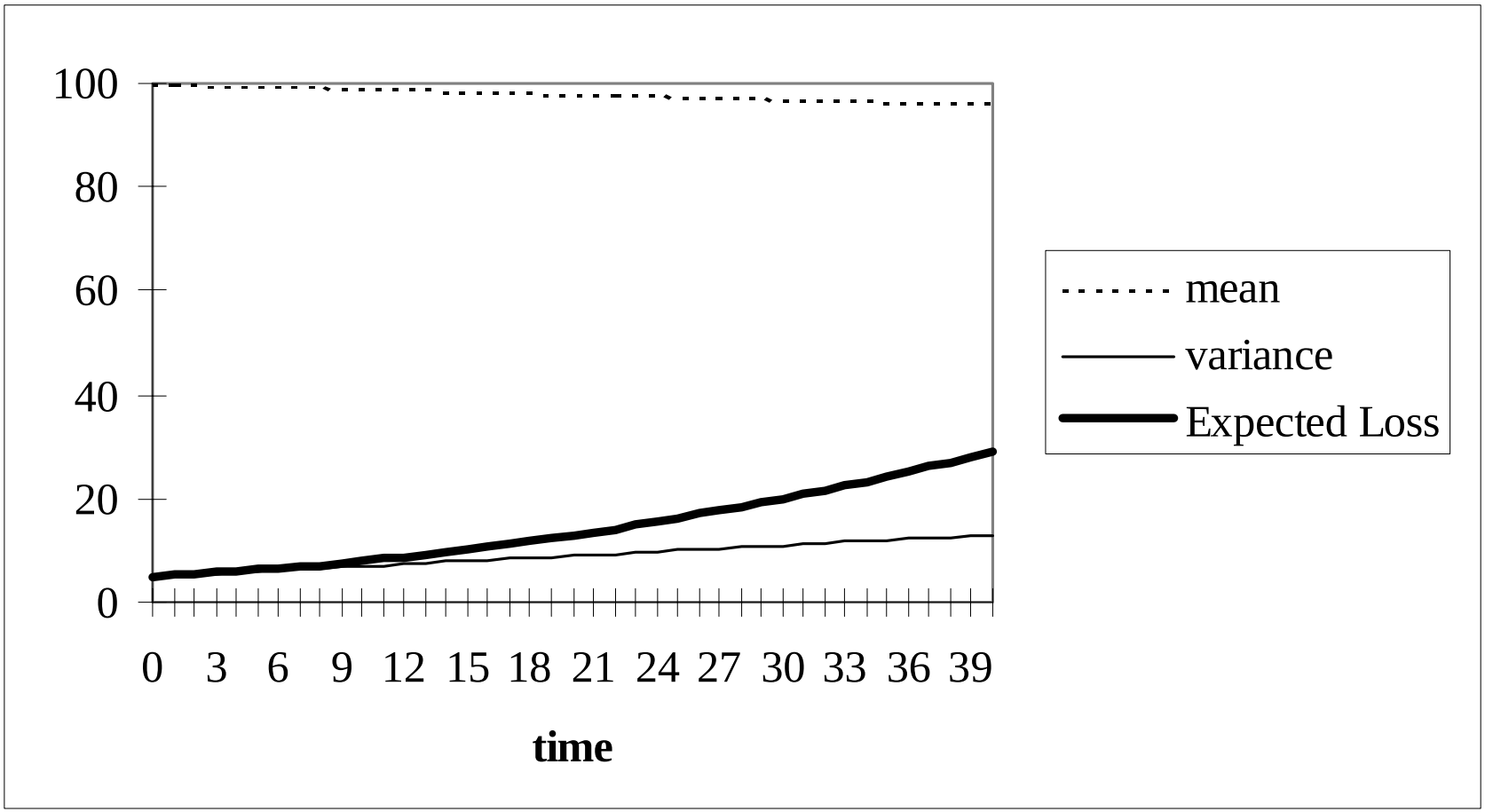
Expected Loss



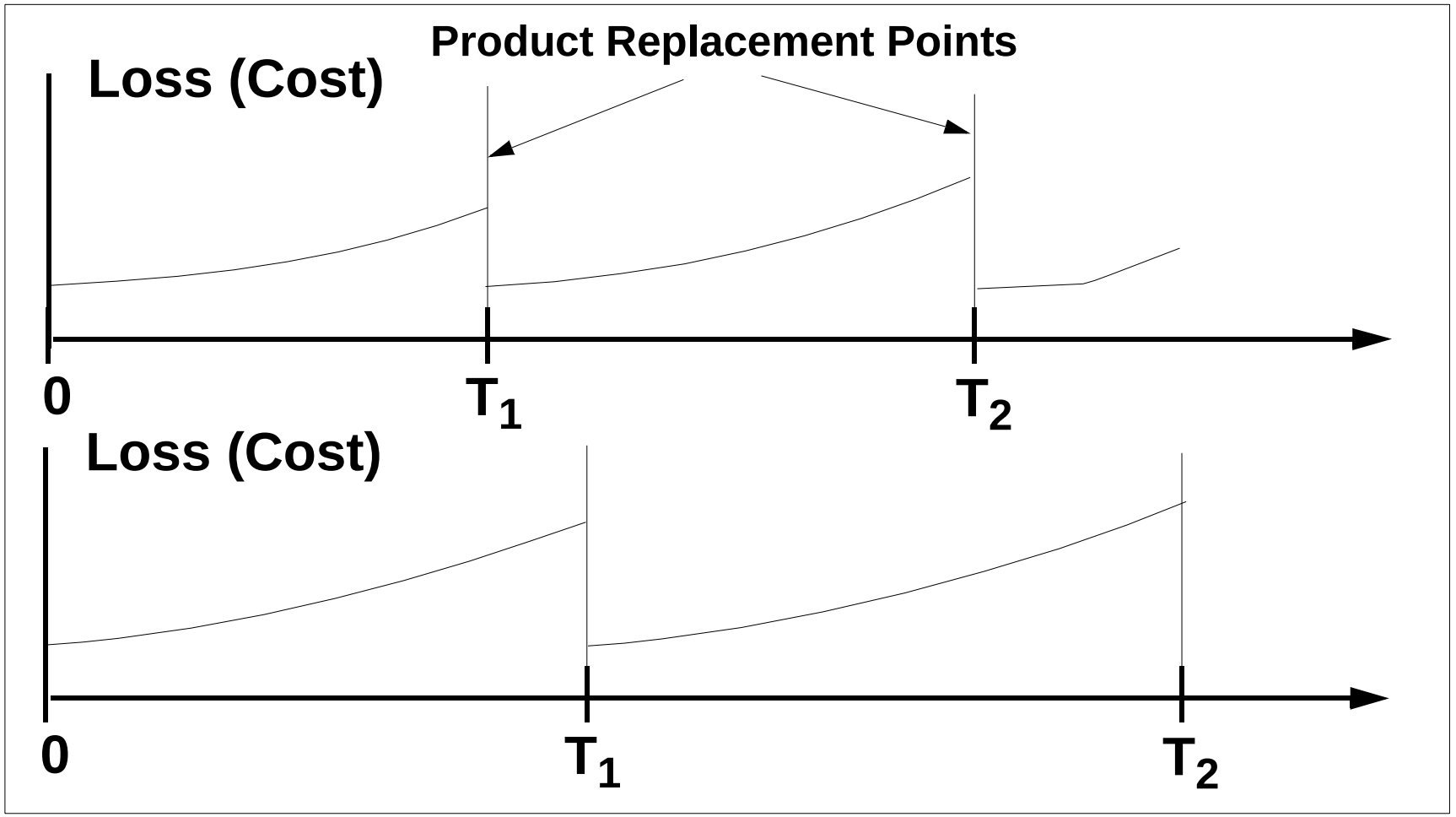
Since the characteristic X is a random varb., loss is also a random varb. - chararacterizes "average" loss

$$E[L(X)] = k\left[(\mu_x - m)^2 + \sigma_x^2\right]$$

Loss Behavior - Deteriorating Product



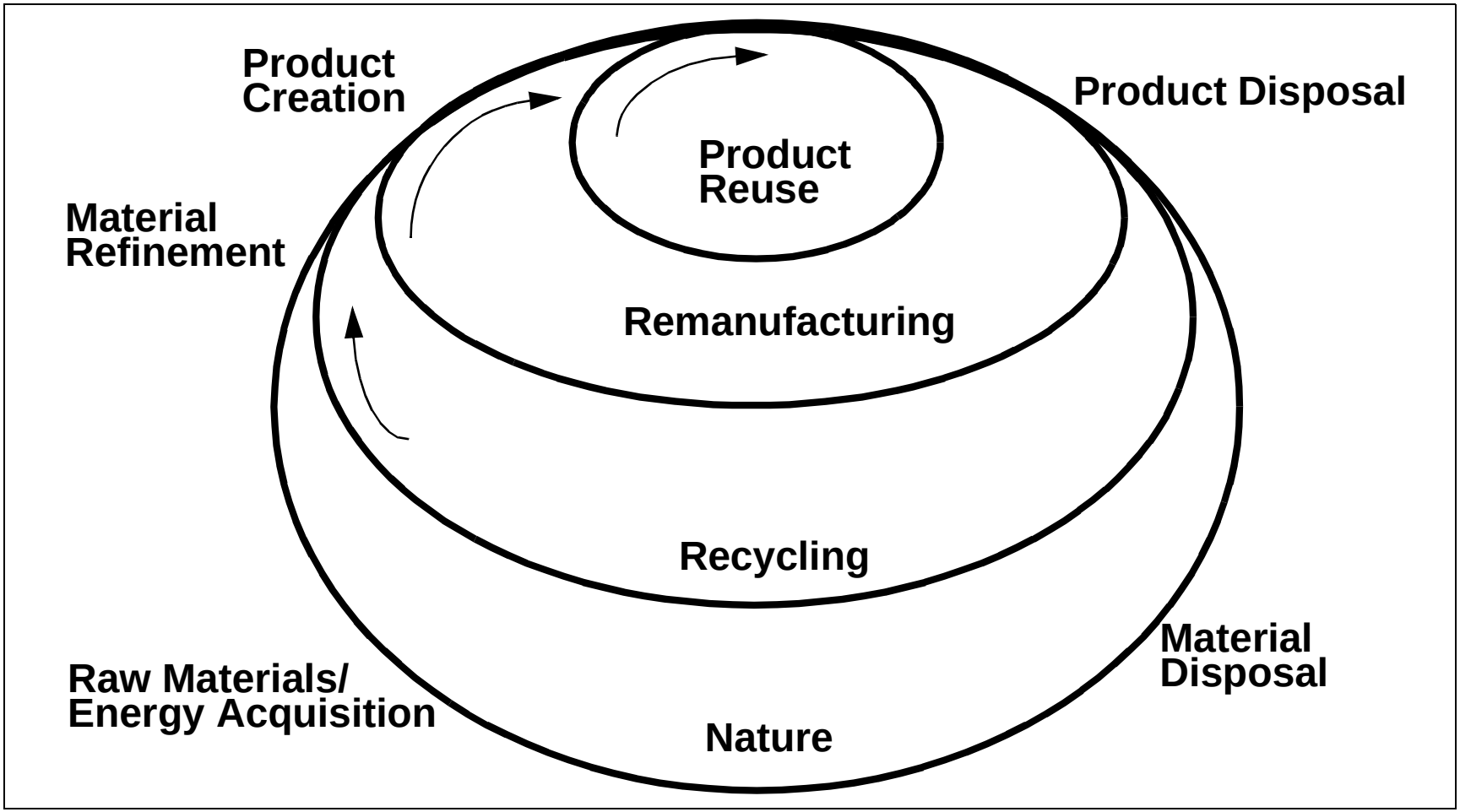
Consider Use & Throw-away Strategy



A Problem with the Loss Function

- **Lengthening the time between product replacements does not seem to produce a societal benefit.**
- **Problem is that the loss function only considers the negative aspects of using a product. We must consider benefits as well.**
- **Previous graph suggests that we consider the cumulative effect of loss (same would apply to benefits).**

Post-Use Product Disposition



Post-use Options

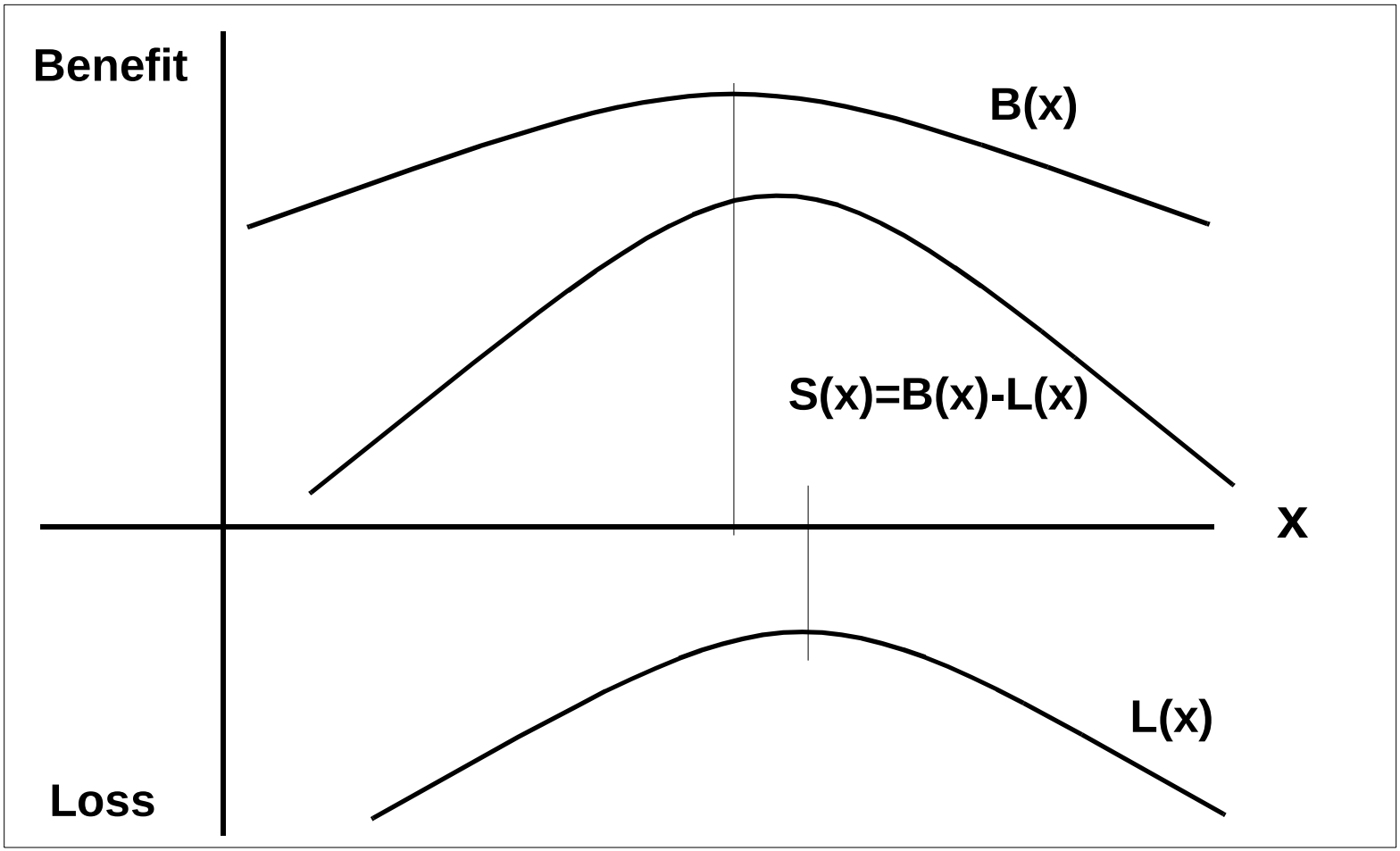
We need a metric that is consistent with our desire to be more environmentally responsible, i.e., that encourages longer use cycles.

Also, if we are seriously looking at “take-back”, we need to know the value of the used products coming back.

High value used products -- refurbishment / reuse
Lower value used products -- recycling

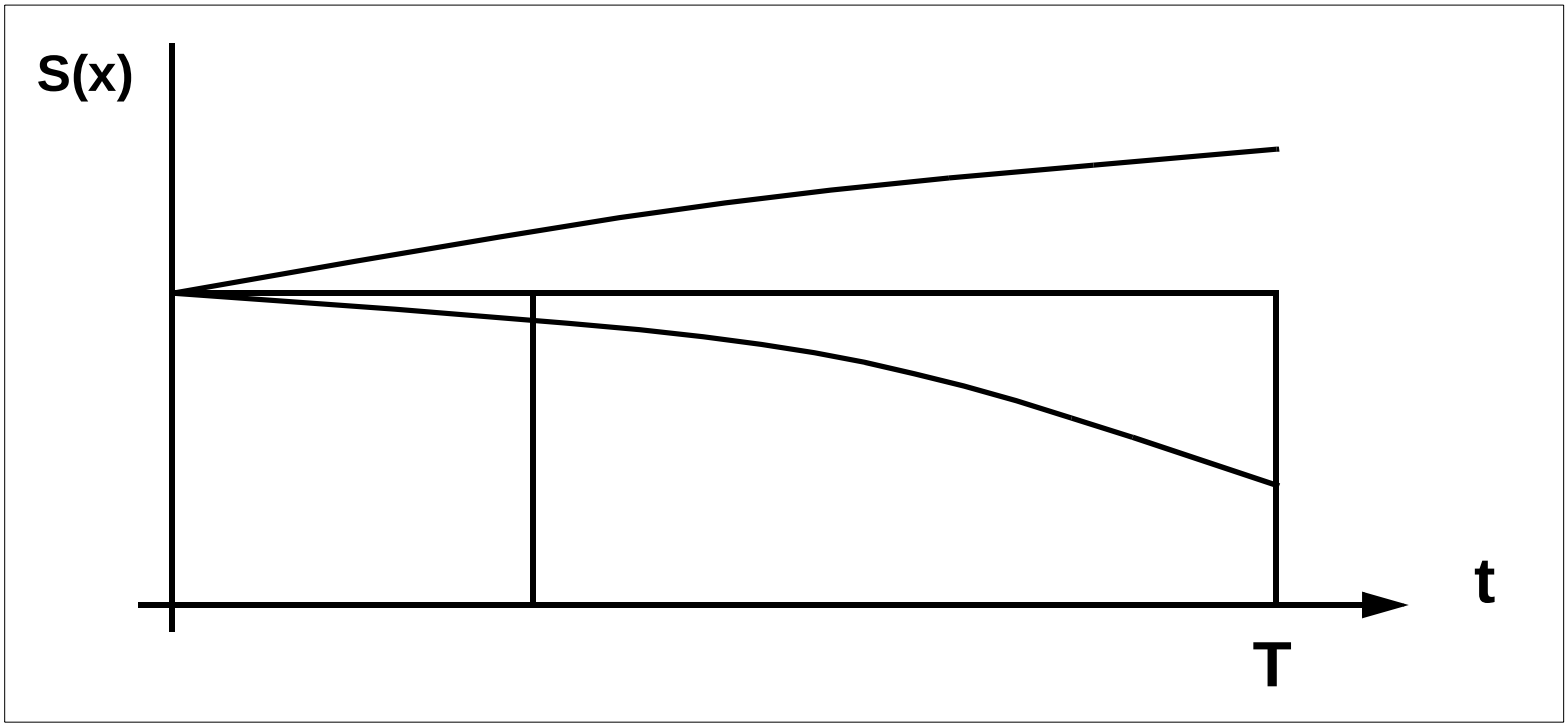
The action to be taken depends on the product value.

A New Metric: Satisfaction



Value

Value Definition: The cumulative satisfaction remaining in a product.



Expected Value

From our previous work, we know that S(x) is

$$S(x) = S_0 + K(x - m)^2$$

The expected satisfaction for a set of products is

$$E[S(X)] = S_0 + K\left[(\mu_x - m)^2 + \sigma_x^2\right]$$

The mean and variance are linear functions of time,

$$\mu_x = \mu_0 + k_0 t$$

$$\sigma_x^2 = \sigma_0^2 + k_1 t$$

Expected Value (cont.)

The value of a product at time, t, is the cumulative satisfaction still left in the product at time t

$$V(t) = \int_{t}^{T} S(t)\,dt$$

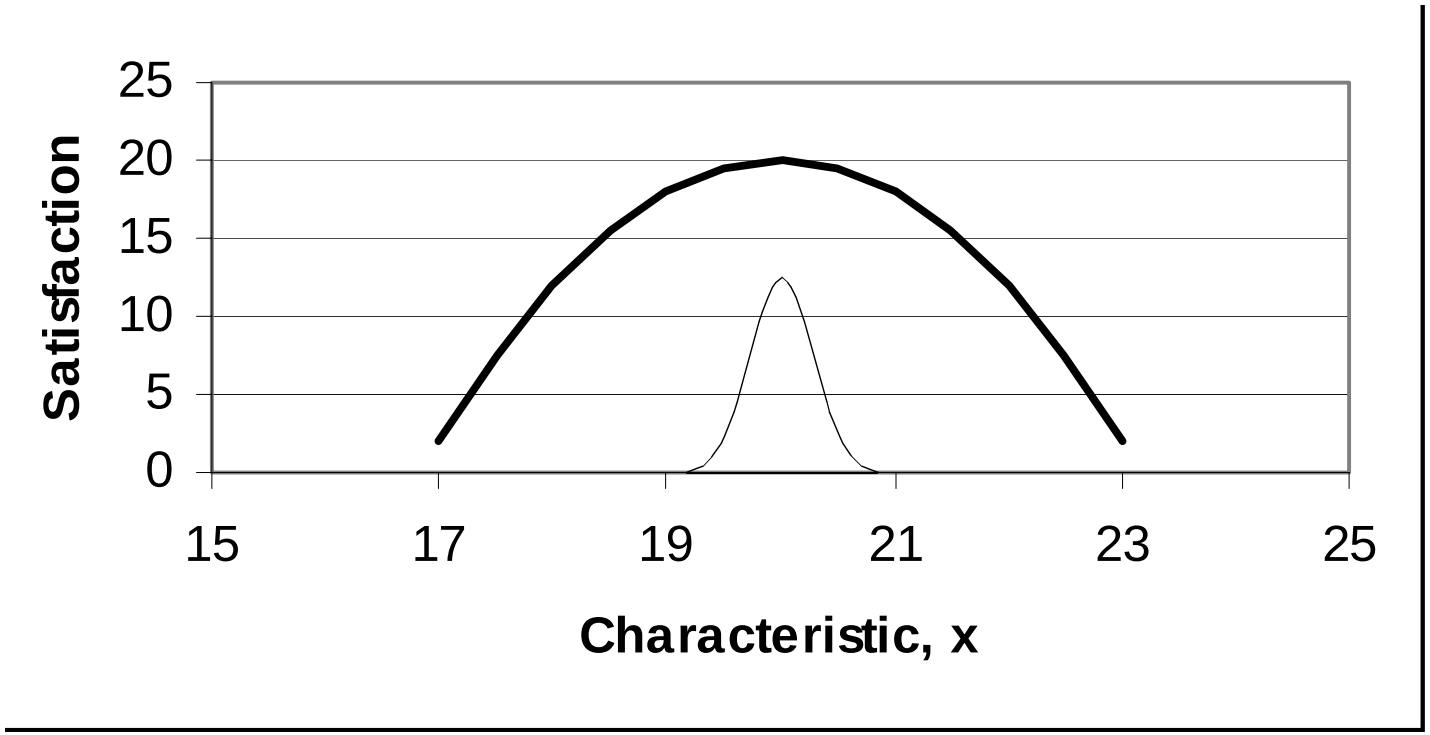
V(0) = the value of a new product

V(T) = the value of a product when it reaches the end of its life -- useful from environment standpoint

CV(t) = V(0) - V(t) = Value consumed up to time t

An Example

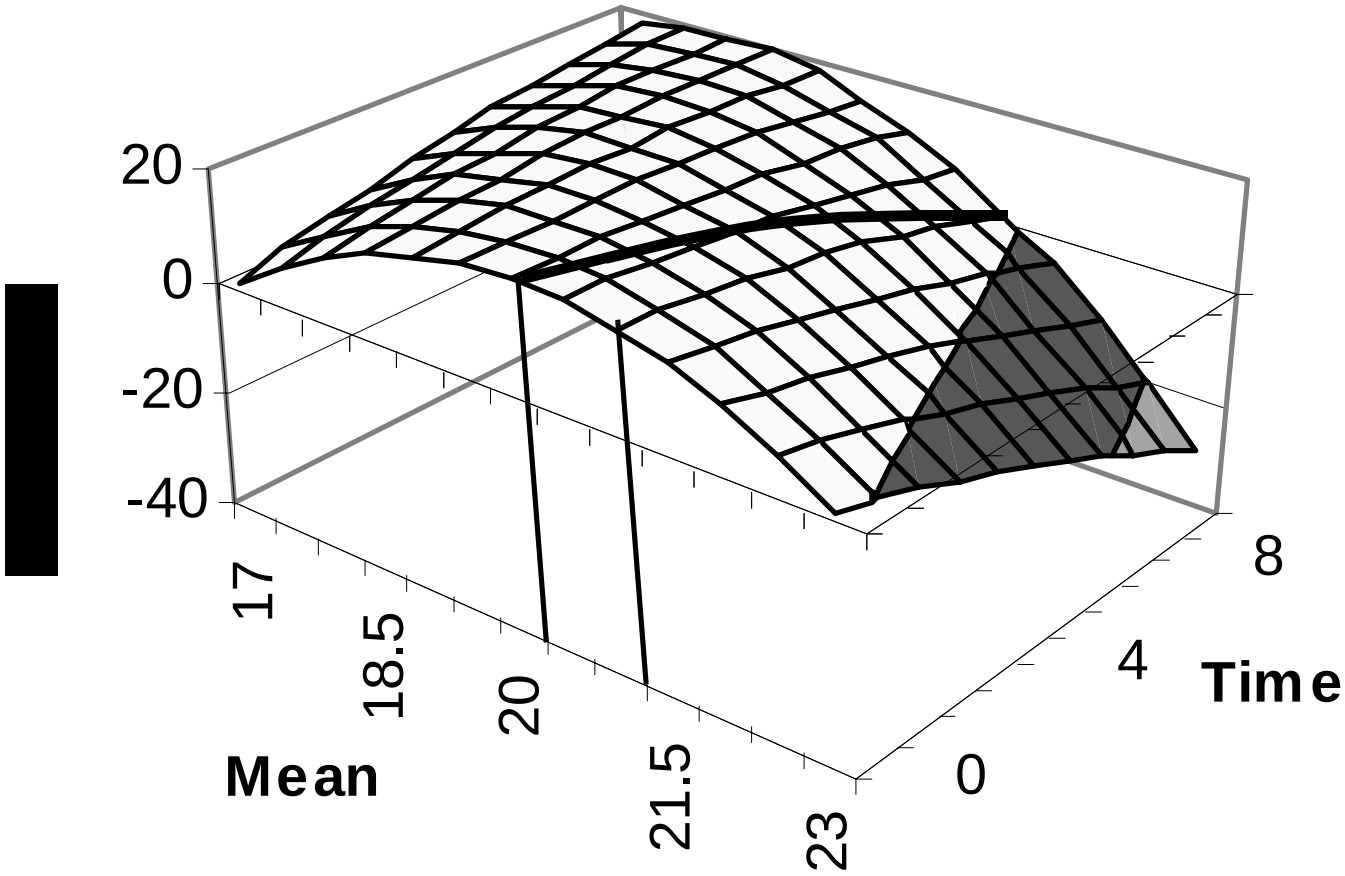
Nominal = 20, k=2



So, want to center manufacturing process at μ = 20.

Satisfaction -- Over Time

(need to consider value function for process centering)

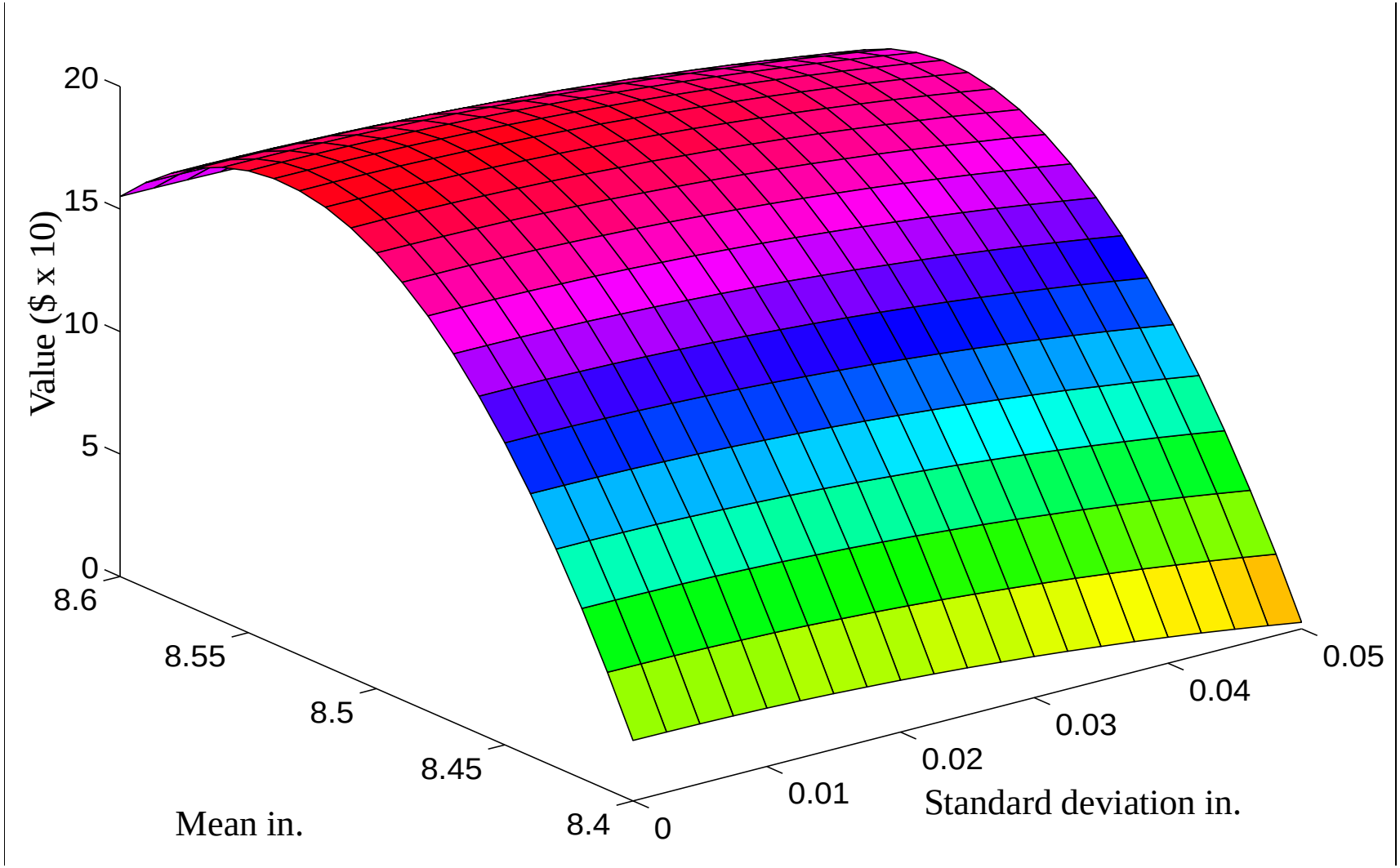


If we center the process at 20, we slowly get worse due to wear & aging.

Maybe we should start with a smaller mean.

Then, on the average we would be closer to the target of 20.

Value Function -- Another Example



Summary

- **What we pay for a product is assumed to be equal to the value remaining in a product.**
- **Product deterioration over time -- product value changes over time.**
- **Satisfaction metric includes both positive and negative aspects of product usage.**
- **Value is the cumulative satisfaction remaining in a product.**
- **Select initial process centering to control value at end of use cycle**