

Universal Design

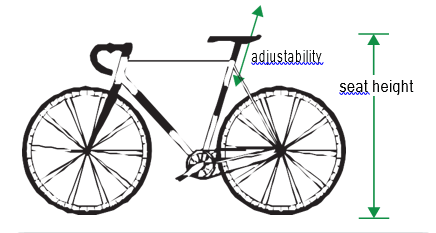
## Designing for Body Size and Shape

## Accommodation

Users that are able to interact with a design in the intended manner are said to be accommodated. Those for whom the design is uncomfortable, unsafe, or are otherwise unable to achieve the desired performance are said to be disaccommodated. One goal of Universal Design is to accommodate users regardless of body size and shape.

## Adjustability

Incorporating adjustability into a design is one method of accounting for body size and shape. For example, a bicycle might have an adjustable seat to ensure a certain level of performance regardless of user leg length. The amount of adjustability is usually determined by identifying the relevant anthropometric measure and quantifying the range in that measure exhibited by the target user population. Reviewing best practices (for example, talking to professionals in a bicycle shop) or conducting a user study can provide insight into how to interpret the data for design.



**Adjustability Example (min and max)**

One rule-of-thumb for bicycles is that seat height should be1.05\*leg length.

Population leg lengthmin = 780mm

Population leg lengthmax= 1036mm

Minimum seat height = 780\*1.05 = 819mm

Maximum seat height = 1036\*1.05 = 1088mm

Required adjustability = 1088-819 = 269mm

**Adjustability Example (1st and 99th percentiles)**

One rule-of-thumb for bicycles is that seat height should be 1.05\*leg length.

Population leg length1st = 805mm

Population leg length99th = 975mm

Minimum seat height = 805\*1.05 = 845mm

Maximum seat height = 975\*1.05 = 1024mm

Required adjustability = 1024-845 = 179mm

## High levels of accommodation can be difficult to achieve with adjustability

A small amount of adjustability can markedly improve accommodation. But higher levels of accommodation, including universal design, can require more adjustability. For measures that are approximately normally distributed (such as leg length), there are fewer individuals in the tails of the distribution. Consequently, accounting for 52mm of variability would accommodate the central 50% of leg lengths in a sample population, but an additional 69mm of variability accounts for the next 40% (90% total). The examples here use the min and max values, but given the long tails in most distributions it can be more practical to use 1st and 99th percentiles.

Graph depicting how small adjustments can achieve improved accomodation.  X-axis depicts frequency of incidence in a population, Y-axis depicts the range of leg length in the population


## Sizing

An alternative to adjustability is sizing. Shoes, for example, are not adjustable. Instead they come in a number of sizes at fixed intervals. The user selects the size that provides the best functionality (for example, fit, comfort, performance, safety). With only a few sizes, users between sizes might not be well accommodated. Increasing the number of sizes can improve accommodation for the entire population, but generally increases cost. As a result, designers must find the relationship between cost and accommodation. Since measures are not uniformly distributed, user demand for sizes near the middle will be greater than demand in the distribution extremes.

Three bikes of different sizes

**Sizing Example**

For some number of sizes (n), where i = size (from 1..n) and x = design parameter of interest, the estimated values for each size are determined by:

target = x (1) + (x (99) – x (1))(2i - 1)/2n

For n=3 sizes, using data from Adjustability example:

Size 1: target (1) = 805 + (975 - 805)(2\*1 - 1)/(2\*3) = 833mm

Size 2: target (2) = 805 + (975 - 805)(2\*2 - 1) / (2\*3) = 890mm

Size 3: target (3) = 805 + (975 - 805)(2\*3 - 1) / (2\*3) = 947mm

## Sizing and Adjustability

Sizing can be augmented through the use of adjustability. Adjustability can improve the ability of a size to meet the needs of its intended users. It can also broaden the range of users that the size accommodates. Similarly, adjustability can be improved through sizing. A single size with a large amount of adjustability might be able to accommodate the needs of a target user group, but may be impractical to create due to physical limitations or cost. Using multiple sizes with smaller amounts of adjustability can mitigate these issues while improving important characteristics like fit, performance, and safety.

Three bikes of different sizes

## Sizing and Adjustability Example

The total required adjustability (∆x) is the same as in the adjustability-only example: ∆x = xupper – xlower

The adjustability per size (∆xi), centred at each size target is: ∆xi = ∆x/n

For some number of sizes (n), where i = size (from 1..n) the design targets are: targeti = xlower + (2i - 1)∆x/2n

For n=3 sizes,

∆x = 975 - 805 = 170mm

Adjustability, ∆xi = 170/3 = 57mm

Size 1: target1 = 805 + (1)(170) / (2\*3) = 833mm

Size 2: target2 = 805 + (3)(170) / (2\*3) = 890mm

Size 3: target3 = 805 + (5)(170) / (2\*3) = 947mm