Changes in Rider Anthropometrics & The Effects on Rail Car Design

APTA Rail Conference
Philadelphia, PA
June 4, 2013

Agenda

- Problem Statement
- Background Knowledge
- Research Approach
- Preliminary Findings
- Conclusions
- Future Recommendations

Problem Statement

- The rail industry currently uses the AW0-4 rating scale to design cars that withstand passenger loading.
  - AW0: total car weight with no passengers in a revenue service ready condition
  - AW1: AW0 + full seated passenger load
  - AW2: AW1 + Standing passenger load of 4 people per m^2
  - AW3: AW1 + Standing passenger load of 6 people per m^2
  - AW4: AW1 + Standing passenger load of 8 people per m^2

Problem Statement

- AW ratings dictate an assumed passenger weight of 155 lbs. per person.
- The average American population weight is now closer to 182 lbs. Should this be the new standard weight?
- Should we continue to design with this type of assumption? Or change the approach?

Background

CDC Survey

US Department of Health and Human Services collects, analyzes and reports statistics about population measurement data.

Continuous collection of surveys, reports published every 4 years.

Anthropometry

The science that defines physical measures of a person's size, form, and functional capacities.

This is used in various fields that require a human element to be considered when designing the given system.

Approach

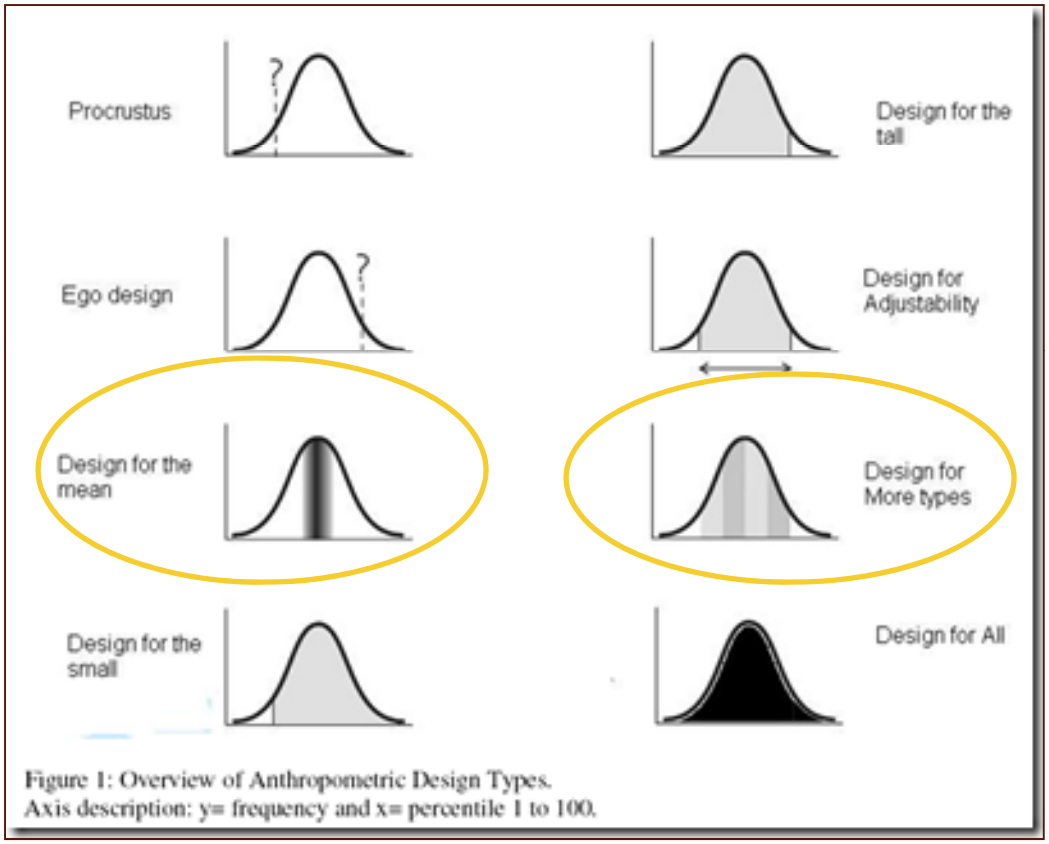


Figure 1: Overview of Anthropometric Design Types.
Axis description: y= frequency and x= percentile 1 to 100.

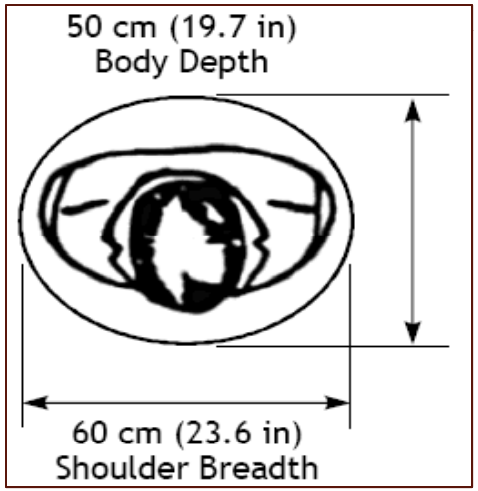
Approach

- Using CDC data and a statistical analysis we can see the effect of this rising population weight.
- Compare the total car weight found using an assumed average passenger weight with a random selection weight.
- Is there a significant difference between an assumed 182 lbs. per person and a scenario with randomly generated weights?

Assumptions

2007-2010 Weight	
Mean	182.8666667
Standard Error	16.94639014
Median	173.5
Mode	#N/A
Standard Deviation	50.83917043
Sample Variance	2584.62125
Kurtosis	-1.508880636
Skewness	***0.3522526***
Range	139.15
Minimum	123.1
Maximum	262.25
Sum	1645.8
Count	9

There is a constant ratio between a person's depth and breadth that can be correlated to the increase or decrease in weight.



The CDC data follows a normal distribution.

Preliminary Findings

										1st Person	2nd	3rd	4th	5th	6th		Total People
1	273.4417	298.3	329.7	211.2958	376.1458	376.1458	278.0208	310.7292		273.4416667	571.7416667	901.4416667	1112.7375	1488.883	Max Met		5
2	315.9625	288.4875	343.4375	233.5375	298.3	294.375	376.8	287.8333		315.9625	604.45	947.8875	1181.425	1479.725	Max Met		5
3	278.0208	233.5375	329.7	345.4	235.5	361.1	392.5	331.0083		278.0208333	511.5583333	841.2583333	1186.658333	1422.158	Max Met		5
4	259.05	345.4	346.0542	345.4	392.5	345.4	376.1458	302.225		259.05	604.45	950.5041667	1295.904167	Max Met			4
5	270.825	300.9167	200.175	392.5	248.5833	327.0833	302.225	235.5		270.825	571.7416667	771.9166667	1164.416667	1413	Max Met		5
6	300.9167	294.375	259.05	329.7	278.0208	343.4375	285.8708	270.825		300.9166667	595.2916667	854.3416667	1184.041667	1462.063	Max Met		5
7	346.0542	331.0083	287.8333	200.175	345.4	266.9	315.9625	244.6583		346.0541667	677.0625	964.8958333	1165.070833	1510.471	Max Met		5
8	345.4	278.0208	392.5	310.7292	200.175	274.75	278.0208	361.1		345.4	623.4208333	1015.920833	1326.65	1526.825	Max Met		5
9	315.9625	331.0083	189.0542	282.6	278.0208	261.0125	359.7917	278.0208		315.9625	646.9708333	836.025	1118.625	1396.646	Max Met		5
10	278.0208	329.7	376.1458	261.0125	329.7	261.6667	211.2958	247.275		278.0208333	607.7208333	983.8666667	1244.879167	Max Met			4
11	282.6	343.4375	300.9167	316.6167	282.6	345.4	282.6	361.1		282.6	626.0375	926.9541667	1243.570833	1526.171	Max Met		5
12	346.0542	248.5833	376.8	261.0125	392.5	236.1542	392.5	300.9167		346.0541667	594.6375	971.4375	1232.45	Max Met			4
13	315.9625	315.9625	345.4	316.6167	261.0125	200.175	345.4	343.4375		315.9625	631.925	977.325	1293.941667	1554.954	Max Met		5
14	343.4375	266.9	261.0125	200.175	200.175	282.6	287.8333	273.4417		343.4375	610.3375	871.35	1071.525	1271.7	1554.3	Max Met	6
15	345.4	270.825	327.0833	314	294.375	300.9167	331.0083	376.1458		345.4	616.225	943.3083333	1257.308333	1551.683	Max Met		5
16	285.8708	247.275	302.225	331.0083	376.8	287.8333	346.0542	329.7		285.8708333	533.1458333	835.3708333	1166.379167	1543.179	Max Met		5
17	222.4167	235.5	392.5	302.225	343.4375	270.825	211.95	392.5		222.4166667	457.9166667	850.4166667	1152.641667	1496.079	Max Met		5
18	316.6167	236.1542	244.6583	261.0125	200.175	376.8	294.375	259.05		316.6166667	552.7708333	797.4291667	1058.441667	1258.617	Max Met		5
19	261.6667	331.0083	361.1	261.0125	294.375	298.3	310.7292	392.5		261.6666667	592.675	953.775	1214.7875	1509.163	Max Met		5
20	288.4875	287.8333	211.2958	189.0542	259.05	315.9625	300.9167	345.4		288.4875	576.3208333	787.6166667	976.6708333	1235.721	1551.683	Max Met	6
21	331.0083	233.5375	327.0833	327.0833	345.4	287.8333	392.5	300.9167		331.0083333	564.5458333	891.6291667	1218.7125	Max Met			4
22	259.05	346.0542	361.1	302.225	235.5	361.1	287.8333	327.0833		259.05	605.1041667	966.2041667	1268.429167	1503.929	Max Met		5
23	270.825	361.1	331.0083	266.9	359.7917	345.4	244.6583	244.6583		270.825	631.925	962.9333333	1229.833333	Max Met			4
24	315.9625	361.1	376.1458	329.7	343.4375	282.6	329.7	248.5833		315.9625	677.0625	1053.208333	1382.908333	Max Met			4
25	300.9167	316.6167	329.7	222.4167	300.9167	261.0125	343.4375	270.825		300.9166667	617.5333333	947.2333333	1169.65	1470.567	Max Met		5
26	361.1	392.5	274.75	302.225	270.825	376.1458	302.225	376.8		361.1	753.6	1028.35	1330.575	Max Met			4
27	315.9625	392.5	261.0125	310.7292	261.0125	345.4	376.8	329.7		315.9625	708.4625	969.475	1280.204167	1541.217	Max Met		5
28	329.7	261.6667	294.375	376.1458	392.5	327.0833	278.0208	392.5		329.7	591.3666667	885.7416667	1261.8875	Max Met			4
29	310.7292	247.275	327.0833	222.4167	343.4375	247.275	327.0833	359.7917		310.7291667	558.0041667	885.0875	1107.504167	1450.942	Max Met		5

Using logic formulae the researcher tested random passenger selections to see how many people actually fit in a square meter. Over 1000 iterations were performed.

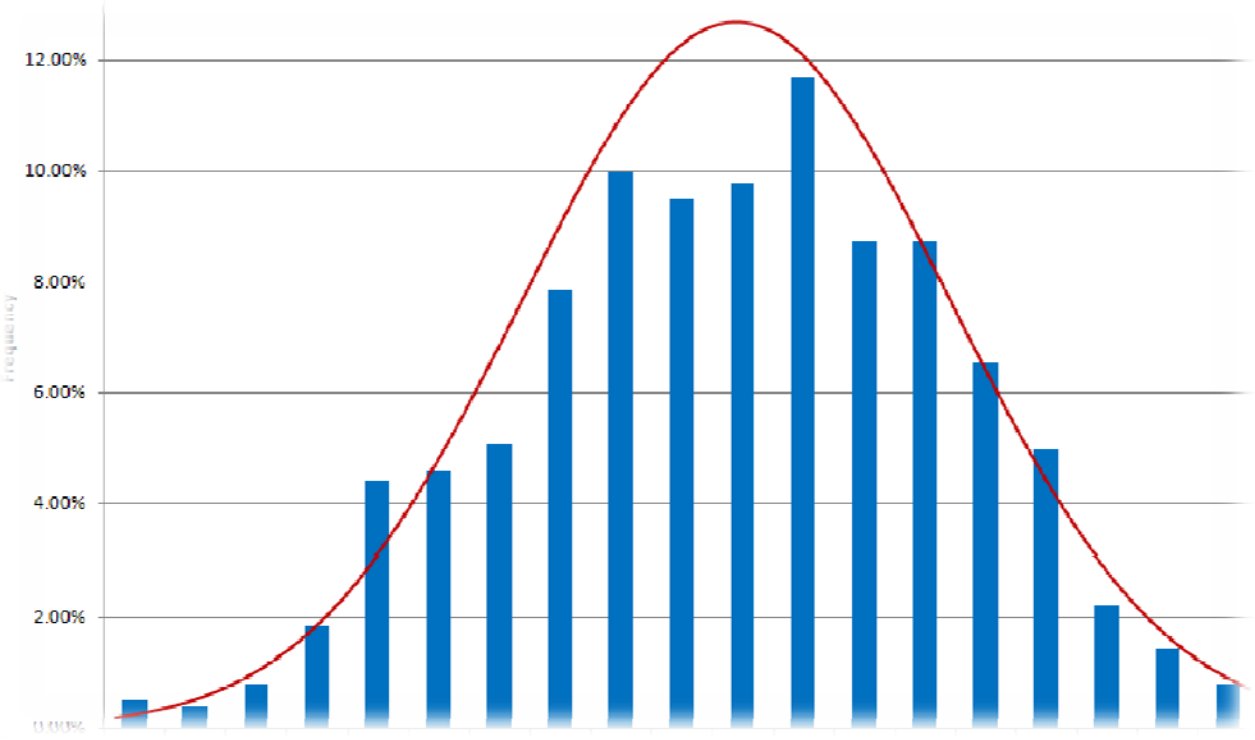
Preliminary Findings

										1st Person	2nd	3rd	4th	5th	6th		Total People
1	273.4417	298.3	329.7	211.2958	376.1458	376.1458	278.0208	310.7292		273.4416667	571.7416667	901.4416667	1112.7375	1488.883	Max Met		5
2	315.9625	288.4875	343.4375	233.5375	298.3	294.375	376.8	287.8333		315.9625	604.45	947.8875	1181.425	1479.725	Max Met		5
3	278.0208	233.5375	329.7	345.4	235.5	361.1	392.5	331.0083		278.0208333	511.5583333	841.2583333	1186.658333	1422.158	Max Met		5

We most frequently see ***5*** people per m^2 of standing space.

Resulting in a total average weight of ***88.9 lbs./sq. ft.***

Preliminary Findings



The standing passenger weights were found to follow a normal distribution.

Preliminary Findings

How does this compare to the current AW based design and a simple increase to 182 lbs. per passenger?

AW2

SB/BD	20.83	20	19.17	18.33	17.5	16.67	15.83	15	14.17
25	**64.3**	67.0	69.9	73.1	76.6	80.4	84.7	89.4	94.6
24	67.0	**69.8**	72.8	76.2	79.8	83.8	88.2	93.1	98.6
23	69.9	72.8	**76.0**	79.5	83.3	87.4	92.0	97.1	102.8
22	73.1	76.2	79.5	**83.1**	87.0	91.4	96.2	101.5	107.5
21	76.6	79.8	83.3	87.0	**91.2**	95.7	100.8	106.4	112.6
20	80.4	83.8	87.4	91.4	95.7	**100.5**	105.8	111.7	118.3
19	84.7	88.2	92.0	96.2	100.8	105.8	**111.4**	117.6	124.5
18	89.4	93.1	97.1	101.5	106.4	111.7	117.6	**124.1**	**131.4**
17	94.6	98.6	102.8	107.5	112.6	118.3	124.5	131.4	**139.1**

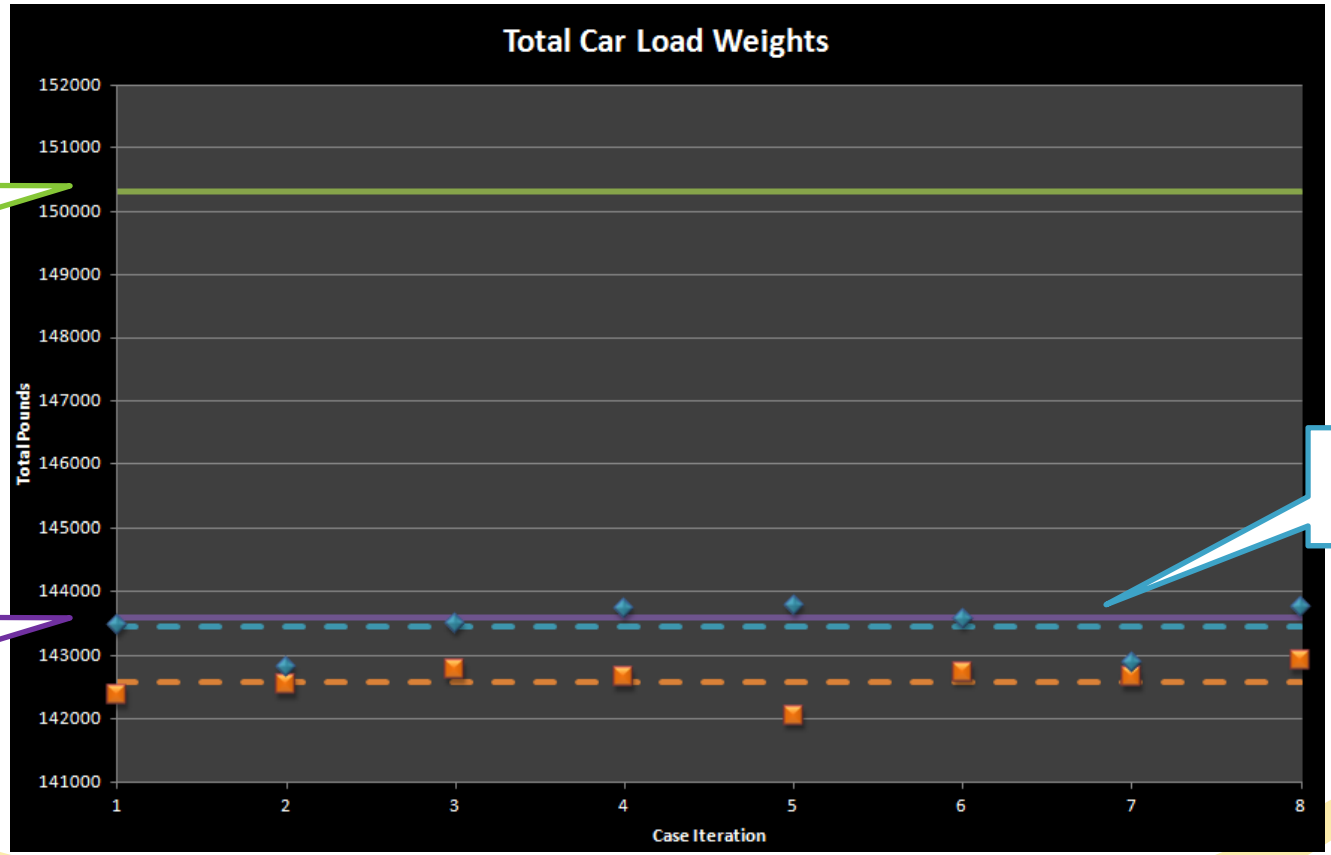
AW3

AW4

The current design assumptions ignore the ***changes in body area*** as weight increases or decreases. When the research used this additional packing factor to reflect a more realistic scenario, ***the increase in weight became balanced by the increase of body area.***

Preliminary Findings

AW3 at 182 lbs.



AW3 at 155 lbs.

Random Scenario Based

Clothing and Personal Items

Using FAA as a comparable industry, add 5 and 10 pounds for summer and winter clothes, respectively.

Average Passenger Weight	Weight Per Passenger
Summer Weights	
Average passenger weight	184 lb
Average male passenger weight	194 lb
Average female passenger weight	173 lb
Child weight (2 years to less than 13 years of age)	76 lb
Winter Weights	
Average passenger weight	189 lb
Average male passenger weight	199 lb
Average female passenger weight	178 lb
Child weight (2 years to less than 13 years of age)	81 lb

FAA adds 16 pounds for carryon luggage.

Clothing and Personal Items

Assume 7 pounds for year round clothing

Most commuters have a large back or purse. Reduce “carryon luggage” to 10 pounds

Recommended Application

Hypothetical Train Car

Seating Capacity of 75

Standing Space 312.15 ft^2

Car Weight 105,000 lbs.

$$155 \times \left(Seats + 0.56 \frac{Pass.}{ft^2} \times Stnd\ Sp \right) + Car$$

$$= 143{,}719.62\ lbs.$$

Recommended Application

Hypothetical Train Car

Seating Capacity of 75

Standing Space 312.15 ft^2

Car Weight 105,000 lbs.

$$182 \times \left(Seats + 0.56 \frac{Pass.}{ft^2} \times Stnd\ Sp \right) + Car$$

$$= 150{,}464.33 \text{ lbs}$$

6745 lb. increase

Recommended Application

Hypothetical Train Car

Seating Capacity of 75

Standing Space 312.15 ft^2

Car Weight 105,000 lbs.

182 x (Seats + 89 x Stnd Sp) + Car

=146,431.35 lbs.

2712 lb increase

Recommended Application

Hypothetical Train Car

Seating Capacity of 75

Standing Space 312.15 ft^2

Car Weight 105,000 lbs.

199 x (Seats + 106 x Stnd Sp) + Car

=153,012.9 lbs

9293 lb. increase

Conclusions

- Average standing passenger weight 89 lbs/ft^2 and a mode of ½ passenger per square foot.
- Assuming 182 lbs. the total would be 91 lbs/ft2, a difference of approx. 2 lbs., multiplied by total standing space of the car can create a significant amount of weight unaccounted for.
- Using AW3 assumptions we would see 103.2 lbs/ft^2, approx 14.2 lbs. greater than what would “typically” be seen.

Conclusions

- Additional weight of clothing and personal items should be considered with any weight increase, this research used 17 pounds.

- As an industry we must design for not only today's population but tomorrow's as well

Future Recommendations

- Although in using the suggested formula any increase in weight or size of passenger should be accounted for, data should be revisited to determine the seated passenger weight.
- How can the industry ensure that all data is always current and relative?
- Possible solution is an APTA standard, required review every 5 years closely aligns with CDC timeline for new data reports.
- Second possible solution is to decide as an industry on a safety factor percentage to be built into RFPs.

Thank You

Samantha Smith
APTA Program Manager- Technical Services
ssmith@apta.com

Questions?