Municipal Solid Waste Generation Varies Across Time and Space

Longitudinal Analyses

# Dataset

## Original

Unload libraries. Attach original data.

## For Analysis

Data set prepared for longitudinal analyses

brookhaven\_long <- brookhaven\_long\_ori  
nyc\_long\_year <- nyc\_long\_year\_ori  
nyc\_long\_month <- nyc\_long\_month\_ori  
seattle\_long <- seattle\_long\_ori  
usepa\_long <- usepa\_long\_ori  
  
  
brookhaven\_long

## # A tibble: 168 × 6  
## Year Month Month\_Year HH lbsHHd gHHd  
## <dbl> <chr> <chr> <dbl> <dbl> <dbl>  
## 1 2004 Jan 01-2004 NA NA NA   
## 2 2004 Feb 02-2004 113930 9.26 4205.  
## 3 2004 Mar 03-2004 NA NA NA   
## 4 2004 Apr 04-2004 NA NA NA   
## 5 2004 May 05-2004 113930 12.0 5434.  
## 6 2004 Jun 06-2004 NA NA NA   
## 7 2004 Jul 07-2004 NA NA NA   
## 8 2004 Aug 08-2004 113930 11.6 5250.  
## 9 2004 Sep 09-2004 NA NA NA   
## 10 2004 Oct 10-2004 NA NA NA   
## # ℹ 158 more rows

nyc\_long\_year

## # A tibble: 14 × 2  
## Year REFUSETONSCOLLECTED\_lbspd  
## <dbl> <dbl>  
## 1 2004 1.96  
## 2 2005 1.89  
## 3 2006 1.86  
## 4 2007 1.81  
## 5 2008 1.75  
## 6 2009 1.73  
## 7 2010 1.68  
## 8 2011 1.76  
## 9 2012 1.69  
## 10 2013 1.67  
## 11 2014 1.64  
## 12 2015 1.62  
## 13 2016 1.62  
## 14 2017 1.63

nyc\_long\_month

## # A tibble: 168 × 2  
## Year\_Month REFUSETONSCOLLECTED\_lbspd  
## <chr> <dbl>  
## 1 2004 / 01 1.78  
## 2 2004 / 02 1.81  
## 3 2004 / 03 1.99  
## 4 2004 / 04 1.98  
## 5 2004 / 05 1.99  
## 6 2004 / 06 2.23  
## 7 2004 / 07 2.03  
## 8 2004 / 08 1.97  
## 9 2004 / 09 2.05  
## 10 2004 / 10 1.85  
## # ℹ 158 more rows

seattle\_long

## # A tibble: 14 × 6  
## Year Population Total\_ppd Total\_Disposal\_ppd Re\_WG\_pppd Res\_Disp\_ppd  
## <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>  
## 1 2004 576906 7.41 4.35 2.68 1.35   
## 2 2005 579779 7.47 4.16 2.66 1.27   
## 3 2006 587755 7.80 4.09 2.73 1.25   
## 4 2007 594339 7.83 4.05 2.74 1.23   
## 5 2008 599055 7.22 3.61 2.64 1.16   
## 6 2009 603155 6.54 3.19 2.59 1.08   
## 7 2010 608660 6.52 3.02 2.59 1.03   
## 8 2011 611249 6.42 2.86 2.54 1.01   
## 9 2012 614283 6.37 2.82 2.55 0.994  
## 10 2013 624045 6.36 2.79 2.51 0.973  
## 11 2014 638784 6.19 2.66 2.46 0.963  
## 12 2015 660908 5.98 2.51 2.34 0.845  
## 13 2016 684136 5.99 2.47 2.31 0.831  
## 14 2017 694513 6.31 2.71 2.29 0.831

usepa\_long

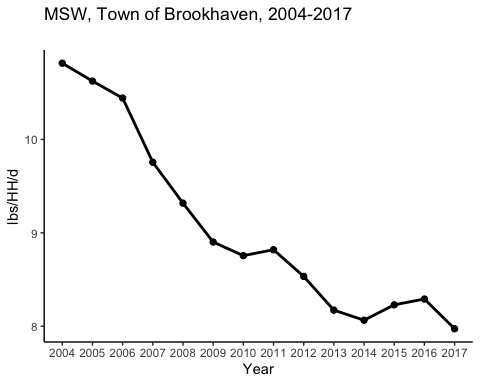
## # A tibble: 14 × 3  
## Year Model lbsPd  
## <dbl> <chr> <dbl>  
## 1 2004 2007 3.16  
## 2 2005 2018 3.23  
## 3 2006 2007 3.16  
## 4 2007 2011 3.12  
## 5 2008 2012 3.04  
## 6 2009 2018 2.89  
## 7 2010 2018 2.93  
## 8 2011 2013 2.88  
## 9 2012 2014 2.88  
## 10 2013 2014 2.9   
## 11 2014 2015 2.92  
## 12 2015 2018 2.93  
## 13 2016 2016-2017 2.94  
## 14 2017 2018 2.95

# Brookhaven

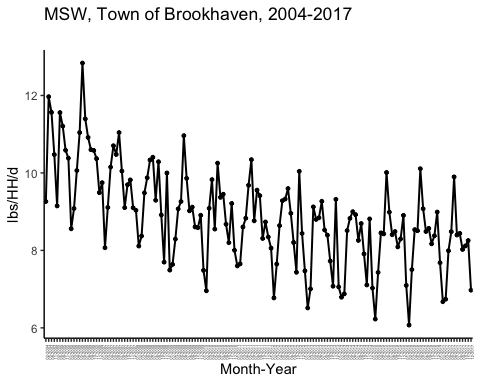
## Visualization

brookhaven\_long %>%  
 group\_by(Year) %>%  
 summarize(lbsHHd = mean(lbsHHd, na.rm=T)) %>%  
 mutate(Year = as\_factor(Year)) %>%  
 ggplot(aes(x=Year, y=lbsHHd, group=1)) +   
 geom\_point(size=1.9) +   
 geom\_line(size=1) +   
 theme\_classic() +  
 labs(x="Year", y="lbs/HH/d", title="MSW, Town of Brookhaven, 2004-2017\n")

## Warning: Using `size` aesthetic for lines was deprecated in ggplot2 3.4.0.  
## ℹ Please use `linewidth` instead.  
## This warning is displayed once every 8 hours.  
## Call `lifecycle::last\_lifecycle\_warnings()` to see where this warning was  
## generated.



na.omit(brookhaven\_long) %>%  
 mutate(Month\_Year = as\_factor(Month\_Year)) %>%  
 ggplot(aes(x=Month\_Year, y=lbsHHd, group=1)) +   
 geom\_point(size=1) +   
 geom\_line(size=.7) +   
 theme\_classic() +  
 theme(axis.text.x = element\_text(angle=90, size = 3)) +  
 labs(x="Month-Year", y="lbs/HH/d", title="MSW, Town of Brookhaven, 2004-2017\n")



## Monotonic trend test

Mann-Kendall test Examines if there is a significant monotonic trend and to which direction measure: lbs/HH/d

round(mmkh(na.omit(brookhaven\_long)$lbsHHd, ci=.95) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -4.957 0.000 2.503 -7.843 0.000 -0.429   
## Sen's slope old.variance new.variance   
## -0.016 394009.333 986352.820

round(mmky(na.omit(brookhaven\_long)$lbsHHd) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -9.215 0.000 0.724 -7.843 0.000 -0.429   
## Sen's slope old.variance new.variance   
## -0.016 394009.333 285402.894

measure: g/HH/d

round(mmkh(na.omit(brookhaven\_long)$gHHd, ci=.95) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -4.957 0.000 2.503 -7.843 0.000 -0.429   
## Sen's slope old.variance new.variance   
## -7.483 394009.333 986352.820

round(mmky(na.omit(brookhaven\_long)$gHHd) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -9.215 0.000 0.724 -7.843 0.000 -0.429   
## Sen's slope old.variance new.variance   
## -7.483 394009.333 285402.894

## Stable seasonality test

Friedman test Examines if there is a stable seasoanality pattern in time-series data measure: lbs/HH/d

fried(ts(brookhaven\_long$lbsHHd, start=2004, end=2017, frequency = 12))

## Test used: Friedman rank   
##   
## Test statistic: 40.67   
## P-value: 0.00002747819

measure: g/HH/d

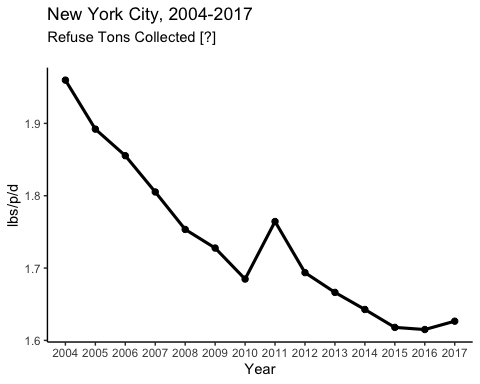
fried(ts(brookhaven\_long$gHHd, start=2004, end=2017, frequency = 12))

## Test used: Friedman rank   
##   
## Test statistic: 40.67   
## P-value: 0.00002747819

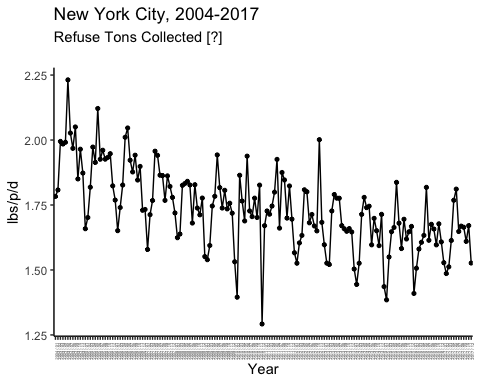
# New York City

## Visualization

nyc\_long\_year %>%  
 mutate(Year = as\_factor(Year)) %>%  
 ggplot(aes(x=Year, y=REFUSETONSCOLLECTED\_lbspd, group=1)) +   
 geom\_point(size=1.9) +   
 geom\_line(size=1.1) +   
 theme\_classic() +  
 labs(x="Year", y="lbs/p/d", title="New York City, 2004-2017", subtitle="Refuse Tons Collected [?]\n")



nyc\_long\_month %>%  
 mutate(Year\_Month = as\_factor(Year\_Month)) %>%  
 ggplot(aes(x=Year\_Month, y=REFUSETONSCOLLECTED\_lbspd, group=1)) +   
 geom\_point(size=1.1) +   
 geom\_line(size=.5) +   
 theme\_classic() +  
 theme(axis.text.x = element\_text(angle=90, size = 3)) +  
 labs(x="Year", y="lbs/p/d", title="New York City, 2004-2017", subtitle="Refuse Tons Collected [?]\n")



## Monotonic trend test

lbs/HH/d

round(mmkh(nyc\_long\_month$REFUSETONSCOLLECTED\_lbspd, ci=.95) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -6.209 0.000 2.144 -9.093 0.000 -0.473   
## Sen's slope old.variance new.variance   
## -0.002 531505.333 1139786.482

round(mmky(nyc\_long\_month$REFUSETONSCOLLECTED\_lbspd) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -14.285 0.000 0.405 -9.093 0.000 -0.473   
## Sen's slope old.variance new.variance   
## -0.002 531505.333 215358.629

## Stable seasonality test

lbs/HH/d

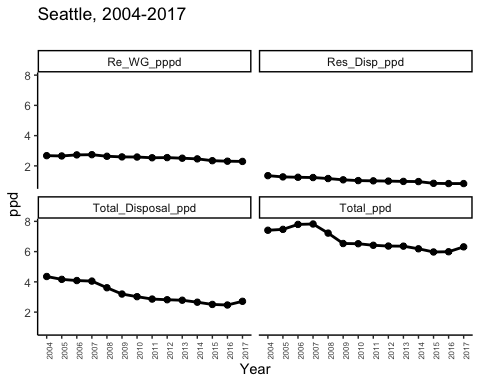
fried(ts(nyc\_long\_month$REFUSETONSCOLLECTED\_lbspd, start=2004, end=2017, frequency = 12))

## Test used: Friedman rank   
##   
## Test statistic: 61.79   
## P-value: 0.000000004298911

# Seattle

## Visualization

seattle\_viz1 <- seattle\_long %>%  
 pivot\_longer(cols = Total\_ppd:Res\_Disp\_ppd, names\_to = "Measure", values\_to = "ppd")  
   
seattle\_viz1 %>%  
 mutate(Year = as\_factor(Year)) %>%  
 ggplot(aes(x=Year, y=ppd, group=1)) +   
 facet\_wrap(~Measure) +  
 geom\_point(size=1.9) +   
 geom\_line(size=1) +   
 theme\_classic() +  
 theme(axis.text.x = element\_text(angle=90, size=6)) +  
 labs(x="Year", y="ppd", title="Seattle, 2004-2017\n")

 ## Monotonic trend test Mann Kendall test ### Total ppd

round(mmkh(seattle\_long$Total\_ppd, ci=.95) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -3.832 0.000 1.000 -3.832 0.000 -0.780   
## Sen's slope old.variance new.variance   
## -0.123 333.667 333.667

round(mmky(seattle\_long$Total\_ppd) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -5.519 0.000 0.482 -3.832 0.000 -0.780   
## Sen's slope old.variance new.variance   
## -0.123 333.667 160.872

### Total disposal ppd

round(mmkh(seattle\_long$Total\_Disposal\_ppd, ci=.95) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -3.215 0.001 2.045 -4.599 0.000 -0.934   
## Sen's slope old.variance new.variance   
## -0.157 333.667 682.452

round(mmky(seattle\_long$Total\_Disposal\_ppd) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -6.315 0.000 0.530 -4.599 0.000 -0.934   
## Sen's slope old.variance new.variance   
## -0.157 333.667 176.940

### Re wg ppd

round(mmkh(seattle\_long$Re\_WG\_pppd, ci=.95) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -4.270 0.000 1.000 -4.270 0.000 -0.868   
## Sen's slope old.variance new.variance   
## -0.033 333.667 333.667

round(mmky(seattle\_long$Re\_WG\_pppd) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -6.822 0.000 0.392 -4.270 0.000 -0.868   
## Sen's slope old.variance new.variance   
## -0.033 333.667 130.718

### Res disp ppd

round(mmkh(seattle\_long$Res\_Disp\_ppd, ci=.95) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -4.818 0.000 1.000 -4.818 0.000 -0.978   
## Sen's slope old.variance new.variance   
## -0.040 333.667 333.667

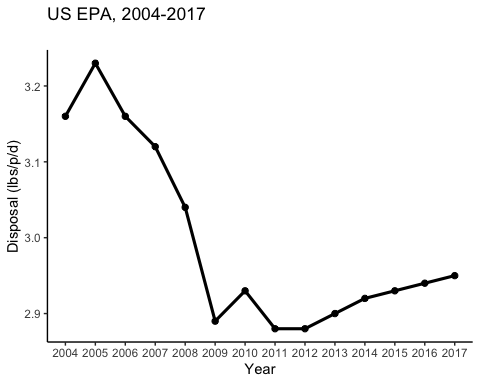
round(mmky(seattle\_long$Res\_Disp\_ppd) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -9.261 0.000 0.271 -4.818 0.000 -0.978   
## Sen's slope old.variance new.variance   
## -0.040 333.667 90.301

# US EPA

## Visualization

usepa\_long %>%  
 mutate(Year = as\_factor(Year)) %>%  
 ggplot(aes(x=Year, y=lbsPd, group=1)) +   
 geom\_point(size=1.9) +   
 geom\_line(size=1.1) +   
 theme\_classic() +  
 labs(x="Year", y="Disposal (lbs/p/d)", title="US EPA, 2004-2017\n")

 ## Monotonic trend test

round(mmkh(usepa\_long$lbsPd, ci=.95) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -1.109 0.267 2.068 -1.595 0.111 -0.330   
## Sen's slope old.variance new.variance   
## -0.020 330.667 683.962

round(mmky(usepa\_long$lbsPd) ,3)

## Corrected Zc new P-value N/N\* Original Z old P.value Tau   
## -1.971 0.049 0.655 -1.595 0.111 -0.330   
## Sen's slope old.variance new.variance   
## -0.020 330.667 216.559