Research Proposal

Measuring Food Waste in Prince George Restaurant: Volume, Model, and Effects

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Today's Menu

Introduction

Food Loss and Waste (FLW) happens everywhere.

- One-third of food is lost or wasted around the world[5].
- Around 1.3 billion tons of FLW is generated annually, and the rate is projected to grow by 44% per year by 2025[2].
- Canada creates about 35 million tons and the largest waste generator per capita in western countries in 2016[12].
- Canada's avoidable FLW is $49.5 million CAD[3].
- In BC, 40% of the waste to landfills is organic waste, the majority is produced from domestic waste[13].

Introduction

Few studies of FLW done on the supply side

- Recent huge discoveries in the food waste research focus on waste generated by households:[1, 9, 11, 14].
- Limited number of studies done on the food supply side.
- Even little estimations of FLW in food service industry.
- E.g. from 1.0% to 15.5% (up to 52% under some conditions) [10].

Introduction

Research Questions

- What is the average volume of food that is wasted during processing and consumption in restaurants?
- What is the extent of food wastage in Japanese restaurants in Prince George?
- What are the main factors contributing to food loss and waste?
- To what extent is a social or environmental impact from food loss waste generated by a single restaurant?
- What approaches are Japanese restaurant operators taking to reduce food waste generation?

Literature Review

What is Food Loss and Waste (FLW)?

Definition of FLW (Source [8])

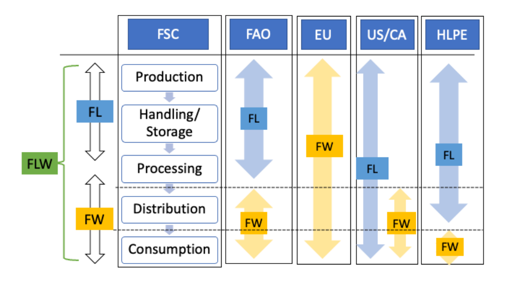
Organization	Definition
Food Loss (FAO)	reduction in weight or quality of food for human consumption
Food Waste (FAO)	edible food discarded following spoilage or after the expiration date
Food Waste (EU)	any food removed from the food supply chain
Food Loss (US/CA)	unused product from the food supply chain
Food Waste (US/CA)	still edible food scraps at disposal

$\Longrightarrow$ No universally accepted definitions of FLW

Literature Review

Dim definition

- Definition of FLW varies among organizations.



General Idea:

- Upstream process of FSC: Food Loss.
- Downstream process of FSC: Food Waste.

Literature Review

Few studies on liquid food waste

Not only Solid but Liquid food

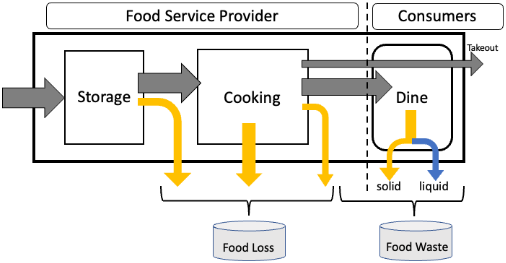
- All these-above defined FLW are solid waste
- e.g. food scraps, peels, or leftovers
- Not only solid but also liquid waste
- Environmental pollutions: soil, water, and air contamination
- Drainage blockages: clog drains and sewage blockages
- Resource Losses: water, energy, land used to produce food

Literature Review

In this research on a restaurant's FLW:

Definition of FLW in Restaurant

- Food Loss: generated by **provider**
- Food Waste: generated by **consumers**
  - Solid Food Waste: solid portion of food waste
  - Liquid Food Waste: liquid portion of food waste



Literature Review

How to measure FLW?

FLW Measurements used in the past research

Method	Note
1. Self-report	individuals report FLW
	low-cost but high dropouts
2. Survey	collect FLW by interview or questionnaire
	cost-effective but not accurate
3. Composition	sample and analysis at lab
	need special knowledge and equipment
4. Mass balance	material flow analysis
	limitation in waste factor assumptions
5. **Direct weight**	directly measure FLW
	most accurate but high cost

What is the main factors of FLW?

8 Classifications ([7])

1. **Society**: culture, awareness and legislation.
2. **Business concept**: a la carte or buffet style.
3. **Product procurement**: raw or frozen; where to buy.
4. **Management**: menu development, inventories.
5. **Professional skills**: untrained mistakes throwing food.
6. **Diners**: preference, taste or presentation mismatch.
7. **Competitors**: existence of other restaurants.
8. **Communication**: with customers and with staff.

Literature Review

Any other potential factors of FLW?

Other factors

- **Calendar**: month, day of week, holidays, long weekend
- **Weather**: temperature, humidity, precipitation

$\Longrightarrow$ Weather conditions, temperature or humidity, or the week of day may cause FLW?

Literature Review

How to test associations between FLW and potential factors?

Regression Model and Strategy

$$Y = X\beta + \epsilon$$

- set-up (additive) regression model
- test whether true coefficient β is zero or not

where,
Y is {daily food waste, liquid waste, solid waste},
X is {temperature, humidity, precipitation, number of customer, daily sales, liquors, day of week}.

Regression analysis on time series might arise a problem.

Linear Regression Model and Assumptions

$$Y = X\beta + \epsilon$$
$$\epsilon \overset{\text{i.i.d.}}{\sim} N(0, \sigma^2)$$

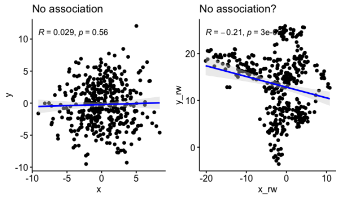
Assumption	Problem
1. $\mathbb{E}(\epsilon) = 0.$	may have trend
2. $Var(\epsilon) = \sigma^2.$	heterocedascity
3. $Cov(\epsilon_i, \epsilon_j) = 0, i \neq j.$	autocorrelation b/w 2 pts
4. $X \perp\!\!\!\perp \epsilon$ and no R.V. X	a point of x influences y
5. ϵ follows Normal dist'n	(other distribution)
6. Linearly independent of X	(multicolinearlity)

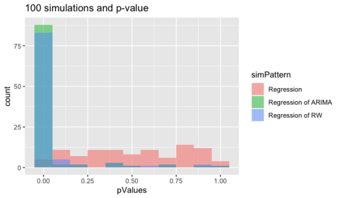
$\Longrightarrow$ **spurious regression**: a conclusion is that an association exists between two variables even though there is no relationship between them at all.

Literature Review

- Create fake two data sets without no association
  1. simply random select
  2. dependent on one before (random-walk)
- Check the relationship between two

Spurious regression



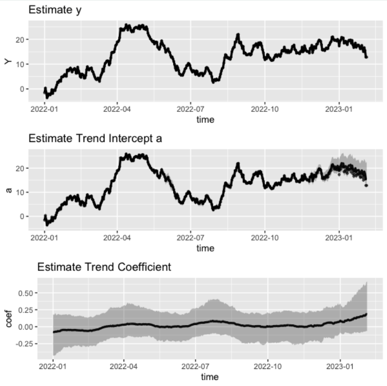


$\Longrightarrow$ If random-walk process, usual regression analysis may achieve false results.

Bayesian Modelling

time-vary coefficients parameter β

$$y_i \sim \mathrm{N}(\mu_i, \sigma_y^2),$$
$$\mu_i = X\beta_i{}^{1},$$
$$\beta_i \sim \mathrm{N}(\beta_{i-1}, \sigma_\beta^2), \forall i \in T.$$



[1] $\mu_i = a_i + b_i * x_i$

Literature Review

What is the consequence of FLW?

Effects of FLW

- **Economic Loss**:
  loss of resources: labour, material, time, and energy
- **Environmental Effects**:
  water pollution, deforestation, soil erosion, and GHG
- **Social Impacts**: food insecurity and social inequality

Reducing FLW can mitigate these economic and environmental impacts. Through better supply chain management, reducing consumer food waste, and increasing food recovery.

Literature Review

Research Goals

- Estimate average FLW
- Any patterns between FLW and business operations
- Any association between FLW and weather conditions
- Estimate economic and environmental impacts

Methods

<u>Which restaurant is to be studied?</u>

Study Area

- **Location**: Japanese restaurant (suburban area of PG)
- **Hours**: lunch and dinner for three hours each
- **Day**: six days of a week (Tue to Sun; Mon closed)
- **Offer**: dine-in & takeouts
- **Items**: sushi & <u>ramen</u> (soup and noodle)
- **Weight**: about 900 g per bowl

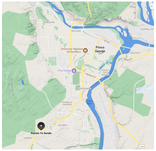
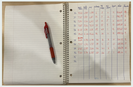


Figure: Research Location Site

Methods

How to capture the FLW?

Collection Apparatus

Bucket for FL	Bucket & Colander for FW
	
	
Weight scale (0.05 - 150 kg)	Pen & notebook
	

Methods

How many samples to be collected?

Sample Size

- **Power analysis**, 114 samples: 90% CI and 10% margin of error with 10 explanatory variables.
- **Rule-of-thumb**, one-in-ten rule suggests 100 observations with 10 predictors[6]
- Green's rule states 130 samples with 10 predictors[4]

Methods

Research Variables

Variables	Note
1.Food Loss	Daily disposed food by kitchen
2.Liquid Food Waste	Daily disposed liquid food by customers
3.Solid Food Waste	Daily disposed solid food by customers
4.# of Customers	Daily number of dine-in customers
5.Sales	Daily sales
6.Liquor	Daily number of liquors sold
7.Takeouts	Daily number of takeout sold
8.Business	Changes in operations / environment
9.Orders	Daily number of orders sold
10.Temperature	Hourly mean temperature each day
11.Humidity	Hourly mean humidity
12.Precipitation	Precipitation

Methods

Multiple Linear Regression (additive) Model

$$Y = X\beta + \epsilon, \quad \epsilon \sim N(0, \sigma_y^2).$$

$$\begin{aligned} food\_waste = {} & \beta_0^1 + \beta_1^1 * temperature + \beta_2^1 * humidity \\ & + \beta_3^1 * precipitation + \beta_4^1 * customer + \beta_5^1 * sales \\ & + \beta_6^1 * liquors + \beta_7^1 * takeouts + \beta_{8,\dots,12}^1 * day + \epsilon^1. \\ solid\_waste = {} & \beta_0^2 + \beta_1^2 * temperature + \beta_2^2 * humidity \\ & + \beta_3^2 * precipitation + \beta_4^2 * customer + \beta_5^2 * sales \\ & + \beta_6^2 * liquors + \beta_7^2 * takeouts + \beta_{8,\dots,12}^2 * day + \epsilon^2. \end{aligned}$$

$\Longrightarrow$ Check each coefficient confidence/credible interval.

Expected Results

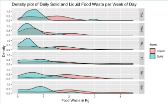
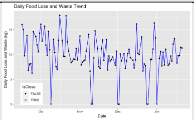
Expected Results

- Estimations of FLW in a restaurant.
- Any patterns / factor of FLW.
- Implications of FLW reduction.

Expected Results

Current Progress

- From Sept. 16, five months.
- Collected over 100 samples.
- Basic analysis (Histogram, Time series plots)
- Finishing statistical model.

Food Waste per Week of Day	Food Loss and Waste Trend
	

Future Plan

September 2022 - March 2023: Data collection

1. Mid of March: 150 samples
2. Take photos for presentation

March 2023 - June 2023: Write up of research paper.

1. Research up on potential factors: weather conditions and calendar effects.
2. Finish up descriptive graphs and stat model, and analyze it.
3. Explore consequence of FLW and estimate its effects

June - July 2023: Prepare for thesis defence.

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Introduction

Literature Review

Definition

Measurements

Potential Factors

Statistical Model

Effects of FLW

Hypothesis

Methods

Study Area

Apparatus

Duration

Variables

Statistical Model

Expected Results

Acknowledgements

References

References

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[14] Michael Von Massow et al. "Valuing the multiple impacts of household food waste". In: *Frontiers in nutrition* 6 (2019), p. 143.

R code: sample size calculation

```
# Single porportion test
pwr.p.test(h=0.3, sig.level=0.05,
           power=0.90, alternative="two.sided")

# One Mean T-test
pwr.t.test(d=0.3, sig.level=0.05,
           power=0.9, type="one.sample", alternative="two.sided")

# Multiple Linear Regression
pwr.f2.test(u=10, f2=0.15, sig.level=0.1, power=0.90)
```

Appendix

R code: spurious regression

```
## No relationship ------------------
set.seed(1) # set rand
m = 0  # mean
v = 10 # variance
Nsample <- 400 # sample size

# simulate two sets of data
x_sim    <- rnorm(Nsample, mean = m, sd = sqrt(v))
y_sim    <- rnorm(Nsample, mean = m, sd = sqrt(v))
simData <- data.frame(x = x_sim, y=y_sim)

# visualization
autoplot(ts(simData[,c(1,2)])) # Time series
ggplot(simData, aes(x=x,y=y)) + geom_point() # 2D scatter plot

# Linear Regression Analysis
mod <- lm(y ~ ., data = simData) # fitted linear model
summary(mod)

## Spurious Regression ------------------
# generate random-walk data
x_sim_rw    <- cumsum(rnorm(Nsample))
y_sim_rw    <- cumsum(rnorm(Nsample))
simData_rw <- data.frame(x_rw = x_sim_rw, y_rw = y_sim_rw)

autoplot(ts(simData_rw[,c(2:3)])) # Time series
ggplot(simData_rw, aes(x=x_rw,y=y_rw)) + geom_point() # 2D scatter plot

mod <- lm(y_rw ~ x_rw, data = simData_rw)
summary(mod)
```

R code: spurious regression

```
# 100 simulations (correct p-value) ----------------
Nsim <- 100 # Number of simulation runs
pValues     <- numeric(Nsim) # Set vectors
pValuesRW   <- numeric(Nsim) # Set vectors for random walk
pValueARIMA <- numeric(Nsim) # Set vectors for ARIMA sim

# Nsim times simulation data
for(i in 1:Nsim){
  # No random walk process
  y <- rnorm(Nsample, sd = sqrt(v))
  x <- rnorm(Nsample, sd = sqrt(v))

  # Random walk simulation data
  y_rw <- cumsum(rnorm(n=Nsample))
  x_rw <- cumsum(rnorm(n=Nsample))

  # ARIMA simulation data
  x_arima <- arima.sim(list(order=c(2,1,1), ar=c(0.2,-0.1),# ARIMA(2,1,1)
                       ma=-0.1), n=Nsample)
  y_arima <- arima.sim(list(order=c(0,1,1), ma=0.2), n=Nsample)#ARIMA(0,1,1)

  mod       <- lm(y ~ x) # linear regression analysis
  mod_rw    <- lm(y_rw ~ x_rw) # linear regression analysis for rw
  mod_arima <- lm(y_arima ~ x_arima) # linear regression analysis for arima

  # Save p-value
  pValues[i]     <- summary(mod)$coefficients[2,4]
  pValuesRW[i]   <- summary(mod_rw)$coefficients[2,4]
  pValueARIMA[i] <- summary(mod_arima)$coefficients[2,4]
}
```

R code: spurious regression

```
# Combine data
simPresult <- data.frame(pValues = c(pValues, pValuesRW, pValueARIMA),
                         simPattern = rep(c("Regression",
                                             "Regression of RW",
                                             "Regression of ARIMA"),
                                           each = Nsim))

# Histograms
histPlot <-
  ggplot(simPresult, aes(x = pValues, fill = simPattern)) +
  geom_histogram(alpha = 0.5, position = "identity", binwidth = 0.1)
plot(histPlot)
```

Appendix

Stan code: dynamic linear regression

```
data{
  int T;          // Number of observations
  vector[T] x;  // explanatory variable
  vector[T] y;  // response variable
}
parameters{
  vector[T] a;          // intercepts
  vector[T] b;          // coefficient
  real<lower=0> s_a;  // s.d. for intercept
  real<lower=0> s_b;  // s.d. for coefficient
  real<lower=0> s_mu;// s.d. for estimated state
}
transformed parameters {
  vector[T] mu;    // estimations of state each observed time

  for(i in 1:T) { // mu = a + b * x for each time
    mu[i] = a[i] + b[i] * x[i];
  }
}
model {
  for(i in 2:T) {  // State transitioned as per the state equation
    a[i] ~ normal(a[i-1], s_a); // a_i = a_{i-1} + N(0,s_a)
    b[i] ~ normal(b[i-1], s_b); // b_i = b_{i-1} + N(0,s_b)
  }
  // Observations are obtained per the given observation equation
  for(i in 1:T){
    y[i] ~ normal(mu[i], s_mu);
  }
}
```