Development of Weather based Restaurant's Sales Prediction Models

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1. Why and What we do?

Why?

○ The situation of small business in Korea is poor

- 47% of new company has closed within 2 years (from Statistics Korea)
  (ref. less than 30% in USA and England)
- In 2016, 1.16M companies were opened but 0.73M ones were closed (from National Tax Services)
- 83% of small business persons are livelihood type, so that his/her success/failure impacts largely to the stability of society.

○ It is needed to help small business companies by supporting technologies for their revenues rising.

1. Why and What we do?

What?

○ analyze correlations between weather variables and sales of business

○ develop weather based sales prediction models

○ help company how to use the prediction models in its business

2. Analyzed data





○ target small business company

- a cold noodle restaurant with 20 seats
- located in residential area,
- other variables except weather status might not mainly impact its sales

○ daily sales of 5 menus & total sales amount

- cold noodle, steamed dumpling, cold/hot rice with acorn jelly, sliced rice-cake soup, spicy chicken soup
- daily sales of all working days in 2014~2016. (about 80% of whole days)

menu	Data duration
Cold noodle	3 years
Steamed dumpling	2 years & 8 months
Rice with acorn jelly	3 years
Sliced rice – cake soup	3 years
Spicy chicken soup	1 year & 3 months

2. Analyzed data

○ observed daily weather variables

-ASOS* data at Seoul Met. Office (from High Impact Weather Analysis System, HIWRC, NIMS)

-criteria to select weather variables

1) weather variables that might be highly correlated with sales

2) easily acquiring variables for operation

3) one typical variable only within correlated weather variables

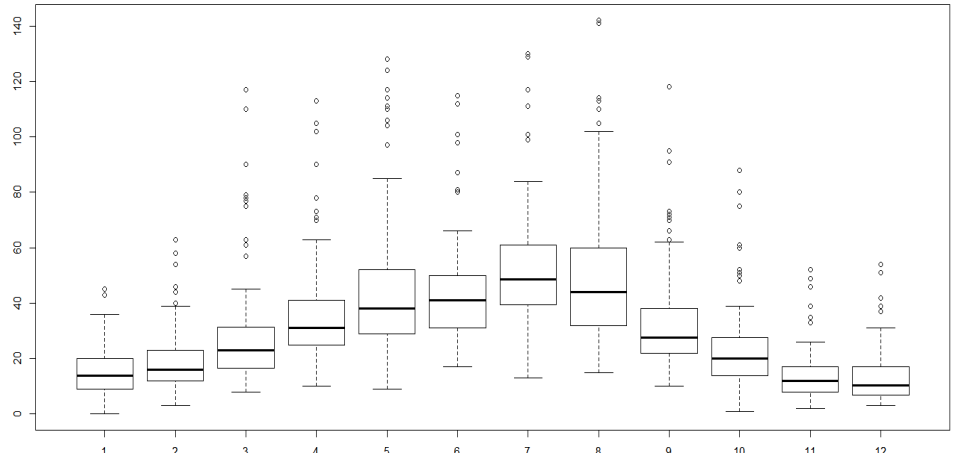
- 11 variables are selected in 63 ones

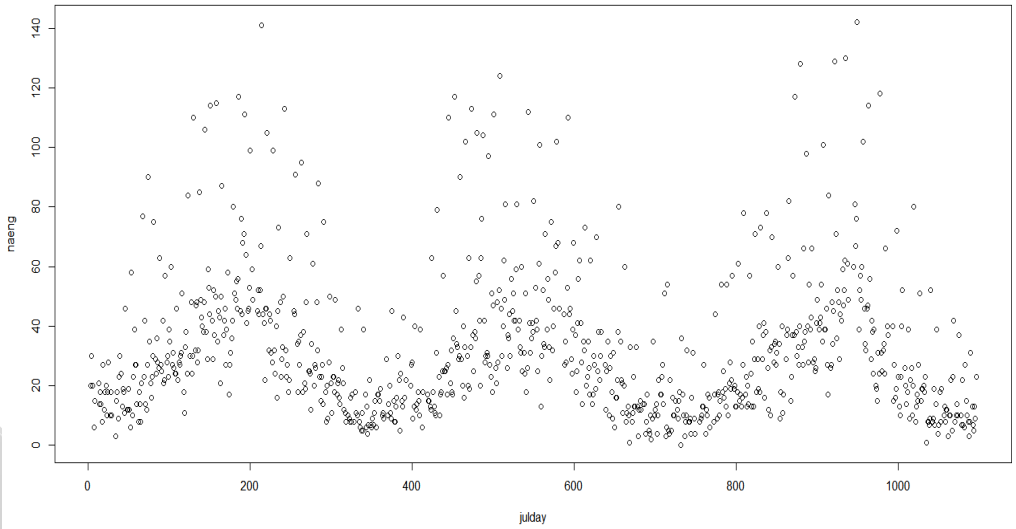
(mean temp, mean wind speed, mean relative humidity, rainfall amount, rainfall duration, max new snowfall, accumulated snowfall depth, mean total cloud amount, mean sea level pressure, total solar radiation, fog duration)

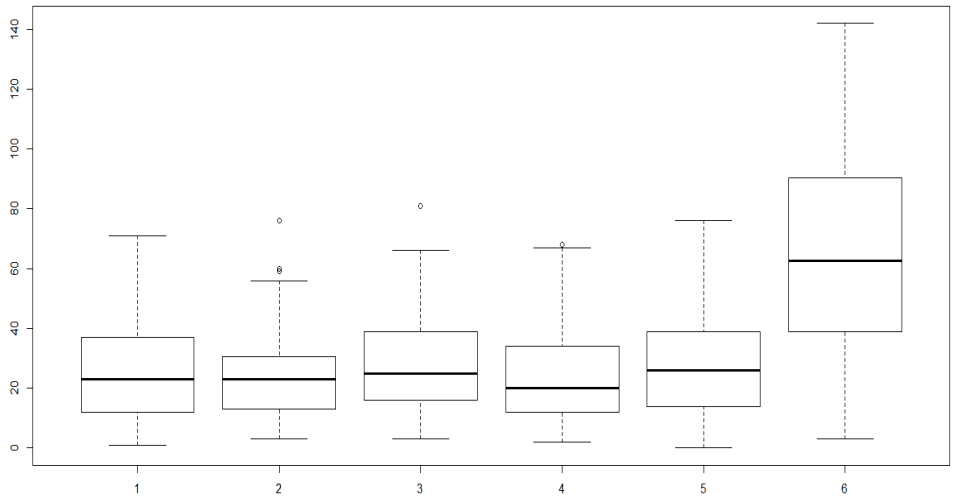
* ASOS : Automatic Synoptic Observation System

3. Analyzing daily sales of cold noodle

- Seasonal variation is large
  - large in summer and small in winter
  - might be highly correlated with temp.
- Daily fluctuation is also large
  - might be impacted by other daily fluctuating variables
- Sales on Saturday is 2.55 larger than that on weekdays
  - grouping Saturday's sales and weekdays one
- Yearly variation is small. – sales is stable.

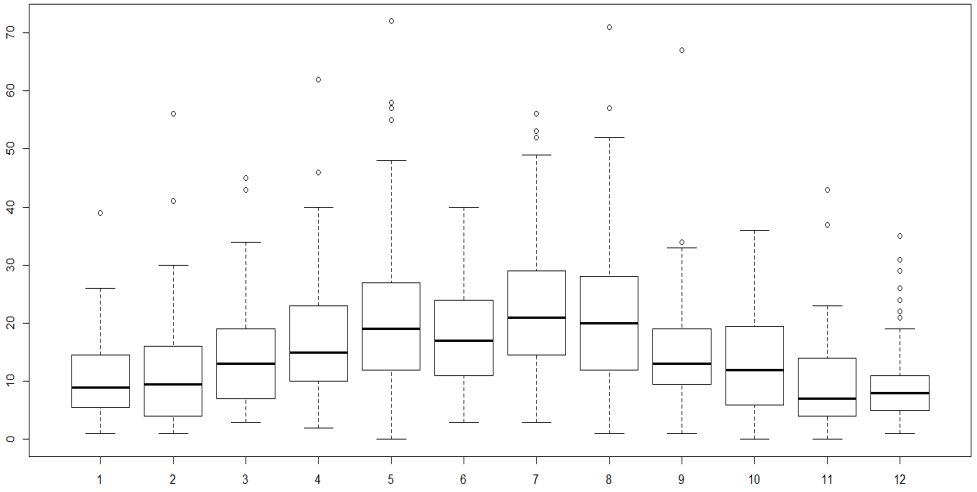


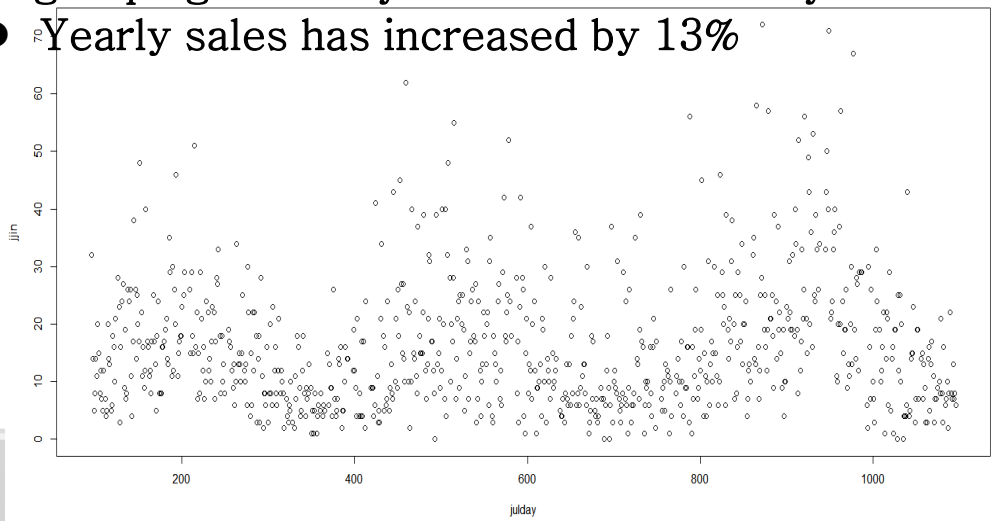


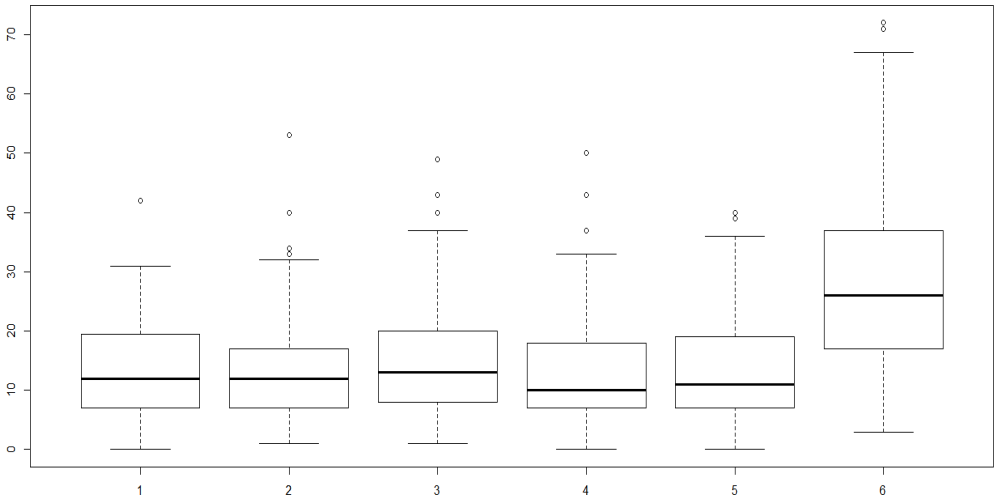


3. Analyzing daily sales of steamed dumpling

- The fluctuation pattern is similar to that of cold noodle
- Seasonal variation is large
  - large in summer and small in winter
  - might be highly correlated with temp.
- Daily fluctuation is also large
  - might be impacted by other daily fluctuating variables
- Sales on Saturday is 2.03 larger than that on weekdays
  - grouping Saturday's sales and weekdays one
- Yearly sales has increased by 13%

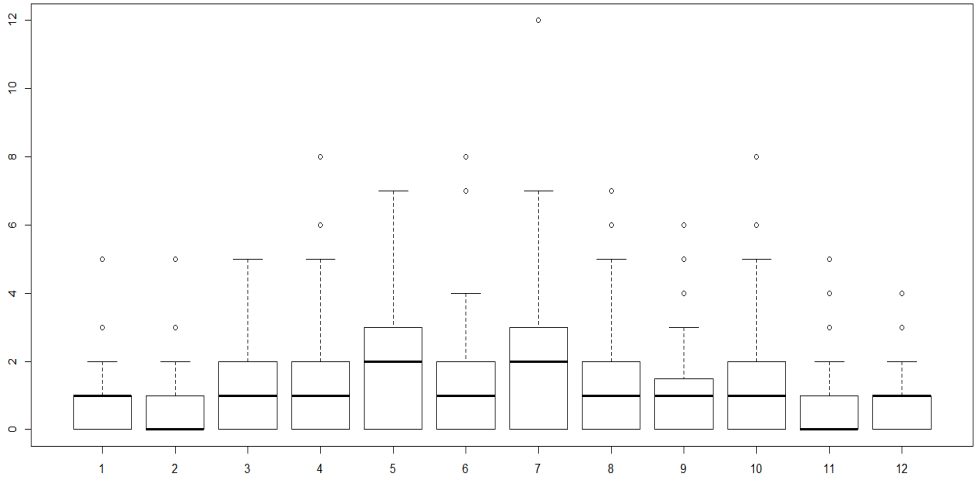


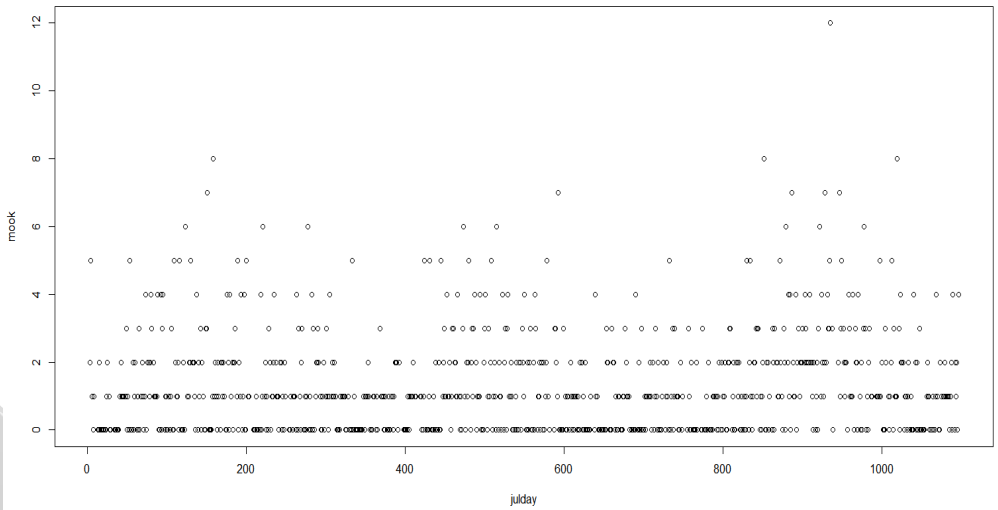


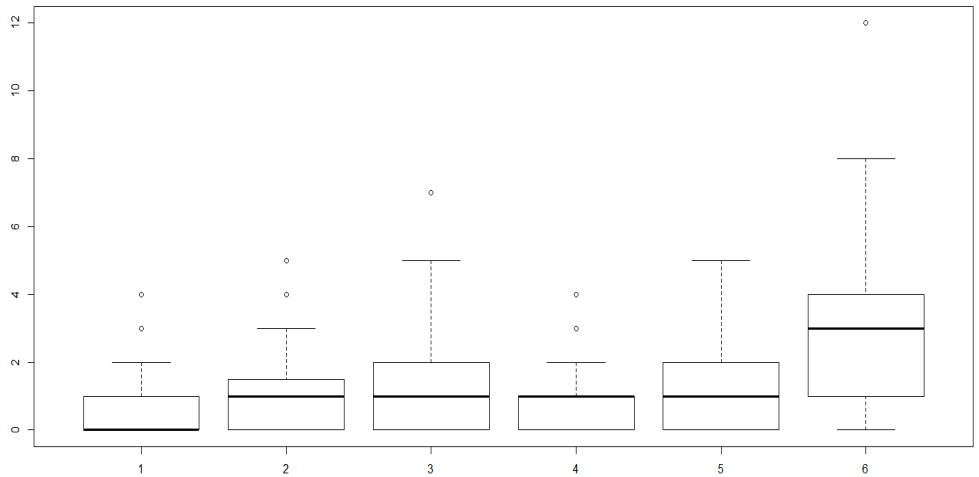


3. Analyzing daily sales of rice with acorn jelly

- daily mean sales is about 1 dish
- Seasonal variation is not clear even though relatively large in summer.
- Daily fluctuation is large
  - might be impacted by daily fluctuating variables
- Sales on Saturday is 3.06 larger than that on weekdays
  - grouping Saturday's sales and weekdays one
- Yearly sales has increased by 15%

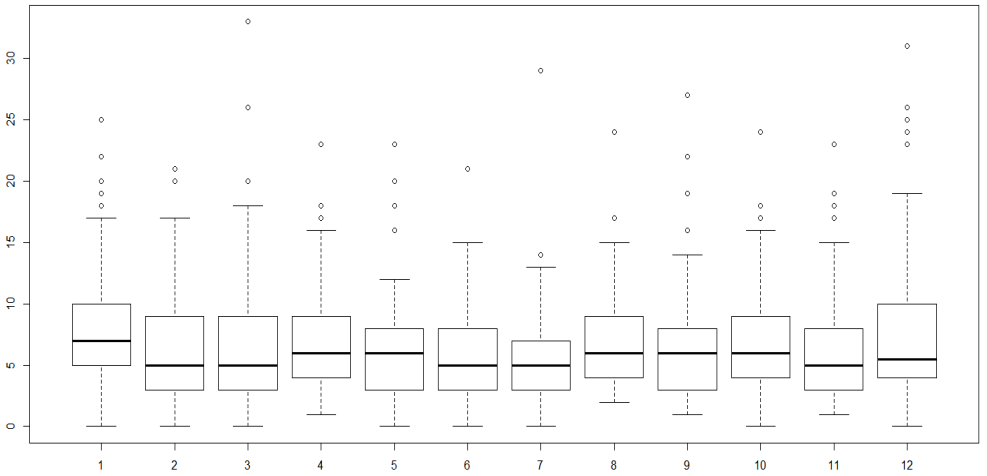


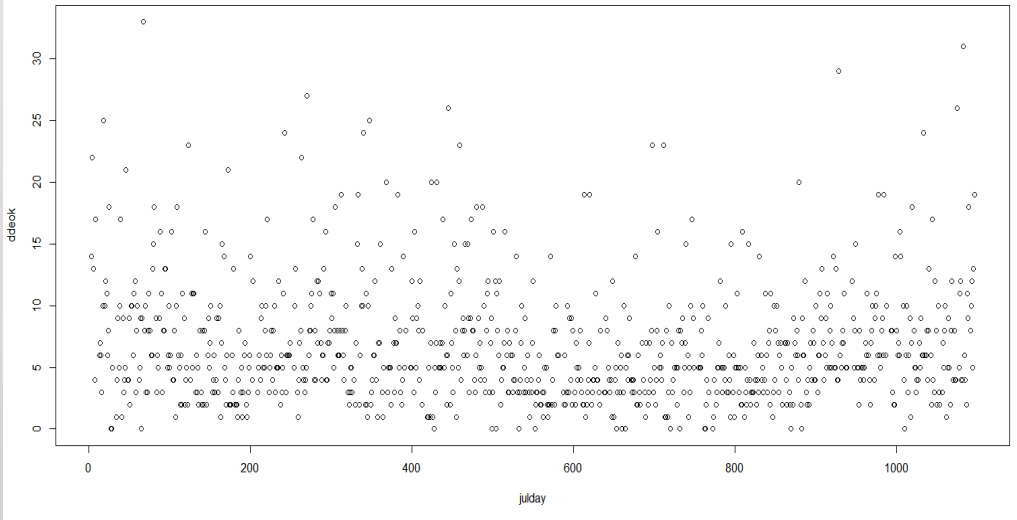


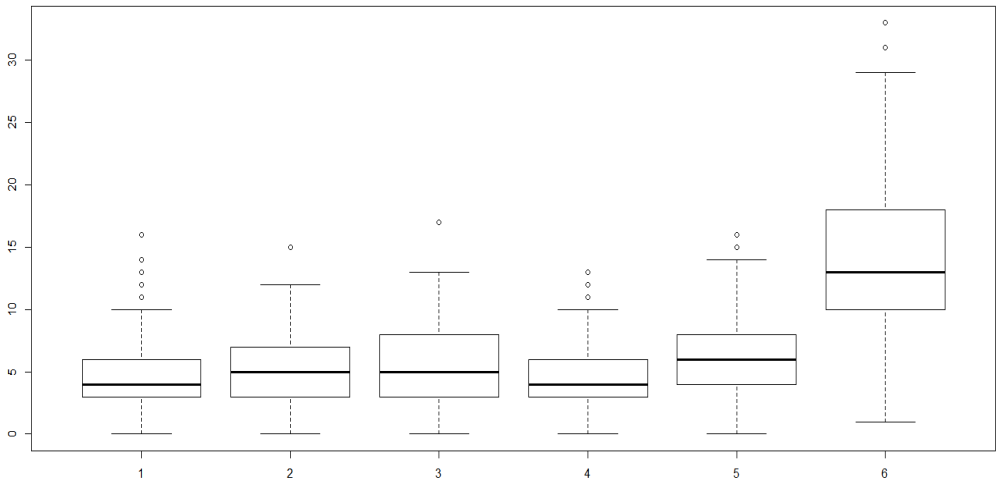


3. Analyzing daily sales of sliced rice-cake soup

- Seasonal variation is not clear
- Daily fluctuation is large
  - might be impacted by daily fluctuating variables
- Sales on Saturday is 2.07 larger than that on weekdays
  - grouping Saturday's sales and weekdays one
- Yearly sales has decreased by 5%

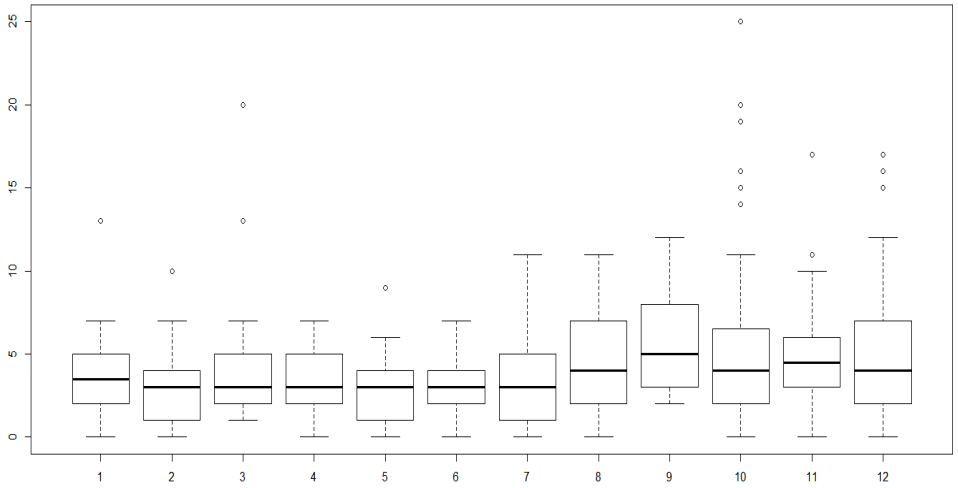


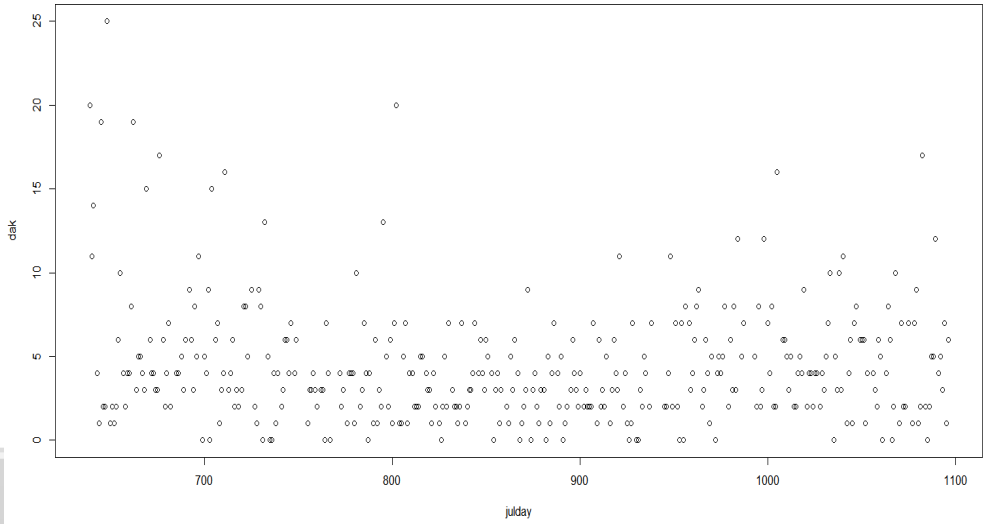


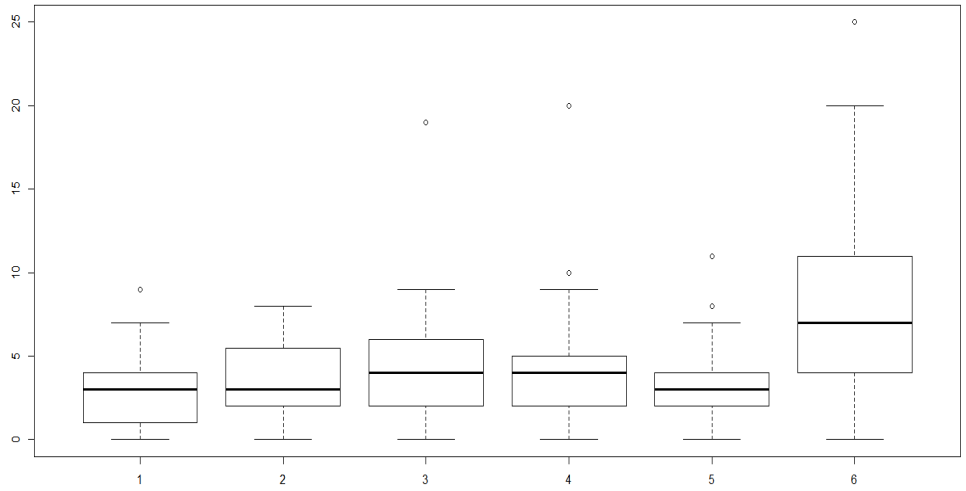


3. Analyzing daily sales of spicy chicken soup

- Sales duration is short, 1 year and 3 month.
- Seasonal variation is seen but not clear
- Daily fluctuation is large
  - might be impacted by daily fluctuating variables
- Sales on Saturday is 2.32 larger than that of weekdays
  - grouping Saturday's sales and weekdays one

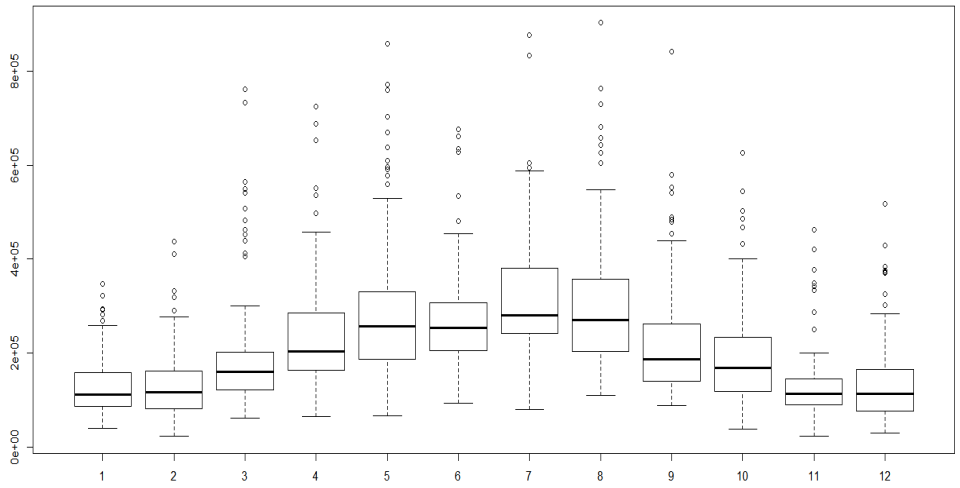


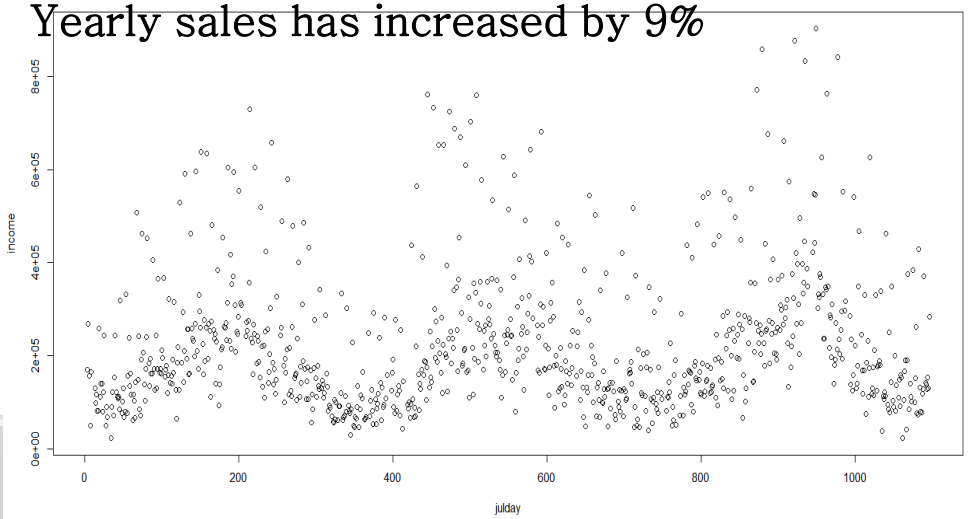


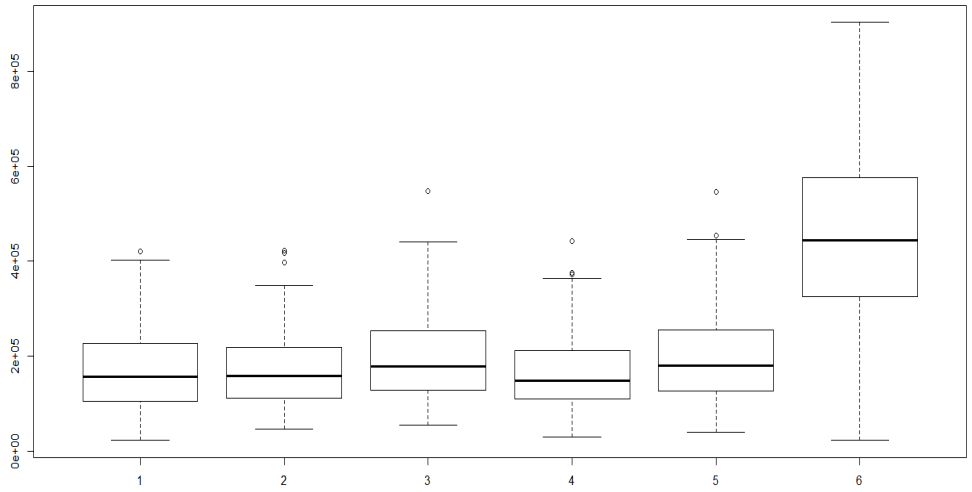


3. Analyzing daily sales of total sales amount

- The fluctuation pattern is similar to that of cold noodle
- Seasonal variation is large
  - large in summer and small in winter
  - might be highly correlated with temp.
- Daily fluctuation is also large
  - might be impacted by other daily fluctuating variables
- Sales on Saturday is 2.53 larger than that on weekdays
  - grouping Saturday's sales and weekdays one
- Yearly sales has increased by 9%

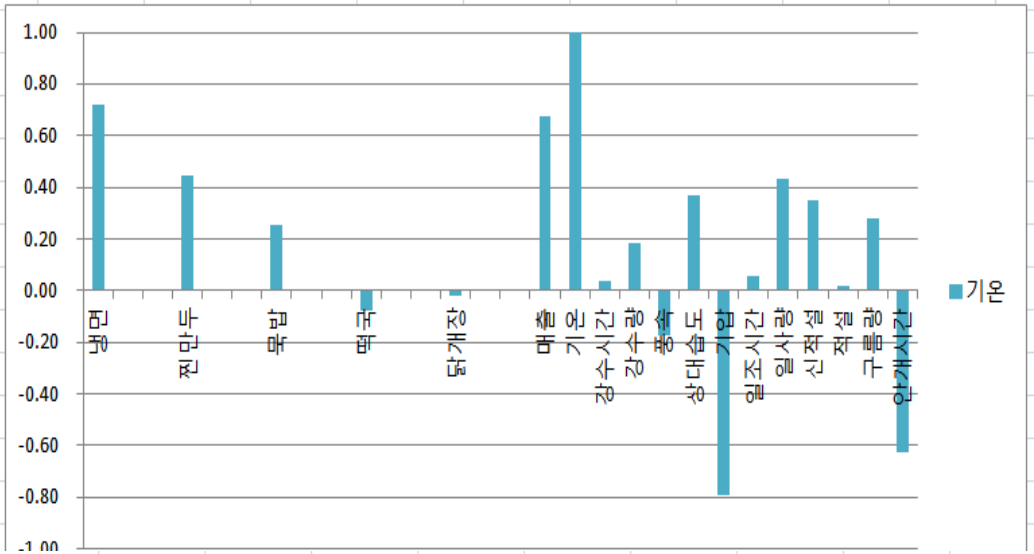


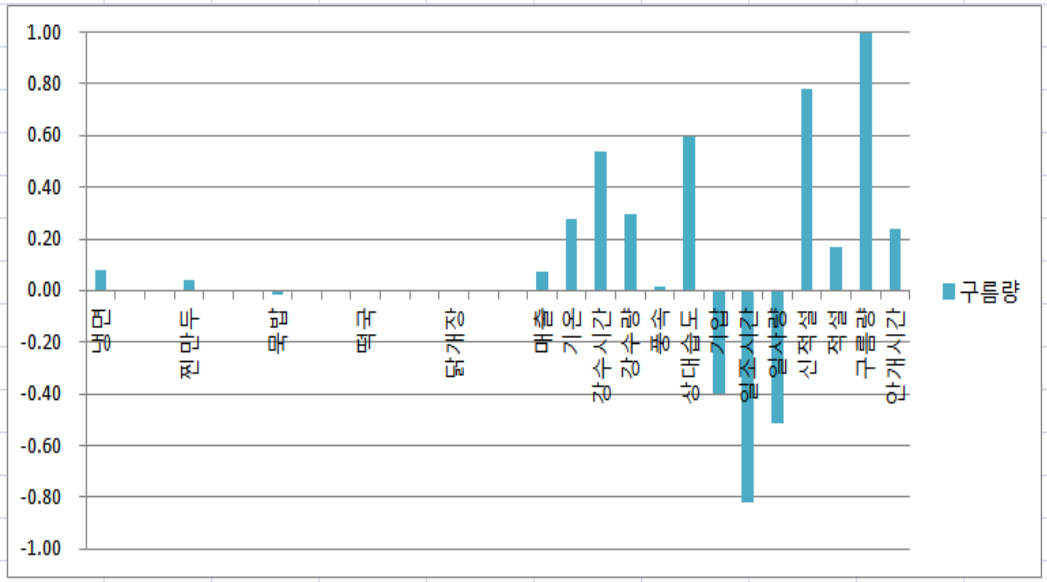


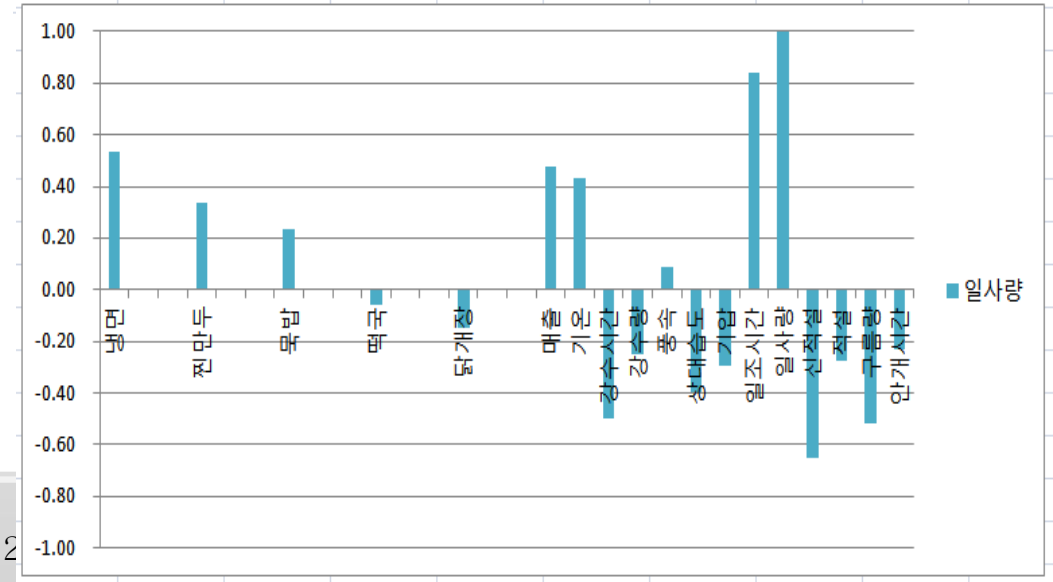


4. Analyzing correlations

- It might be grouped by (cold noodle, dumpling, rice with acorn jelly) group & (rice-cake soup, chicken soup) one
- Temp & solar radiation have
  - high positive correlation with (cold noodle, dumpling, rice with acorn jelly) group
  - low negative correlation with (rice-cake soup, chicken soup) group
- Total cloud amount has almost no correlation with sales of all

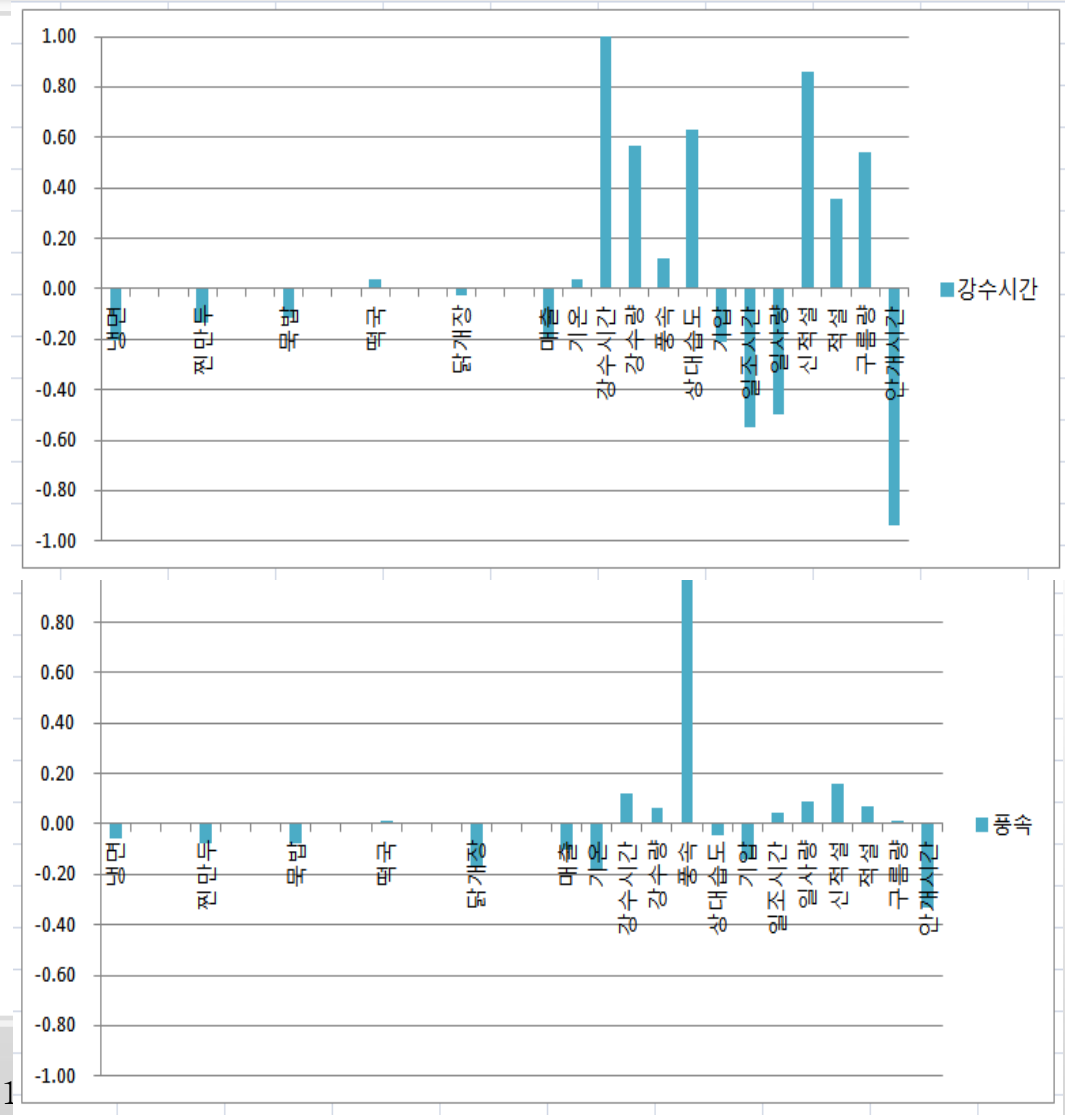






4. Analyzing correlations

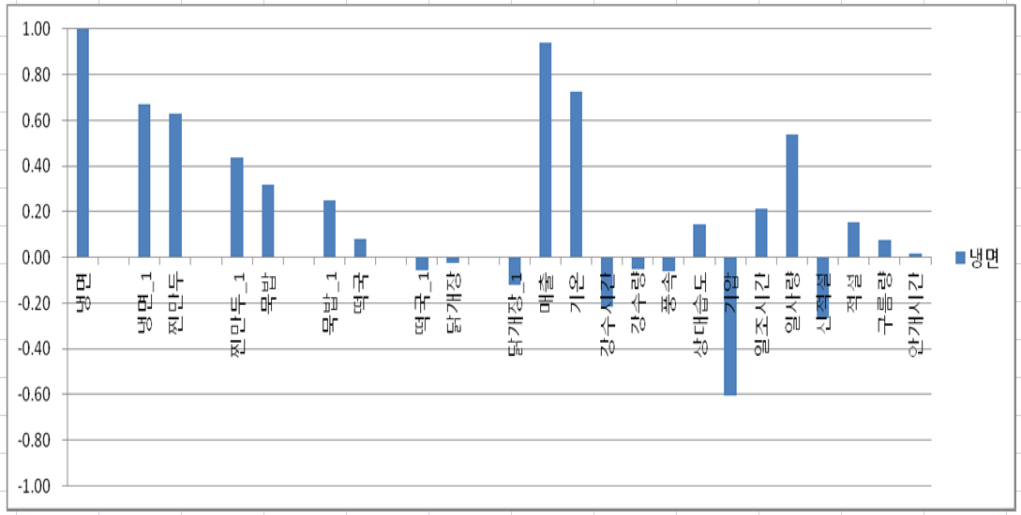
- Rainfall duration has
  - low negative correlation with (cold noodle, dumpling, rice with acorn jelly) group
  - almost no correlation with (rice-cake soup, chicken soup)
- Wind speed has low negative correlation with sales of all

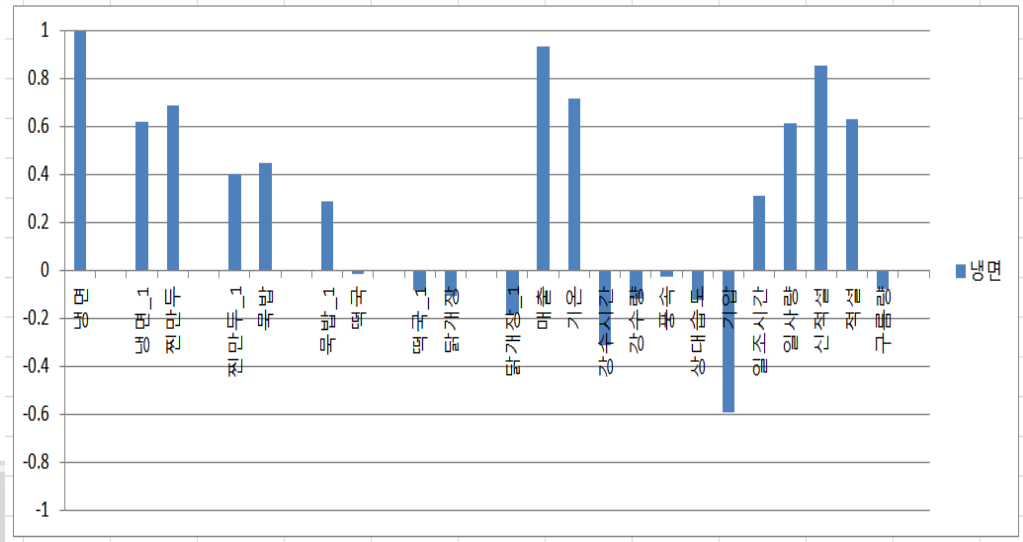


5. Developing sales prediction models of cold noodle

- Highly correlated variables with sales of weekdays and that of Saturday are similar.
  - previous day's/week's sales, dumpling sales, total sales amount, temp, solar radiation, pressure
- Develop multi regression models with R program
  - they have highly adjusted R^2 of 0.89 & 0.92

group	R^2	models
Whole period	0.81	sales = 1.14293 x temp + 0.30932 x solar radiation − 0.78347 x cloud amount + 2.3477 x day index
Weekdays	0.89	sales = 0.79174 x temp + 0.52651 x cloud amount + 0.89698 x solar radiation + 0.45736 x day index
Saturday	0.92	sales = 0.1571 x previous week's sales + 1.4724 x temp + 1.6488 x solar radiation + 2.3477 x day index

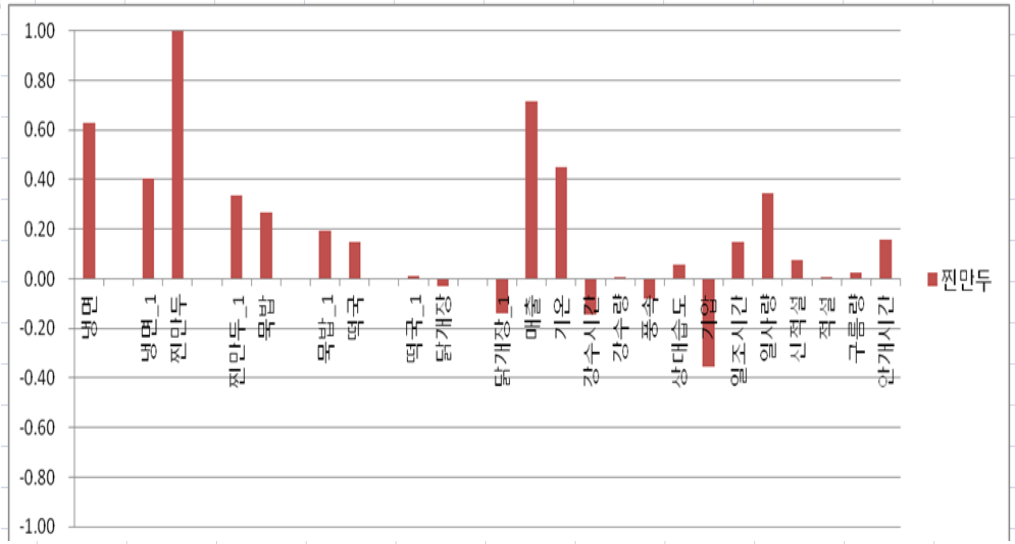


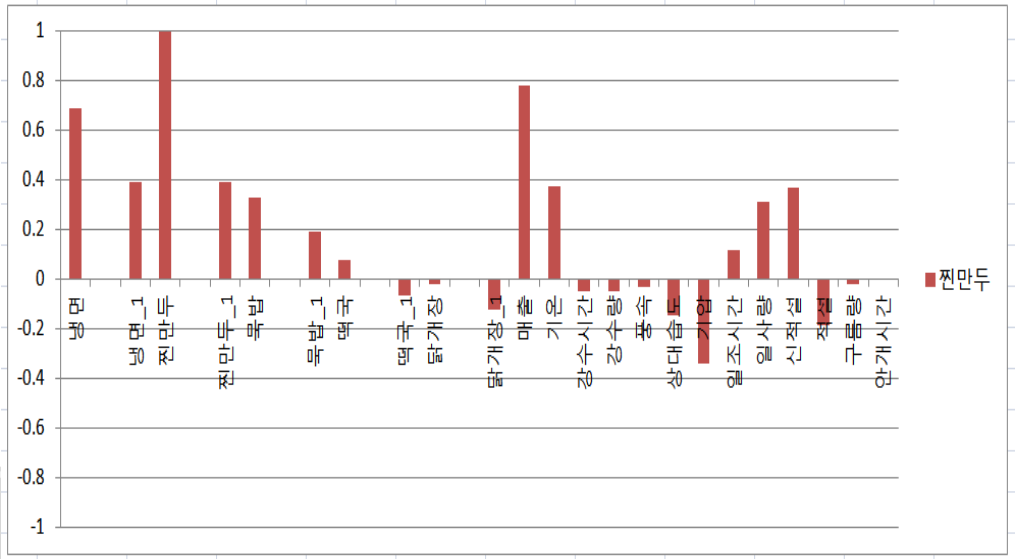


5. Developing sales prediction models of dumpling

- Highly correlated variables with sales of weekdays and that of Saturday are similar.
  - cold noodle sales, total sales amount, temp, solar radiation, pressure
- Develop multi regression models with R program
  - they have highly adjusted R^2 of 0.77 & 0.82

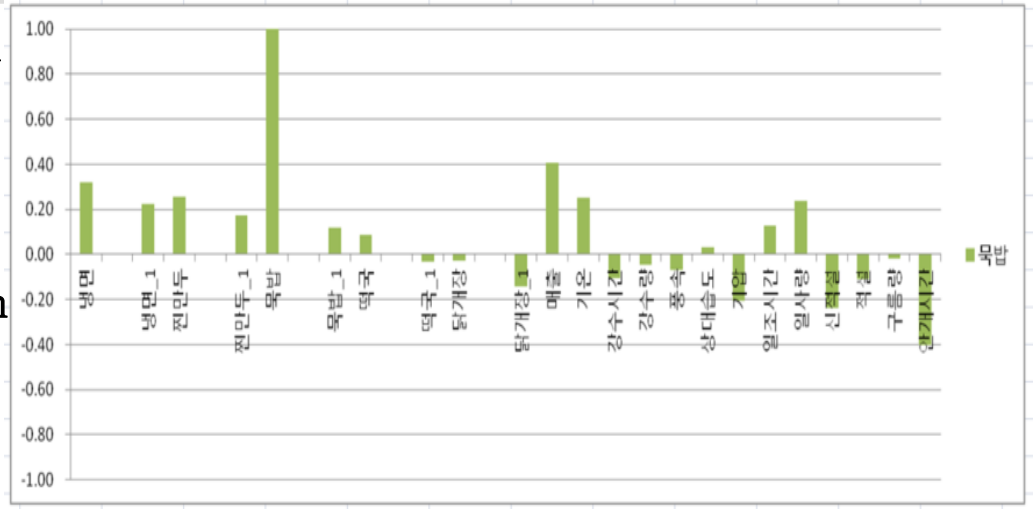
group	R^2	models
Whole period	0.73	sales = 0.57039 x cloud amount + 0.57958 x solar radiation + 1.75773 x day index
Weekdays	0.77	sales = 0.3196715 x temp + 0.0054094 x pressure + 0.2708529 x solar radiation
Saturday	0.82	sales = 0.33917 x previous week's sales + 1.25367 x cloud amount + 0.94757 x solar radiation

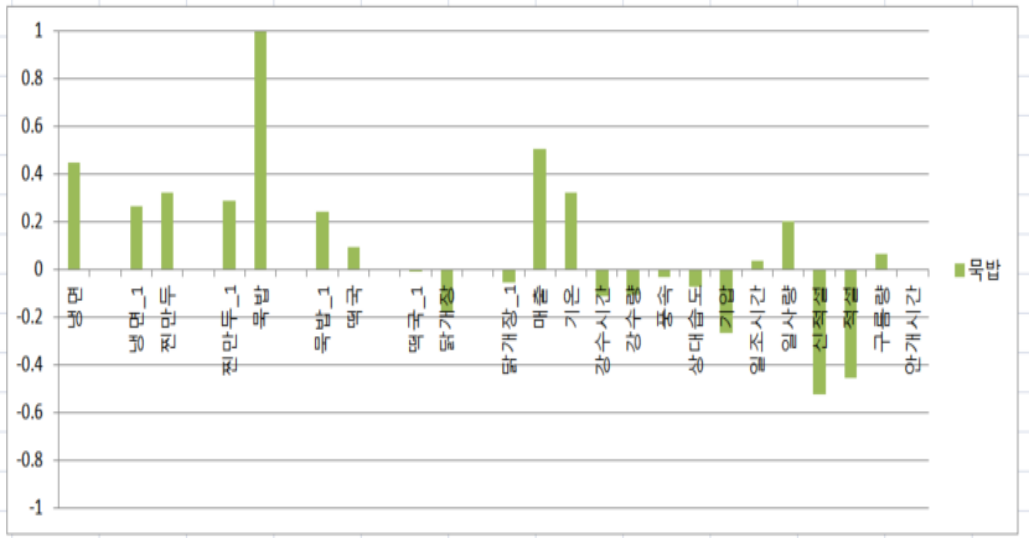




5. Developing sales prediction models of rice with acorn jelly

- Correlated variables with sales of weekdays and that of Saturday are similar.
  - no highly correlated variables.
  - temp. and fog duration are relatively highly correlated
- Develop multi regression models with R program
  - they have adjusted R^2 of 0.49 & 0.70



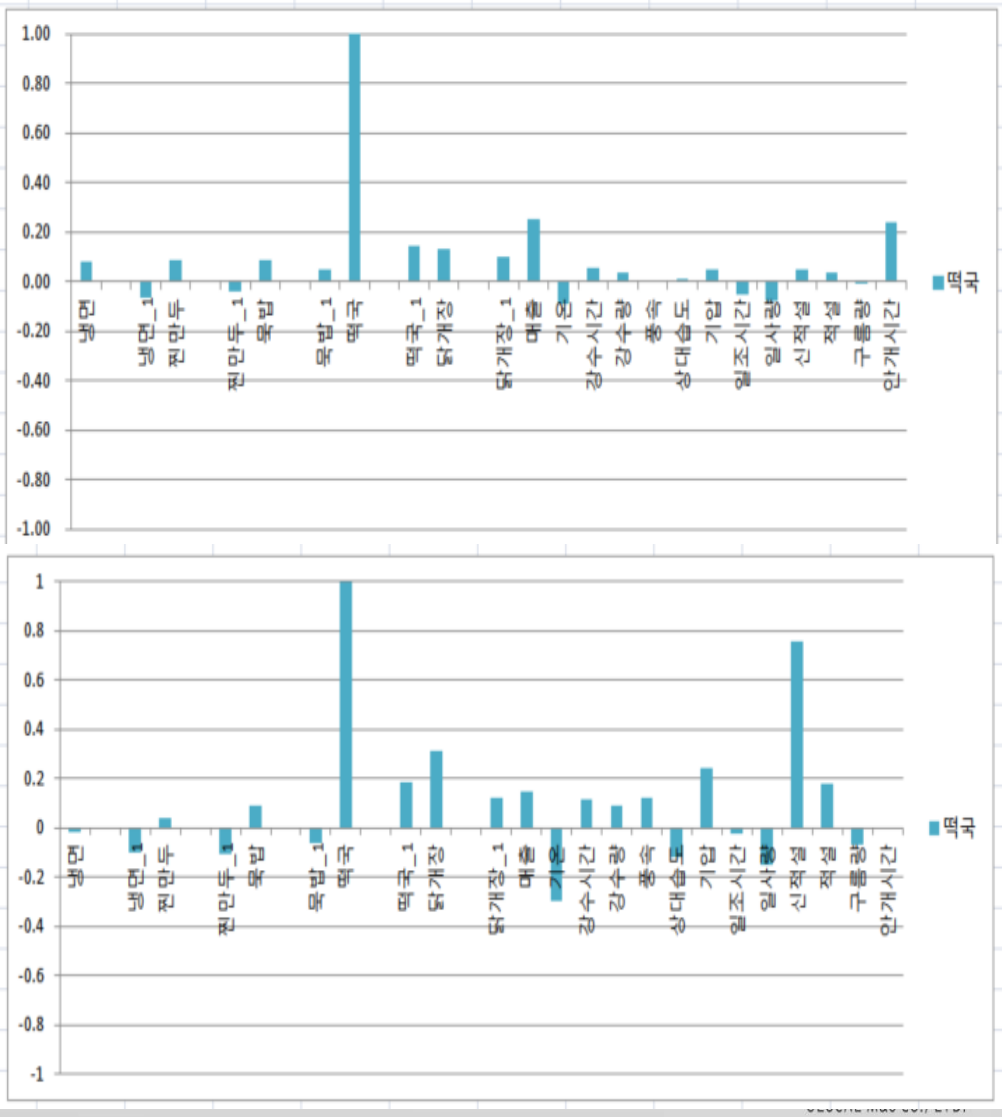


group	R^2	Models
Whole period	0.53	sales = 0.028578 x temp + 0.275532 x day index
Weekdays	0.49	sales = 0.59860 x temp + 0.033816 x solar radiation + 0.085233 x day index
Saturday	0.70	sales = 0.06771 x temp + 0.33997 x day index

5. Developing sales prediction models of rice-cake soup

- No correlated variables with sales of weekdays and that of Saturday
- Develop multi regression models with R program
  - they have adjusted R^2 of 0.73 & 0.85

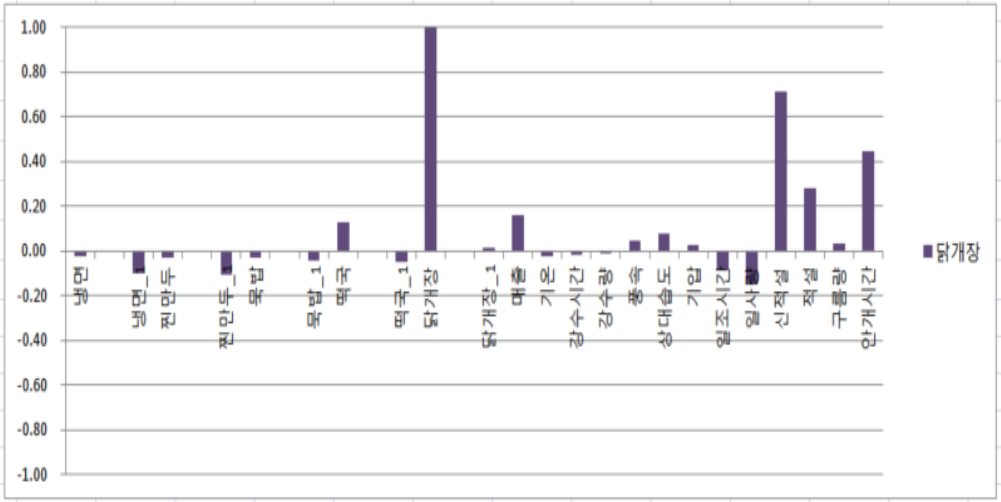
group	R^2	Models
Whole period	0.73	sales = 0.54717 x wind speed + 1.50697 x day index
Weekdays	0.73	sales = 0.72046 x wind speed + 0.17108 x cloud amount + 0.06314 x solar radiation + 0.57422 x day index
Saturday	0.85	sales = −0.39412 x cloud amount − 0.24779 x solar radiation + 3.15630 x day index

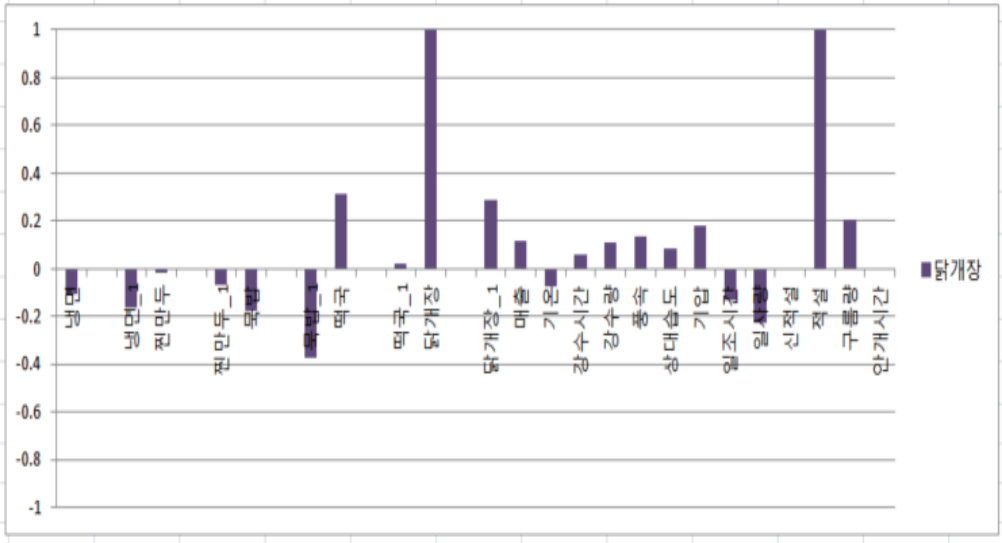


5. Developing sales prediction models of chicken soup

- No correlated variables with sales of weekdays and that of Saturday
- Develop multi regression models with R program
  - they have adjusted R^2 of 0.71 & 0.77

group	R^2	Models
Whole period	0.66	sales = 0.0027308 x pressure − 0.0854114 x solar radiation + 0.7385845 x day index
Weekdays	0.71	sales = 0.0040272 x pressure − 0.0509985 x solar radiation
Saturday	0.77	sales = 0.3526 x temp + 1.719 x wind speed + 0.4438 x pressure − 0.2206 x solar radiation − 74.9577 x day index





6. summary

○ The seasonal / daily fluctuation patterns of sales of menus are different from one another

- Cold noodle and steamed dumpling have highly seasonal variation. They impacted by temp.
- All menu has large daily fluctuation, so that all might be impacted by daily fluctuating variables

○ It is grouped by weekdays sales and Saturday one

○ Sales prediction models were developed by multi regression model of R program

- they have highly adjusted R^2 of 0.70 ~ 0.92. except that of weekdays' sales models, 0.49 (it is usually accepted if R^2 > 0.65 (Kim, E.- J., et al, 2016))

○ The prediction models could be used easily because all input variables could be acquired from KMA's daily forecast.

○ issues happened to apply this scheme to other companies

1) rare digitalized data, 2) backward in opening the data, 3) somewhat big burden for small companies to do the project, 4) etc.

Thanks !

Q & A