DYNAMIC PRICING ALGORITHM

Outline

- Introduction & Background
- Related Work
- Data Collection
- Our proposed method
- Result & conclusion

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Introduction & Background

- Drivers often spend much time in parking and could have frustrated experiences.
- Related topics (M. Tsai & C. Chu, 2012) can be categorized in 3 aspects:
  - Parking search
    - (W. Lam et al, 2006) considers temporal and spatial interactions between traffic and parking congestion.
  - Parking Reservation
    - (Teodorovic & Lucic, 2006) decides to accept/reject parking request by inventory control and revenue management.
  - Parking Pricing
    - (D’ Acierno et al., 2006) works on destination parking and origin-destination parking

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Related Work

- (D’ Acierno et al., 2006)
  - Destination parking policy
    - Only consider the parking lot price
  - Origin-destination parking policy
    - Consider about the traffic situation like highways, rail systems
    - The objection function depends on the society global cost, including
      - Operational net costs of transit system
      - Local administration parking revenue
      - User cost (monetary and temporal)
      - Extra cost like air/noise pollution
  - It is purely theoretical and only based on mathematical assumptions

Related Work

- (Tian et al., 2018)
  - Reservation-based revenue management
  - Objective function is to maximize the total profit gain given reservation time
  - Its demand function is based on price, which can be linear or exponential
  - Model parking request through Poisson process
    - Accept request as long as there is available spots
  - It is a purely mathematical model based on mathematical assumptions

Motivation

- Revenue , utilization, convenient
- Real parking dataset from Seattle
- Curve fitting
- Priced-based and time-based demand function

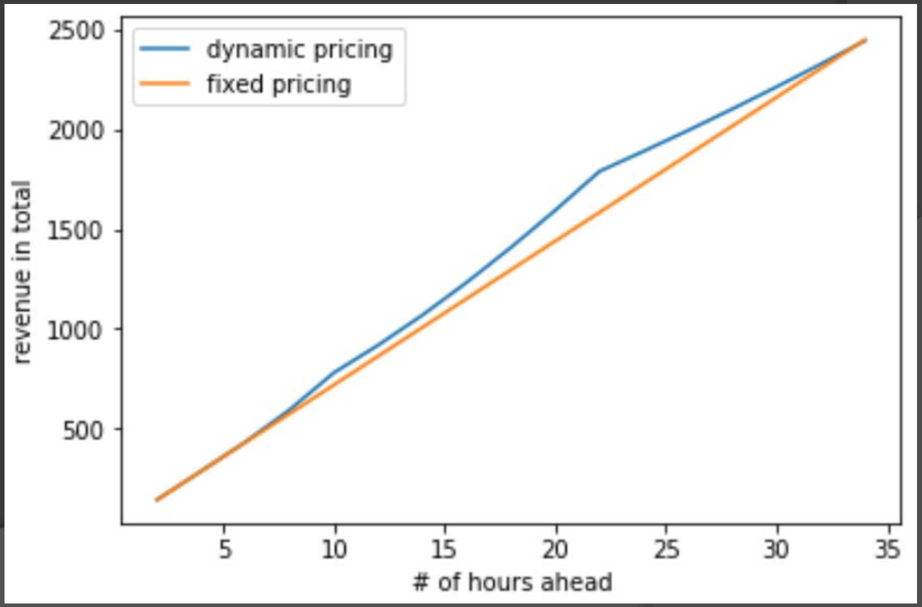
Reservation-based Model

- Tian, Q., Yang, L., Wang, C., & Huang, H. J. (2018). Dynamic pricing for reservation-based parking system: A revenue management method. *Transport Policy*, *71*, 36-44.

$$V(X^t, t) = \max_{P^t}\{Q_0 V(X^t, t-\Delta t) + Q_1[\sum_{i=u}^{v} P_i^t + V(X^t - e_{[u,v]}, t-\Delta t)]\}$$

$$Q_1 = \Lambda(X^t, P^t)\Delta t$$

$$\Lambda(X^t, P^t) = \sum_{u=1}^{N} \sum_{v=u}^{min\{N,u+n\}} \lambda_{[u,v]}^t (X^t, P^t)$$



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Data Collection

- 62,577,106 records from 2012 – 2017
- 5.21 GB

Table 1: Data Format for On-street Parking Data in Seattle

Name	Type	Description
TransactionId	integer	Unique identifier number for a record
TransactionDateTime	timestamp	Date and time of the record
TransactionDate	timestamp	Record date
timeStart	string	Parking starting time
timeExpired	string	Parking ending time
Duration_mins	integer	Length of parking in minutes
Amount	double	Payment amount in dollars
PaymentMean	string	Payment in credit card, coin, phone, etc.
MeterCode	integer	Pay station identifier
ElementKey	integer	Street segment identifier

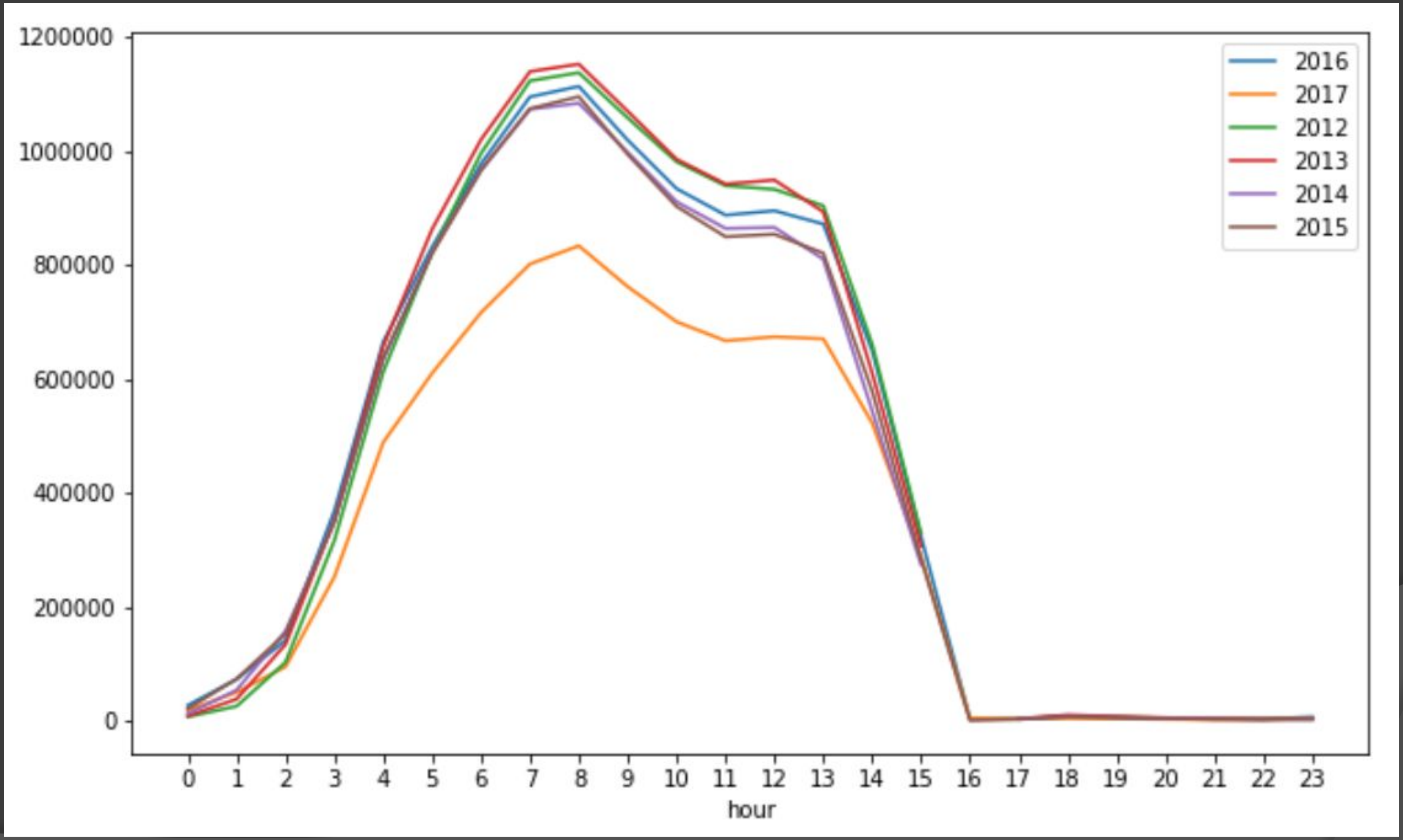
Data Collection

- Define parking demand as number of parking requests within a time range

	A	B	C	D	E	F	G	H	I	J
1	TransactionId	TransactionDateTime	TransactionDate	timeStart	timeExpired	Duration_mins	Amount	PaymentMean	MeterCode	ElementKey
2	13968676	2012-01-01T22:07:59Z	1/1/2012	22:07	23:22	75	2.5	COINS	10015002	25706
3	13968818	2012-01-01T23:30:59Z	1/1/2012	23:30	1:30	120	4	CREDIT CARD	10023002	25710
4	13968824	2012-01-01T22:45:59Z	1/1/2012	22:45	0:45	120	4	CREDIT CARD	10096002	9357
5	13968660	2012-01-01T22:51:59Z	1/1/2012	22:51	0:51	120	4	CREDIT CARD	10210002	25718
6	13968821	2012-01-01T23:28:59Z	1/1/2012	23:28	0:38	70	2.25	CREDIT CARD	10223002	2789
7	13968820	2012-01-01T23:50:59Z	1/1/2012	23:50	1:50	120	3	CREDIT CARD	12093002	39393

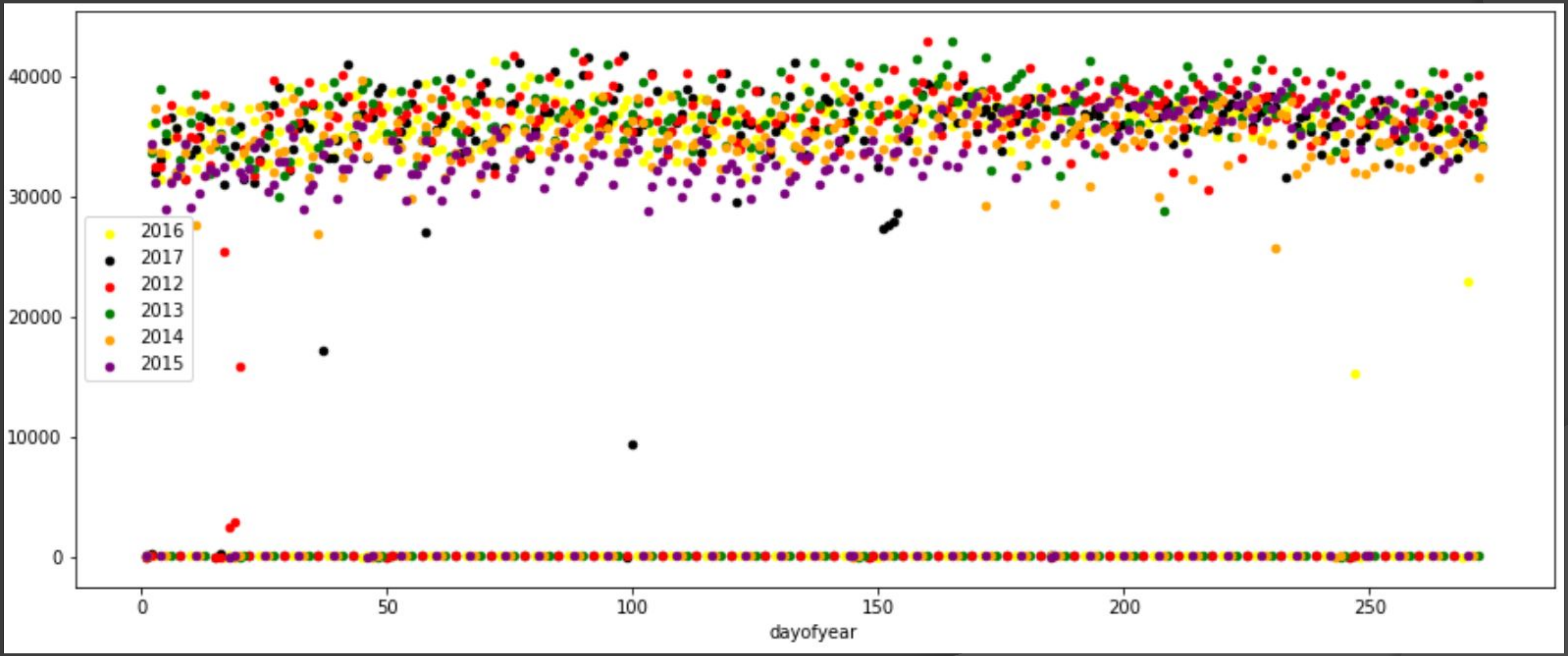
Data Collection

- Hourly Parking Demand



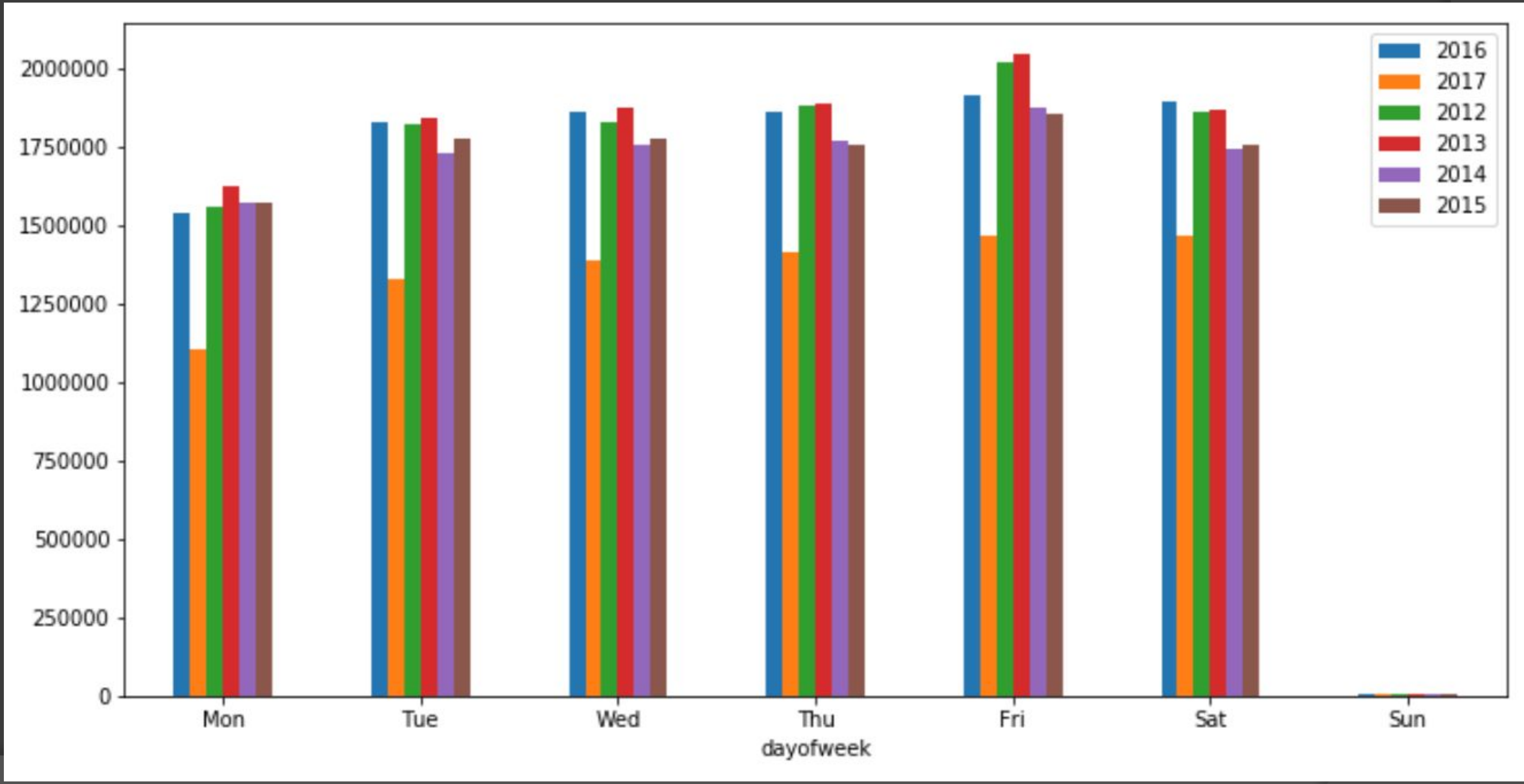
Data Collection

- Daily Parking Demand



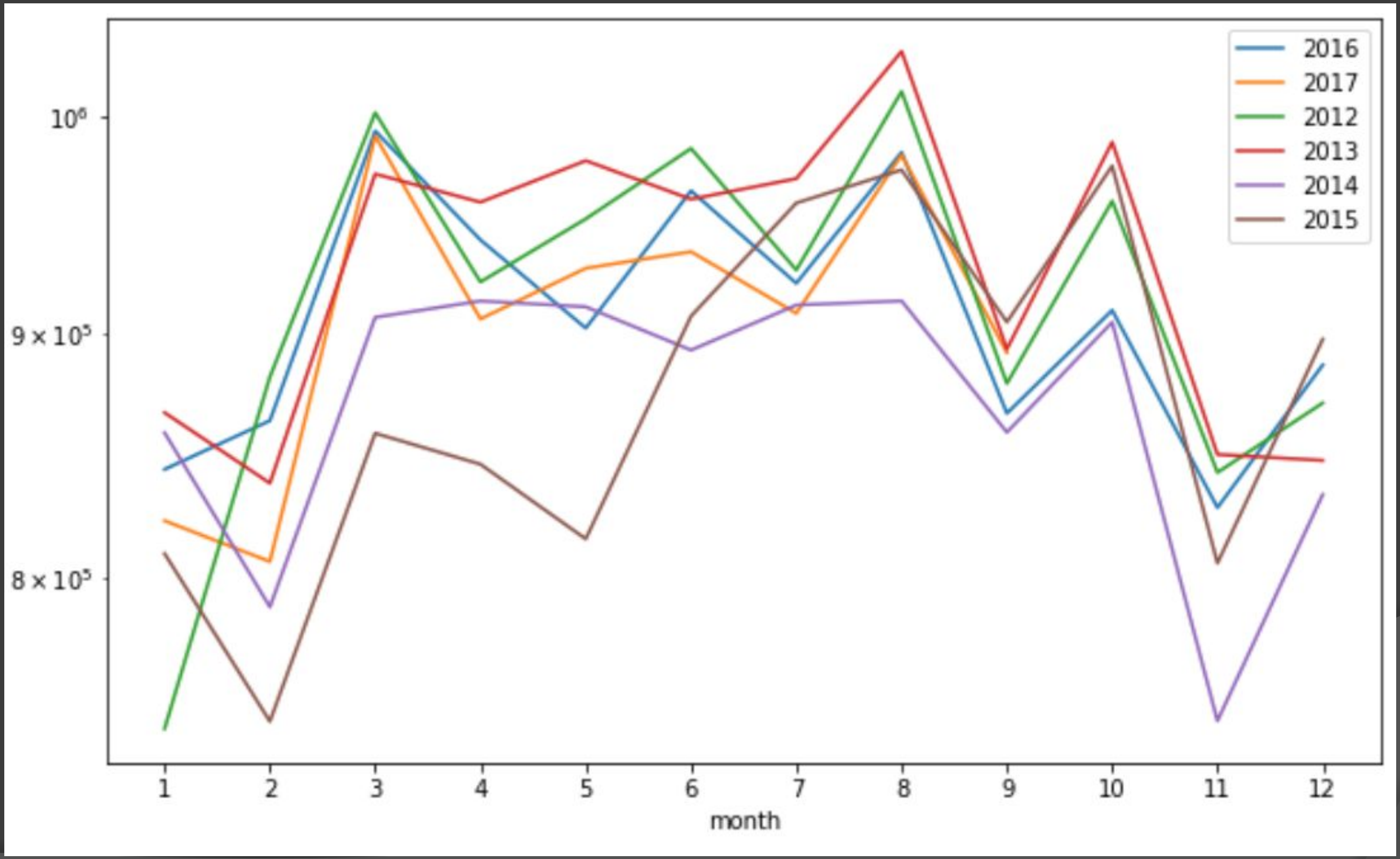
Data Collection

- Weekly (free on Sunday at Seattle)



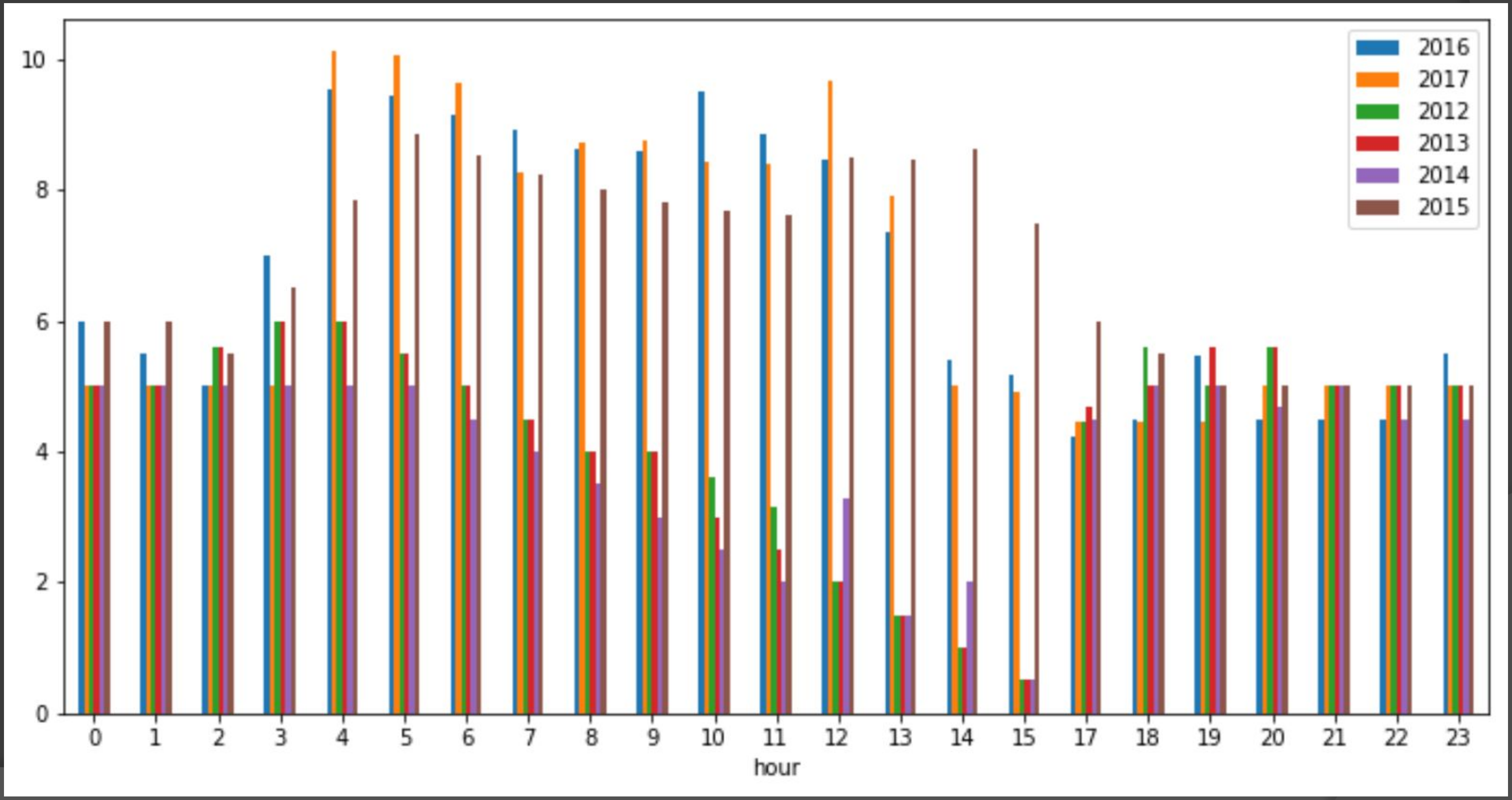
Data Collection

- Monthly Parking Demand

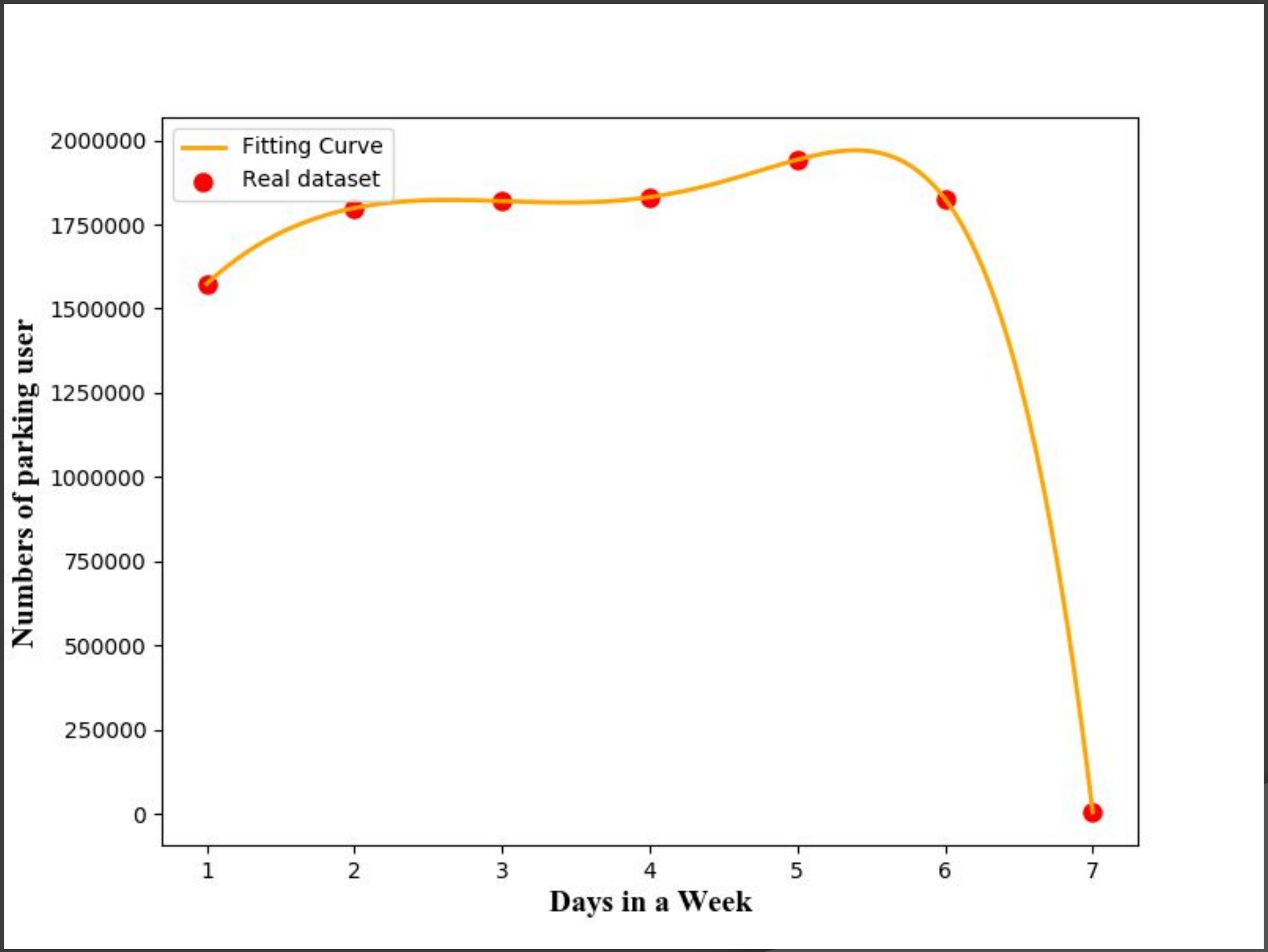


Data Collection

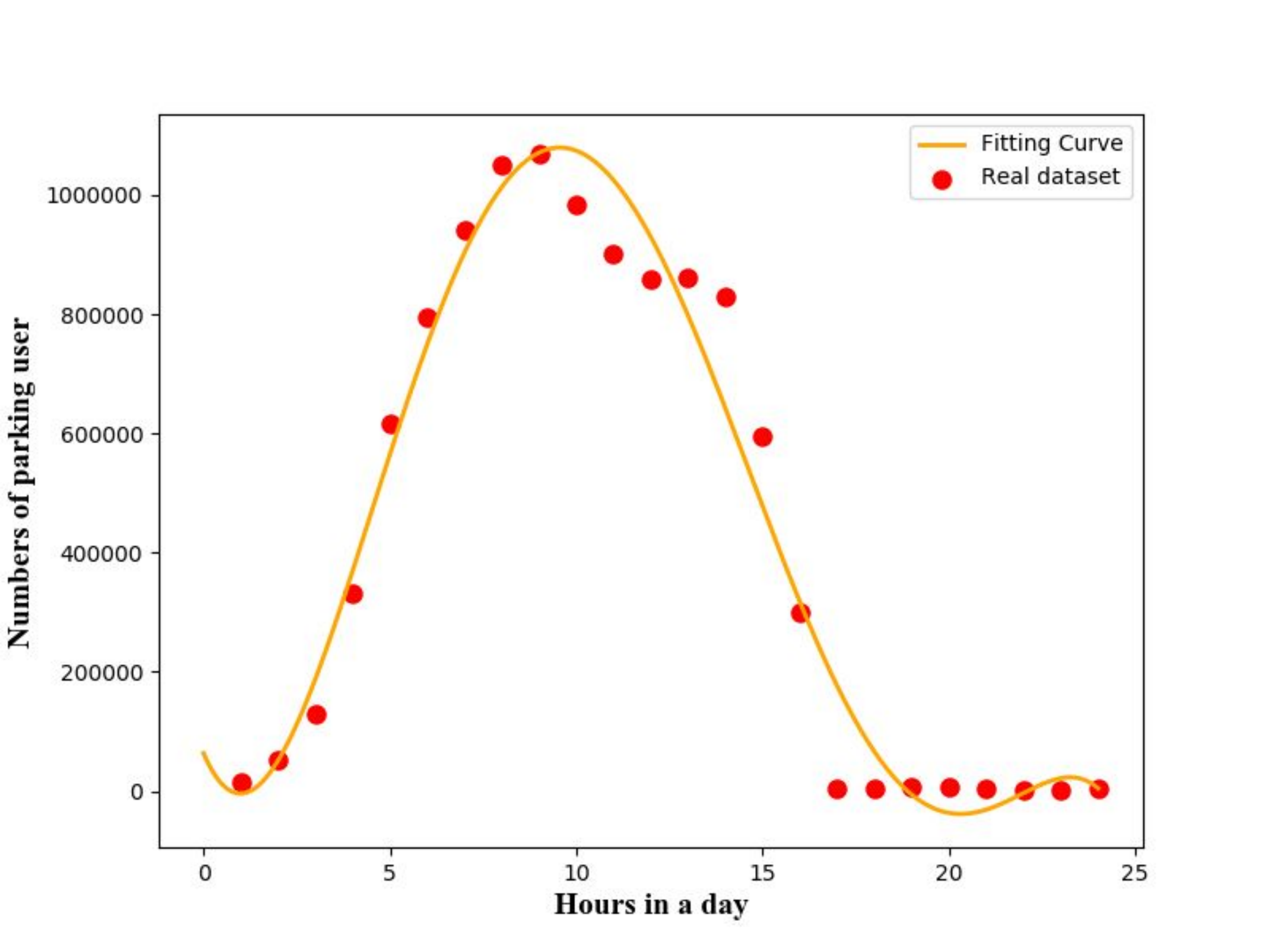
- Length of Stay



Data fitting



Data fitting



Data fitting: time-based demand function

- Data fitting for Months Dm(t) (coefficient)
- Data fitting for Weeks Dw(t) (coefficient)
- Data fitting for Hours Dh(t)
- Final time-based demand function

$$D(t)=Dw(t)*\ Dw(t)*\ Dh(t)$$

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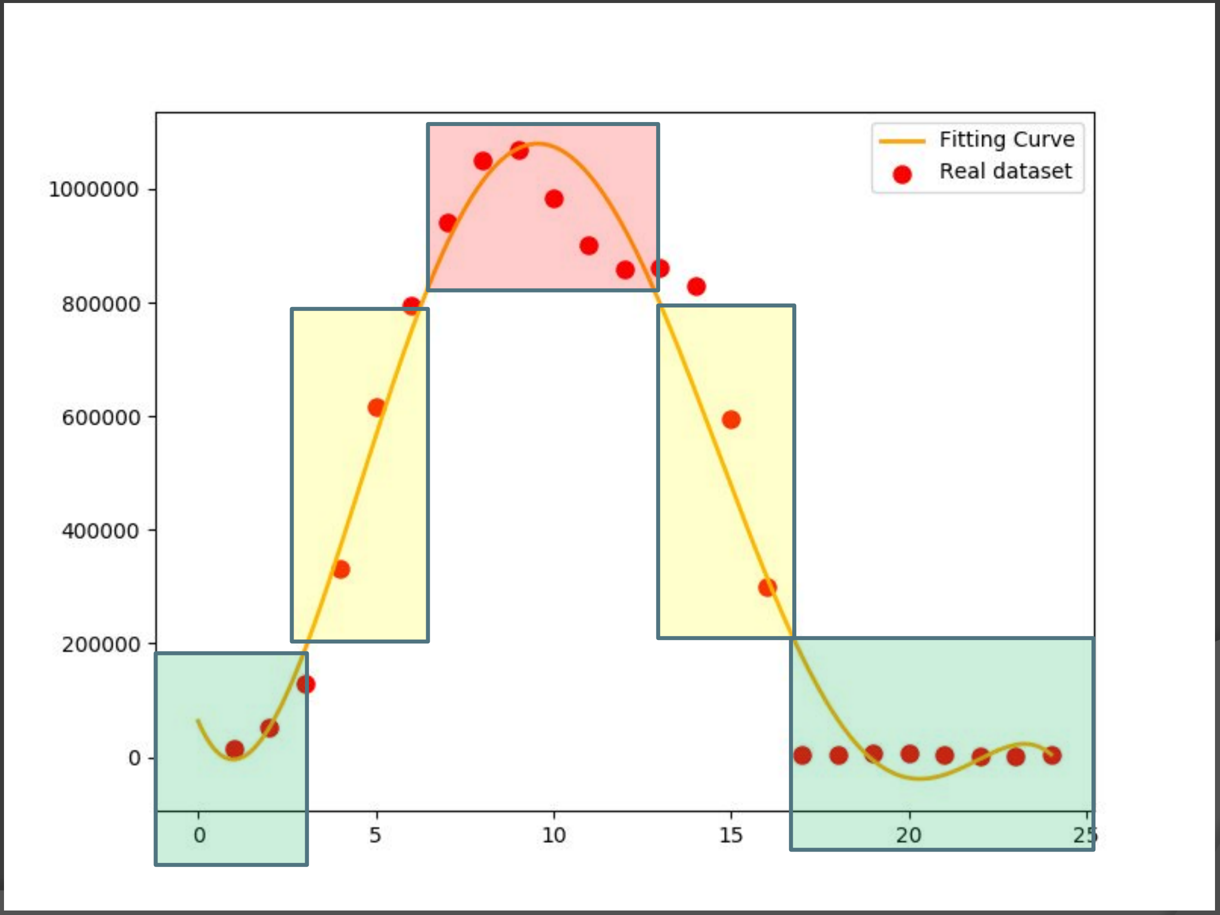
Multi-modules based method

- The whole day is divided into several parts

Peak Time

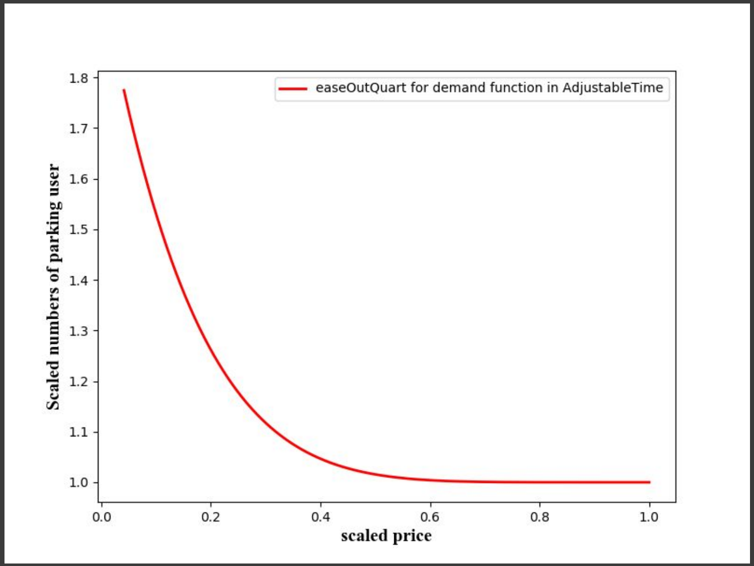
Adjustable Time

Free Time



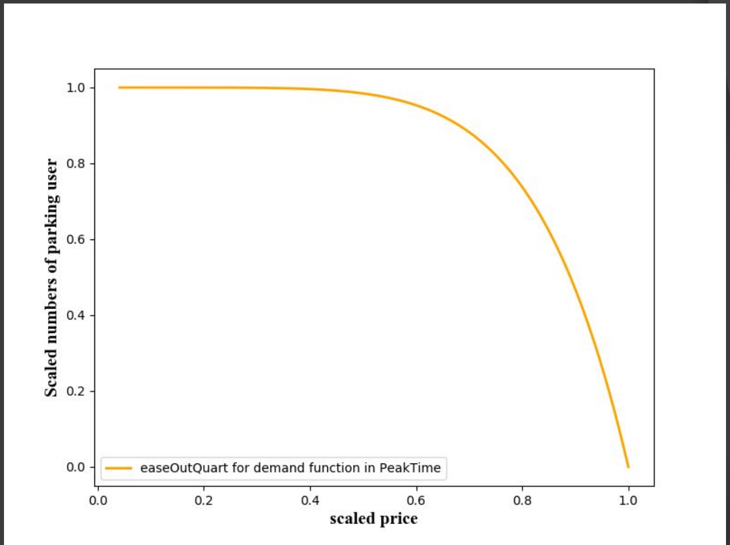
Multi-modules based method

- Adjustable time:



Decrease the price
Increase the user

Peak time:



Increase the price
Decrease the user

Final demand function

- Time-based demand function

$$D_t(t) = a * t^6 + b * t^5 + c * t^4 + d * t^3 + e * t^2 + f * t^1 + g$$

- Price based demand function

Peak Time

$$D_p(p) = C * \left(\left(1 - \frac{p}{Max\{P\}} \right)^K - 1 \right) + D$$

Adjustable Time

$$D_p(p) = -C * \left(\left(\frac{p}{Max\{P\}} \right)^K - 1 \right) + D$$

Final demand function

- Modified by the price based demand function

$$TS - \Delta \leq D_p(p) * D_t(t) \leq TS + \Delta$$

$$Max\left\{\int_t^T D_p(p) * D_t(t)\, d_t\right\}$$

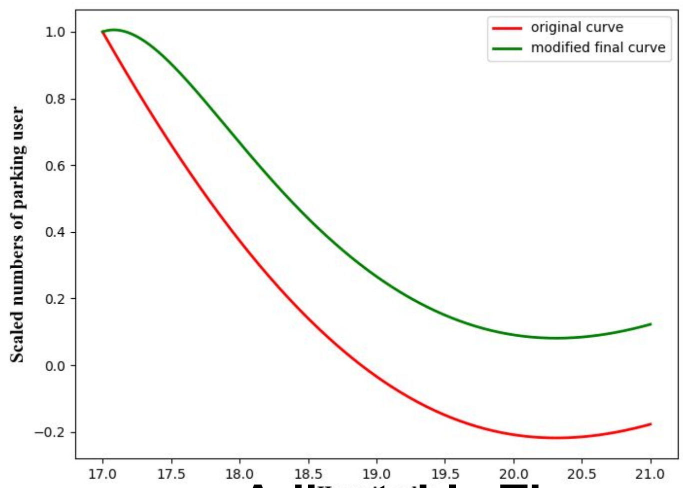
Peak Time

$$TS \leq D_p(p) * D_t(t)$$

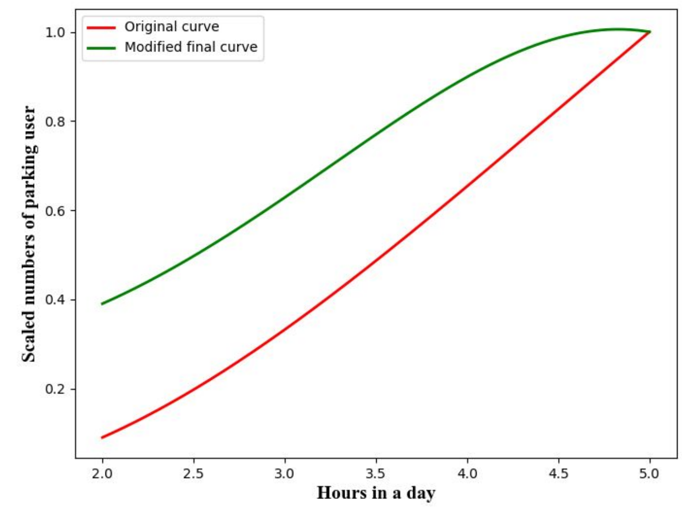
$$Max\left\{\int_t^T D_p(p) * D_t(t)\, d_t\right\}$$

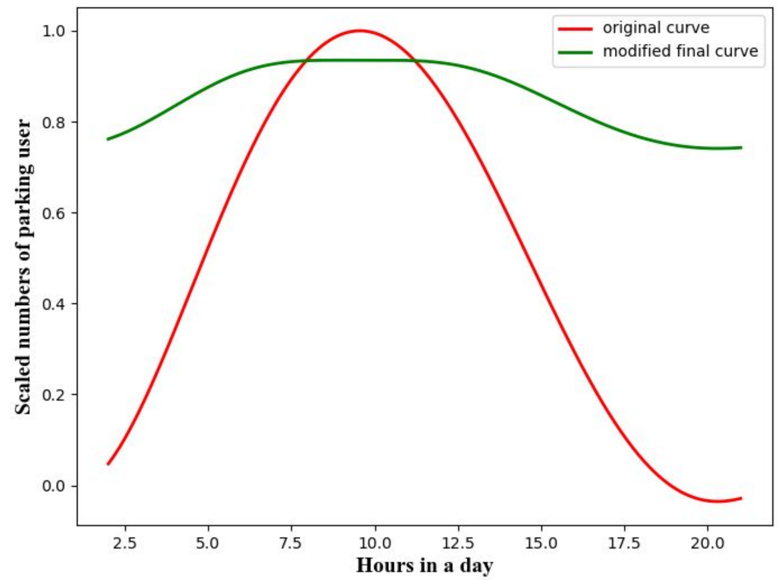
Adjustable Time

Final demand function



Adjustable Time





Peak Time

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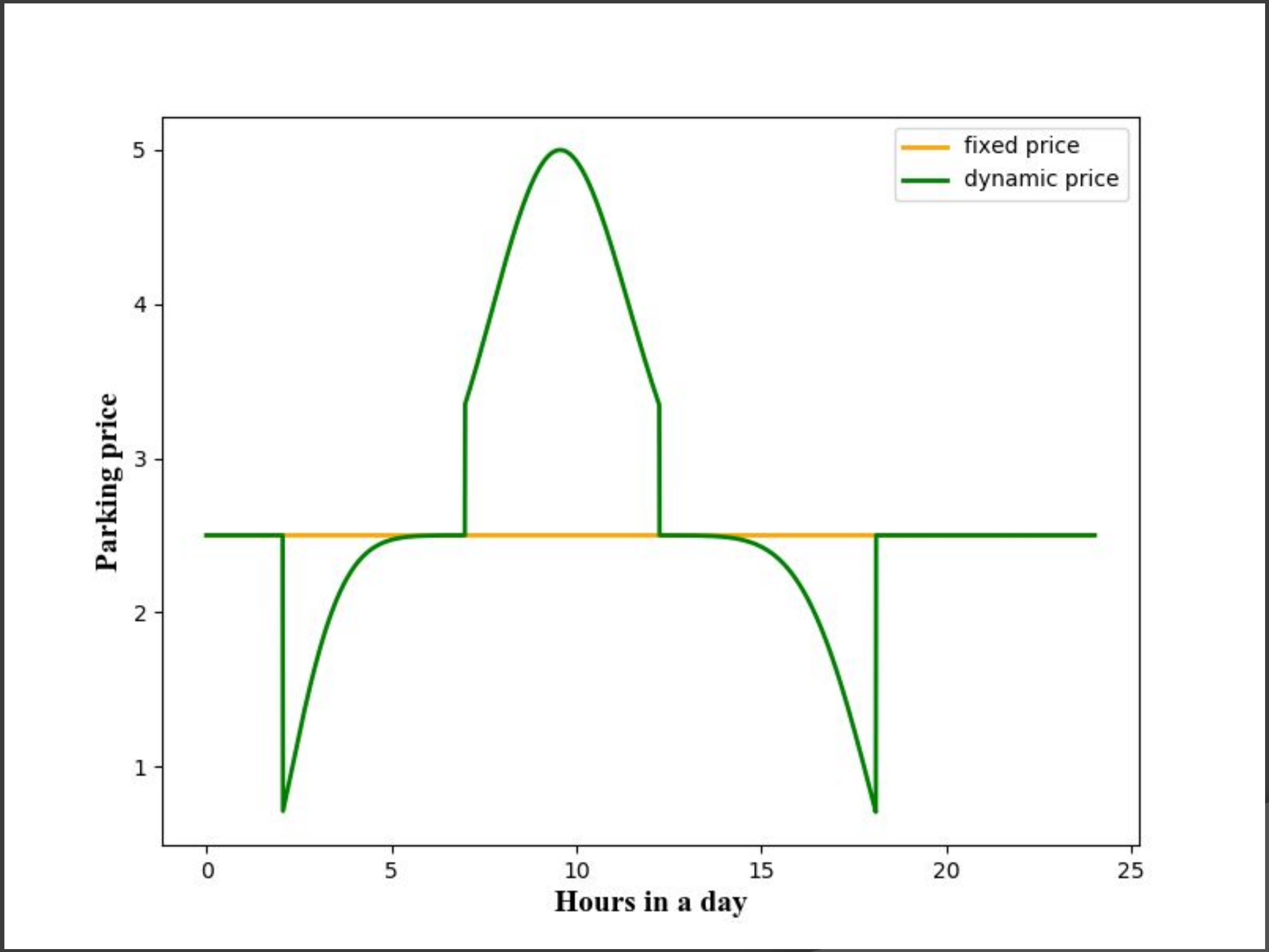
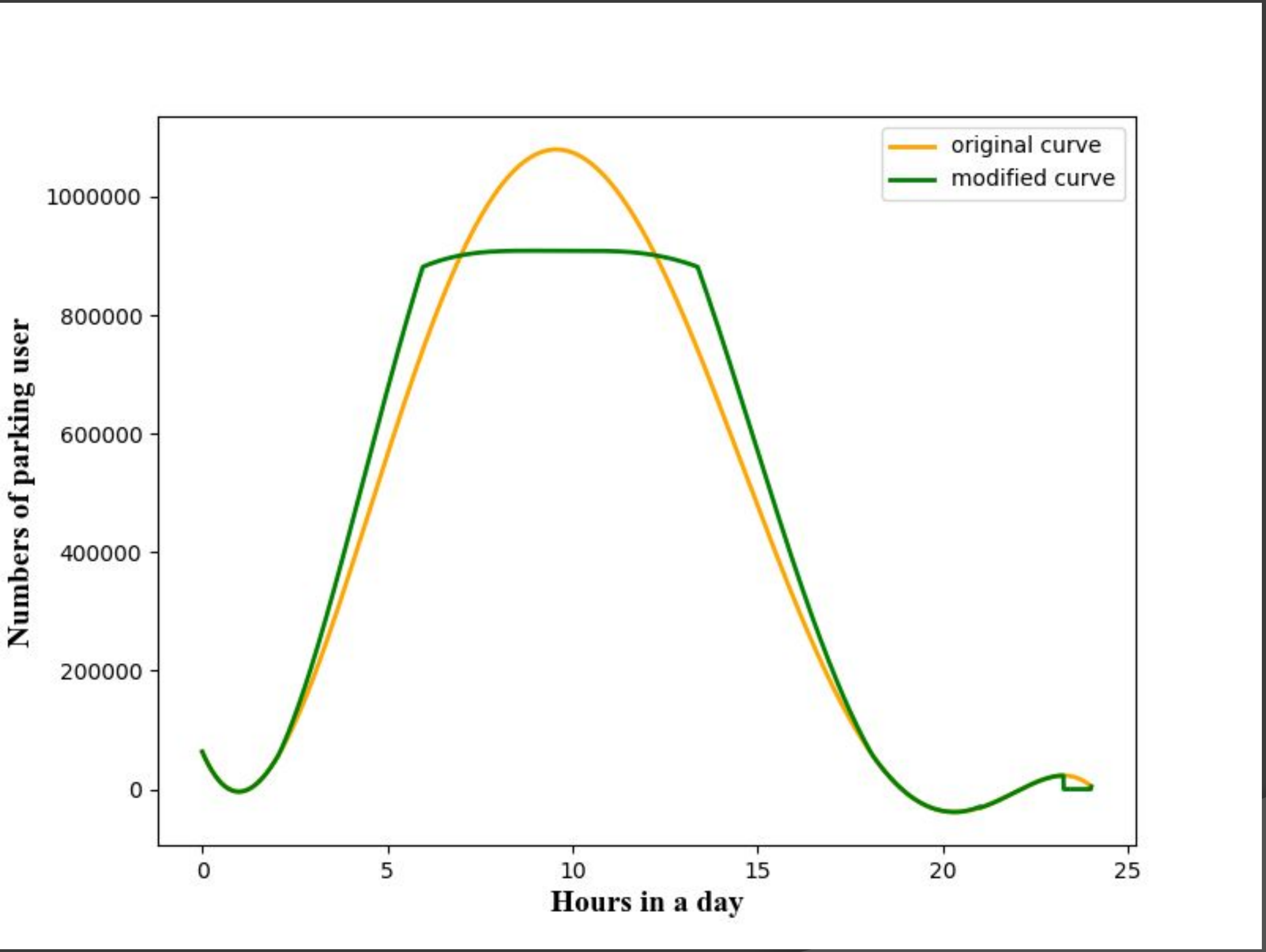
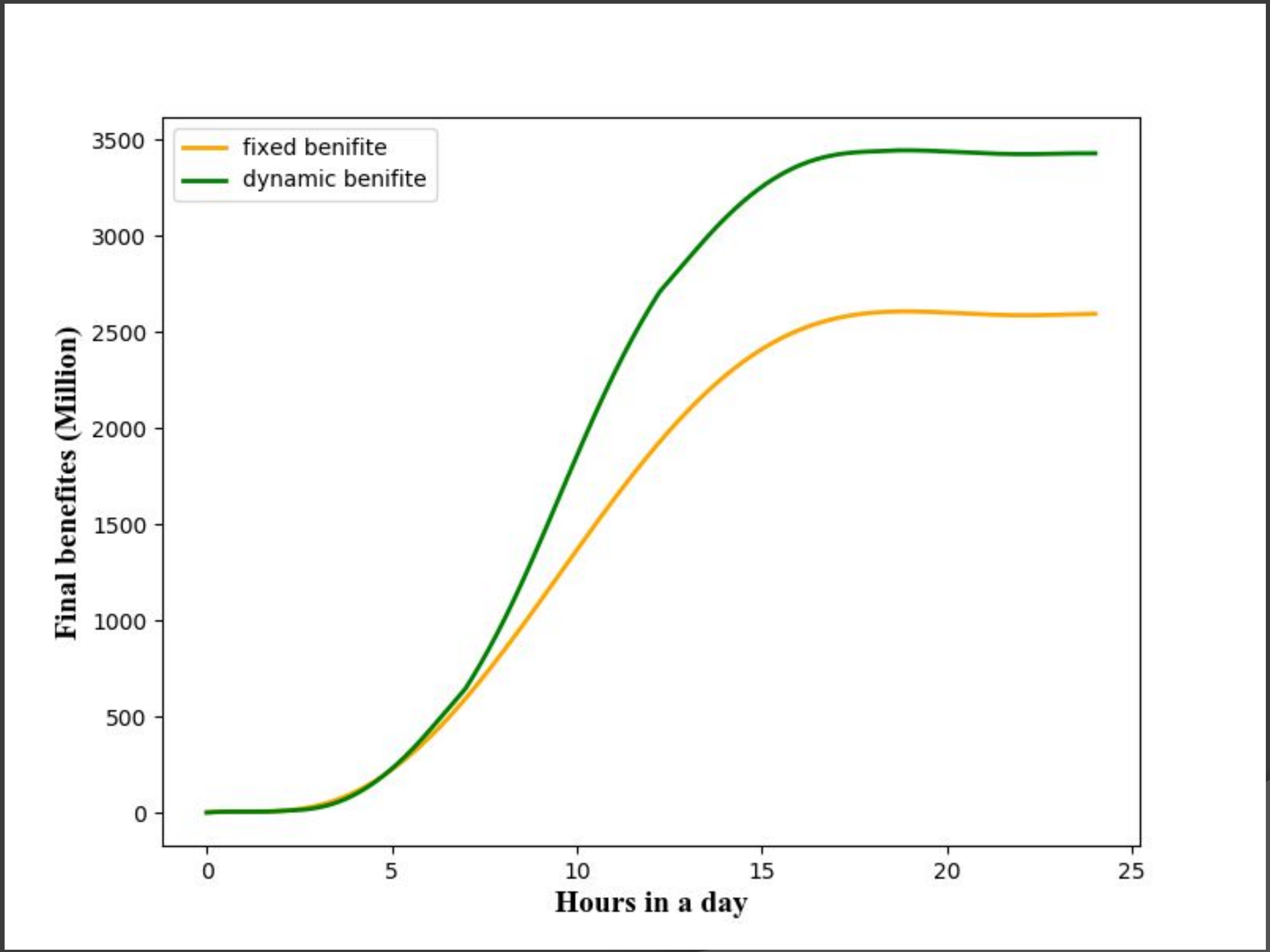
Final price


fixed price
dynamic price
5
4
3
2
1
Parking price
0
5
10
15
20
25
Hours in a day

Final demand function



Final benefits



Conclusion

- We design a multi-module based dynamic pricing system

- Adjust the number of user.
- Increase the final benefit.

Work with the system