



Revenue Management in Last-Mile Logistics

Overview of models, applications and extensions

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Agenda



I. Motivation

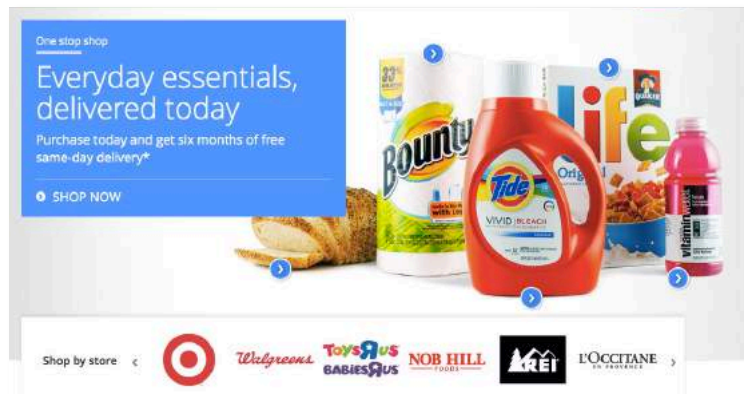
**II. State-of-the-art in Revenue Management research applied to
Last-Mile Delivery**

III. Extensions and new problems



MOTIVATION

Delivery service is an critical component of the e-commerce value proposition



The market for e-grocers is also rapidly expanding



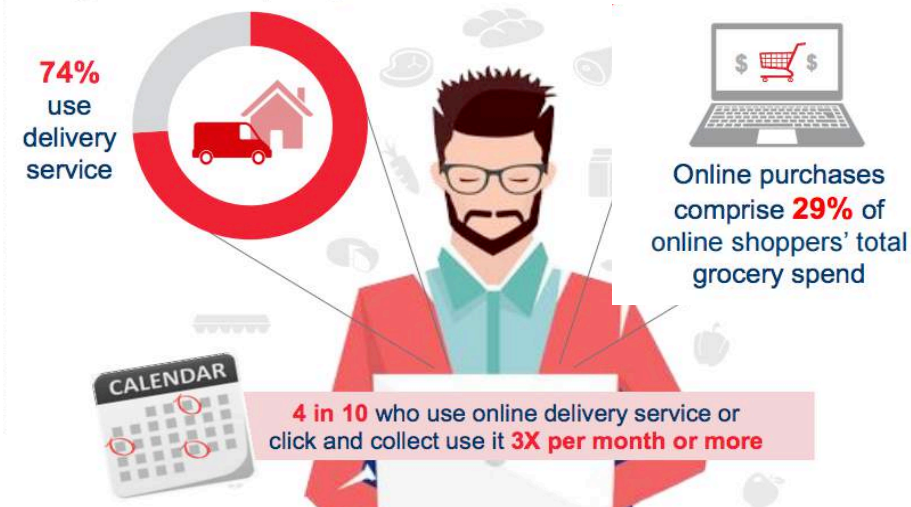
- Market studies predict a 30 - 40 % US market share over next 10 years
- Flexibility of delivery/pick-up options is key value proposition for consumers

Service Decisions:

- Which **options** to offer? (e.g. next-day vs. 2-day)
- At which **price** ?



Shoppers who shop for groceries online...



Diversified service-pricing offerings driven by business and context



Groceries

amazon fresh

2 Select date & time

APR 30 Today | **MAY 1 Monday** | MAY 2 Tuesday | MAY 3 Wednesday

Doorstep Delivery (You don't need to be present.)
Learn more

- Before 6:00am
- 4:00pm - 6:00pm
- 6:00am - 8:00am
- 6:00pm - 8:00pm
- 8:00am - 10:00am
- 8:00pm - 10:00pm
- 10:00am - 12:00pm

OR

Attended Delivery (You must be present.)
Learn more

- 6:00am - 8:00am
- 4:00pm - 6:00pm
- 8:00am - 10:00am
- 6:00pm - 8:00pm Reserved for you
- 10:00am - 12:00pm
- 8:00pm - 10:00pm

Amazon charges a fixed (\$9.99) price for any time window. Free for orders above \$40.

Walmart offers differentiated pricing per time-slot. **Pick-up** at store is free. Minimum orders size enforced (e.g. \$50)



Today	Tomorrow From \$7.00	Thu 04 From \$7.00	Fri 05 From \$7.00	Sat 06 From \$7.00	Sun 07 From \$7.00	Mon 08 From \$7.00
<input type="radio"/>	8am - 10am					\$10.00
<input type="radio"/>	9am - 11am					\$10.00
<input type="radio"/>	10am - 12pm					\$10.00
<input type="radio"/>	11am - 1pm					\$10.00
<input type="radio"/>	12pm - 2pm					\$10.00
<input type="radio"/>	1pm - 3pm					\$9.00
<input type="radio"/>	2pm - 4pm					\$8.00

Diversified service-pricing offerings driven by business and context



Dry Goods

Choose your Prime delivery option:

- Wednesday, May 10
\$5.99 - One-Day Shipping
- Thursday, May 11
FREE Two-Day Shipping
- Monday, May 15
FREE Standard Shipping
- Tuesday, May 16
FREE No-Rush Shipping
Get a \$1 reward for select digital items. [Details](#)

Choose a shipping preference

- Group my items into as few shipments as possible.
- I want my items faster. Ship them as they become available. (at additional cost)



Amazon offers differentiated lead-time/price. Incentive for no-rush service.
Unattended service.

Americanas.com (B2W, Brazil) also offers differentiated lead-time/price. Free for largest lead-time or scheduled delivery.
Attended service.



The screenshot shows the 'opções de entrega' (delivery options) section on the Americanas.com website. It features four radio button options: 'a jato' (até 1 dia útil, R\$ 9,99), 'rápida' (até 3 dias úteis, R\$ 4,99), 'econômica' (até 5 dias úteis, GRÁTIS), and 'agendada' (a partir de 29/05, GRÁTIS). Below this is the 'agende sua entrega' (schedule your delivery) section, which includes two dropdown menus: 'Selecione a data' and 'Selecione o turno'.

Research questions for our review paper



What is the state-of-the art in revenue management (RM) research applied to last-mile delivery (LMD)?

Which research extensions and new problems should be introduced considering the evolution and trends in LMD ?

Revenue management finds its origin in the airline industry



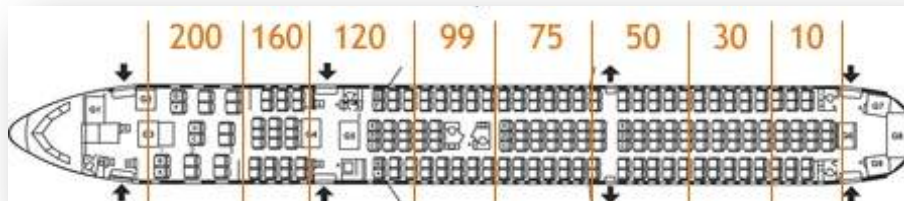
Airline deregulation act of 1978

- Loosen price control of market
- Entry of low-cost charter airlines
- PeopleExpress offered fares as low as 50% to 70% compared to traditional airlines



Response of American Airlines

- Purchase restrictions
- Capacity-controlled fares



Last-Mile Delivery shares properties with airline operations from a RM standpoint



Agatz (2013)
Campbell & Savelsbergh (2005)

Revenue management potential

- Heterogeneous market
- Limited short-term capacity flexibility

Control Policies

- **Quantity control**
 - What service to offer where and when?
- **Price control**
 - What price to charge where and when?

	donderdag 18 mei	vrijdag 19 mei	zaterdag 20 mei	zondag 21 mei	maandag 22 mei	dinsdag 23 mei	woensdag 24 mei
08:00-10:00							7,95
08:00-14:00			6,50		6,95	4,95	3,95
09:00-11:00							8,95
10:00-12:00					8,95	7,95	
12:00-14:00			7,95				7,95
16:00-18:00		vol			7,95		5,95
16:00-21:00		vol	5,95		6,95	4,95	4,95
17:00-19:00			6,95				
18:00-20:00			6,95				
18:00-22:00		7,95	5,95		6,95	5,95	5,95
19:00-21:00		8,95				7,95	7,95

	dinsdag 2 mei	woensdag 3 mei	donderdag 4 mei	vrijdag 5 mei	zaterdag 6 mei	zondag 7 mei	maandag 8 mei
07:00-08:00			6,95	7,95	8,95		7,95
08:00-10:00			7,95	8,95	8,95		8,95
08:00-14:00			4,95	6,95	6,50		6,95
09:00-11:00			8,95	9,95	8,95		9,95
10:00-12:00			7,95	8,95	7,95		8,95
11:00-13:00			vol	7,95	7,50		8,95
12:00-14:00			7,95	8,95	7,95		7,95
16:00-18:00		vol	7,95	8,95	7,95		7,95
16:00-21:00		4,95	6,95	7,95	5,95		6,95
17:00-19:00			7,95	8,50	6,95		7,95
18:00-20:00			7,95	8,95	6,95		7,95
18:00-22:00			5,95	7,95	5,95		6,95
19:00-21:00			7,95	8,95	6,95		7,95
20:00-22:00			7,95	8,95	6,95		7,95
21:00-22:30			6,95	7,95	5,95		6,95

Last-Mile Delivery has specific challenges in addressing revenue management



Delivery fee depends on products sold

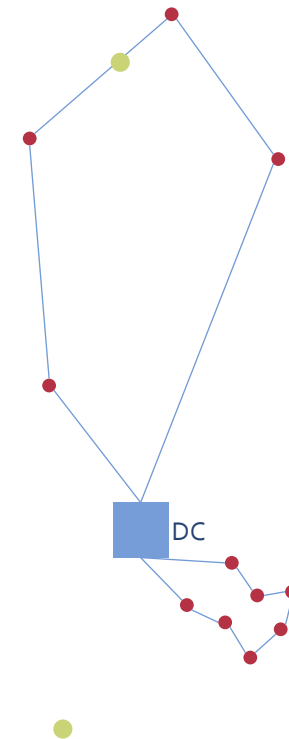
- If customers don't like delivery options they are lost
- We risk losing revenue on order

Available capacity and delivery cost are variable

- Order location
- Location of other orders
- Opportunity cost associated to future orders

Goal

- Maximize profit trough
- Matching demand to supply by
- Influencing customer purchase behavior using
- Price and quantity controls





LITERATURE REVIEW

REVENUE MANAGEMENT IN LAST MILE DELIVERY

Available literature can be categorized on four dimensions



Control Policy: Quantity & Price

Static vs. dynamic models

- Static models focus on tactical planning decisions
- Dynamic models take all current information into account

Static decision:
Do not offer time-slot
in this area

Dynamic decision:
Based on current
orders I don't accept
any new orders

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16:00-21:00		vol	5,95		6,95	4,95	4,95
17:00-19:00			6,95				
18:00-20:00			6,95				
18:00-22:00		7,95	5,95		6,95	5,95	5,95
19:00-21:00		8,95				7,95	7,95

Available literature can be categorized on four dimensions



Control Policy: Quantity & Price

Static vs. dynamic models

- Static models focus on tactical planning decisions
- Dynamic models take all current information into account

Routing approximation

- Cost of delivery depends on routing cost
- Trade-off between accuracy and computation time
 - VRP Heuristics
 - Seed-based approximation (cf. Fisher and Jaikumar (1981))
 - Routing approximation (cf. Daganzo (1987))

Customer choice

- The prices to offer depend on the preference of each customer
- If we are not able to capture customer choice our suggested prices are off
 - Exogenous probability
 - Utility based multinomial logit models

15 years of RM-LMD research categorized by modeling approach



	Control	Time-frame	Routing	Customer choice
Campbell and Savelsbergh [5]	Quantity	Dynamic	VRP Heuristics	Exogenous probability
Campbell and Savelsbergh [6]	Price	Dynamic	VRP Heuristics	Exogenous probability
Asdemir et al. [4]	Price	Dynamic	-	Multinomial logit
Agatz et al. [1]	Quantity	Static	Continuous approximation	Take whatever available
Hernandez et al. [11]	Quantity	Static	VRP Heuristics	Exogenous probability
Ehmke and Campbell [10]	Quantity	Dynamic	VRP Heuristics	Exogenous probability
Cleophas and Ehmke [7]	Quantity	Dynamic	VRP Heuristics	Exogenous probability
Klein et al. [13]	Price	Static	Seed-based approximation	Non-parametric rank-based
Yang et al. [17]	Price	Dynamic	VRP Heuristics	Multinomial logit
Klein et al. [12]	Price	Dynamic	Seed-based approximation	Multinomial logit
Yang and Strauss [16]	Price	Dynamic	Continuous approximation	Multinomial logit

Key take-aways:

- Models for both control types have been introduced
- Applications at the planning level (**static**) and tactical-operational level (**dynamic**)
- Routing approximations for tractability
- Evolution in customer choice models

Literature on dynamic models aims to capture opportunity cost in real-time



Standard framework for dynamic pricing in attended home-delivery Yang et al. (2016)

$$V_t(\mathbf{x}) = \max_{\mathbf{g}} \left\{ \lambda_t \sum_{s \in S(\mathbf{x})} P_{s,S(\mathbf{x})}(\mathbf{g}) [r + g_s + V_{t+1}(\mathbf{x} + \mathbf{1}_s)] \right. \\ \left. + [1 - \lambda_t \sum_{s \in S(\mathbf{x})} P_{s,S(\mathbf{x})}(\mathbf{g})] V_{t+1}(\mathbf{x}) \right\}$$

$$V_{T+1}(\mathbf{x}) = -C(\mathbf{x}), \forall \mathbf{x} \in X$$

\mathbf{x} = Vector of accepted orders for time slot s
 X = all \mathbf{x} that denote feasible delivery schedule
 $C(\mathbf{x})$ = Minimum delivery cost at time T given \mathbf{x}
 $S(\mathbf{x})$ = Available time slots given \mathbf{x}
 \mathbf{g} = Price vector offered to a customer for time slot s
 λ_t = Probability of an order arrival in period t
 r = Revenue of an order before distribution

- Customer Choice**
- Probability of ordering in time-slot given
 - Based on MNL model (Yang, 2016a)

$$\mathbf{g}^* = \arg \max_{\mathbf{g}} \sum_{s \in S(\mathbf{x})} P_{s,S(\mathbf{x})}(\mathbf{g}) [r + g_s - O_{xts}]$$

$$O_{xts} = V_{t+1}(\mathbf{x}) - V_{t+1}(\mathbf{x} + \mathbf{1}_s)$$

- Opportunity cost**
- Delivery of accepted orders
 - Loss of capacity (inability to serve future orders)
- Routing**
- VRP Heuristics (Yang, 2016a)
 Seed-based approximation (Klein, 2016)
 Continuous approximation (Yang, 2016b)

Available literature on the LMD-RM problem builds on common assumptions



Customer Service

- (Non-) overlapping time-windows

Product Exchange

- Attended delivery
- Home delivery

In 2 Tage (Do., 04.05.)		In 3 Tage (Fr., 05.05.)	
07		07	
08		08	
09	08:00 - 10:00 0,00 €	09	08:00 - 10:00 0,00 €
10	07:30 - 13:30 0,00 €	10	07:30 - 13:30 0,00 €
11	Ausgabe 0,00 €	11	10:00 - 12:00 0,00 €
12	11:00 - 13:00 0,00 €	12	11:00 - 13:00 0,00 €
13		13	
14		14	
15	15:00 - 17:00 0,00 €	15	15:00 - 17:00 0,00 €
16	16:00 - 18:00 0,00 €	16	16:00 - 18:00 0,00 €
17		17	
18	14:30 - 22:00 0,00 €	18	14:30 - 22:00 0,00 €
19	17:00 - 19:00 0,00 €	19	17:00 - 19:00 0,00 €
20	18:00 - 20:00 0,00 €	20	18:00 - 20:00 0,00 €
21	19:00 - 21:00 0,00 €	21	19:00 - 21:00 0,00 €
22	20:00 - 22:00 0,00 €	22	20:00 - 22:00 0,00 €



Distribution

- Homogenous fleet
- Short-term fixed fleet capacity

Order preparation

- Unrestricted



Winkenbach and Janjevic(2017)



Extensions to current models and new problems

FUTURE RESEARCH IN LMD-RM

On-demand platforms as Uber and Lyft can be used to flexibly increase capacity



Distribution

- Homogenous fleet
- Short-term fixed fleet capacity
- Flexible crowd-sourced capacity



Delivery to close to customer pick-up locations provides extra flexibility



Product Exchange

- Attended delivery
- Home delivery
- Pick-up



Most dry-goods delivery commits to lead-times instead of time-windows



Customer Service

- (Non-) overlapping time-windows
- Lead-time



opções de entrega

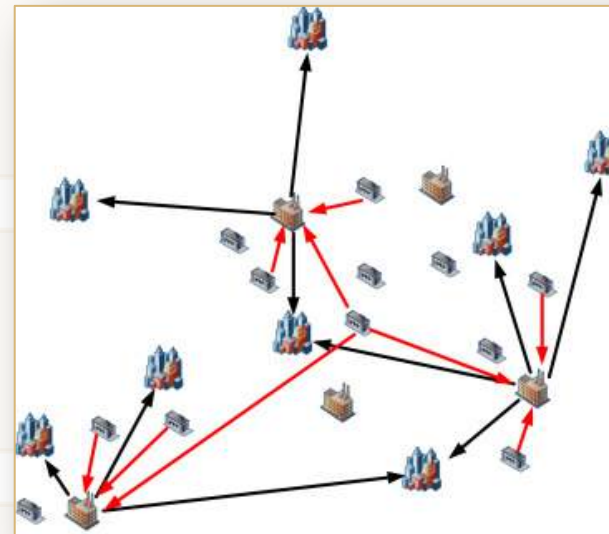
<input type="radio"/> a jato até 1 dia útil R\$ 9,99	<input type="radio"/> rápida até 3 dias úteis R\$ 4,99
<input type="radio"/> econômica até 5 dias úteis GRÁTIS	<input checked="" type="radio"/> agendada a partir de 29/05 GRÁTIS

Different service can be provided to products with a different origin

Order preparation

- Unrestricted

- Inventory delays



Conclusions

- Significant opportunities for RM models to select and price Last-Mile Delivery services
- Available modeling frameworks simultaneously consider **RM** (control, time-frame and customer choice) and **routing** problems.
- Applications have focused on **attended home-delivery** inspired by problems in **e-grocery** deliveries
- Trends in e-commerce offer a variety of new relevant applications
- Future research opportunities range from extensions to existing frameworks to new problems



Thank you.

Questions?

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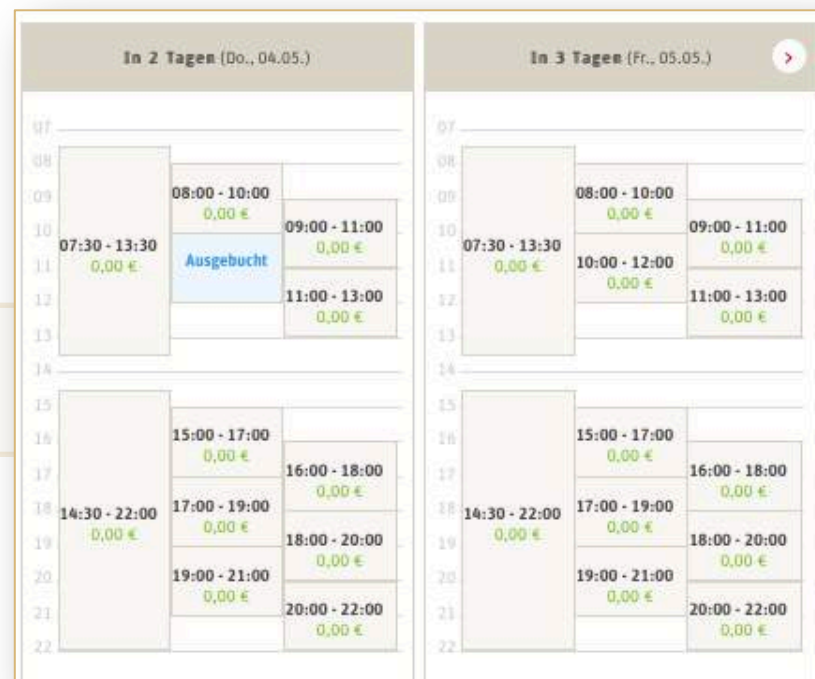
megacitylab.mit.edu

Orders need to be delivered within a specific time-window



Customer Service

- (Non-) overlapping time-windows



Product is delivered to customers home and no aggregation of customers exists



Customer Service

- (Non-) overlapping time-windows

Product Exchange

- Attended delivery
- Home delivery



Winkenbach et al. (2017)

Delivery using a homogenous fleet inflexible to handle short-term fluctuations



Customer Service

- (Non-) overlapping time-windows

Product Exchange

- Attended delivery
- Home delivery



Distribution

- Homogenous fleet
- Short-term fixed fleet capacity



Winkenbach et al. (2017)

Products are available at the same time and can be delivered in any time-window



Customer Service

- (Non-) overlapping time-windows

Product Exchange

- Attended delivery
- Home delivery

In 2 Tage (Do., 04.05.)		In 3 Tage (Fr., 05.05.)	
07		07	
08		08	
09		09	
10	07:30 - 13:30 0,00 €	10	07:30 - 13:30 0,00 €
11	08:00 - 10:00 0,00 €	11	08:00 - 10:00 0,00 €
12	09:00 - 11:00 0,00 €	12	09:00 - 11:00 0,00 €
13	11:00 - 13:00 0,00 €	13	11:00 - 13:00 0,00 €
14		14	
15		15	
16		16	
17	15:00 - 17:00 0,00 €	17	15:00 - 17:00 0,00 €
18	16:00 - 18:00 0,00 €	18	16:00 - 18:00 0,00 €
19	17:00 - 19:00 0,00 €	19	17:00 - 19:00 0,00 €
20	18:00 - 20:00 0,00 €	20	18:00 - 20:00 0,00 €
21	19:00 - 21:00 0,00 €	21	19:00 - 21:00 0,00 €
22	20:00 - 22:00 0,00 €	22	20:00 - 22:00 0,00 €



Distribution

- Homogenous fleet
- Short-term fixed fleet capacity

Order preparation

- Unrestricted



Winkenbach et al. (2017)

Companies need to keep track of customer behavior given different prices



	dinsdag 2 mei	woensdag 3 mei	donderdag 4 mei	vrijdag 5 mei	zaterdag 6 mei	zondag 7 mei	maandag 8 mei
07:00-08:00			6,95	7,95	8,95		7,95
08:00-10:00			7,95	8,95	8,95		8,95
08:00-14:00			4,95	6,95	6,50		6,95
09:00-11:00			8,95	9,95	8,95		9,95
10:00-12:00			7,95	8,95	7,95		8,95
11:00-13:00			vol	7,95	7,50		8,95
12:00-14:00			7,95	8,95	7,95		7,95
16:00-18:00		vol	7,95	8,95	7,95		7,95
16:00-21:00		4,95	6,95	7,95	5,95		6,95
17:00-19:00		vol	7,95	8,50	6,95		7,95
18:00-20:00		7,95	8,95	8,95	6,95		7,95
18:00-22:00		5,95	7,95	7,95	5,95		6,95
19:00-21:00		7,95	8,95	8,95	6,95		7,95
20:00-22:00		7,95	8,95	8,95	6,95		7,95
21:00-22:30		6,95	7,95	7,95	5,95		6,95

Last-mile delivery operations are characterized by the following factors



Customer Service

Product Exchange

Distribution

Order preparation