UNIVERSITÄT DUISBURG ESSEN

Open-Minded

MERCATOR SCHOOL OF MANAGEMENT

# How Much to Tell Your Customer?
# –
# An Overview of Selling Strategies with Incompletely Specified Products

(EJOR, 2020)

https://doi.org/10.1016/j.ejor.2019.02.008
https://ssrn.com/abstract=3327168

Prof. Dr. Jochen Gönsch
AGIFORS RM 2021

Universität Duisburg-Essen
Mercator School of Management
Chair of Service Operations
Germany

www.msm.uni-due.de/so

Copyright © by Jochen Gönsch. Published by AGIFORS with permission.

# Jochen Gönsch

UNIVERSITÄT DUISBURG ESSEN
*Open-Minded*

- **CV**
  - 2006: Master Business Administration with Computer Science (TU Darmstadt)
  - 2006-2015: PhD, Habilitation (University of Augsburg)
  - Since 2015: Full Professor for Service Operations (*University of Duisburg-Essen*)
  - Among the top 5% of German Business Administration researchers (Wirtschaftswoche-Ranking 2020/21)
  - *Teaching* at University of Augsburg, Catholic University Eichstätt-Ingolstadt, Goethe-University Frankfurt am Main, CSU-Pueblo (Colorado/USA) and Vietnamese-German University (HCMC/Vietnam). Courses included *Maths for Business Administration, Operations Research, Logistics, Introduction to Matlab, and Pricing & Revenue Management*

Wirtschafts Woche

- **Research Focus: Modeling & Optimization at the Customer/Firm Interface**
  - Analytics, Operations Research: (Approximate Dynamic Programming/Reinforcement Learning, LP, Heuristics)
  - *Pricing & Revenue Management*
  - Innovative Mobility/Logistics (Shared Mobility, *Airline Schedule Planning*)
  - Closed-Loop Supply Chains
  - Renewable Energies, Energy Storage

## Agenda

**1 Introduction**

2 Strategic Operations Management: Economics of Incompletely Specified Products (ICSPs)

3 Empirics: ICSPs in the real-world

4 Operations: Revenue Management with ICSPs

5 Conclusion

# Many examples for Incompletely Specified Products (ICSPs)

UNIVERSITÄT DUISBURG ESSEN
*Open-Minded*

## 1. Select departure airport

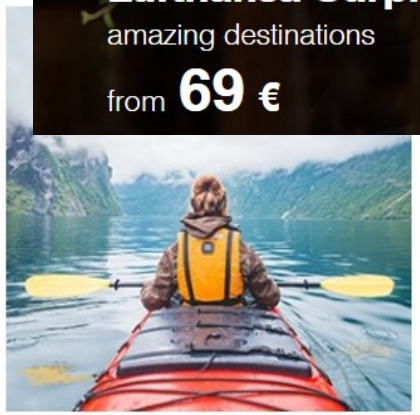
Frankfurt/Main ✔ | Munich

## 2. Choose your travel topic and be surprised by exciting destinations

Worth Seeing from 69 €

Go East from 79 €

Arts and Sights from 79 €



The Great Outdoors from 89 €

Follow the Sun from 89 €

Urban Adventures from 99 €

Party On from 99 €

For Lovers from 99 €

Hotwire

★★★★
$79
per room per night
Continue

The White House - Capitol Hill area hotel

Bed choice

Details Area map

We are still gathering reviews for this property.

Hotwire Hot Rate

You get the lowest prices.
We hide the hotel name.
Learn why

Lowest Price Guaranteed | Best value

★★★★
$99
per room per night
Continue

Dupont Circle - Embassy Row area hotel

Bed choice

Details Area map

Recommended in 85 % of Hotwire customer reviews

Hotwire Hot Rate

When brand-name hotels use us to fill rooms that would otherwise go unsold, their prices are deeply discounted. Hotels don't want to publicize rates this low, so we hide their name until after booking.

Lowest Price Guaranteed | Best value

priceline.co.uk

Sign-In | My Profile | My Trips | Check Your Request | Help

Select A Quality Level For Your Hotel

- 5-Star Luxury
- 4-Star Superior
- 3-Star Quality
- 2-Star Economy

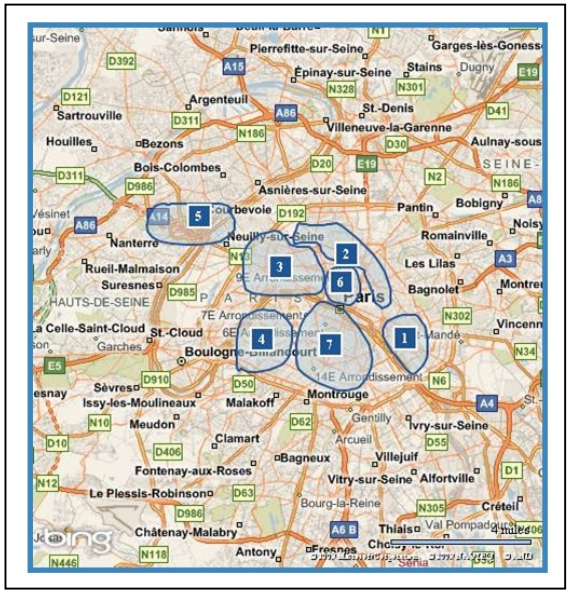
Select The Areas Where You Want To Stay

Select the areas in Paris, France where you want to stay. You'll always stay in a nationally recognized name-brand or quality independent hotel.

Improve Your Chances - Select 2 or More Areas Below:

1 Bastille - Bercy Area Details
2 Batignolles - Montmartre - Republique Area Details
3 Champs Elysees - Opera Quarter West Area Details
Eiffel Tower - Port De Versailles - Montparnasse Area

See Map Below



SIXT IN THE USA

RIU Hotels & Resorts

Riu Sparreise

**Lassen Sie sich von uns überraschen.**
**Und dabei sparen Sie.**

Und so funktioniert es:
Sie wählen die Hotelkategorie und ein Urlaubsgebiet und überlassen uns die Wahl Ihres Urlaubsortes und Hotels.

Spanien

Unser Riu Spartipp ✵✵✵✵, Costa del Sol

Doppelzimmer, Halbpension,
1 Woche mit Flug
pro Person ab € 427

Fuerteventura

Riu Palace Sparreise ✵✵✵✵½, Inselweit

Doppelzimmer, Halbpension,
1 Woche mit Flug
pro Person ab € 569

ECONOMY CLASS
UPGRADE
231
26B
0081A
Boarding Pass | Carte d'accès à bord

Lufthansa

Priority Check-in
First Class
GOLD
Business Class

NORWEGIAN
ATLANTIC
SALMON
2% MILK
CLOVER
SONOMA
ORGANIC
QUINOA
VIRGIN
OLIVE
OIL
PARMESAN
GOOD USE
BREAKFAST
Sausage
FIELD ROAST
IMPERFECT
FOODS

www.sociofly.com

# We need structure

UNIVERSITÄT DUISBURG ESSEN
*Open-Minded*

**Incompletely Specified Product (ICSP):**

*You do not know what you buy.*

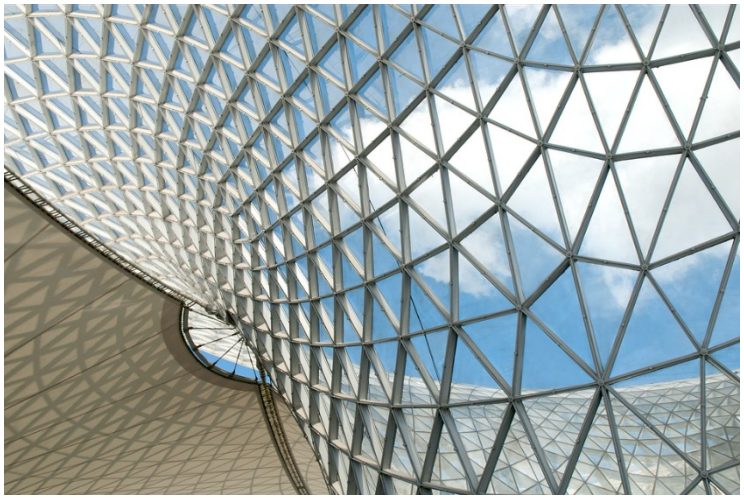
Customer obtains one of several pre-specified *component products*.

**Benefits of supply-side substitution**

- New dimension for *market segmentation: strengths of customer preferences*
- Lower *demand uncertainty*
- Higher *capacity utilization*

**Challenges**

- Increased *complexity*
- Adaption of *capacity management* necessary



Expo 2010 Shanghai Structure - Pixabay

# What drives the use of ICSPs?

UNIVERSITÄT DUISBURG ESSEN
*Open-Minded*

## 3 key properties of ICSPs

- Component products are *differentiated* ...
  - ... *vertically:*
    All customers prefer the same component.
  - ... *horizontally:* Tastes.
- *Flexibility*:
  - *Explicit*:
    Customers are *aware* they are buying an ICSP
    
  - *Implicit*:
    Customers are *not aware* of buying an ICSP
    
- *Assignment timing*:
  - *Immediately* after purchase
  - *Postponed*

## 2 key challenges addressed with ICSPs

- *Capacity*
  - Inflexible
  - Uncertain
- *Demand*
  - Preferences uncertain
  - Heterogeneous valuations
  - Level uncertain

Public Domain Picture

# ICSPs have many names in practice

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

Overview of application areas.

| Industry | Area | Demand uncertainty | Capacity | Solution approach (ICSP) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Popular description | Differentiation | Flexibility | Assignment time |
| Electronics | CPU, RAM | | Fixed mix | Upgrade | V | Implicit | n.a. |
| Media | TV/web ads | | Uncertain | Selection, scheduling | H | Explicit | pp. |
| (Online) retailing | Fashion, apparel | Preferences, het. valuat. | | Lucky/mystery/grab bag | H, [V] | Explicit | n.a. |
| Production | ATO, MTO | Het. valuat. | | Selection, due date quoting, scheduling | [V] | [Implicit] | pp. |
| Retailing | Food | | Uncertain | Farm basket | H | Explicit | n.a. |
| Transportation | Cargo | | | Routing flexibility | H | Implicit | pp. |
| Travel | Airlines | Het. valuat. | | Opaque prod. | H | Explicit | im. |
| Travel | Airlines | Level | | Upgrade | V | Implicit | pp. |
| Travel | Car rental | Het. valuat. | Uncertain | Mystery car | V | Explicit | pp. |
| Travel | Car rental | Level | Uncertain | Upgrade | V | Implicit | pp. |
| Travel | Cruises | Preferences | | Travel roulette | H | Explicit | pp. |
| Travel | Hotel | Het. valuat. | | Opaque prod. | H, [V] | Explicit | im. |
| Travel | Hotel | Level | | Upgrades | V | Implicit | pp. |
| Travel | Package holidays | Preferences | | Travel roulette | H | Explicit | pp. |

Capacity is always limited in the short run and not completely flexible in the long run. ATO: assemble-to-order, MTO: make-to-order, het. valuat.: heterogeneous customer valuations, V: vertical, H: horizontal, pp.: postponed, im.: immediate.

# ICSPs are researched in 3 communities

UNIVERSITÄT DUISBURG ESSEN
*Open-Minded*

**Strategic Operations Management**

- *Stylized models*, focus on basic aspects like when ICSPs are beneficial
- Key aspects: often *endogenous demand*, rational forward-looking customers

**Empirics**

- *Describe* real-world ICSPs
- Often focus *customer behavior* and estimate demand models
- Some derive *recommendations* for tactical decisions like price differences

**Operations: Revenue Management**

- Focus on operations: *Manage capacity during booking* horizon, avoid overselling
- Assignment timing important
- Product design only captured via *exogenous demand*

**Table 2**
Terms commonly used in the literature.

| This paper | Strategic operations management | Empirics | Operations |
|---|---|---|---|
| ICSP | Opaque/flexible/probabilistic product | Opaque(/flexible) product | Opaque/flexible product, upgrade |
| Selling with ICSPs | Opaque selling/channel, probabilistic selling | Opaque selling/booking/ channel/website | RM with (supply-side) substitution, RM with flexible/opaque products, RM with upgrades |
| Selling without ICSPs | Transparent selling, traditional/full information channel | Transparent channel/website, full information channel/website | Traditional RM |
| Component product | Component product | – | Alternative, (execution) mode |
| Regular product | Regular/brand/ transparent product | – | Regular/specific product |
| Opaque product | Often used interchangeably | Often used interchangeably | Sometimes used interchangeably |
| Flexible product | | | |
| Probabilistic product | | | Not considered |
| Upgrade | Vertically differentiated component products | – | Upgrade |

–: No specific common term.

## Agenda

1 Introduction

**2 Strategic Operations Management: Economics of Incompletely Specified Products (ICSPs)**

3 Empirics: ICSPs in the real-world

4 Operations: Revenue Management with ICSPs

5 Conclusion

# The Economics of ICSPs

UNIVERSITÄT DUISBURG ESSEN
*Open-Minded*

**Research question:**

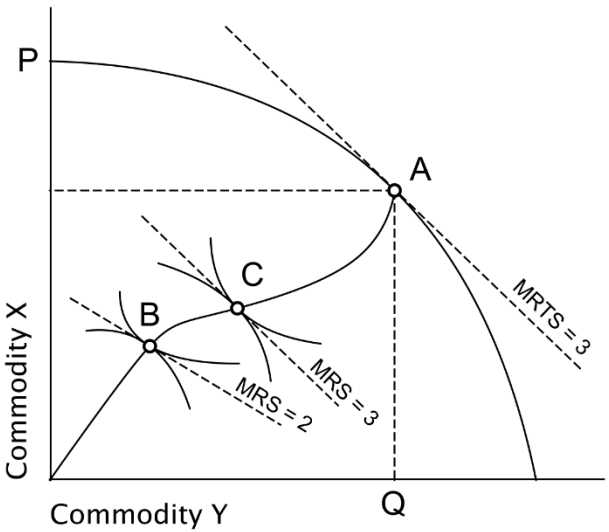
*When and how should ICSPs be offered?*

***Methodology:*** **Stylized models, usually with**

- *Endogenous demand* from
  - *Stochastic* individual *valuations*
  - *Endogenous design:* price, assignment probability, …
- Infinite number of *infinitesimally small customers*
- Model becomes *deterministic (fluid approximation)*
- Aggregate view *without lapse of time* (no new information revealed)

***Key research issues*** **(# papers)**

- What makes ICSPs beneficial? (2)
- Comparison to other segmentation approaches (5)
- Vertical differentiation (3)
- Inventory issues (5)
- Assignment timing (4)
- Competition (7)




Commons.Wikimedia.org

**Table 3**
Strategic operations management (OM) literature on ICSPs.

| | Endog. variables | Demand uncertainty | # periods | Probab. product | Limited capacity | Remarks |
|---|---|---|---|---|---|---|
| | What makes ICMPs beneficial? | | | | | |
| Jiang (2007) | Price, ass.-prob. | No | 1 | Yes | No | |
| Fay and Xie (2008) | Price, ass.-prob. | No [pref.] | 1 | Yes | No [yes] | |
| | Comparison to other segmentation approaches | | | | | |
| Fay and Xie (2010) | Price | No | 1, 2 | Yes | No | Comparison to advance selling |
| Rice et al. (2014) | Price, inventory | No [pref.] | 2 | Yes | Yes | Comparison to markdown |
| Anderson and Xie (2014) | Price | No | 1 | No | No [yes] | NYOP vs. posted price |
| Ogonowska and Torre (2014) | Price | No | 1 | Yes | Yes, uncertain | NYOP vs. posted price |
| Feng et al. (2018) | Price | No | 1 | Yes | No | NYOP vs. posted price |
| | Vertically differentiation | | | | | |
| Huang and Yu (2014) | Price | No | Infinite | Yes | No | Bounded rationality |
| Zhang et al. (2015) | Price, ass.-prob., quality | No [level] | 1 | Yes | Yes | |
| Ren and Huang (2017) | Price, ass.-prob. | Level | 2 | Yes | Yes | Comp. to last minute selling |
| Biyalogorsky et al. (2005) | Price | Level | 2 | Yes | Yes | |
| | Inventory issues | | | | | |
| Fay et al. (2015) | Price, product number/type | No | 1 | Yes | No | Number of products |
| Zhang et al. (2016) | Inventory, price | Preference | 1 | No | Yes | |
| Zhang et al. (2018) | Inventory | Preference | 1 | No | Yes | No disaggregate choice |
| Elmachtoub and Wei (2016) | Only assignment | Level, pref. | Many | No | Yes | Also operational issues |
| Chen and Bell (2017) | Price, booking limits | Level | 1 | No | Yes | Also operational issues |
| | Assignment timing | | | | | |
| Geng (2016) | Price, [ass.-prob.] | No | [1] | Yes | Yes | Congestion/queueing |
| Xu et al. (2016) | Price | No | [1] | Yes | Yes | Congestion/queueing |
| Wu and Wu (2015) | Price | Level | 3 | No | Yes | |
| Fay and Xie (2015) | Price, inventory | Preference | 1 | Yes | Yes | |
| | Competition | | | | | |
| Fay (2008) | Price, inventory | No | 1 | Yes | No [yes] | |
| Shapiro and Shi (2008) | Price, inventory | No | 1 | Yes | No | |
| Jerath et al. (2010) | Price | Level | 2 | Yes | Yes | Comp. to last minute selling |
| Cai et al. (2013) | Price | No | 1 | Yes | No | Asymmetric retailers |
| Chen et al. (2014) | Price | Level | 2 | Yes | Yes | NYOP vs. posted price |
| Chao et al. (2016) | Price | No | 1 | Yes | No | Vertical differentiation |
| Mao et al. (2018) | Price, revenue sharing | No | 1 | No | Yes | Interplay with intermediary |

## Agenda

1 Introduction

2 Strategic Operations Management: Economics of Incompletely Specified Products (ICSPs)

**3 Empirics: ICSPs in the real-world**

4 Operations: Revenue Management with ICSPs

5 Conclusion

# Empirical papers analyze ICSPs in aviation and hotels

UNIVERSITÄT DUISBURG ESSEN
*Open-Minded*

**Overview**

- *Description* of real-world ICSPs
- *Immediate assignment* ("opaque products")
- *Customer behavior* and demand model estimation
- Some derive *recommendations* for tactical decisions like price differences

**Focus on travel industry (# papers)**

- Passenger aviation (5)
- Hotels (9)

**Table 4**
Empirical literature investigating ICSPs.

| | (Main) Data source | Unknown to customer | # observations | Aim/method, remarks |
|---|---|---|---|---|
| | Passenger aviation | | | |
| Granados et al. (2008) | Sales of airline tickets for 46 US city pairs 2003–2004 via online travel agencies (regular/ICSP) | Opaque online travel agency, probably airline and exact departure/arrival time | 2580 | Estimation of industry-level demand functions (linear and Cobb–Douglas) for ICSPs |
| Mang et al. (2012) | Query and booking data from a Australasian low cost carrier's opaque product sales website | Variable opaque product: customers self-select possible departure date ranges and assignment timing | 42,264 | Analyze customer purchase behavior (descriptive, binary probit), postponed assignment |
| Post and Spann (2012) | Booking data from Lufthansa low cost subsidy Germanwings from 2009–2010 | Variable opaque product: customers self-select possible destinations | Not provided | Description of IT, sketch of impact with descriptive statistics |
| Lee et al. (2012) | Booking data from a European airline 08/2008–08/2009 | See Post and Spann (2012) | Not provided | Estimation of multidimensional binary logit model |
| Granados et al. (2018) | Ticket sales of a major international airline for 712 city pairs, 5 months of 2005 | See Granados et al. (2008) | 4388 | Calibration of a market response model (proprietary) |
| | Hotels | | | |
| Lee and Jang (2013) | Survey with US students | Hotel brand and exact street address | 346 | ANOVA of fairness of regular price when opaque product offered |
| Courty and Liu (2013) | Price and availability information crawled from Hotwire and hotels for 7 US cities | Hotel brand and exact street address | 4550 opaque prices, 7601 regular prices | Analyze opaque discount using regressions |
| Tappata and Cossa (2014) | Opaque bookings from Betterbidding.com, crawled regular rates for US hotels | Hotel brand and exact street address | 3817 | See Courty and Liu (2013) |
| Chen and Yuan (2014) | Focus groups with US students | No details, opaque online travel agency | 12 participants | Structural coding/qualitative |
| Chen and Yuan (2016) | US consumer panel | Hotel brand and exact street address | 500 | Analyze structural equation model describing buying process |
| Chen et al. (2017) | US consumer panel | See Chen and Yuan (2016) | 396 | See Chen and Yuan (2016) |
| Huang et al. (2018) | Online survey in Hong Kong | See Chen and Yuan (2016) | 120 respondents | See Chen and Yuan (2016) |
| Xie et al. (2016) | Online survey imitating online booking of US hotels | Hotel brand and exact street address | 5310 from 531 respondents | Estimation of multinomial logit model to compare regular, ICSPs with posted price/bidding |
| Xie et al. (2017) | See Xie et al. (2016), addition of a similar, second survey | See Xie et al. (2016) | Plus 5140 from 514 res. | See Xie et al. (2016) |

# Key findings

**Passenger aviation**

- Granados et al. (2008):
  - Data: 2,580 obs. of *sales of airline tickets* for 46 US city pairs 20 03–20 04 via online travel agencies (regular/ICSP)
  - *Observed discount: 38%*
  - Optimal discount: 81%

- All papers: *Positive effects on demand and bottom line*

**Hotels**

- Courty and Liu (2013)
  - Data: 1,251 obs. for *price and availability* from Hotwire and hotels for 7 US cities
  - *Discount: 40%,* 12% less in airport area
  - Higher discount in markets with high product differentiation (more customer heterogeneity)

- Tappata and Cossa (2014)
  - Data: 3,871 obs. of *opaque bookings* from Betterbidding.com, regular rates for US hotels
  - *Discount: 47%* (Priceline's NYOP) and 38% (Hotwire)

## Agenda

1 Introduction

2 Strategic Operations Management: Economics of Incompletely Specified Products (ICSPs)

3 Empirics: ICSPs in the real-world

**4 Operations: Revenue Management with ICSPs**

5 Conclusion

# What changes in RM with ICSPs?

UNIVERSITÄT DUISBURG ESSEN
*Open-Minded*

- Incorporation of ICSPs into *operational decision-making* processes and systems
  - Classic *transaction-oriented view*:
    *No updates* of beliefs, valuations
    -> *exogenous product design, prices, demand*
  - Key issue: *Manage capacity* during booking horizon, avoid overselling
    Focus: *Develop and test methods*
  - Assignment timing important:

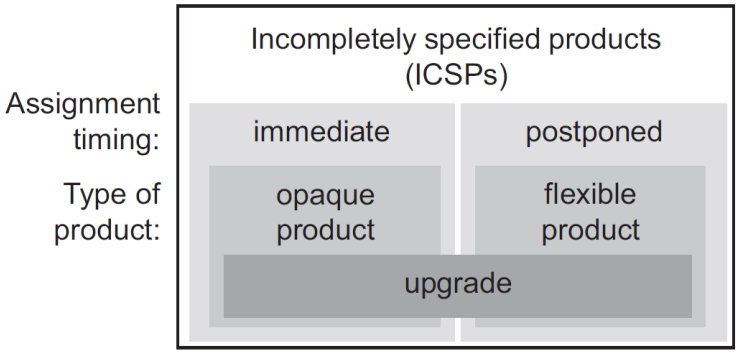



**Fig. 3.** Product types of ICSPs considered on an operational level.

# Methods for RM with opaque products in various industries

UNIVERSITÄT DUISBURG ESSEN
*Open-Minded*

**Table 5**
Literature on capacity control with opaque products.

| | Industry/setting | Choice | Method |
|---|---|---|---|
| Talluri (2001) | Passenger aviation with route choice | – | LP |
| Chen et al. (2003) | Air cargo with routing flexibility | – | LP, SP |
| Kimms and Klein (2005) | Various | – | LP |
| Spengler et al. (2007) | Make-to-order: iron and steel | – | Multidimensional knapsack |
| Büke et al. (2008) | Passenger aviation with route choice | Buy up | SP |
| Chen et al. (2010) | Passenger aviation with two flights | – | MDP |
| Gönsch and Steinhardt (2013) | Generic | – | MDP |
| Xiao and Chen (2014) | Retailing, two products | – | MDP, continuous-time |
| Sayah and Irnich (2018) | Passenger aviation with two flights | – | MDP |
| Sayah (2015) | Passenger aviation with two flights | – | MDP |
| Elmachtoub and Wei (2016) | Online retailing | Various | MDP, infinite horizon |

LP: linear programming, MDP: Markov decision process, SP: stochastic programming.

- Focus on *modelling and solution methods*

# Flexible products are extensively researched

UNIVERSITÄT DUISBURG ESSEN
*Open-Minded*

**Table 6**
Literature on capacity control with flexible products.

| | Industry/setting | Choice | Method | Capacity management |
|---|---|---|---|---|
| | General contributions | | | |
| Gallego and Phillips (2004) | Passenger aviation with two flights | – | 2 periods, MDP | Surrogate |
| Gallego et al. (2004) | Generic | –, generic | MDP, LP | Commitments |
| Petrick et al. (2010) | Generic | – | LP | Immediate assign., commitments, ta., surrogate, … |
| Petrick et al. (2012) | Generic | – | LP | Commitments, ta. |
| Gönsch et al. (2014) | Generic | – | LP, MDP | Commitments |
| Koch et al. (2017) | Generic | Generic | MDP, generic | Commitments -> surrogate |
| Cheung and Simchi-Levi (2016) | Generic | Generic | LP | Commitments |
| Vock (2015) | Generic | – | LP | Commitments |
| | Applications of flexible products | | | |
| Bartodziej and Derigs (2004) | Air cargo | – | LP | Commitments |
| Bartodziej et al. (2007) | Air cargo | – | LP | Commitments |
| Kimms and Müller-Bungart (2007) | TV ads | – | LP | Commitments |
| Popescu and Crama (2016) | TV ads | – | MDP | Commitments |
| Roels and Fridgeirsdottir (2009) | Web ads | – | MDP, LP | Commitments |
| Chevalier et al. (2015) | Service/production | – | MDP | Commitments |
| Germs and van Roreest (2011) | Production | – | MDP | Commitments |
| Guhlich, Fleischmann, and Stolletz (2015) | MTO, single-stage | – | LP | Commitments |
| Guhlich, Fleischmann, Mönch et al. (2015) | ATO, multi-stage | – | LP | Commitments |
| Gössinger and Kalkowski (2015) | MTO, single-stage | Proprietary | LP | Commitments |
| Elmachtoub and Levi (2016) | Production | – | Online alg. | Commitments |
| Elmachtoub and Levi (2015) | Production | – | Online alg. | Commitments |

ATO: assemble-to-order, MTO: make-to-order, LP: linear program, MDP: Markov decision process, ta.: temporary assignment.

# The methods evolved over time.

UNIVERSITÄT DUISBURG ESSEN
*Open-Minded*

- Gallego et al. (2004)
  - *Generalized MDP formulation* for flexible products in arbitrary resource networks
  - Choice-based DLP (*CDLP*)

- Petrick et al. (2010, 2012)
  - Integration into various RM models
  - *How to use* models with flexible products over time, *trade-off flexibility/complexity*

- Gönsch et al. (2014)
  - DLP does not capture the *value of flexibility*, i.e. the benefit of flexible over opaque products

- Cheung and Simchi-Levi (2016)
  - *Approximate solution* methods for CDLP
  - E.g. *polynomial algorithm* for demand learning with sublinear regret

- Koch et al. (2017)
  - *Transformation* of RM problem with flexible products *to standard RM problem* (surrogate formulation)
  - Via FME, state space may explode

# Upgrades are well known.

UNIVERSITÄT DUISBURG ESSEN
*Open-Minded*

**Table 7**
Literature on capacity control with upgrades.

| | Industry/setting | Type | Method | Capacity management | imm./postp. assig. equivalent |
|---|---|---|---|---|---|
| Alstrup et al. (1986) | Airline, two resources, overbooking | Upgrade/ downgrade | MDP | Commitments | No |
| Karaesmen and van Ryzin (2004) | Generic, overbooking | Upgrade | MDP | Commitments | No |
| Gallego and Stefanescu (2009) | Standard capacity control | Upgrade | MDP | Commitments | No |
| Steinhardt and Gönsch (2012) | Standard capacity control | Upgrade | MDP | Immediate reduction, commitments | No, [yes] |
| Gönsch et al. (2013b) | Generic, single leg | Upgrade | EMSR | Immediate reduction | Yes |
| Ivanov (2015) | Hotel with 3 room types | Upgrade/ downgrade | Marginal revenue | Not applicable | Not applicable |
| McCaffrey and Walczak (2016) | Single-leg, two resources | Upgrade | MDP | Commitments | Yes |
| Gönsch and Steinhardt (2015) | Passenger aviation | Upgrade | MDP | Commitments, immediate reduction | Yes |
| Geraghty and Johnson (1997) | Car rental, single leg | Upgrade | EMSR | Immediate reduction | Yes |
| Fink and Reiners (2006) | Car rental | Upgrade | Network flow | Immediate reduction | No |
| Oliveira et al. (2014) | Car rental | Upgrade/ downgrade | Network flow | Immediate reduction | No |
| Guerriero and Olivito (2014) | Car rental | Upgrade, one-step | DLP | Immediate reduction | No |
| Shumsky and Zhang (2009) | Generic, one hierarchy | Upgrade, one-step | MDP | Immediate reduction | Yes |
| Wu et al. (2011) | Retail | Upgrade | MDP | Immediate reduction | Yes |
| Yu et al. (2015) | Retail | Upgrade | MDP | Immediate reduction | Yes |

EMSR: expected marginal seat revenue, DLP: deterministic linear program, MDP: Markov decision process

- *Postponement not necessary* for
  - Single leg, one hierarchy, full cascading upgrades
  - Same for airline upgrading (independent on each leg of the network)

# Research on (dynamic) pricing is still scarce.

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

**Table 8**
Literature on pricing with ICSPs.

| | Industry/setting | Choice | Type | Method |
|---|---|---|---|---|
| | Dynamic pricing | | | |
| Anderson and Xie (2012) | Hotel | Nested logit | Opaque | MDP |
| Sierag (2017) | Generic | Arbitrary | Flexible | MDP, heuristic |
| Huang et al. (2017) | Generic | Valuations | Opaque | MDP |
| Ceryan et al. (2018) | Retail | Valuations | Flexible | MDP, heuristic |
| | Static pricing | | | |
| Zouaoui and Rao (2009) | Generic | Logit | n.a. | Analytical |
| Post (2010) | Generic | Proprietary | n.a. | Heuristic |
| Bai et al. (2015) | Generic | Utility | n.a. | Heuristic |

MDP: Markov decision process.

## Agenda

1 Introduction

2 Strategic Operations Management: Economics of Incompletely Specified Products (ICSPs)

3 Empirics: ICSPs in the real-world

4 Operations: Revenue Management with ICSPs

**5 Conclusion**

# Conclusion

UNIVERSITÄT DUISBURG ESSEN
*Open-Minded*

**Summary**

- Many *examples* from practice
- Already some research
- Different *areas largely ignore each other*

**Outlook**

- Opacity: *Flexibility/attractiveness trade-off*
- Risk-aversion
- Demand learning
- *Additional sources of variation*
  (e.g. Cleophas et al. 2017)

Pexels, Ann H.

UNIVERSITÄT DUISBURG ESSEN

*Open-Minded*

# Thank you!

Prof. Dr. Jochen Gönsch

Chair of Service Operations
Mercator School of Management
Universität Duisburg-Essen
Lotharstraße 65
47057 Duisburg, Germany

T +49 203 379-4369
F +49 203 379-1760
jochen.goensch@uni-due.de
www.msm.uni-due.de/so