TradeExtensions™

OR in Electronic Negotiations

Arne Andersson

Nov 2008

Presented at Seminar Day on Usage of Operations Research in Aarhus, Denmark

Content

1. E-Commerce and OR Techniques
2. Short History
3. Designing a Flexible Platform for Advanced Electronic Negotiations
4. Examples of what you can do with a generic optimizing negotiation platform
5. Experiences and Comments

Content

1. **E-Commerce and OR Techniques**
2. Short History
3. Designing a Flexible Platform for Advanced Electronic Negotiations
4. Examples of what you can do with a generic optimizing negotiation platform
5. Experiences and Comments

Mathematical Programming

Maximize expression **subject to** constraints.

Negotiaion: A seller tries to

Maximize
income
subject to
bid constraints.

Example 1

	Bid A	Bid B	Bid C	Bid D	Bid E
Commodity 1	100	102	x		
Commodity 2	103	99		x	x
Commodity 3	100			x	x
Commodity 4	105	106	x		x
Comb price			200	205	305

Example 1

	Bid A	Bid B	Bid C	Bid D	Bid E
Commodity 1	100	102	x		
Commodity 2	103	99		x	x
Commodity 3	100			x	x
Commodity 4	105	106	x		x
Comb price			200	205	305

- Column A contains four bids on commodities 1, 2, 3, 4.
  We denote these bids as: A1, A2, A3, A4.
- In the same way, column B contains three bids: B1, B2, B4.
- Columns C, D, E contains one combinatorial bid each, denoted C, D, E.

In order to apply Integer Programming, we define one binary variable per bid:

- A1 is 1 if bid A1 wins, otherwise A1 is 0.
- A2 is 1 of bid A2 wins, otherwise A2 is 0. etc…

We can now express the income from bid A1 as

100 * A1

i.e. if A1 = 1 the income from bid A1 is 100, otherwise the income is 0.

Example 1

	Bid A	Bid B	Bid C	Bid D	Bid E
Commodity 1	100	102	x		
Commodity 2	103	99		x	x
Commodity 3	100			x	x
Commodity 4	105	106	x		x
Comb price			200	205	305

Maximize

100 A1 + 103 A2 + 100 A3 + 105 A4
+ 102 B1 + 99 B2 + 106 B4 + 200 C + 205 D + 305 E

subject to

A1 + B1 + C = 1 (only one bid can win Commodity 1)
A2 + B2 + D + E = 1 (only one bid can win Commodity 2)
A3 + D + E = 1 (only one bid can win Commodity 3)
A4 + B4 + C + E = 1 (only one bid can win Commodity 4)

Example 1

Optimal solution:
B1 = 1, B4 = 1, D= 1,
all other variables are 0.
Income: 413.

	Bid A	Bid B	Bid C	Bid D	Bid E
Commodity 1	100	102	x		
Commodity 2	103	99		x	x
Commodity 3	100			x	x
Commodity 4	105	106	x		x
Comb price			200	205	305

Maximize
100 A1 + 103 A2 + 100 A3 + 105 A4
+ 102 B1 + 99 B2 + 106 B4 + 200 C + 205 D + 305 E

subject to

A1 + B1 + C = 1	(only one bid can win Commodity 1)
A2 + B2 + D + E = 1	(only one bid can win Commodity 2)
A3 + D + E = 1	(only one bid can win Commodity 3)
A4 + B4 + C + E = 1	(only one bid can win Commodity 4)

Example 2

Same bids:
what is my best income if I sell only three of the four commodities?

	Bid A	Bid B	Bid C	Bid D	Bid E
Commodity 1	100	102	x		
Commodity 2	103	99		x	x
Commodity 3	100			x	x
Commodity 4	105	106	x		x
Comb price			200	205	305

Example 2

Same bids:
what is my best income if I sell only three of the four commodities?

	Bid A	Bid B	Bid C	Bid D	Bid E
Commodity 1	100	102	x		
Commodity 2	103	99		x	x
Commodity 3	100			x	x
Commodity 4	105	106	x		x
Comb price			200	205	305

Maximize

100 A1 + 103 A2 + 100 A3 + 105 A4
+ 102 B1 + 99 B2 + 106 B4 + 200 C + 205 D + 305 E

subject to

A1 + B1 + C =	1	(only one bid can win Commodity 1)
A2 + B2 + D + E =	1	(only one bid can win Commodity 2)
A3 + D + E =	1	(only one bid can win Commodity 3)
A4 + B4 + C + E =	1	(only one bid can win Commodity 4)

Example 2

Same bids:
what is my best income if I sell only three of the four commodities?

	Bid A	Bid B	Bid C	Bid D	Bid E
Commodity 1	100	102	x		
Commodity 2	103	99		x	x
Commodity 3	100			x	x
Commodity 4	105	106	x		x
Comb price			200	205	305

Maximize

100 A1 + 103 A2 + 100 A3 + 105 A4
+ 102 B1 + 99 B2 + 106 B4 + 200 C + 205 D + 305 E

subject to

A1 + B1 + C = x1 (x1 = 1 only if Commodity 1 is sold)
A2 + B2 + D + E = x2 (x2 = 1 only if Commodity 2 is sold)
A3 + D + E = x3 (x2 = 1 only if Commodity 2 is sold)
A4 + B4 + C + E = x4 (x2 = 1 only if Commodity 2 is sold)

Example 2

Same bids:
what is my best income if I sell only three of the four commodities?

	Bid A	Bid B	Bid C	Bid D	Bid E
Commodity 1	100	102	x		
Commodity 2	103	99		x	x
Commodity 3	100			x	x
Commodity 4	105	106	x		x
Comb price			200	205	305

Maximize

100 A1 + 103 A2 + 100 A3 + 105 A4
+ 102 B1 + 99 B2 + 106 B4 + 200 C + 205 D + 305 E

subject to

A1 + B1 + C = x1 (x1 = 1 only if Commodity 1 is sold)
A2 + B2 + D + E = x2 (x2 = 1 only if Commodity 2 is sold)
A3 + D + E = x3 (x2 = 1 only if Commodity 2 is sold)
A4 + B4 + C + E = x4 (x2 = 1 only if Commodity 2 is sold)
x1 + x2 + x3 + x4 = 3

Example 2

Same bids:
what is my best income if I sell only three of the four commodities?

	Bid A	Bid B	Bid C	Bid D	Bid E
Commodity 1	100	102	x		
Commodity 2	103	99		x	x
Commodity 3	100			x	x
Commodity 4	105	106	x		x
Comb price			200	205	305

Maximize

100 A1 + 103 A2 + 100 A3 + 105 A4
+ 102 B1 + 99 B2 + 106 B4 + 200 C + 205 D + 305 E

subject to

A1 + B1 + C = x1 (x1 = 1 only if Commodity 1 is sold)
A2 + B2 + D + E = x2 (x2 = 1 only if Commodity 2 is sold)
A3 + D + E = x3 (x2 = 1 only if Commodity 2 is sold)
A4 + B4 + C + E = x4 (x2 = 1 only if Commodity 2 is sold)
x1 + x2 + x3 + x4 = 3

Example: e-Sourcing with optimization

e-Sourcing vs traditional production planning / supply chain management:

Bids rather than collected (internal) data.

Example: e-Sourcing with optimization

Minimize
cost function
subject to
bid constraints
and business rules

e-Sourcing with optimization and scenario analysis (”What-if” analysis)

Minimize
cost function
subject to
bid constraints
and business rules

Try different business rules until you are happy with the outcome

Another example: Two-sided market

Maximize
surplus
subject to
bid constraints from buyers and sellers

Maximize
turnover
subject to
bid constraints

Potential goal for a market-maker charging its clients based on transaction volume

Content

1. E-Commerce and OR Techniques
2. **Short History**
3. Designing a Flexible Platform for Advanced Electronic Negotiations
4. Examples of what you can do with a generic optimizing negotiation platform
5. Experiences and Comments

Some (incomplete) History

- First combinatorial auctions done by Net Exchange in 1993.
- Later in 1990's: Schneider Logistics, using solver from Net Exchange, used emailed Excel sheets to serve its client in combinatorial bidding.
- Late 1990's: Combinatorial auctions get more attention in the AI-related field of multi-agent systems.
- Being unaware of traditional optimization techniques, some researchers develop their own heuristic algorithms for handling the simplest cases of combinatorial auctions

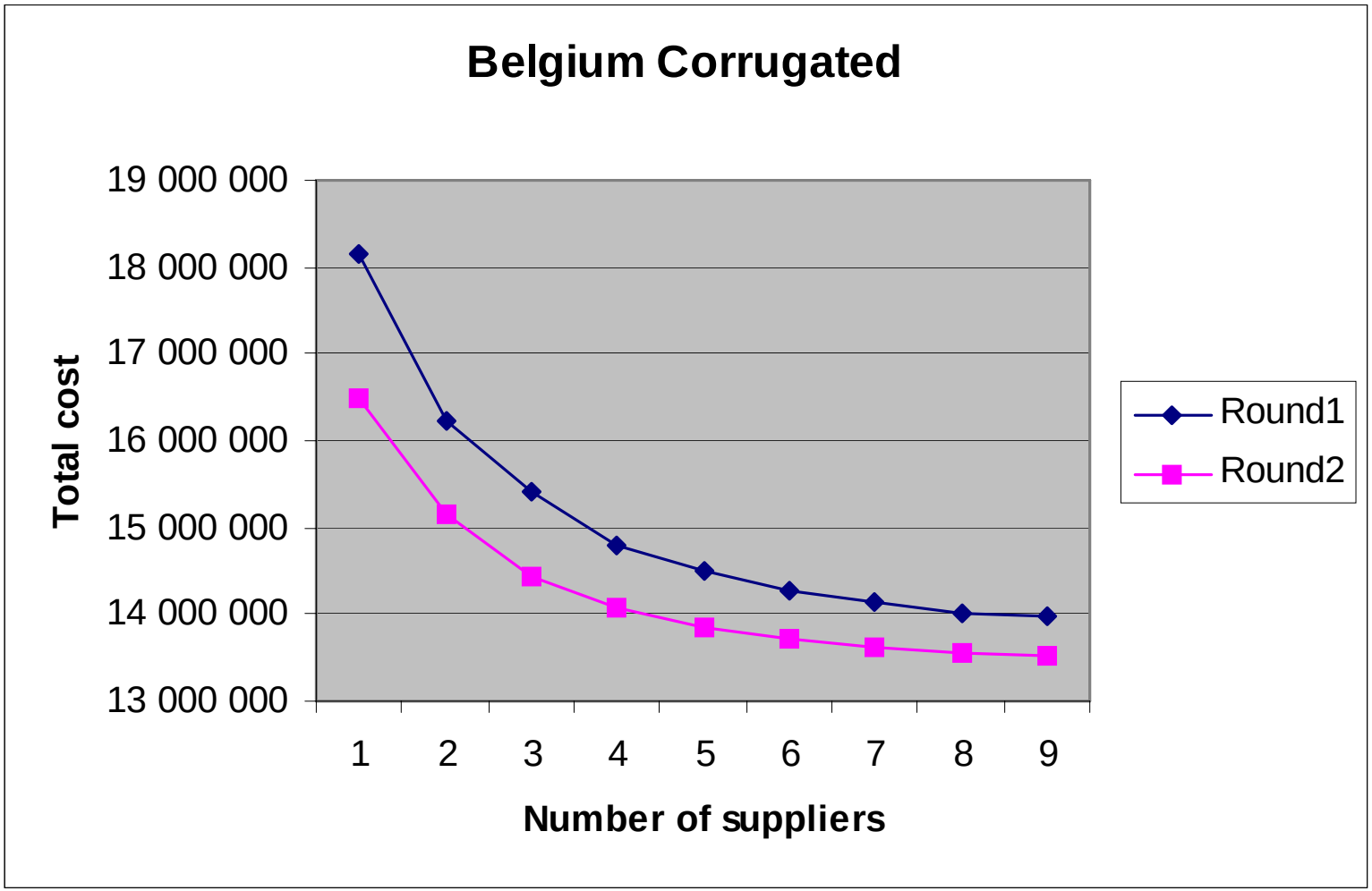
Some (incomplete) History

- In 1999, we wrote a paper pointing out the usefullness of Integer Programming.
- As we pointed out, these basic facts are obvious for anyone with an OR or optimization background.
- As typical for AI, there were some claims of some ”super algorithms” being much faster than an OR approach, but these claims have more or less disappeared.
- Of course, there are always special cases...

Our History

- In 2000, Trade Extensions was formally founded
- 2000: Two-sided combinatorial bid matching (project together with OM Technology aiming at power exchanges)
- 2000-2002: more projects, including
  - The world's first on-line combinatorial auction with direct feedback to bidders (packaging sourcing for Volvo, performed early 2001)
  - Dynamic solution of scenarios combining package bidding with business rules (like adding a penalty for each extra allocated supplier per region, etc)

Example of ”what-if” in early packaging sourcing for Volvo, examining tradeoff between number of suppliers and total cost



Content

1. E-Commerce and OR Techniques
2. Short History
3. **Designing a Flexible Platform for Advanced Electronic Negotiations**
4. Examples of what you can do with a generic optimizing negotiation platform
5. Experiences and Comments

Our Initial Design Challenge

- A general-purpose platform
  - Data is simply defined as lots, lot fields, bid fields, etc with no specific semantics attached
  - Tools for designing bid forms etc.
- Powerful tools for defining the semantics
  - Allow flexible formulas based on any fields
  - Create a toolbox for creating business rules based on any fields, any thinkable measure, etc.
  - Goal: As flexible as low level MIP, easy enough to use by a typical trained buyer/seller/trader.
- Good algorithmic understanding on how to treat the underlying MIP problems
  - Smart modelling and translations
  - Transforming MIP problems into simpler ones, based on knowledge of occurring special cases, etc
- Combine all this with activity rules, bidding rules, bid feedback, project management tools, document handling, role hierarchies etc

Our Initial Design Challenge

Result:

- When our competitors need several man weeks to create a customer-specific project including programming of user-interface etc, we can create it in days or hours, no programming needed, just defining proper input fields and business rules in the existing platform

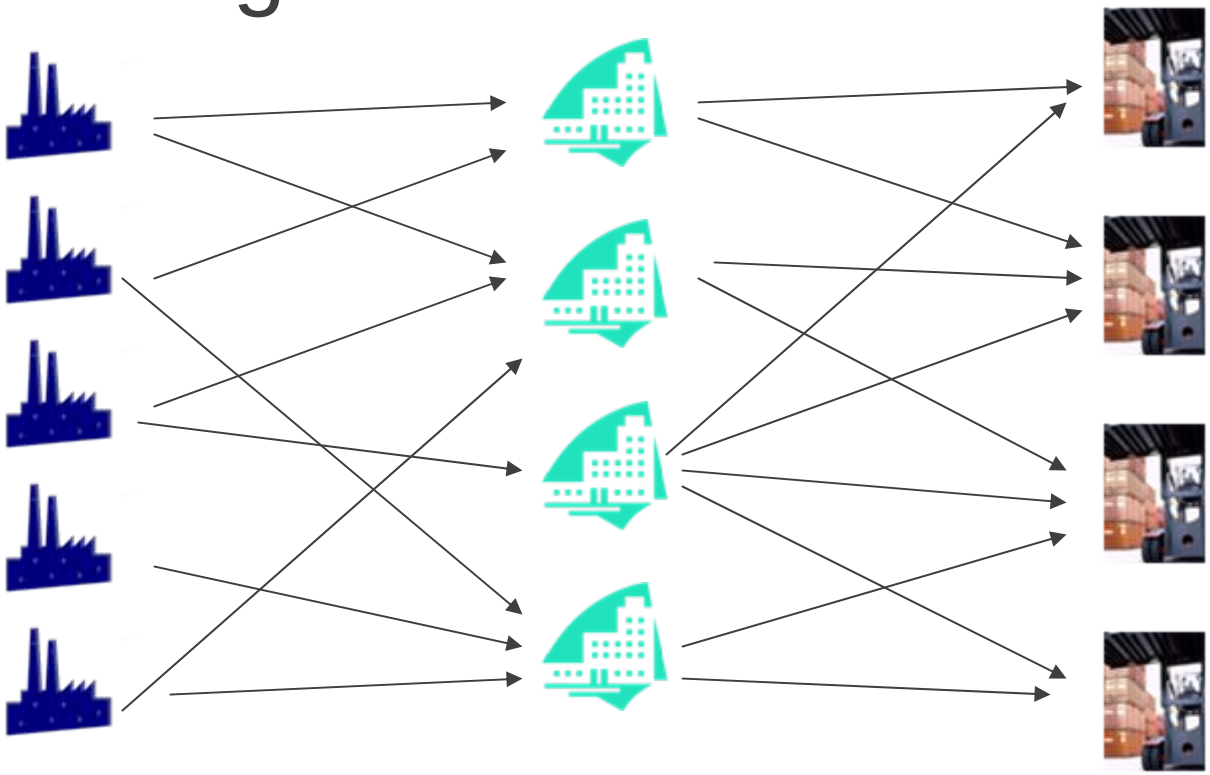
Content

1. E-Commerce and OR Techniques
2. Short History
3. Designing a Flexible Platform for Advanced Electronic Negotiations
4. **Examples of what you can do with a generic optimizing negotiation platform**
5. Experiences and Comments

Related things you can do

- Multi-level supply chains, worked example follows
- Two-Sided Market with Multiple Buyers and Multiple Sellers
  - Directly in sourcing GUI:
    - Alt 1: Define pairs of buy and sell lots, define a rule that applies per lot pair and ensures volumes match.
    - Alt 2: Separate lots for bidders at buy or sell side.
  - Customized GUI, unchanged solver
- Optimize number of facings per product on the shelves of a Retail Store
  - Let each product be a lot, and each facing a bid, where the rate of the i:th facing corresponds to the profit of placing this facing on the shelf.
  - Define business rules limiting the total space per shelf etc.
- Warehouse optimization
  - Lots describe different routes between origins, warehouses and destinations
  - Bids reflect different costs, such as price per ton x km
  - Rules on e.g. number of warehouses (cost of extra warehouses)
  - Result: Optimal set of warehouses
- In essence, a large number of optimization problems can be relatively nicely modelled in the e-commerce tool thanks to focus on generality and flexibility

Supply Chain Example: Printing a Catalogue



Paper Mills

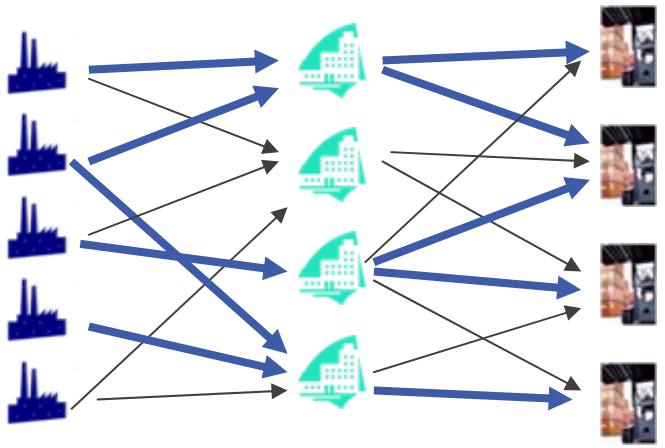
Printers

Distribution Centers

Many parameters to consider

Find matching volumes. Optimize with regards to:

- Bids from paper mills and from printers
- Maximum capacities
- Volume discounts
- Paper waste
- CO2 footprint
- etc



Adding More Steps in the supply chain:

- Include bids from carriers to handle transport between Paper Mills, Printers, and Distribution Centers (not included here)

Examples of Business Rules

Hard Limit Rules Wiki Help

Add Rule
Add 5

	Name	Scope selected by the following filters	Apply Rule Per	Limit Type	Relative To
H1 Edit	Capacity Per Print Plant	Bidders: Printers	From Print Plant	Allocation (M kgs or copies)	Max Total Volume (M Copies)
H2 Edit	Weekly Print Capacity	Bidders: Printers	From Print Plant Week	Allocation (M kgs or copies)	Printing Capacity Per Week (M Copies)
H3 Edit	Number of printers per Edition	Bidders: Printers Lots: DC Germany or UK [INVERTED FILTER]	Edition	Number of Bidders	

Apply this rule to the Printers, and on all lots except Germany and UK

Apply this rule once per Edition

Limit the number of allocated printer suppliers

Using the rules in a Scenario

Hard Limit Rules | Edit | (Active settings made for this scenario) Wiki Help

	Rule Definitions					Settings For This S		
	Name	Scope selected by the following filters	Apply Rule Per	Limit Type	Relative To	Min Limit	Max Limit	Min Conditi (i.e. at least this or not
H1	Capacity Per Print Plant	Bidders: Printers	From Print Plant	Allocation (M kgs or copies)	Max Total Volume (M Copies)		1.00	
H2	Weekly Print Capacity	Bidders: Printers	From Print Plant Week	Allocation (M kgs or copies)	Printing Capacity Per Week (M Copies)		1.20	
H3	Number of printers per Edition	Bidders: Printers Lots: DC Germany or UK [INVERTED FILTER]	Edition	Number of Bidders			1.00	

Allocate each Printer at most its total capacity

Allocate each Printer at most 1.2 x weekly capacity (i.e. we anaylze the case where we loosen the capacity limits slightly)

At most one printer per Edition, except for Germany and UK

Using rules for balancing the Supply Chain

Name	Scope selected by the following filters	Apply Rule Per	Limit Type	Relative To	Min Limit	Max Limit
Balance		Print Plant Code Paper Grade	Allocation × "Paper Consumption (M kgs)"			0.00

Balance the chain for each Print Plant and Paper Grade

Paper Consumption is negative for paper mills and positive for printers

Max limit is zero means that the amount of delivered paper must be at least the amount consumed

Content

1. E-Commerce and OR Techniques
2. Short History
3. Designing a Flexible Platform for Advanced Electronic Negotiations
4. Examples of what you can do with a generic optimizing negotiation platform
5. **Experiences and Comments**

General Observation

- Virtually any thinkable optimization problem occurring in electronic negotiations can be modelled and treated with OR techniques
- With proper design of a general-purpose platform, this works fine in practice
- You need to carefully model the problems, transform MIP problems, etc, to get good solver performance.
- You must respect the fact that we are dealing with NP-hard problems. As long as you and your client are aware of this, there is always a proper way to treat very complex instances.

Managed Problem Complexity

- 5-level supply chain
- Hundreds of thousands of bids
- Tens of thousands of lots
- Thousands of bidders
- Millions of bid parameters
- Volume discounts, What-If scenarios, etc
- It works!

Experiences: Related important issues

Good optimization analysis requires good data

- Bid collection
- Feedback
- Termination
- Bid evaluation
- Bid analysis

Bid collection

- On-line, web-browsers
- Bid forms, e.g. MS Excel
- Data validation
  - Data types
  - Range checks
  - Checks on relations between values
- Sorting and viewing lots / items
  - Predefined
  - Bidder controlled
  - Dynamically, e.g. By closing time
- Collection of sub-parameters
- Collection of general parameters, certifications, capacities, discounts etc.

Feedback

- On bid total or by parameter:
  - Rank
  - Best bid / distance to best bid
- Conditional feedback
  - For example, show any of thee above only if best bid has passed a certain value or change is sufficiently large

Termination

- Fixed times
- Prolongations
  - Based on e.g. latest bid on the lot
  - Based on bids on other lots
  - In parallel, sequence or independently

Bid evaluation / rating

- Mathematical expressions to compute bid values from parameters and sub-values

Bid analysis

- Reports for quickly identifying outlier bids, e.g. based on median or historical price
- Ditto for outlier parameter values in bids
- Analysis of competitiveness of bidders, optionally with special analysis of historically awarded lots
- Analysis of bidder activity