Scientific Committee 2009

"Vehicle loading optimization with stochastic supply"

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1. Main Message

From manual optimization over decomposed deterministic sub-problems to a multi-period stochastic policy.

"Local optimima over available data
vs
global policy including uncertainty".

2. Industrial Case

Coils to be loaded on truck : **BIN-PACKING**
Objective function *min cost* :
Truck (fixed + tons) + Penalty for double un/loadings
Constraints :
Weight constraint usually 1-2, sometimes 3 coils per truck

Data :
1 production site Liège (B)
800 customers in Europe (Germany and France)
350 trucks per day

MANUALLY UNTRACTABLE

3. Rules and Manual Optimization

Consequence : Problem decomposed over

1. Time = period per period with the actual stock
2. Space = ZIP code, lander or department
3. Customer = customer per customer

RULES : DIVIDE TIME AND SPACE TO GET SMALLER SUB-PROBLEMS

Results : Tractable instances manually optimized including up to 10 coils representing 7-8 trucks

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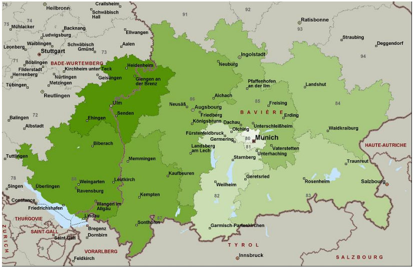
4. One-period Deterministic : METHOD

- MIP approach to handle large instances
- Merge ZIP codes or departments (up to 10) to create large sizes instances up to 100 coils and act over

SPACE



Optimization technique : EXACT

Patterns Generation and Set Covering Problem

Generation of all feasible loaded trucks, their costs and selection of the cheapest composition (Cplex)

4. One-period Deterministic : MODEL

Indices : i for M coils, j for N patterns

Parameters :

- A_{ij} pattern j contains coil i
- C_j cost of shipping pattern j

Variables : $x_j \in \{0, 1\} \forall j = 1, ..., N$

Objective Function : $min\ Z = min \sum_{j=1}^{j=N} C_j x_j$

Constraints :

$\sum_{j=1}^{j=N} A_{ij} x_j \geq 1 \forall i = 1, ...M$ every coil is sent

Advantages : Pattern includes weight constraint, pattern costs penalties and complex truck cost function

Option : differents kinds of trucks and fleet size limits

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4. One-period Deterministic : RESULTS

In Bavaria compare to individual optimization on ZIP Codes 80 to 89, over industrial instances,

1. the **number of trucks** is reduced by 16,9%
2. and the **cost** by 12,7 %

These are well-known techniques.

New dimension **TIME** : multi-period setting

Creation of a new model that takes into account **production forecasts** over a rolling horizon.

Penalties related to time : Inventory and Time-Windows

5. Multi-period Deterministic

	Periods				
Coils Weight	**P1**	**P2**	**P3**	**P4**	**P5**
A *0.6*	1	*TW*			
B *0.8*		1		*TW*	
C *0.3*				1	
D *0.2*	1	*TW*	*TW*	*TW*	
E *0.4*	1		*TW*		

Costs, penalties and limits

- inventory cost P-INV
- late or early delivery TW +/- 1 period P-EAR or P-LAT
- not allowed TW $\geq$ +/- 2 periods
- one period delivery time
- P-INV < P-EAR < P-LAT < Truck cost

DECISIONS : WAIT or SEND for coils in PERIOD 1

e.g. : AD(P1) + E(P2) + B(P3) vs AE(P1) + BD(P3)

TW (OK) + 1 P-INV + 1 P-INV vs P-EAR + 2 P-INV

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5. Multi-period Deterministic

Model formulation

Pattern generation and set covering problem

More efficient than alternative formulations

A pattern is a truckload of coils which are available at a given time t

It means from availability date to last TW + 1 P

Pattern cost indexed by t includes as a basis the truck cost based on the load + the penalties : inventory, earliness or lateness

The **set covering problem** is similar to the previous one with a new index t

Current implementation : patterns are generated off-line, no delayed column generation technique or dedicated set-covering algorithm

Tractable 100 coils over 3 periods

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6. Multi-period Stochastic

Forecasts contain uncertainty on production availability

	Periods				
Coils Weight	**P1**	**P2**	**P3**	**P4**	**P5**
A *0.6*	1	*TW*			
B *0.8*		0.9	0.1	*TW*	
C *0.3*			0.2	0.8	
D *0.2*	1	*TW*	*TW*	*TW*	
E *0.4*	1		*TW*		

New objective function : *"Minimize expected cost"*
Scenarios tree : Deterministic equivalent with scenarios and non-anticipativity constraints

- e.g. : 4 scenarios
  1. B(P2) C(P3) Pr(0.18)
  2. B(P2) C(P4) Pr(0.72)* Most likely available
  3. B(P3) C(P3) Pr(0.02)
  4. B(P3) C(P4) Pr(0.08)

Policy : find solution for P1, implement, update data (remove P1, add a P) and repeat over the rolling horizon

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7. Scenario Sampling

Drawback : huge number of scenarios
Limit for optimization over all scenarios 22 coils 3 periods
Sample to solve over a subset of scenarios

SCENARIOS SELECTION

1. Monte-carlo random generation of scenarios
2. Stratified generation of scenarios

SAMPLE SIZE

1. use the largest sample size that we can handle
   1 x [N] e.g. : N = 1-20-50-100 scenarios

SOLUTION VALIDATION

- Variance due to scenario sampling
- Compare policies from a collection of results

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8. Results

5 solutions techniques or policies

1. One-period Deterministic repeated on every period
2. Multi-period Deterministic with most likely availability
3. Stochastic with all scenarios
4. Stochastic with sampling (Monte-Carlo generation)
5. Stochastic with stratified sampling

Cost function : coils sent and expected cost for not sent
Instances : 22 coils, 6 periods, rolling horizon P1, P2, P3
Sample size : 10 - 50 compare to thousands
Computation time : including scenario generation

Policies	Sample size	Value	Computation Time
One-period Deter.		6750	0.1 sec
Multi-period Deter.	(1)*	6202	0.1 sec
Stoch. All Scenarios	All	6192	417 sec
Stoch. Samp. Rand.	10	6192	2.5 sec
Stoch. Samp. Rand.	50	6197	3.1 sec
Stoch. Samp. Strat.	10	6200	1 sec
Stoch. Samp. strat.	50	6189	4.2 sec

9. Conclusions and Perspectives

Conclusions

- New model Transportation/Production
- Pattern generation seems an appropriate formulation to include penalties

Perspectives

- Perform more computational tests to handle realistic instances
- Add a delayed column generation technique and a dedicated algorithm for the set-covering
- Compare the policies using larger instances
- Determine the value added by successive enrichments of the model from deterministic to multi-period to stochastic
- Use consensus functions which aggregate several solutions obtained from different scenario samples