A MILP model for joint product family and supply chain design

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Outline

1 Introduction

2 Literature review

3 Optimization model

4 Experiments

5 Conclusion

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Issues that are investigated

Integrated supply chain design

Allocation and physical flows of products within the logistical network

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[Baud-Lavigne et al., 2010] : sequential design of product family and supply chain can be sub-optimal

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Aim of this presentation

1. provide an optimization model for joint product family and supply chain design
2. analyze the complexity of the model

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Literature review on product and supply chain design

Mass customization [Pine, 1993]

modular design : a product is a set of module

postponement : generic product differentiated at the end of the process

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Supply chain design with Bill of Materials constraints

- MILP models
- recently studied [Paquet et al., 2004]

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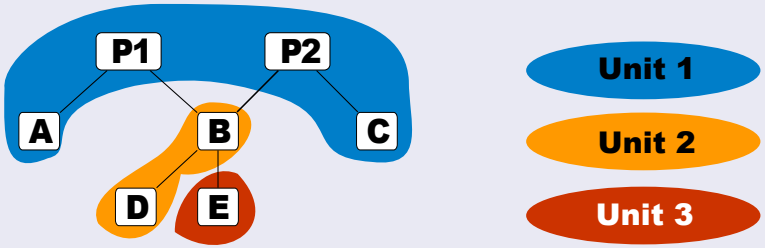

Literature review on **joint** product and supply chain design

- Product family has to be defined : customer needs
  Generic bill-of-materials : [Lamothe et al., 2006]

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- Product family is defined : industrialization
  - Modular conception : [El Hadj Khalaf et al., 2010]
  - Complex BOM : scenario based optimization [ElMaraghy and Mahmoudi, 2009]
    Fully integrated model [Chen, 2010]

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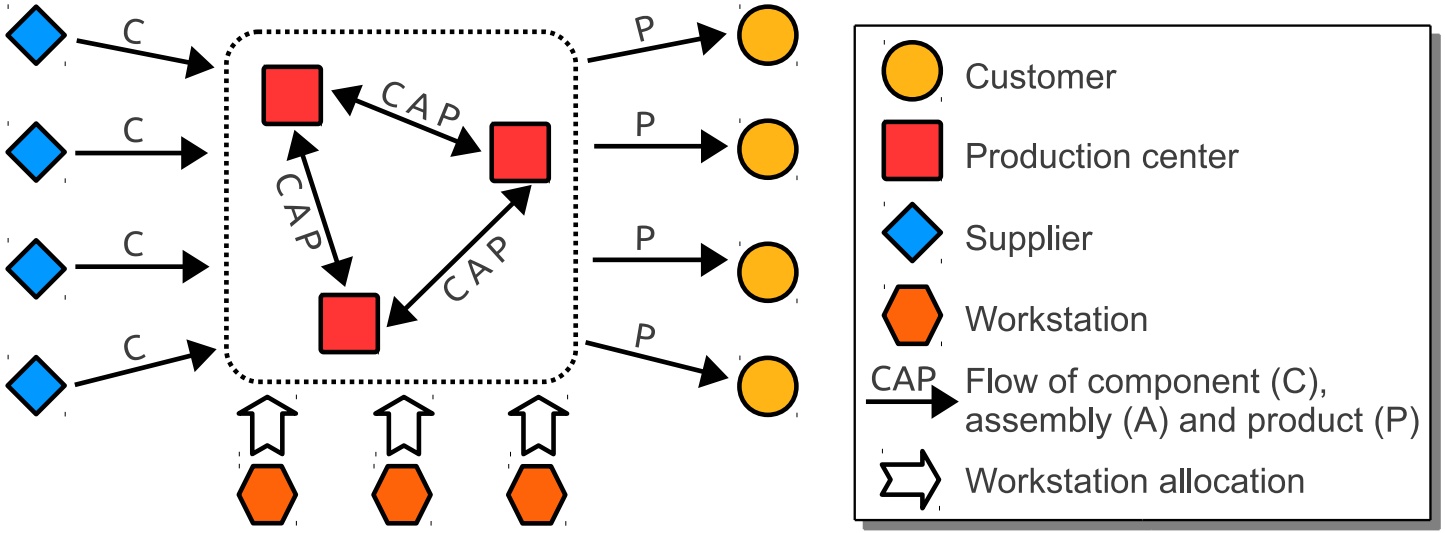
Generic supply chain network :



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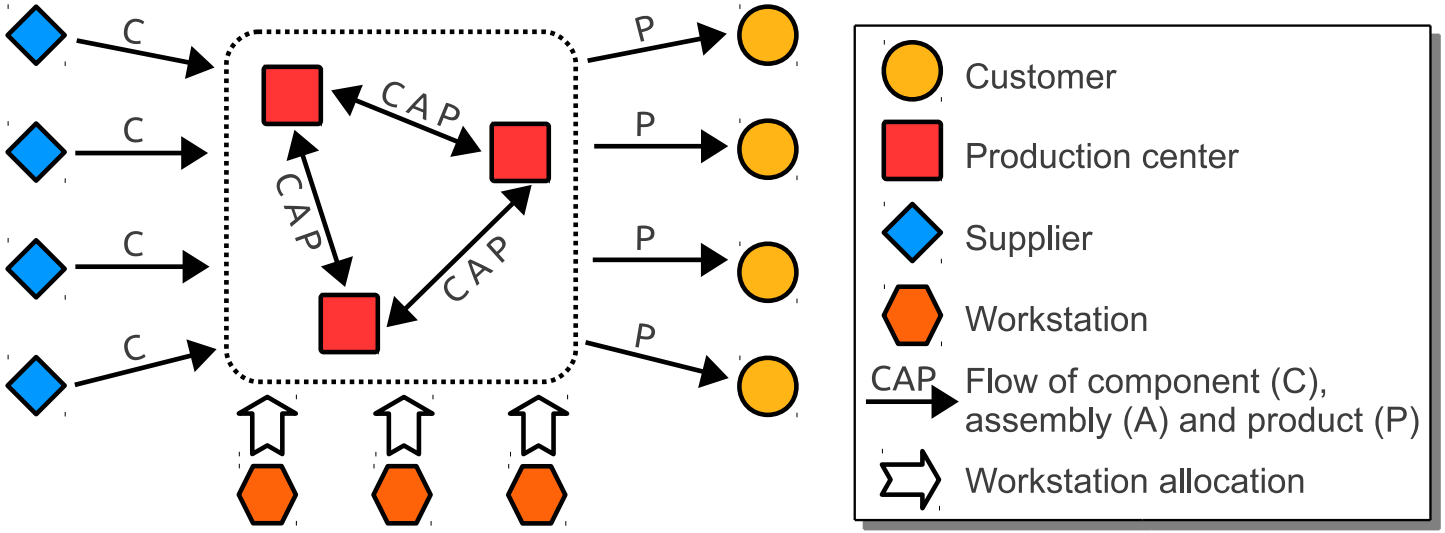

Strategical level

- Facility location
- Supplier selection

Supply chain design

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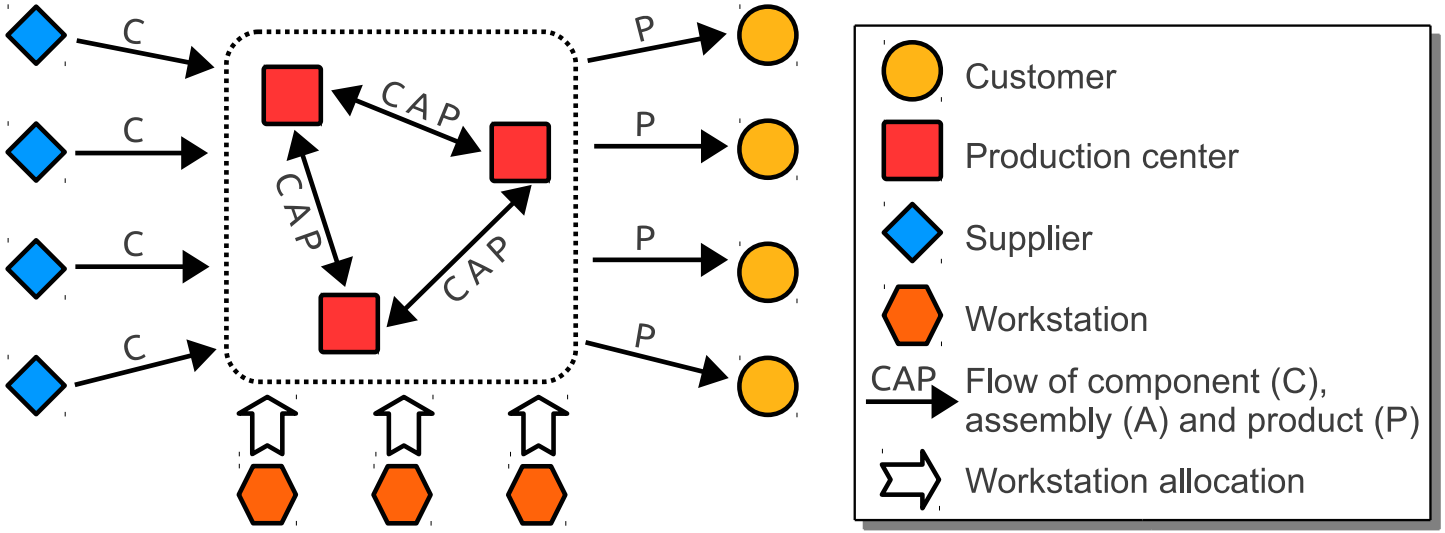


Strategical level

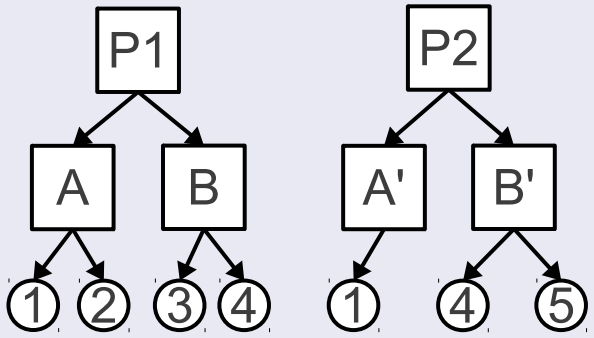
- Facility location
- Supplier selection

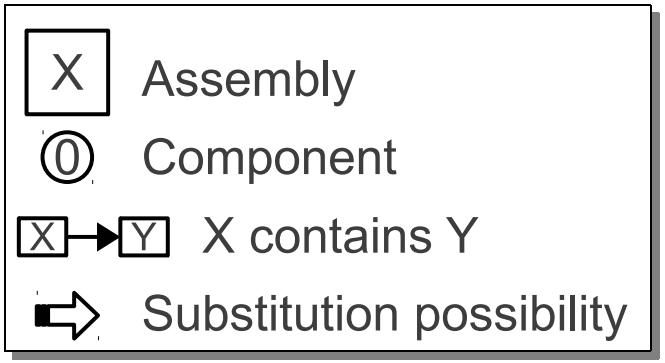
Tactical level

- Product allocation
- Physical flows
- Production line investments

Substitution possibilities

Initial BOM





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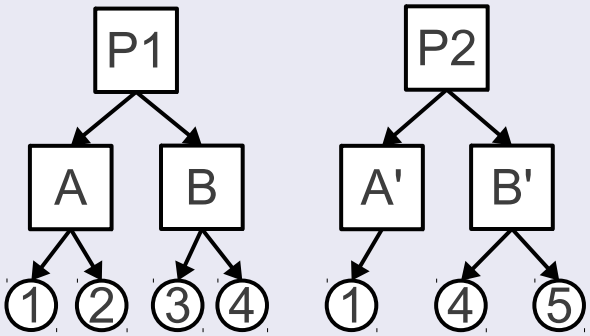
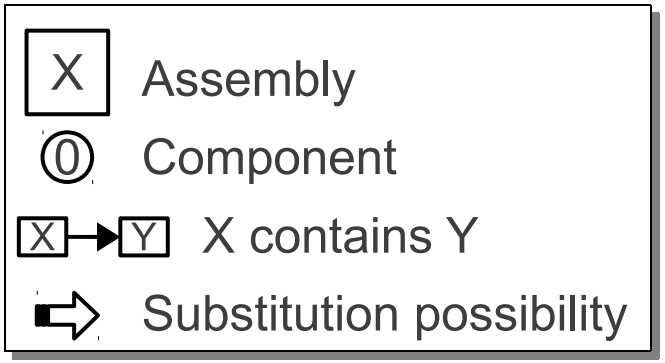
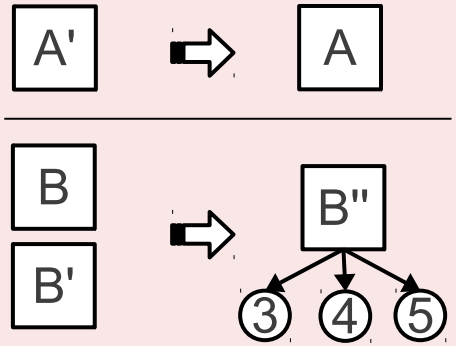




Standardization



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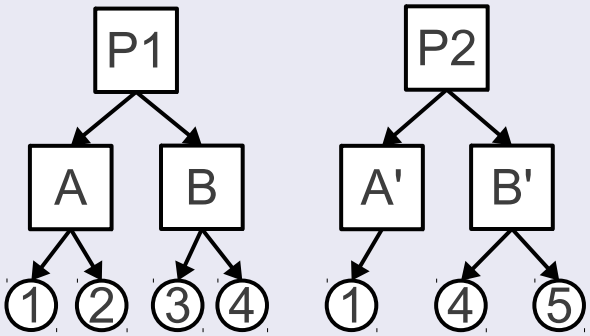

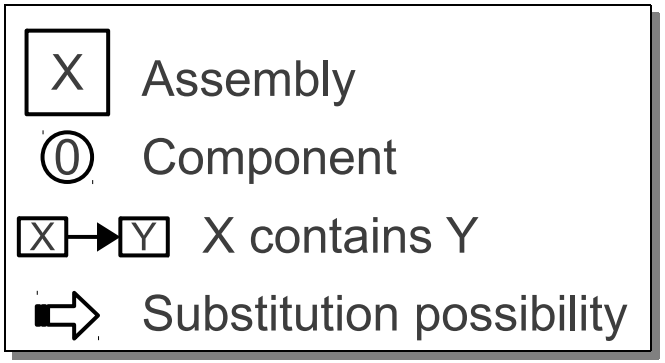

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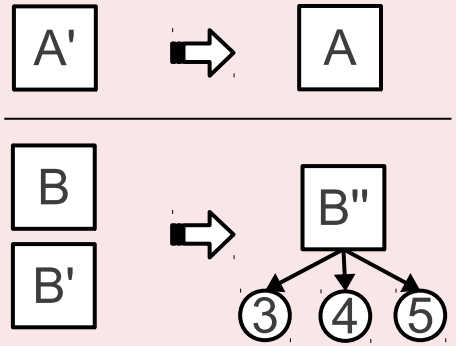
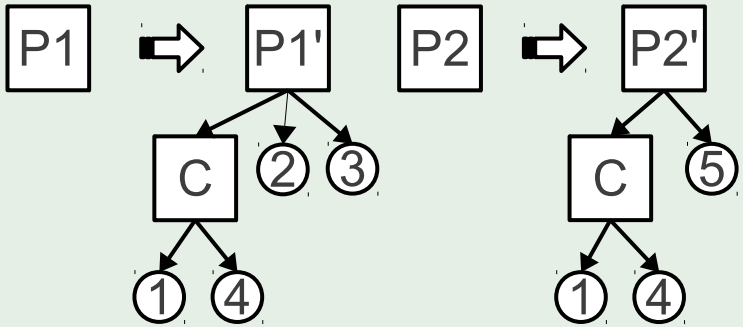


Alternative operation sequence



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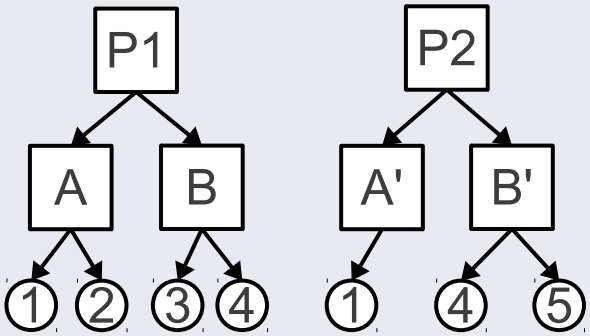

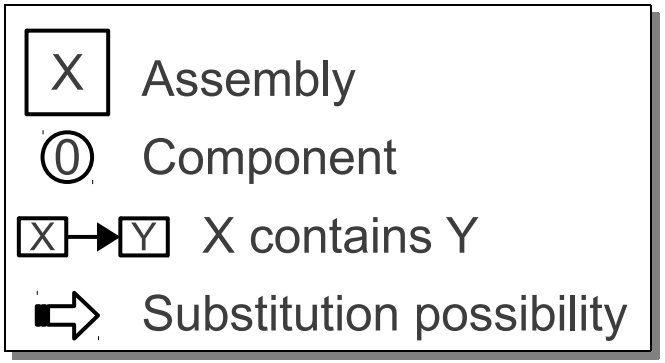

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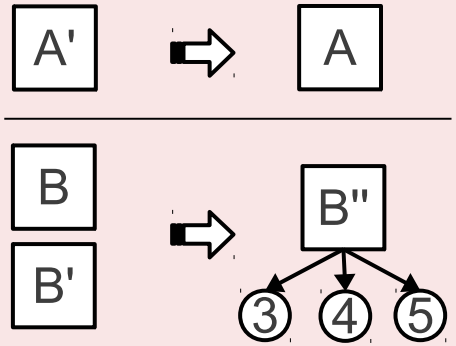

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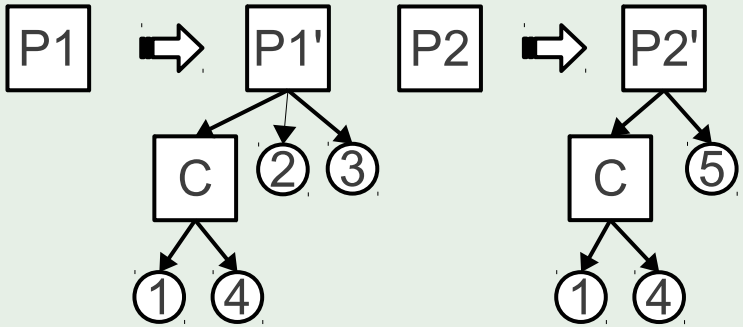

+ Externalization

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MILP model with the following variables

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- Real variables :
  - Part flows : quantity of part p from unit i to unit j.
  - Production of assemblies p on unit i / procurement of components p from supplier i.
  - Part substitutions : quantity of part p that replaces q on unit i.

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- Integer variables :
  - Number of workstation in each production center

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Mathematical model

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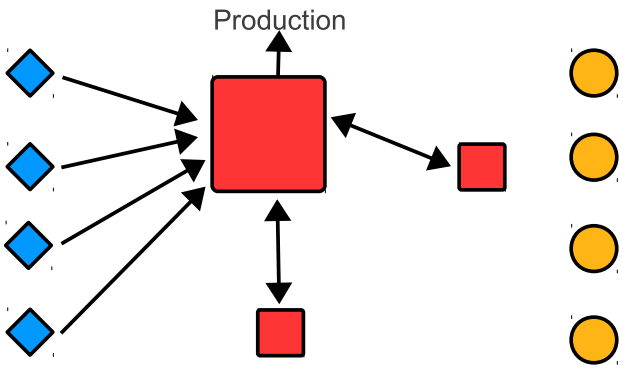

Flow constraints

Constraint at each node for each part.
The flow is pulled by the demand.

Mathematical model

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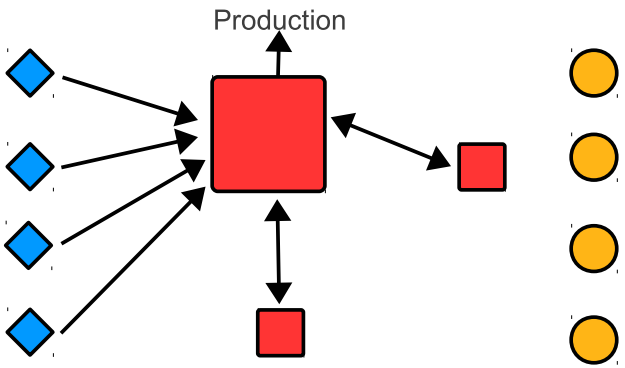

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Boolean and integer constraints

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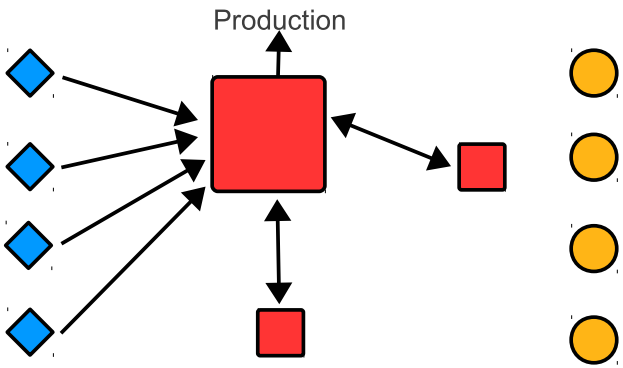

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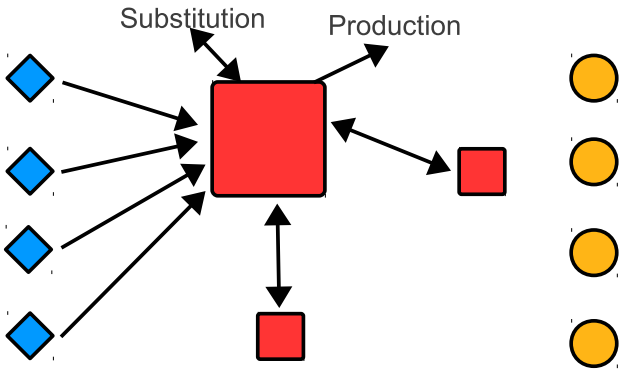

Substitution integration

Substitution variables are added within the flow constraints.

Mathematical model : drawbacks

Complexity

NP-Complete

Sub-problem : facility location

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Complexity

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Substitution issues

Substitution possibilities are free
Two products can be made in different manners

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Design of experiments

- Resolution method
  - ILOG CPLEX 10.2 Java libraries
  - 2.50 Ghz Xeon CPU, 6GB RAM

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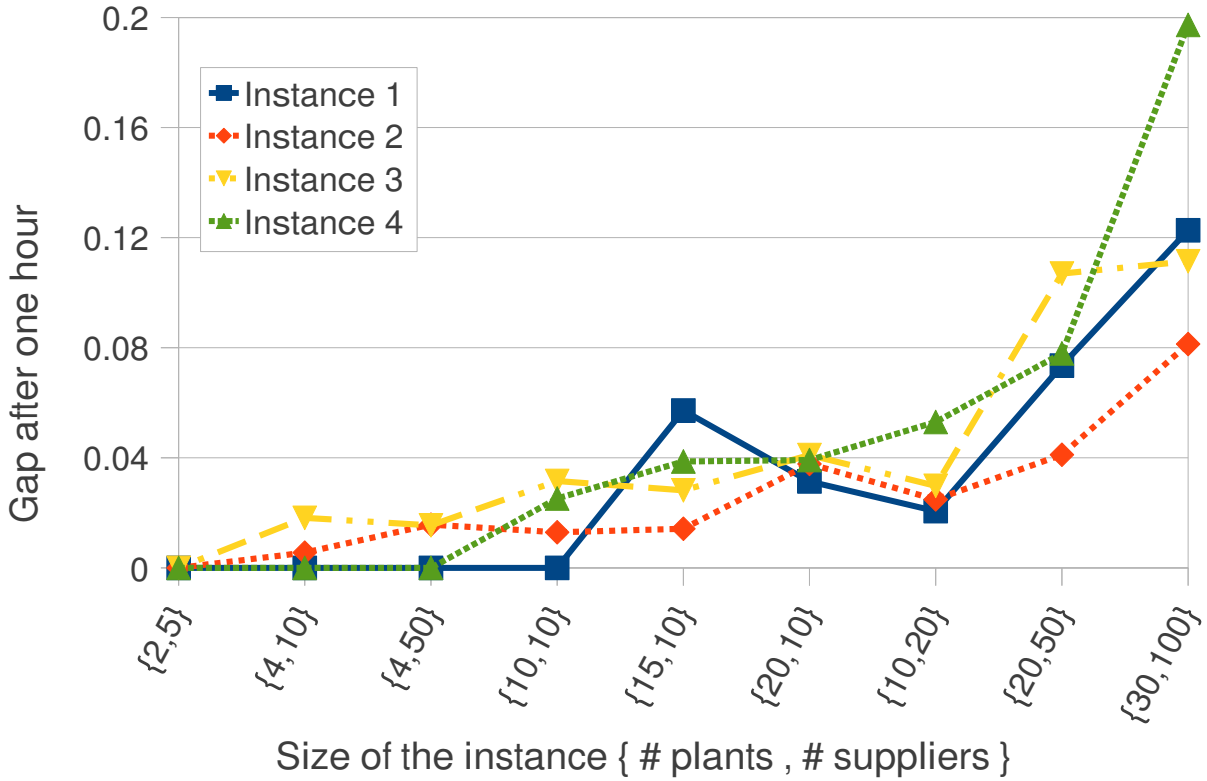
- Resolution method
  - ILOG CPLEX 10.2 Java libraries
  - 2.50 Ghz Xeon CPU, 6GB RAM
- Aim of the experiments
  - Assessing instance size that can be solved efficiently
  - Characterizing where the complexity comes from
  - Testing if substitution possibilities has influence on resolution length

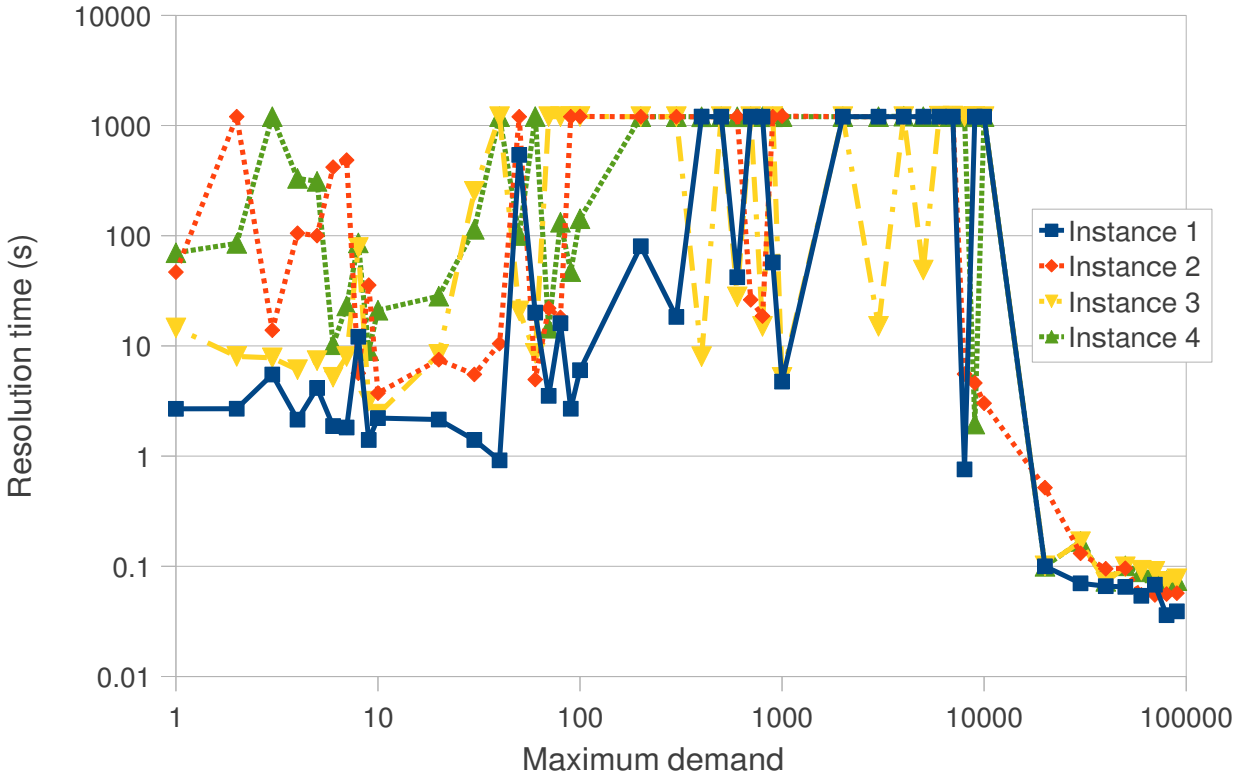
Instance generation

- Suppliers, production centers and customers are set randomly
- A BOM generator have been developed. It gives a product family with the standardization possibility.
- Details in the paper

Instance size



Demand variation



Substitution impact

Comparison of 8 instances with and without substitution

Instance	1	2	3	4	5	6	7	8
Substitution benefits (%)	.9	2.0	1.4	19.6	5.5	.4	3.3	-
Gap (%)								
with substitution	.06	.11	.29	.07	1.68	.41	1.43	-
without substitution	.04	.13	.32	.07	1.83	.50	1.41	-
Processed nodes								
with substitution	619001	373030	52301	18194	8615	17101	5509	-
without substitution	663114	355273	50215	23413	21733	16807	5530	-

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Conclusion

- Substitutions integrated in the flow constraints
- Correlation between the difficulty and the size of the instance
- Importance of the balance between fixed and variable costs
- Substitution does not worsen nor improve the resolution

Perspectives

Exact resolution methods

- Valid inequalities
- Decomposition methods as Benders

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Unique BOM constraint

- Different decision variables
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Sustainable design problematic

- Carbon footprint integrated via costs
- Products are an important part of carbon footprint
- Demand can be influenced by carbon footprint

References

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