

**KOMSA** Combination of optimisation methods and material flow analysis for the improvement of the operational material use

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## Combination of Optimisation Methods and Material Flow Analysis for the Improvement of Operational Material Use (KOMSA)

### The concept and its implementation

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Ciba

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**KOMSA** **Agenda**

- Background: Research project KOMSA – ideas and goals
- An example: The Two-Crude-Oil-Refinery
- Terminology: the standard optimisation model of OR
- Formulation by means of Material Flow Networks
- The framework of the KOMSA optimisation tool
- Solution with the prototype of our software tool
- Conclusions and Outlook

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**KOMSA** **What is KOMSA about?**

**Material Flow Analysis**

- analysis of material flow systems
- assessment of (**real**) material flows
- improvement analysis

**Operations Research**

- mathematical = parametric representation of (**virtual**) system designs/ operation modes
- algorithms to find best feasible solution

⇒ synthesis: material flow based optimisation

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**KOMSA** **KOMSA (1) – Research Questions**

- Objectives fit, methods either?
- How to map material flow based optimisation problems with material flow networks (MFNs)?
  - advantages? drawbacks?
  - application fields?
- How to optimise an existing MFN? Is that always possible?
- Which type of optimisation problem (OP) results?
- What are appropriate algorithms to solve them?

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**KOMSA (2) – Software Development**

- enhance existing material flow modelling software Umberto® → module for algorithmic optimisation
  - formulation of material flow based OP: optimisation cockpit
  - implementation of appropriate algorithms
  - link to existing optimisation packages
- conserve experimental modelling approach of Umberto
  - flexibility in process specification
- user-friendly model formulation
  - adaptation of material flow network concept

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**KOMSA (3) – Application**

- industrial partners: increase resource efficiency
  - Ciba speciality chemicals, Lampertheim
  - Hanomag Hardening Center, Hannover
- develop exemplary cases for optimisation module
  - test software
  - guidelines for future users
- description of potential application fields


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**What next...**

- a small example for a material flow based OP
- framework of the KOMSA tool
- how to solve the material flow based OP using the tool
- some ideas on using material flow networks to formulate OPs

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**An example: the “Two crude oil” refinery**



- fictitious refinery in Hamburg
- processes two different crude oils
  - from Venezuela 3000t/d
  - and from Saudi-Arabia 3000t/d

and produces:

- Gasoline
- Jet fuel
- Lubricants



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**KOMSA** **The company's objectives**

- meet demand (constraints)

	Lower limit [t/d]	Actual output [t/d]
Gasoline	2.000	2.100
Jet fuel	1.500	1.800
Lubrificants	500	1.500

- minimise costs (objective)

	Saudi	Venezuela
Price [€/t]	19.25	14
Transport [€/t*1000km]	0.1	0.1
Distance [km]	7.500	10.000

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**KOMSA** **How to influence the company's costs?**

- two crudes
  - different prices and transport distances
  - differ in chemical composition  $\Rightarrow$  product mix
- respective quantities of the crudes  $\Rightarrow$  **decision variable**

Product	Venezuela (t/t crude)	Saudi (t/t crude)
Jet fuel	0.2	0.4
Lubrificants	0.3	0.2
Gasoline	0.4	0.3
Losses	0.1	0.1

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**KOMSA** **Standard Model of Operations Research**

$$\begin{aligned} \min \quad & 20x_1 + 15x_2 \\ \text{s.t.} \quad & 0.3x_1 + 0.4x_2 \geq 2.0 \\ & 0.4x_1 + 0.2x_2 \geq 1.5 \\ & 0.2x_1 + 0.3x_2 \geq 0.5 \\ & x_1 \leq 9 \\ & x_2 \leq 6 \\ & x_1, x_2 \geq 0 \end{aligned}$$

- objective function
- 2 decision variables
- (algebraic) constraints
  - inequalities
  - equations

$\Rightarrow$  no start value (actual state of the system) necessary

$\Rightarrow$  decision variables  $\rightarrow$  degrees of freedom  $\rightarrow$  ranges!

$\Rightarrow$  constraints  $\rightarrow$  "interaction"

example taken from: Rardin (2000)  
Optimization in Operations Research

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**KOMSA** **"Two-Crude-Oil" as Material Flow Network**

- Model variables  $\vec{x} = (\vec{j}, \vec{p}, \vec{s})$ 
  - 6 material flows
  - 0 parameters and stocks
- Causality
  - topology of network
  - transition specifications
- Objective
  - cost accounting

$\Rightarrow$  maps actual state

$\Rightarrow$  model variables  $\rightarrow$  (calculated) values!

$\Rightarrow$  constraints?

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### KOMSA Different Modelling Paradigms

- $\vec{x} = (\vec{j}, \vec{p}, \vec{s})$  = vector with all model variables
- usually, e.g. LCA: given the functional we obtain a unique  $\vec{x} = \vec{x}(j_0)$
- Optimisation:** independent components of  $\vec{x}$  span solution space, search for optimal  $\vec{x}^*$

⇒ include degrees of freedom (choices) in the model!

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### KOMSA Matching of Concepts

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### KOMSA The Role of Transitions

- 6 model variables, 6 decision variables?
- transition specification: equations reduce degrees of freedom!

⇒ Transitions are effectively constraints

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### KOMSA System Enlargement: Include Transport

- include transport
- add many model variables (~20 material flows, 2 trans.-parameters)
- but: adds no degrees of freedom!

⇒ because: network structure adds constraints!

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### KOMSA Places as Constraints... some Examples

	$j_1 = j_2$	connection	1 DoF
	$s_{i+1} = s_i + j_1 - j_2$	store	3 DoF
	$j_1 = j_2 + j_3$	bifurcation	2 DoF
	$s_{i+1} = j_1 + j_2$	merging	2 DoF

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### KOMSA Include Cost-Information

⇒ cost accounting: existing feature of Umberto®

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### KOMSA Include additional Constraints

⇒ adding constraints: not yet part of Umberto®

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### KOMSA Framework of the KOMSA tool

- optimisation algorithms
  - Nelder-Mead/Complex
  - Genetic
  - Particle Swarm
- and packages

- complete definition of the OP (objective, constraints,...)
- choose algorithms, set parameters,...
- controls optimisation procedure

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## KOMSAS Generation of Objective Function

**Choice of Objective:** Cost Efficiency Indicator

Location	Volume	NameID	Quantity	Unit	Lower Limit	Upper Limit	Price	Cost	Type	Description	Balance
C1	10	10	10	kg	0	0	0	0	Param	Variable C1 in T1	-
T1	10	10	10000	kg	0	0	0	0	Param	Variable C1 in T1	-
T3	10	10	5	kg	0	0	0	0	Param	Variable C1 in T3	-
T3	10	10	700	kg	0	0	0	0	Param	Variable C1 in T3	-
A2	10	10	200000	kg	0	0	0	0	Good	Material 1238	Output
A2	10	10	100000	kg	0	0	0	0	Good	Material 1238	Output

**Objective Function:**  $Min \rightarrow 0.00113 \cdot 0.021118$

**All available variables:** (Table as above)

**Annotations:**  
 - Type of objective (points to 'Type' column)  
 - automatic generation (editable) (points to 'Description' column)

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## KOMSAS Selection of Decision Variables

Location	Volume	NameID	Quantity	Unit	Lower Limit	Upper Limit	Type	Description
C13	9	A7	300000	kg	0	300000	Good	Material 1238
C13	9	A9	300000	kg	0	300000	Good	Material 1237

**Annotations:**  
 - Selection and explicit Constraints (points to 'Quantity' column)  
 - Implicit constraints on several decision variables (points to 'Description' column)

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## KOMSAS Algorithm and Constraints

**Choice of optimisation algorithm:** Simplex

**Set Method Parameters:** (Red box: Set specific parameters)

**Define constraints on dependent model variables if any:** (Red box: Constraints on dependent model variables)

**Set Algorithm Options:** Simplex, Max. Iterations: 20, Max. Loops with No Improvements: 5

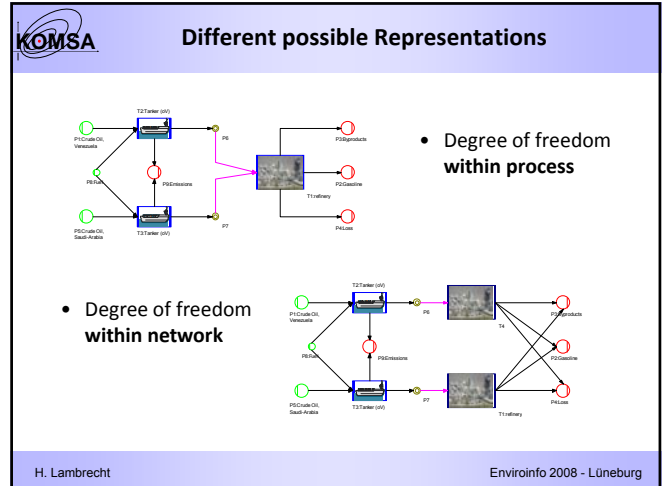
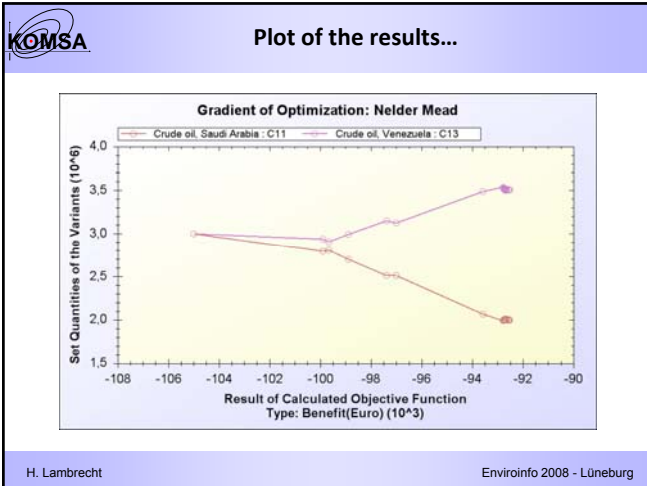
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## KOMSAS Results

Iteration	Volume	Quantity	Location	Lower Limit	Volume	Unit	Type	Evaluation/Objective Function
0	C13	300000	A9	10	C13	kg	Good	88
1	C13	270000	A7	10	C13	kg	Good	90
2	C13	200000	A9	10	C13	kg	Good	92
3	C13	270000	A7	10	C13	kg	Good	94
4	C13	200000	A9	10	C13	kg	Good	96
5	C13	270000	A7	10	C13	kg	Good	97
6	C13	200000	A9	10	C13	kg	Good	98
7	C13	270000	A7	10	C13	kg	Good	99

**Annotations:**  
 - Values of decision variables (points to 'Volume' column)  
 - Objective (points to 'Evaluation/Objective Function' column)  
 - Plot... (points to 'Iteration' column)

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- KOMSA** **Conclusions**
- Material flow models (Umberto)
    - are “natural” starting point for parameter optimisation
    - useful for structuring decision problems concerning material flow systems (strong causality, material flows)
    - Efficiency and effectiveness of algorithms  $\leftrightarrow$  ease of model formulation
  - Simulation-based optimisation approach operational as prototype
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- KOMSA** **Outlook**
- Further experiences  $\rightarrow$  test cases!
  - Algorithms: Interface to Matlab Optimisation Toolbox
  - Role of transitions and places
    - substitutional inputs
    - flexible combined production
    - bifurcations
    - deduce: modelling principles for material flow based OPs.
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Thank you !