Enabling Warehouse CAD – Semantic Template for Model Based Warehouse Analysis and Design

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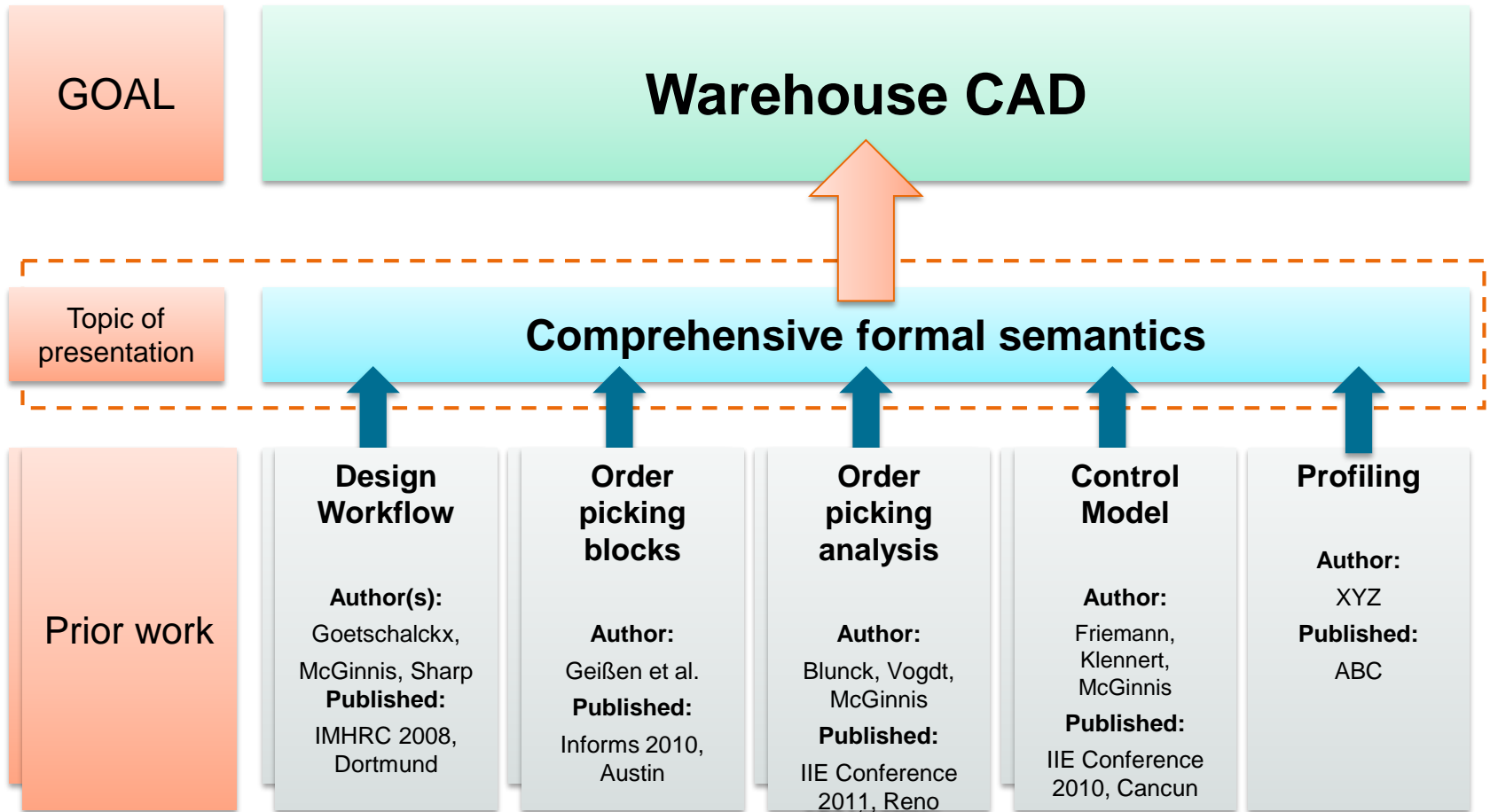
Outline

- Motivation

- Prior work / Context

- Design concept

- Design semantics

- Warehouse semantics

- Integrated semantics

- Future Work / Remaining challenges

Motivation

- **GOAL: Model driven approach for warehouse analysis and design – Warehouse CAD**

  - Tools that enable new warehouse designs to be completed faster, cheaper, and with better resulting performance require a formalized understanding of the artifact and a standard representation of its components.

- → Need for comprehensive formal semantics defining the meaning of symbols used for describing **(i)** warehouse resources and activities, **(ii)** warehouse control, **(iii)** intermediate abstractions used during design, and **(iv)** the warehouse design process
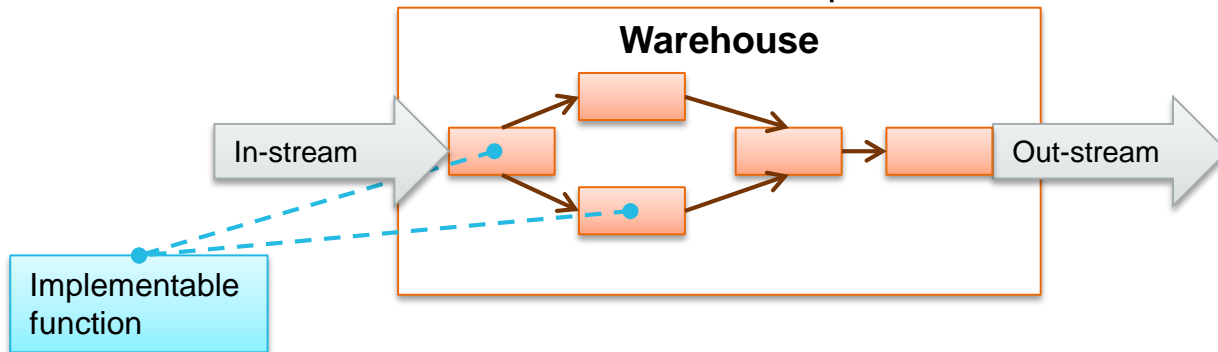
Prior work / context

GOAL

Warehouse CAD

Topic of presentation

Comprehensive formal semantics

Prior work

Design Workflow

Author(s):
Goetschalckx, McGinnis, Sharp
Published:
IMHRC 2008, Dortmund

Order picking blocks

Author:
Geißen et al.
Published:
Informs 2010, Austin

Order picking analysis

Author:
Blunck, Vogdt, McGinnis
Published:
IIE Conference 2011, Reno

Control Model

Author:
Friemann, Klennert, McGinnis
Published:
IIE Conference 2010, Cancun

Profiling

Author:
XYZ
Published:
ABC

Design concept: Functions & streams

- **Starting point:** Most abstract warehouse specification possible:
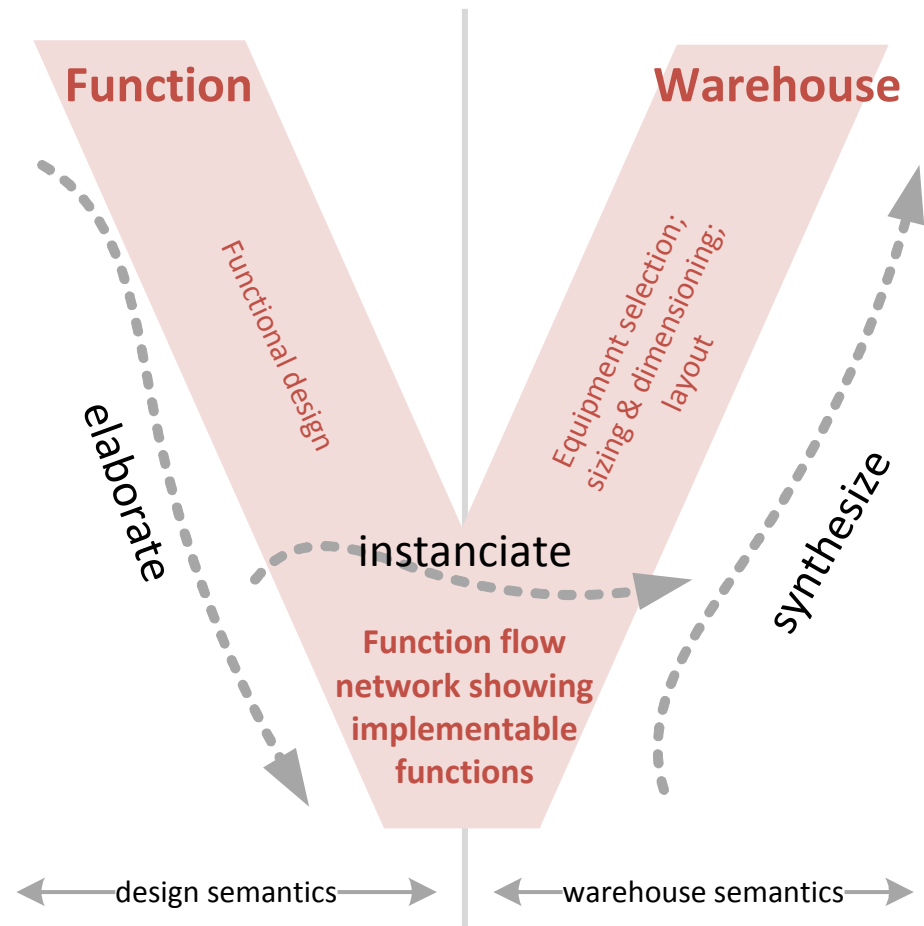
In-stream → **Warehouse** → Out-stream

- **Functional design:** Creating 1st iteration function flow network (FFN) by splitting up streams up to the point of implementable functions ($\rightarrow$ design semantics)
    - Nodes split up streams or join streams $\rightarrow$ transformation of streams
    - Arcs conserve streams $\rightarrow$ transformation of place

Warehouse

In-stream → Out-stream

Implementable function

- **Warehouse design:** Designing nodes and arcs of FFN ($\rightarrow$ warehouse semantics)

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# Systems engineering process for warehouses

- **Design semantics ≠ Warehouse semantics**

- **Design semantics** used during functional design phase → until implementable functions are identified (functional decomposition)

- **Warehouse semantics** used during operation strategy & equipment selection, sizing & dimensioning, defining department and overall layout

Function   **Warehouse**

Functional design

Equipment selection; sizing & dimensioning; layout

elaborate   *synthesize*

instanciate

Function flow network showing implementable functions

← design semantics →   ← warehouse semantics →

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Design semantics – Functional Design

- **Design semantics**

  - supports functional design

  - depicts functions and streams

  - describes **what** should be done / shows which transformations should take place and their rates / deviations

- **Functional design from most simple warehouse specification, which is**

  - Warehousing function: Transforming input streams into output streams

- **Function flow network showing implementable functions**

  - Functions transforming time, space, orientation, quantity, compilation, status, value

  - E.g. check quality, transport/put away, store, pick, assemble, palletize, pack

Design semantics

- Functional Design Example: Simple; 1st iteration Function Flow Network
- Possibility of splitting up functions and streams in subsequent iterations
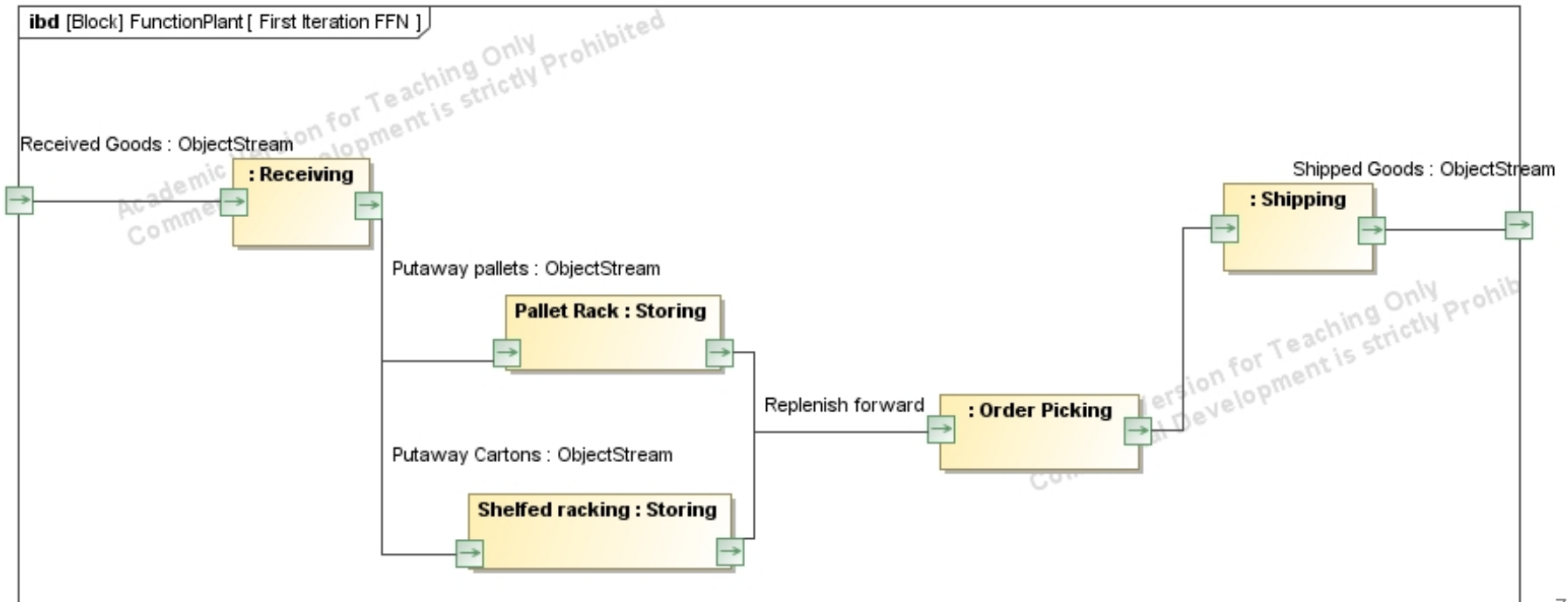
Warehouse semantics

- **Warehouse semantics**
  - describes **how** sth. should be done
  - depicts detailed warehouse specification
    - includes processes, structure, resources, and requirements
    - includes warehouse control
    - "easy" readable and accessible
    - allows different views on artifact

  - supports analysis and design of arcs and nodes of FFN
    - Enable model transformation and model execution

  - enable creation of libraries/pre-defined components to capture expert knowledge

Specifying order picking (warehouse semantics)
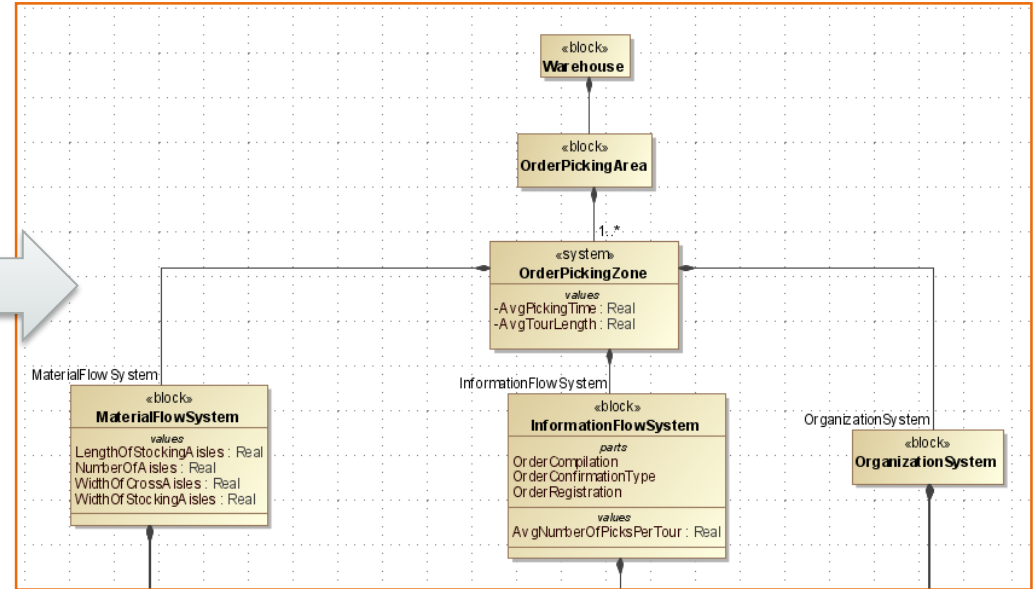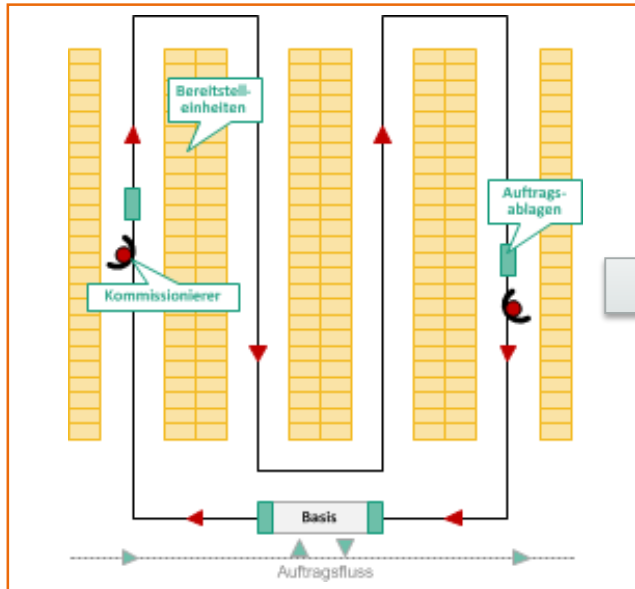
Geißen et al., *"Evaluation of Decision Criteria to Select Efficient Order Picking Systems"* at Informs Conference 2010, Austin
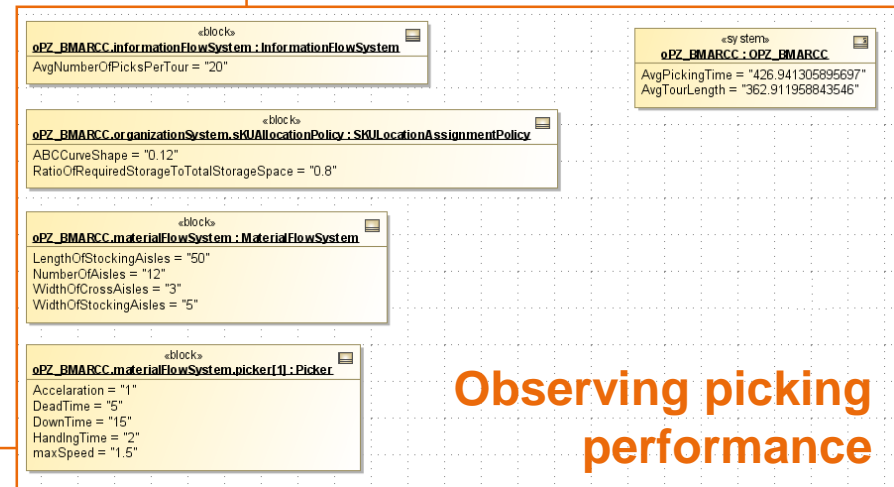

Blunck, Vogdt, McGinnis, *"Formal Design Models for Order Picking Systems"* at IIE Conference 2011, Reno

- Library element *"Order picking with static supply of staging units"* (left) (captured expert knowledge)

- Cut out from specification in adherence to warehouse semantics (right)

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Analysis of order picking (warehouse semantics)

Design decision support

**Observing picking performance**
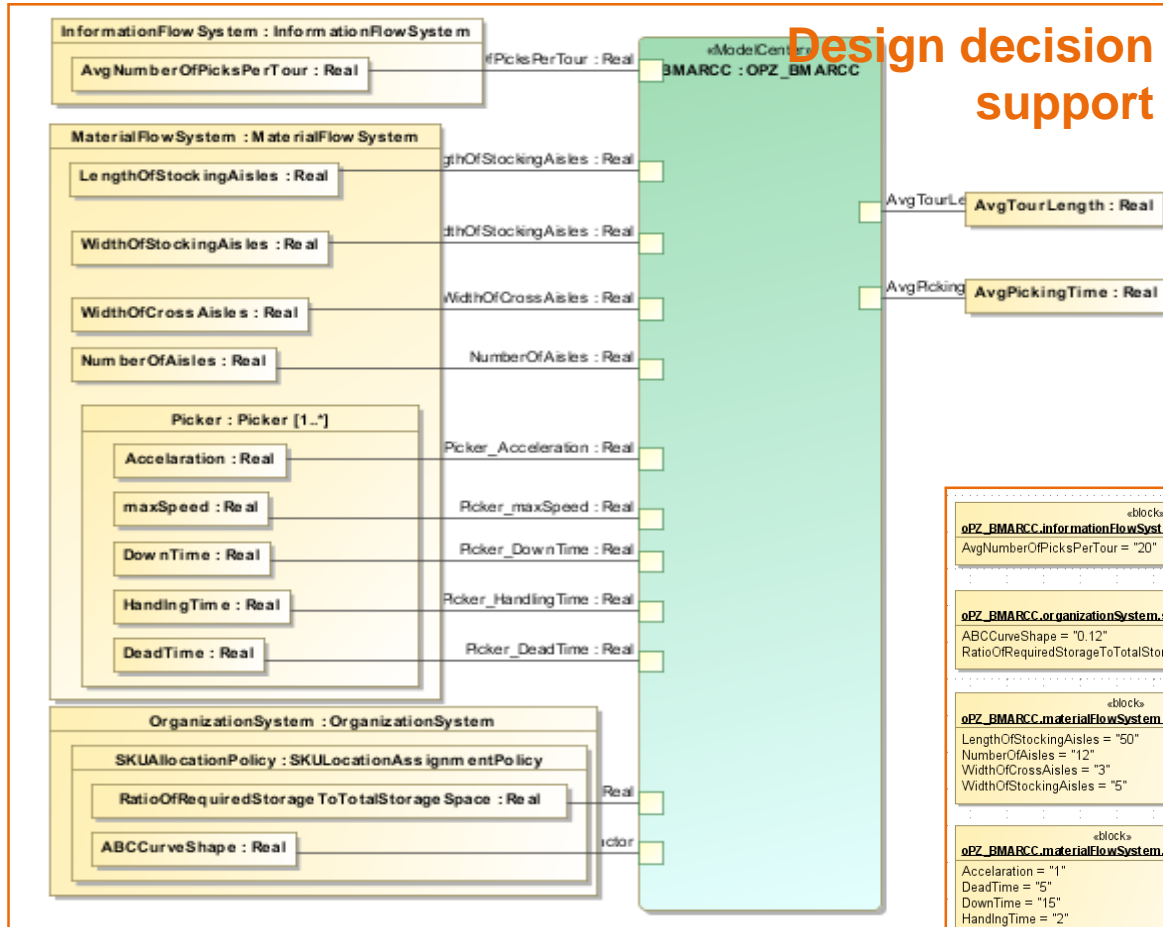
- Used parameters are part of warehouse semantics
- → Combination of existing models and warehouse semantics

Blunck, Vogdt, McGinnis, "*Formal Design Models for Order Picking Systems"* at IIE Conference 2011, Reno
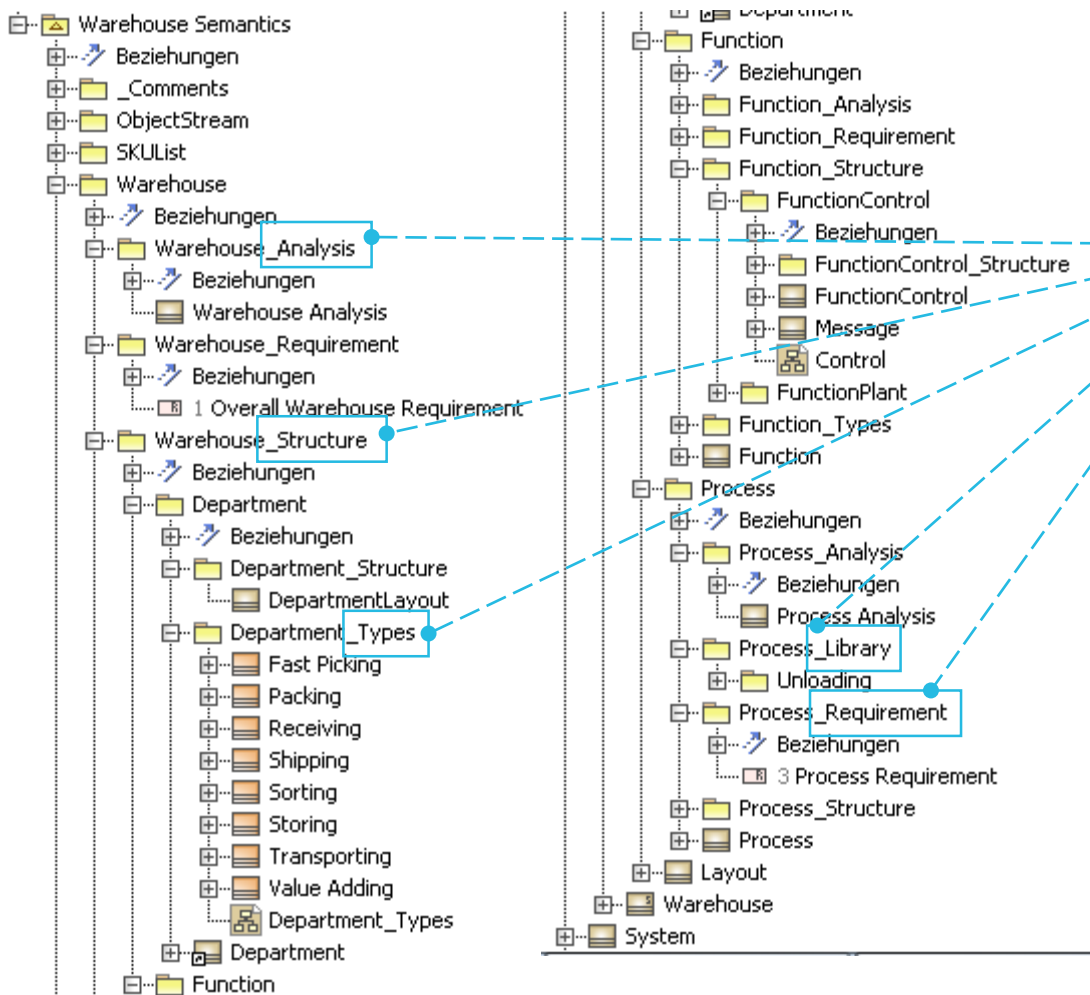
Integrated semantic model

- Integrating **design semantics** and **warehouse semantics** within **ONE** semantic model

Integrated semantic model
(SysML)

Design semantics | Warehouse semantics
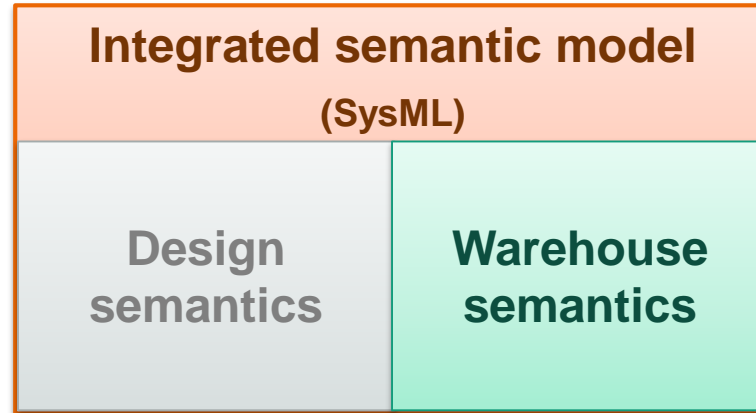
- **Support of whole warehouse design process**

  - **from functional design to**

  - **detailed specification**

  - → **enabling consistent Warehouse CAD**

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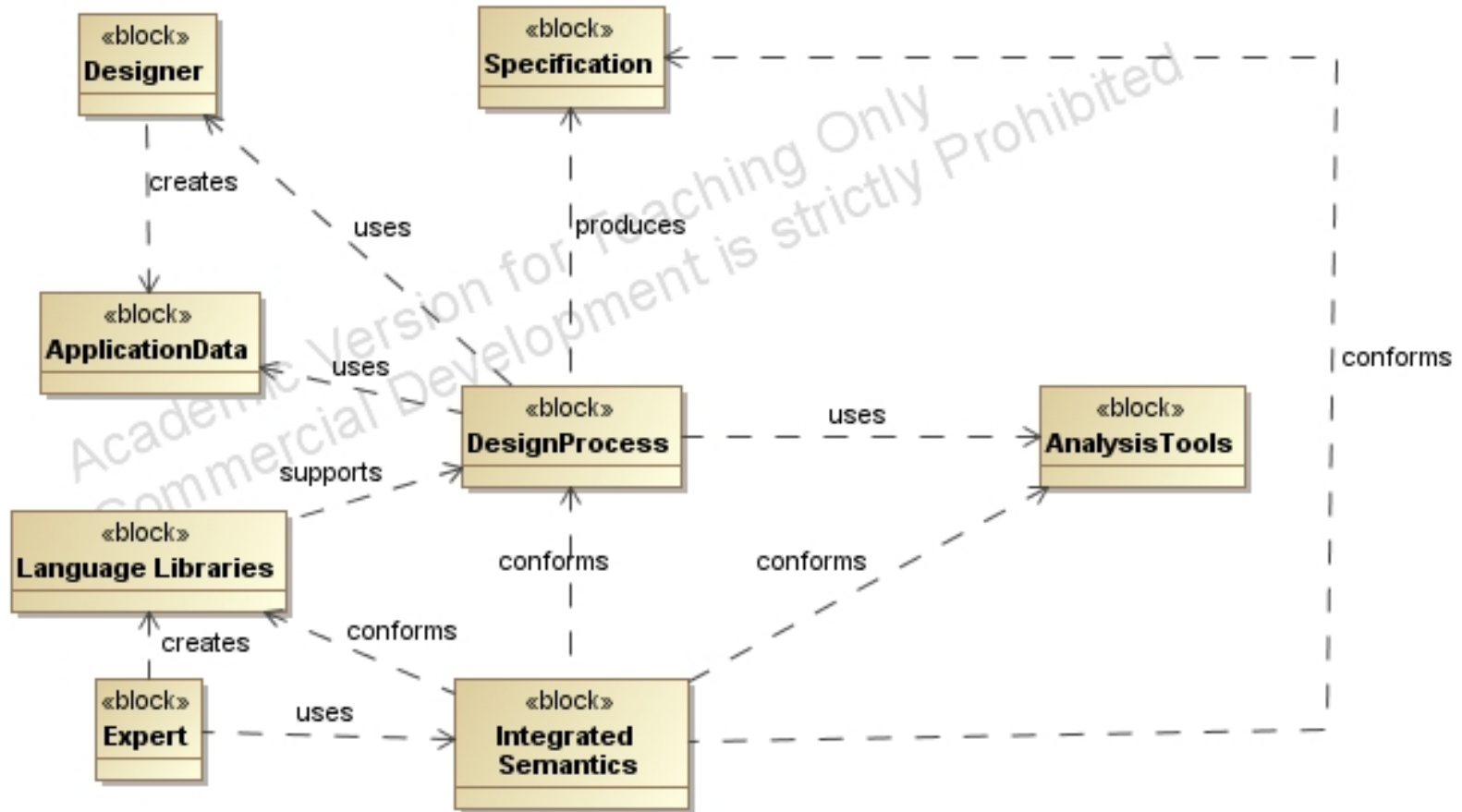
Adapting INCOSE´s *"Cookbook for MBSE with SysML"*

➔ using repeating expressive descriptors

➔ containment tree "easy" to access and to update

➔ enabling division of labor, because knowledge of subsystems bundled within subfolders

Views on **warehouse elements** and **libraries**:

■ analysis, behavior, structure, requirement, types

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SysML representation of Integrated semantic model (top level)
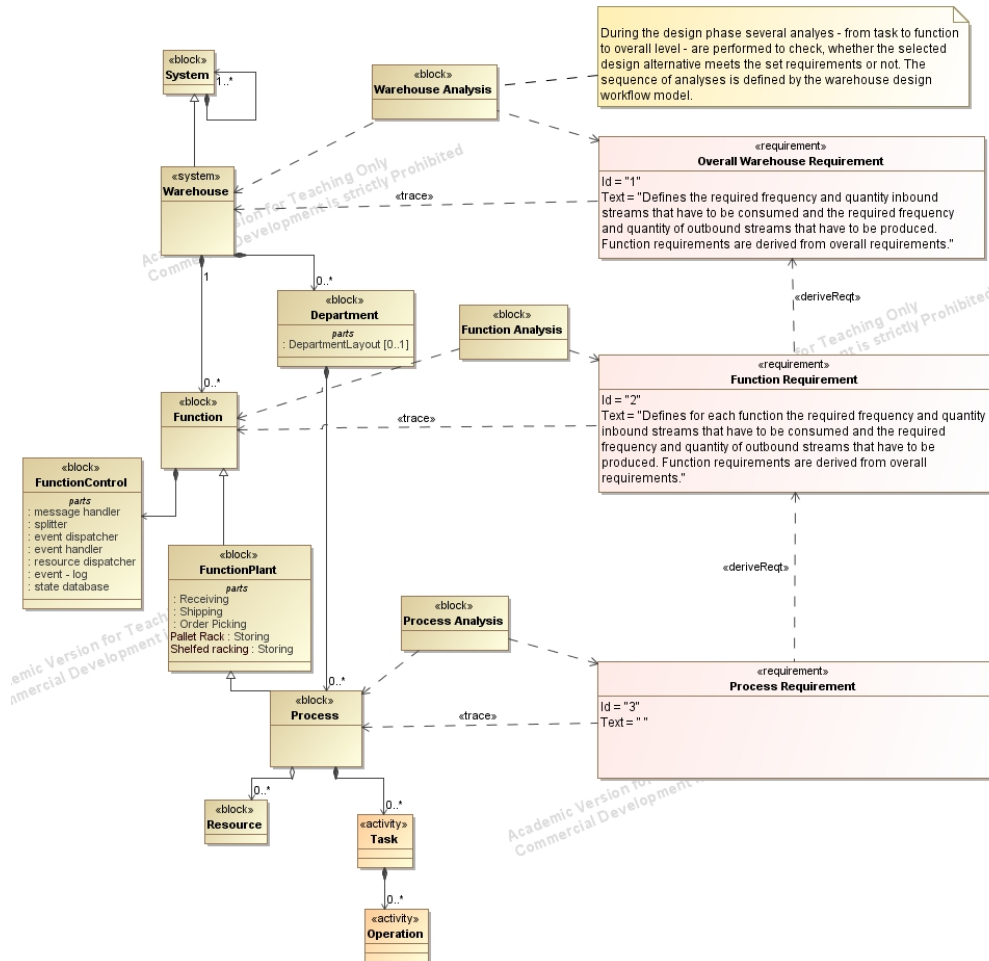
- Identify what types of tools for which tasks are best
    - How to link these tools with SysML semantics
    - Model transformation
- Creation of comprehensive libraries
- Further semantics-checks and extensions of semantics

- Implementing *Integrated Warehouse CAD-Framework*

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We are glad to answer your questions!