GEFÖRDERT VOM

Bundesministerium für Bildung und Forschung

BETREUT VOM

Projektträger Forschungszentrum Karlsruhe (PTKA)

Modularization and Simulation-Based Optimization of Work Piece Handling in Manufacturing Cells

J. Fleischer, J. Wieser
wbk Institute of Production Science
Dept. of Mechanical Eng.
Universität Karlsruhe (TH)
Germany

HarWeST PTW chiron Cross Hüller SOMMER automatic LIEBHERR VERZAHNTECHNIK GMBH BLEICHERT wbk

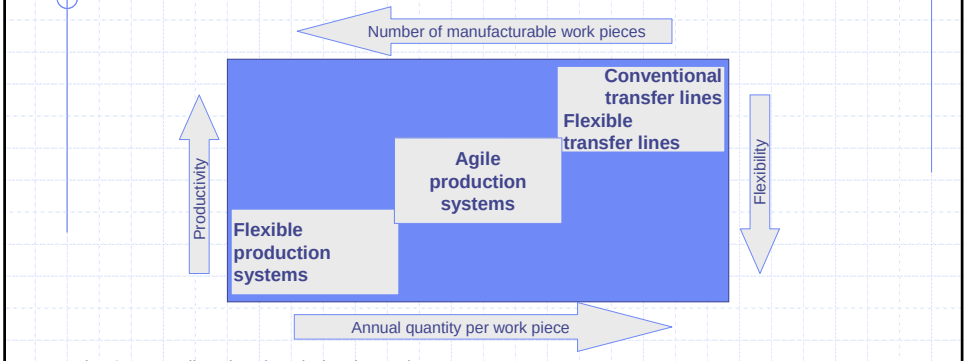
Outline

Introduction

Model modularization for the simulation and optimisation of agile production systems

Conceptual design of a simulation-based configurator for agile production systems

1. Overview of Production Systems



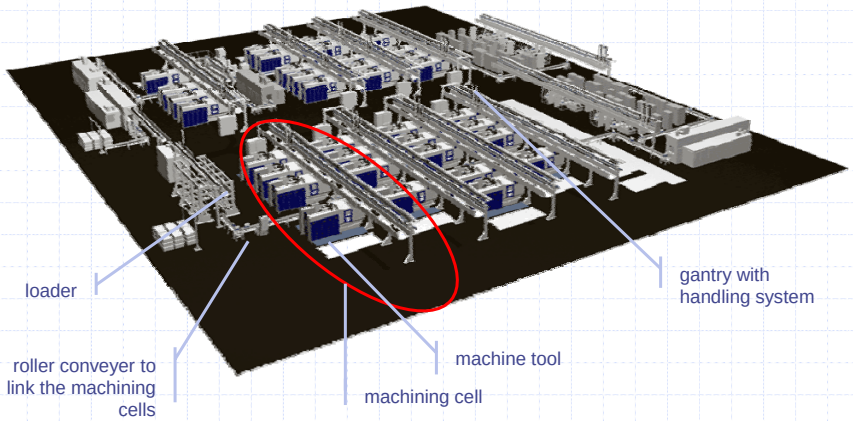
Example: Cross-Hüller plant in Windsor/Kanada

Agile Production System | Machining Cell | Machine Tool

Source: Bürger, Cross Hüller

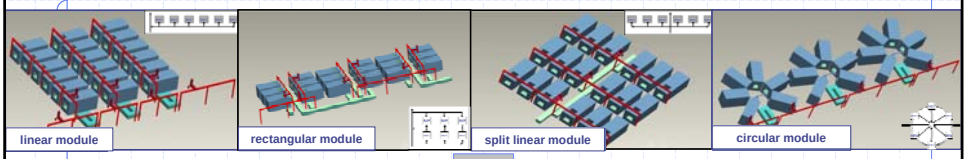
1. The Components of an Agile Production System

Agile production systems offer flexibility, high utilisation and high output.



Source: Cross Hüller

1. Initial Situation



Desired product

- lot size
- machining time
- costs
- quality
- …

Architecture

Configuration of a suitable production system including components

Components

- machining centres
- belt conveyors
- handling systems
- clamping fixtures
- gantry loader
- …

Shortcomings:

- non-holistic approach
- configuration is based on empirical values

2. Objective

- Determination of the floor space arrangement (architecture) of the system
- Identification of the required capacity in terms of transport and handling systems
- Estimate of total system availability
- Use of synergy effects between machine tool and periphery

Holistic configuration of production systems on the basis of technical data

- Compliance with requirements through smaller system dimensions
  ➔ **cost savings!**
- Shorter planning process for production systems
  ➔ **time savings!**

2. Approach

- Analysis and modularization of production systems
- Identification of the main influence parameters (architecture, machining time, production programme, transport performance*)
- Development of a modular simulation model
- Simulation, evaluation and optimisation of the utilisation and output of different production system configurations (statistical design of experiments, factorial design of experiments, systems theory approach)
- Determination of the required capacity in terms of transport and handling facilities under consideration of availability values
- Definition and weighting of criteria for the assessment of production systems
- Development of a system configurator for production systems on the basis of process simulation

HarWeST

*: Combination of speeds and accelerations of gantry loader, belt conveyors, input and output buffers, cell interlinkage

wbk

Outline

Introduction

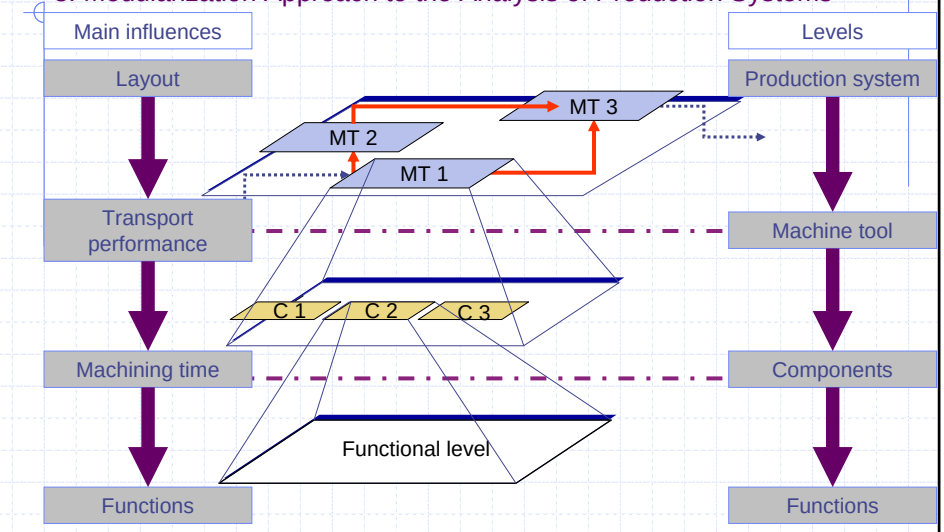
Model modularization for the simulation and optimisation of agile production systems

Conceptual design of a simulation-based configurator for agile production systems

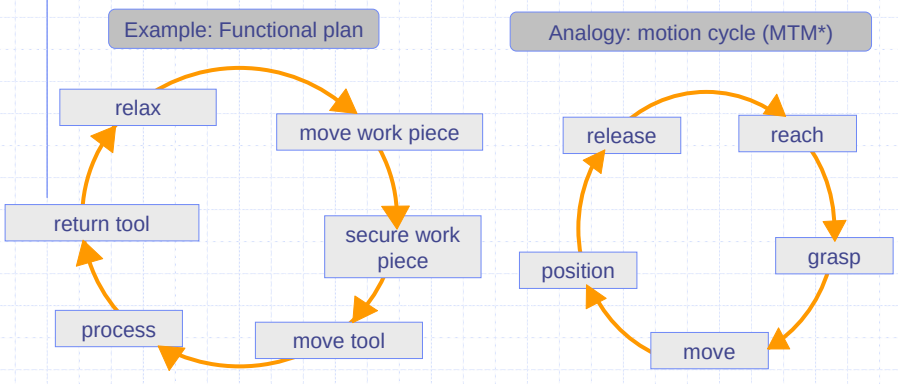
HarWeST

wbk

3. Modularization Approach to the Analysis of Production Systems



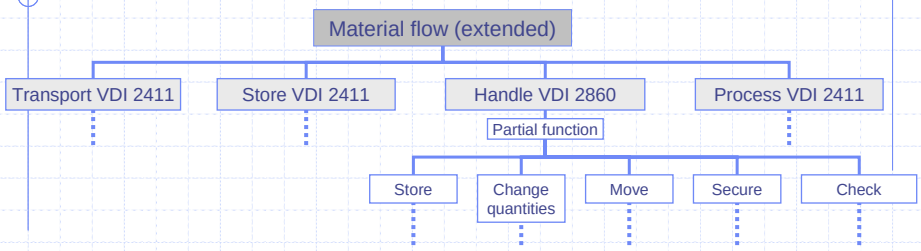
3. Definition: Functions



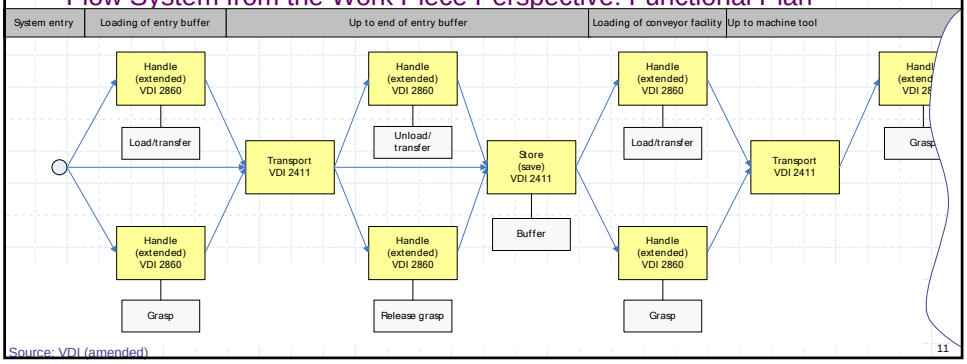
Definition of Functions:
Predefined basic modules complemented with simulation-capable influence factors and adapted to the specific process
(compares to MTM* basic motion with influence factors).

*: Methods Time Measurements

3. Material Flow/Functional Plan (Section)



Flow System from the Work Piece Perspective: Functional Plan

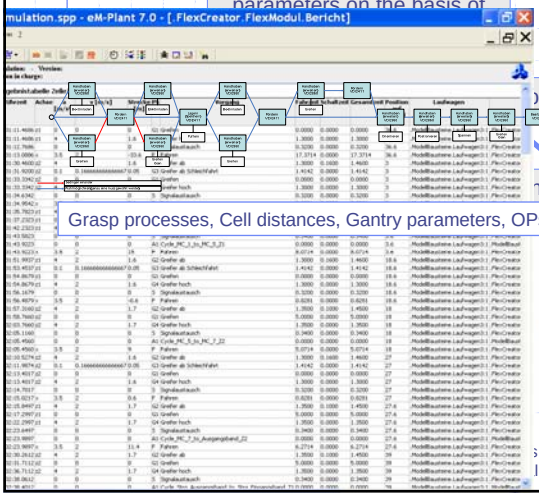


Source: VDI (amended)

4. Modularization Transfer to the Simulation Model

Parameterisation of production systems

Identification of the model parameters on the basis of



nation of cells into

Grasp processes, Cell distances, Gantry parameters, OPs, …

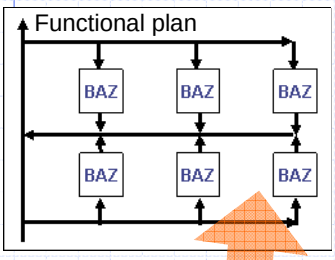
Simulation and readout of results

Compilation of an output report

s for the Future Series
l Parts

4. Simulation Overview

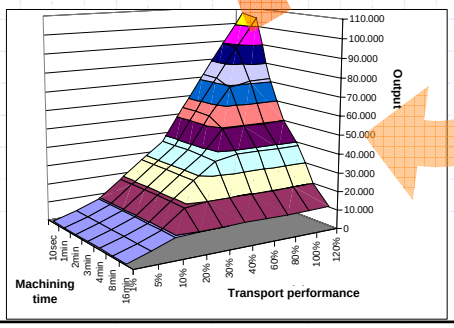
Functional plan



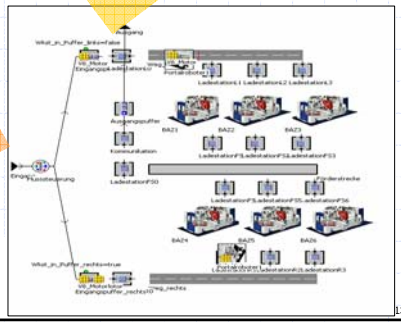
Input data

Downtimes are caused at	Operational availability	MTTR	MTBF
Machining centre (at all modules)	**95%** →	9min 18sec	2h 56min 7sec
Gantry robot (at all modules)	97% ←	**9min 17sec**	**5h 2min 46sec**
Conveyor line (rectangular module only)	**98%** →	10min	8h 9min 9sec
Turntable (circular module only)	**97%** →	9min 17sec	5h 2min 46sec

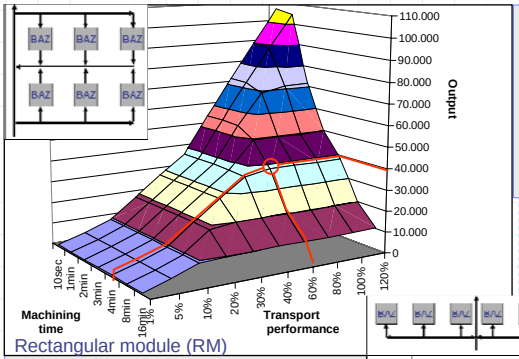
Results



Simulation



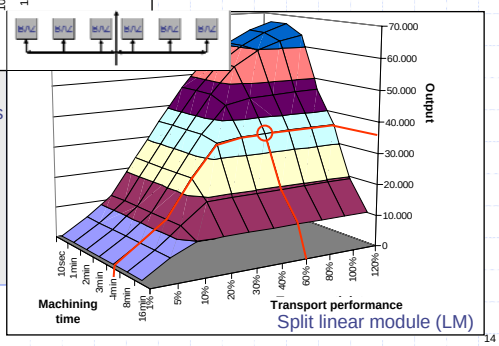
4. Results Rectangular and Split Linear Module (Section)



Rectangular module (RM)

Example:
- **simulation period:** 21 days
- **machining time:** 4 min
- **design:** 6 MC per cell, modul comprises 3 cells
- **transport performance*:** 60 %
- **output:** approx. 36.000 (LM) or 38.000 (RM) respectively

Conclusion:
- The longer the machining time, the less significant the impact of the layout structure.
- The impact of transport performance* is lower than expected.
- An increase in machining time allows for transport performance* to be gradually reduced.



Split linear module (LM)

*: Combination of speeds and accelerations of gantry loader, belt conveyors, input and output buffers, cell interlinkage

5. Definition and Weighting of Evaluation Criteria

The project partners defined and evaluated the characteristics / criteria by means of paired comparison at the meeting held on October 19th 2004 at the Cross Hüller company in Ludwigsburg.

Basis of evaluation : 0: column more important 1: column and row equally important 2: row more important

Characteristics/Criterion
Output
Utilisation
Investment costs
Operating cost
Floor space requirements
Volume flexibility/Expandability
Product flexibility
Development expenditure
Accessibility (tool change, setup)
Accessibility (safety)
Infrastructure, media supply
Leakproofness, chip transport, splash guard
Operational safety (operator exposure)
Total availability, backup strategy

First place: Accessibility, operational safety
Third place: Output
Fourth place: Total availability

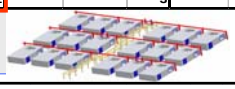
5. Cost/Benefit Analysis

Total (absolute): 3: better; 2: good; 1: limited; Max. sum (weighted): 30

Cost/Benefit analysis — **Maximum value** 3

Criteria	Weighting	Linear Num. value	Linear Rating	Linear Weighted value	Split linear Num. value	Split linear Rating	Split linear Weighted value	Rectangular Num. value	Rectangular Rating	Rectangular Weighted value	Circular Num. Value	Circular Rating	Circular Weighted rating
Output [units]	11%	73.470	2	0,22	73.778	2	0,22	76.038	3	0,33	73.686	2	0,22
Utilisation [%]	10%	0.84	2	0,2	0.84	2	0,2	0.86	2	0,2	0.84	2	0,2
Investment costs [€]	10%	7,50m	2	0,2	7,49m	2	0,2	8,41m	1	0,1	7,26m	1	0,1
Operating costs [€]	7%			0			0			0			0
Floor space requirements	4%	140	3	0,12	130	3	0,12	160	2	0,08	220	1	0,04
Volume flexibility / Expandability	3%		3	0,09		3	0,09		3	0,09		1	0,03
Product flexibility	4%		3	0,12		3	0,12		1	0,04		3	0,12
Development expenditure	2%		3	0,06		3	0,06		1	0,02		1	0,02
Accessibility (tool change/setup)	5%		3	0,15		3	0,15		2	0,1		1	0,05
Accessibility (safety)	12%		3	0,36		3	0,36		2	0,24		1	0,12
Infrastructure: media supply	3%		3	0,09		3	0,09		2	0,06		1	0,03
Leakproofness, chip transport, splash guard	7%		3	0,21		3	0,21		2	0,14		1	0,07
Operational safety (operator exposure)	12%		3	0,36		3	0,36		2	0,24		2	0,24
Total availability, backup strategy	10%		2	0,2		3	0,3		3	0,3		2	0,2
Total:				**2,38**			**2,48**			**1,94**			**1,44**
Compliance:				**79%**			**83%**			**65%**			**48%**
Rank:				**2**			**1**			**3**			**4**

The split linear layout offers the greatest potential.



Outline

Introduction

Model modularization for the simulation and optimisation of agile production systems

Conceptual design of a simulation-based configurator for agile production systems

1. Initial Situation
2. Objective and Approach
3. Modularization
4. Simulation
5. Evaluation
6. Design of Configurator
7. Summary

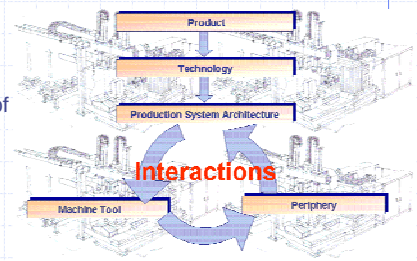
6. Overview of Configurator

Initial situation:

- Determination of the floor space arrangement “on paper“ (mere planning)
- Required components are designed to maximum specifications
- An estimate of the availability and the potential impact of capacity bottlenecks is not possible

Objective:

- Development of a “system configurator“ for interlinked production systems on the basis of process simulation
- Optimum situation-specific selection of architecture, machine tool and periphery

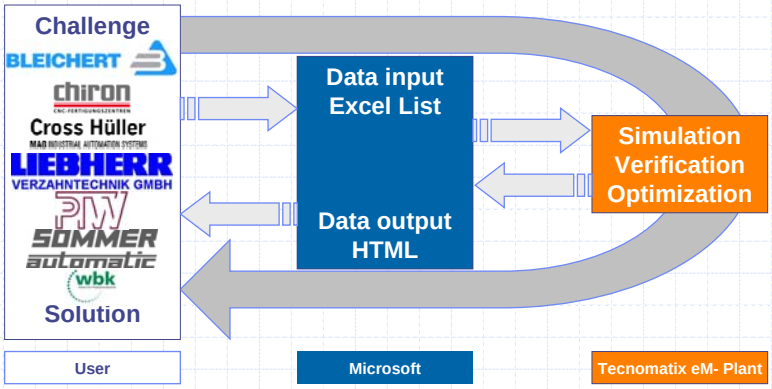


Specific features:

- Clear and simple user prompting
- Parameter input and output via a standard software
- Automatic layout generation
- Automatic simulation
- Data structure generation
- Variable product, production and optimisation conditions

6. Function Principle of the Configurator

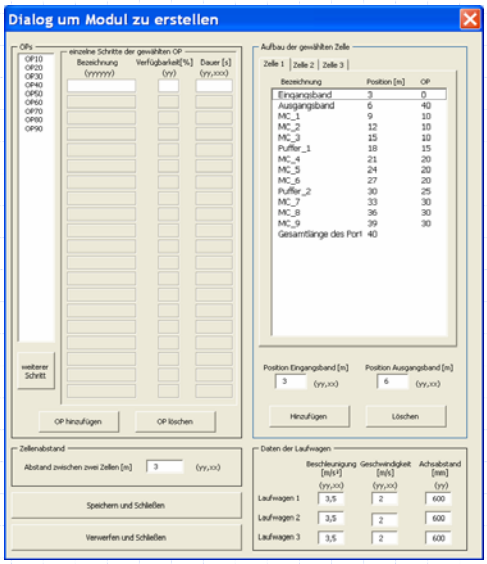
The configurator algorithm comprises three stages:



6. Input (Selection)

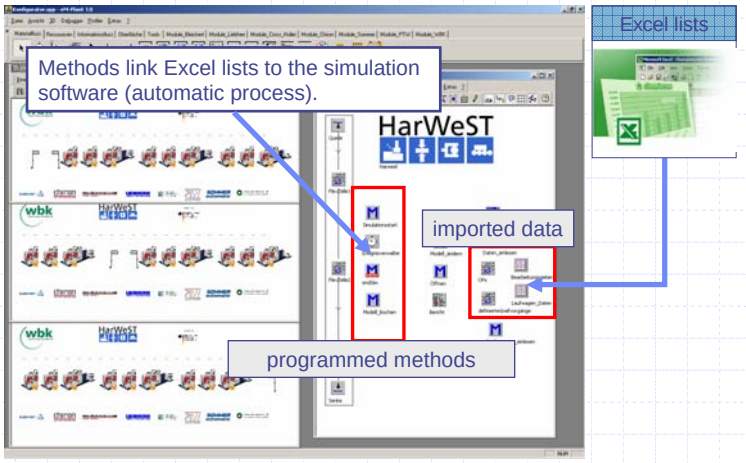
The user can determine the production system parameters via Excel tables or chose from the library:

- Determination of operations (25 max.) with individual steps (20 max. each):
  - name of step
  - availability [%]
  - duration [sec]
- Cell design
  - position of entry conveyor [m]
  - position of exit conveyor [m]
  - Position of machining stations [m]
  - position of buffer [m]
  - allocation of operations to the different machining stations
  - distance between cells [m]
- Definition of sliding carriage:
  - acceleration [m/s²]
  - speed [m/s]
  - centre distance [mm]
- Gripper definitions (separate entry mask)



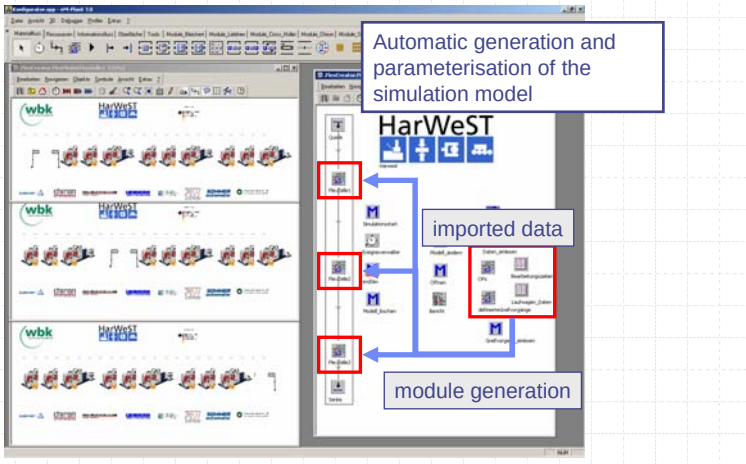
6. Setup of Simulation Model I/II

The architecture, the parameters and the detailed gripper processes are automatically transferred from the imported tables to the predefined method modules of the Tecnomatix eM-Plant process simulation software.



6. Setup of the Simulation Model II/II

The simulation model is automatically generated on the basis of the imported data.



6. Characteristics of a Production Cell

- **Autonomous control generation**
- **Trouble-free completion with additional machine tools and buffers**
- **Consideration of**
  - machine tool downtimes
  - differences in machine tool machining and setup times
  - buffer capacities used

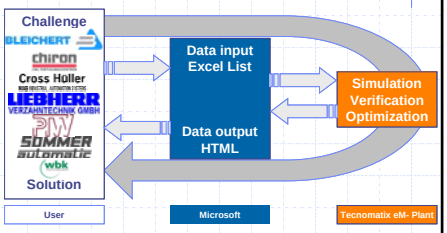
7. Summary

Initial situation/Challenge

- Determination of the floor space arrangement "on paper" (mere planning process)
- Required components are designed to maximum specifications
- Estimate of availability and the potential impact of capacity bottlenecks (not always possible!)

Objective

- Design of a configurator for interlinked production systems on the basis of process simulation by taking a holistic approach



Result

- Conclusions on total system availability, impact of individual components
- User-oriented tool for easy compliance with specifications through „slower" systems with smaller dimensions
  - ➔ **cost savings!**
- Shorter production system planning processes
  - ➔ **time savings!**

…. thank you for your attention!

wbk Institute of Production Science
Dept. of Mechanical Eng.
Universität Karlsruhe (TH)
Kaiserstrasse 12
76131 Karlsruhe, Germany
Tel. +49-721-608-6022
E-mail: wieser@wbk.uka.de
www.wbk-ka.de, www.harwest.de