Production control applications in the automotive industry
- Examples from Fraunhofer IITB projects -

Shenyang, November 23, 2007
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1. Some general remarks on automation
1. Definitions (Quelle: Eversheim, W; Schuh, G.: Betriebshütte)

Mechanization:= substitution of human activities by mechanical activities with the help of technical equipment.

Automation:= to establish a process by technical means in a way that a human must nor constantly neither in a fixed cycle be acting for the function of the process.

Talking about automation deals with the degree of exchanging human work with technical means. In the following we discuss this by adding the aspect of substitution of production factors.
1. Objective conditions in industrial manufacturing

- Customer individual products, high variety in product options and packaging
- Lot sizes are decreasing

![Diagram showing steps of production and market variety]

- Basic options
- Color options
- Assembly options
- Additional modules

Steps of production:
- Reduce variety in manufacturing
- Less standardized modules
- Move customer specific options to the end of the production process
1. Objective conditions in industrial manufacturing (2)

- Globalization: companies act world wide according to different conditions of manufacturing sites

- Management support
- Language, culture, techn. tradition
- Supply of energy and media
- Conditions for manufacturing sites
- Offered services
- Transport and logistics
- Labor costs
- Staff qualification labor supply
- Economic conditions

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1. Objective conditions in industrial manufacturing (3)

- Companies act world wide according to different conditions of manufacturing sites: why companies establish production sites abroad

- Cost of production factors: 65%
- Market development: 60%
- Decreased distance to customers: 34%
- Taxes, transfers, subsidies: 21%
- Presence of competitors: 16%
- Local content-requirements: 15%
- Capacity constraints: 12%
- Technology development: 8%
- Currency adjustment: 6%
1. Functional aspects for automation

- Utilization degree, availability
- Quality, reproducibility
- Requirements for qualification of staff
- Physical limits for workers
- Flexibility in capacity utilization
- Quantity of output
- Special process requirements, e.g. clean rooms
- Possibilities for small lot sizes
- Improvement of labor conditions
- Manufacturing complex parts

Automation
## 1. Cost aspects for automation (1)

Simplified structure of prime cost

<table>
<thead>
<tr>
<th>Prime cost</th>
<th>Overhead</th>
<th>Running costs</th>
<th>Depreciation building</th>
<th>Depreciation on equipment</th>
<th>Labor cost</th>
<th>Material cost</th>
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</tbody>
</table>

Main impact of the technological level, e.g. automation, on:
- head count,
- type of equipment,
- type of building and utilities

The technological level impacts structure and number of prime cost!
1. Cost aspects for automation (2)
1. Cost aspects for automation (3):
break-even curve for two different levels of automation

Assumption:
Absolute cost level is the same for both cost structures

Cost/revenues vs. Output

- Green line: revenues
- Red line: High level of automation
- Blue line: Low level of automation

Break-even points:
- 69% for high level of automation
- 81% for low level of automation
1. Cost aspects for automation (4):
break-even curve for two different levels of automation

Production systems with a high level of automation lead to cost structures with a high level of fixed costs.

A high level of manual work leads to cost structures with a high degree of variable cost.

A production system with a high level of fixed costs reacts much more sensibly to variations in capacity utilization than a production system with lower degree of fixed costs.

In the profit zone (on the ‘right hand side’ of the break-even point) profit increases faster in case of increasing capacity utilization if automation level is higher (higher fixed costs).
Produktionsfactors human work, equipment, space can substitute eachother to a certain degree.
2. Automotive manufacturing
2. World Automotive Production 2006  (Source: Globus/VDA/dpa; Produktion13092006)
2. Status in the automotive industry (Quelle: Nueno, P.; IESE Business School, Barcelona)

Overcapacity

Overcomplexity
- models
- countries
- alliances

Overcompetition
- weak financials through the value chain

Pressure from the capital markets
- globalization
- facilitating concentration
- volatile, short term behavior
- changes in management

Unfriendly government
- block exemption (GVO)
- emissions
- taxation
- crowded infrastructure
2. Core factors for successful automotive companies

(source: Bischoff, J.; et.al.: Automobilbau mit Zukunft)
2. Core factors for successful automotive companies

(source: Bischoff, J.; et.al.: Automobilbau mit Zukunft)

Three key success factors for future automotive production:

1. Adaptivity
2. Realtime ability
3. Production in networks
2. Key success factors for future automotive production

(source: Bischoff, J.; et.al.: Automobilbau mit Zukunft)

1. Adaptivity

• concerning plants and buildings

• regarding facilities, machines, lines and tools

• of processes and methodologies
2. Adaptivity and flexibility is TOP priority for European automotive companies (source: MANUFUTURE Germany, September 2007)
2. Key success factors for future automotive production (2)
(source: Bischoff, J.; et.al.: Automobilbau mit Zukunft)

2. Real time ability

• integration of information technology from planning to operations

• intelligent management of information and decisions without gaps

• implementation of monitoring systems to permanently access key performance indicators
2. Real time ability, e.g. by closed loop between production monitoring and sequence setup

Real time data from production to be used for short term planning, e.g. sequence setup.
2. Key success factors for future automotive production (3)
(source: Bischoff, J.; et.al.: Automobilbau mit Zukunft)

3. Production in networks

• management of suppliers

• effective optimization of networks

• supplier parks
Development of added value of suppliers
(source: FAST study)
3. Manufacturing Execution Systems for automotive production

- example for a successful production monitoring systems
3. Manufacturing Execution Systems in a factory’s IT hierarchy (Source: Betriebshütte, VDI 5600)

**Enterprise level**
- Rich client
- Terminal
- Server
- Rich client

**Manufacturing level**
- PC
- Control server
- PC

**Cell level**
- Cell server
- Supervisory PLC
- Control server

**Shop floor**
- PLC
- PLC
- PLC
- Data acquisition

**ERP-Systems**
- Control server

**Manufacturing Execution Systems**
- SCADA systems

**Automation technology**
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3. Worldwide market volume for Manufacturing Execution Systems in the automotive industry

3. Production monitoring architecture applying software agent technology

- Engineering server
- Visualization client (control room)
- Visualization client (shop floor)
- Visualization client (office)
- Monitoring server
- Media-server
- Alarm-server
- ProVis-cernel
- Online-DB
- Factory intelligence system (statistics, KPIs)
  - Web-Service
  - Web Genesis
  - DB
- PLC
- MMS-station
- OPC-station

= common for body, paint, trim shop

app. 900 clients

app. 150 PLCs per shop

Other systems, especially those using order information

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3. Production monitoring architecture applying software agent technology (2)

ProVis.Agent (Online-) Engineering

Engineering-Server

ProVis.Agent-kernel

- process image
- process variables (PV)
- I/O-Communication level
  - I/O-channels

IntegraMCG

- PLC

Media server

Visualization

Alarm server

- Logfiles
- Alarms
- Messages
- Data aggregation
- Reports

Other applications

TCP/IP

OPC/Agents

Agents

Other applications

Visualization

Alarm

Media server

Other applications

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3. System architecture as working in Daimler Bremen and Woerth plants

Monitoring client
Visualization
Operation

Factory intelligence system
Production assistant
Media-Server
Alarm server

Monitoring server (PV’s)

IntegraMCG
OPC
MMS
DB03
TCP/IP

IO

Observation

Database

Other IT-systems, e.g. body identification, sequence planning, PLUS, etc.

= Software agents
3. Introduction to the ProVis.Agent kernel

Services in the ProVis.Agent kernel

- Visualization service
- Operating service
- Process image service
- Shift model service
- Data access service
- I/O-service
- DB service

Core functionalities

- e.g. OPC-Server for ProVis.Visu
- e.g. for accessing engineering data

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3. Highlight of production monitoring: online simulation

Online simulation...

- ...is add on function within ProVis.Agent®
- ...simulates output and buffer contents for the coming shifts
- ...is already linked to the PMC-systems by agents
3. Central monitoring and control room

Control room C-class trim shop
Daimler AG, Bremen plant

Control room trim shop Golf V
VW AG, Wolfsburg plant

Picture: Daimler

Picture: VW
3. Example for monitoring a part of the assembly line in the Bremen plant
3. Example for web-based factory intelligence system
3. Major benefits for IITBs customers

- Most innovative software tools and technologies to be used in manufacturing plants.

- Direct view from each client in the plant to actual situation on the shop floor; unlimited number of clients to be used (up to 1,000).

- High transparency of the situation on the shop floor in real time.

- Assignment of work orders to machines according to best production plans concerning e.g. lead time, work in process, setup times, capacity load, etc.

- Less investment costs for software licences compared to commercial competitors.

- Strong local partners who can provide excellent service and 1st/2nd level support.
3. Manufacturing Execution Systems for automotive production

- general aspects of sequencing
3. Effects of disturbed sequence due to unexpected facility breakdown

Car body final assembly

Calculated sequence: 1 2 3 4 5 6 7 8 9 10 \ldots 99 100

Actual sequence: 1 2 4 5 6 7 8 9 10 \ldots 99 100

JIS provided parts

Remove provided parts and commission them

Provision of removed parts
3. Project example from Hyundai Motor Company: simulation of keeping sequence (source: FhG-IPK/HMC)
3. Project example Hyundai Motor Company: conceptional approach for control and order management (source: FhG-IPK/HMC)

- Enterprise level (Production planning)
- Plant level (Production control)
- Shop level (Production execution)

Enterprise level:
- Daily amount
- Weekly forecast

Plant level:
- Possible modification of T/S in y-timeslides (acc. #PBS)
- X-timeslides plan (acc. #WBS)

Shop level:
- Possible modification of P/S order in x-timeslides (acc. #WBS)
- Local planning on storage demand
- Possible modification of daily sequence

Press shop
Body shop
Paint shop
Trim shop

ORDER
PREVIEW (time shifted)
MATERIAL ORDER
FORECAST (time shifted)
Plan / Forecast

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3. Establishing closed loops between production monitoring and order management

Use of link between production monitoring and sequence planning

- Customer order options
- Daily sequence
- Start body shop
- First call off
- Detailed call off 1
- Detailed call off 2 according to tag signal
- Adapted PBS out
- Unexpected facility breakdown
- Material provision

Which pearls = customer orders are concerned by breakdown?
Which work plans require the disturbed facility?

Tier 0.5

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3. Manufacturing Execution Systems for automotive production

- integration of MES components
3. Current status in automotive factories (1)

- Today’s automotive plants use a large number of different software systems on the manufacturing execution level. These software systems are not yet integrated and support separate tasks such as production order control (sequence setup), production monitoring, vehicle identification, worker information and others.

- Shop floor people use production monitoring tools that are based on production quantities. In the case of a facility breakdown or quality inspection results they only know that a certain number of vehicles is affected. They can neither identify the customer orders related to these vehicles nor their options.

- The vehicle identification and tracking itself has weakpoints, such as fixed read/write points, missing feedback from the manufacturing process, and is thus completed by redundant systems for body tracking calculation, PLC signals, scanning of paper information, etc.
3. Current status in automotive factories: examples for IT-systems on the manufacturing execution level (2)

- Planning of new equipment, "digital factory«, ramp-up until full output
- Short time simulation and forecast:
  - hypothetical output
  - equipment availability
  - buffer status
- Body/object identification, localization and tracking systems
- Quality management and feedback of inspection results
- Production monitoring and control; Supervisory Control And Data Acquisition (SCADA)
- Alarming, maintenance and repair according to facilities status, maintenance order management
- Order control, sequence setup, material control and provision
- Worker information system

Isolated, stand alone IT-systems
3. How IT-systems can be integrated

Option 1: an integrated and modular system from a single source

Module 1 | Module 2 | Module 3
Module 4 | Module 5 | Module n

Pros:
+ integrated solution from one supplier
+ real time computing possible

Cons:
- high complexity
- high invest and adaptation costs

Option 2: several systems with a common data base

System 1 | System 2 | System 3
System 4 | System 5 | System n

Data base

Pros:
+ use of commonly accepted technologies

Cons:
- common database not available for stand alone systems
- common data model required (CIM)

Option 3: new and existing systems cooperate via an agent platform

System 1 | System 2 | System n

Agent platform

User assistant

Pros:
+ existing systems can be integrated
+ information can be used borderless

Cons:
- Technology not yet proven in production
3. Components of production related IT for Hyundai Motor Company

[Source: FhG-IPK – Hyundai Motor Company, Ulsan]
3. Future manufacturing execution systems: horizontally integrated

Requirement:

links between those production related applications, which data is required at a certain work station

Source: AUDI
3. Missing link between production monitoring (»automation world«) and sequence setup (»logistics world«)

Visualization clients

Monitoring server

Online-DB

Body (object) identification (localization)!

Logistics management systems, e.g. sequence setup

Clients

Media-server

Alarm-server

ProVis-cernel

PLC

MMS-station

OPC-station

Body (object) identification (localization)!
3. Today's body identification by RFID-Tags on the car body

(source: http://transpondernews.com/info/confiden.html)
3. Today's body identification and communication of ID-data to related applications

Legend
- Antenna
- Mobile tags on the car bodies

Characteristics
- Number of read-/write-points is limited by number of antennas on the shop floor
- Ident data is computed by logistics management IT
- Connection between logistic and production monitoring system is missing
3. Objectives for connection of production monitoring and object identification/localization

- Real time information concerning all car bodies in body, paint, trim shop, rework and distribution

- Reading id/positioning patterns and matching them with product options and/or manufacturing orders

- Distribute id/positioning data to concerned IT-components on the different levels, e.g. PLC, planning systems, etc.

- Hand over manufacturing orders from planning system to the PLC and its buffer

- Reduction and simplification of today’s systems, e.g. mobile tags, body tracking calculation, bar codes/data matrix, etc.

- Provision of linked information concerning production status, facility status, id/position of car bodies and status of customer orders, if possible in real time
3. Approach: localization of car bodies and connection to production monitoring

Legend

Antenna network

- Tag/sender
- Reference sender

Characteristics

- Each body is tracked permanently
- Data of ID-system is analyzed separately, logistics management system is relieved
- Connection of logistics management and production monitoring system (see next chart)
3. Horizontal ‘integration’ of production monitoring, body identification and sequence setup on the manufacturing exec. level

Planning level IT

| Order management | Logistics | Data Warehouse |

Initiate material withdrawal

Feedbacks

Order data, assembly options, body options, variant parts, ...

Sequence setup system

NEW!

Ident Monitoring system (highly available)

Body-ID, place

Localization-/RFID-IT

Localization hardware

Identification hardware body shop (read/write devices)

Identification hardware paint shop (read/write devices)

Ident.-/localization hardware assembly (read/write devices)

Localization hardware finish after end of line

Localization hardware distribution

Prod.-monitoring, e.g. ProVis-Agent

Commands, order data

Feedback

PLC

PLC

Initiate material withdrawal
3. Benefits for customer from automotive industry

- Reduction of non-productive time by help system, e.g. for work orders, parts to be picked and assembled, car body type, etc.

- Higher quality of information, e.g. concerning reports that use both data from logistics and facility monitoring

- Car body related information is presented by the PMC’s visualization system => only one user interface

- Possibilities to build up closed loops between production monitoring and sequence planning, e.g. for unexpected downtimes

- By integrating identification and logistics difficulties in the supply chain become visible

- Redundant data storage can be reduced by integration of production related IT-systems

- Localization and identification of finished cars after the end of the assembly line can be done with one technology
3. Manufacturing Execution Systems for automotive production

- central visualization and control room concept
3. Current IT-infrastructure within a press shop

New control room: visualization of entire pressshop and its equipment

- Reporting system: breakdowns, availability, cycle times, etc.
- Production order control with ERP-system
- Alarming and failure management
- Inventory control systems
- Media-server for ANDON-boards
- Camera detection for scrap disposal
- Visualization stamping lines and scrap lines
- Access-database for dies
- Control of AGVs
- Data acquisition at presses
- Inventory control systems
3. Current process flow

Scrap disposal

Transport by train

Finished blanks

External body shop

Finished blanks

Blanking process = value added

Stamping process = value added

Blank process hall 1

High storage hall 1

Stamping lines hall 1

Finished parts storage

Scrap disposal hall 1

Scrap disposal hall 2

Internal body shop

Other customers

Finished blanks

Stamping lines hall 2

Transport by train

Blank process hall 2

High storage hall 2

Finished blanks

Transport by train

External coil storage

Finished blanks
3. How to design a central control room

- Monitoring system must enable entire process overview from the very beginning to the finished parts

- People in the control room must be able to see relevant information on a glance

- User must be able to see entire process and detailed pictures of a facility he can navigate

- Possibility for interaction between user and system as well as between large displays and work station, dynamic figures instead of static displays

Source: ABB
3. Design options for the central control room

Fraunhofer IITB:
people in the new control room must be able to watch the entire process chain!

Current idea

<table>
<thead>
<tr>
<th>Blanking process</th>
<th>Transport</th>
<th>Stamping process</th>
<th>Scrap disposal</th>
</tr>
</thead>
</table>

Proposed solution

<table>
<thead>
<tr>
<th>Blanking process</th>
<th>Stamping process</th>
<th>Scrap disposal</th>
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</table>

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3. Design options for the central control room (2)

Cross-linking of existing applications through an integration platform; pick relevant data for central control tasks and visualize it in shared application.

Existing applications keep their functionality and autonomy; people in charge of existing systems will keep their know-how and their responsibility for the systems administration.

Only data that are worth combining will be combined and integrated via the integration platform; stand alone systems keep alive.
3. Details of the chosen option

Overall picture allowing overview over the entire process, e.g. on a large central display.

In case of an alarm the concerned process indicates a failure; by clicking on the process people in the control room can navigate through the pictures easily on their desktop.

Existing applications can be started directly by clicking the buttons.
3. Details of the chosen option (2)

Draft architecture of the integration platform:

- 'active component', d.h. application gets data from existing systems

- Standard interface to the central visualization via OPC

- Existing systems communication interfaces are still used, e.g. data base access, RFC 1006, etc.
3. Details of the chosen option (3): layout of the control room
3. Manufacturing execution systems for automotive production

- integration of MES with digital factory
3. Digital operation is part of the digital factory
3. Digital operation is part of the digital factory (2)

Digital operation: interaction of...

...super ordinate information technology

...virtual or real controls (PLCs, CNCs, robot controls)

...virtual or real machines
3. Reference model for factory planning: connection of planning and operations

<table>
<thead>
<tr>
<th>Design</th>
<th>Engineering</th>
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<tbody>
<tr>
<td>Idea</td>
<td>Concept</td>
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<tr>
<td>Planning</td>
<td>Realization</td>
</tr>
<tr>
<td>Ramp up</td>
<td>Operation</td>
</tr>
</tbody>
</table>

Project management

- CAD-/CAE-Systems
- DF*-Systems
- DF-Systems
- DF-Systems

Manufacturing execution systems for:
- Detailed scheduling
- Tool management
- Material management
- Staff management
- Data acquisition
- Key performance indicators
- Quality management
- Information management

*DF= Digital Factory systems, e.g. DELMIA, Siemens UGS, etc.

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3. Digital operation includes…

- Mechanical design of equipment
  - CAD-Systems (see VDI 2249), EDM-/PDM-systems (see VDI 2219)
- Equipment drawings, BOMs
- Electrical design of equipment
- Connection diagrams, IO-configuration
- Software development
- PLC-programs, machine visualization

- Electric planning systems
- PLC-engineering systems (see IEC 61131, VDI/VDE 3850)
3. Main idea for connection of planning and operations

- CAD-System
- Digital factory tools
- ERP-system (SAP)
- Manufacturing orders
- Sequence planning system
- Customer order
- Production, shop xy
  - Engineering
  - Report-DB
  - Production monitoring level
  - Cell level
  - Cell level
  - PLC
  - PLC
  - PLC
  - PLC
  - PLC

Use information from the factory planning process inside the 'world of automation'
4. Benefits from early connection of planning and operation

today:

- Specification
  - functions
  - KPIs
  - criteria for approval
- Mechanical facility construction
- Electrical facility constr.
- Manufact./assembly
- Commissioning
- Ramp up

Implementation and engineering of production monitoring & control

in the future:

- Specification
- Mechanical facility construction
- Manufact./assembly
- Commissioning
- Ramp up

Implementation and engineering of production monitoring & control

Virtual commissioning
Thank you for your attention!
Production control applications in the automotive industry
- Examples from Fraunhofer IITB projects -

Shenyang, November 22, 2007

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