Basic presentation:

Helsinki, 7./8. February 2013

The latest developments in warehousing and materials management / material handling

Table of contents

0. Summary

The goal of this paper is, to show a new approach, how the efficiency of materials management could be improved.

This paper starts with a review, how material handling has supported logistics tasks in former times. This review shows that material handling was always an enabler of logistics, to fulfill the demands of supply chains.

Current and future requirements for materials management & handling systems will be shown on practical experience. The main tasks of Supply Chain management and materials management are described.

A major reason for permanent increasing tools and strategies in materials management business are **"unstable"** processes.

A holistic approach, based on **intelligent** material handling is needed. The new approach leads to optimized and more precise processes.

To bring more intelligence into Material handling mainly means to modify the design characteristics.

Many developments in material handling are shown. The most important developments are described in detailed including their realization and their goals.

The conclusion of this paper is:

- Material handling systems are fit for future and enable more efficient supply chains.
- Furthermore the used technologies and developments are already part of **"Industry 4.0".**
- Fully automated solutions will have all characteristics to become much more efficient as manual based systems, therefore fully automated systems will increase strongly.
- Industry 4.0 will help European production and logistics companies to compete with Asia´s power and to have success in the future global struggle.

1. Introduction

Before we try to define the latest trends in warehousing and materials management and to give an outlook for the future direction of material handling, it is necessary to take a look back to the beginning of logistics in industrial business.

The main task of logistics in former times was to fulfill the transport function the move of any kind of good from place A to place B. Logistics was one of the support tools for production systems. The logistics functionalities 40 years ago were more material handling with a small part of materials management.

Figure 1: Material handling application at the beginning 70s

Material handling at the beginning of the nineteen seventies was even at this time a very innovative business. We have to consider that IT- and controls technology was on a very low level but with creative engineering solutions we could solve even very complex material handling tasks.

Figure 1 shows a material handling application for the automotive industry.

The author has experience of 40 years in logistics and he started his career when PLC´s were not invented and Barcode was in development and not in use. The identification and tracking of load units like body skids was done by use of magnetic drums and for window tracking hardware based shift registers were used.

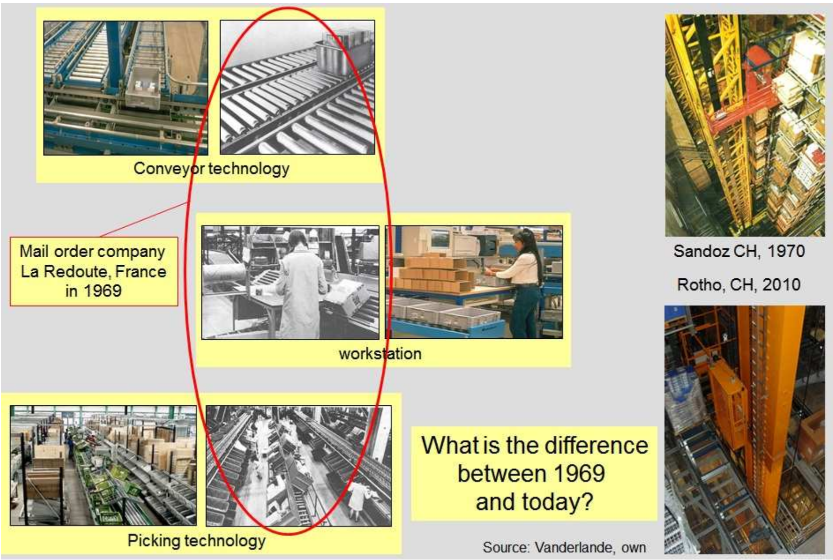


Figure 2: Automation in 1969 – today

Within the last decades the logistics functionalities have changed dramatically as well as economies have changed in the same way.

Naturally material handling functionalities have changed in the same way.

When you take a look at figure 2, you cannot believe that between some of the photos is a difference of ca. 40 years.

At a first glance the structure and design of conveyors, cranes and workstations are the same but there are huge differences in dynamic capacity, functionality and characteristics like robustness, flexibility and standardization.
Meanwhile logistics is a core element of all business areas. Today logistics enables companies to define strategies and to create unique selling points and logistics is one of the conditions for globalization.
Material handling is a great success story too because it enables logistics to control and supervise integrated supply chains.
This short review showed clearly the innovative characteristics of the business area “Material Handling” in past.

With the following chapters of this paper the author will show how the efficiency of materials management can be improved. A new approach is shown, called **“Intelligent material handling”.**

The basis of this new approach is the increasing number of innovations in material handling.

Therefore one has to concentrate on those, which are the most important ones and which bring the most benefit to customers and users.

2. Requirements for Materials Management and Handling Systems

To show very clearly the requirements on materials management in this days and age, we first have to focus on change in economy. Figure 3 shows a short listing how the world and the requirements in generally have changed. This listing is by fare not complete.

Besides the listed requirements we can consider a continuous reduction of inventories along the whole supply chain and increase of involved parties.

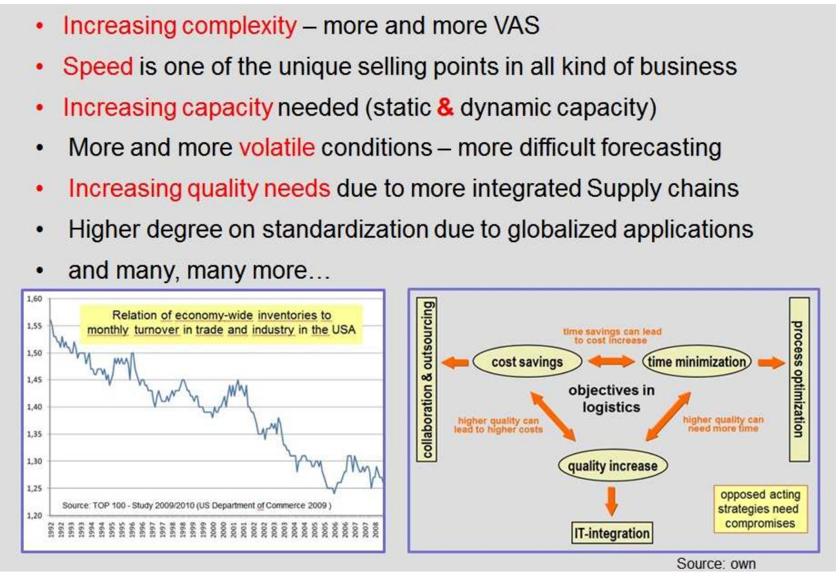


Figure 3: Change in economy

Tough and worldwide competition leads to price struggle. Logistics solutions have to find a compromise between opposed acting strategies. For example:

- time savings can lead to cost increase
- higher quality can lead to cost increase too
- higher quality can need more time

The best way to show the challenging requirements is to give a specific example.

Figure 4 shows an often needed application in consumer logistics. It shows the requirements in food retail business.

- shorter delivery cycles (sometimes several times per day)
- smaller quantities
- increasing assortment in food retail in general
  (more and more categories and doubling of part # in the last 15 years)
- freshness in shelf
- sequence requirements for picking
  (family grouping according layout of PoS, heavy before light, etc.)
- reduced inventory and time savings by use of cross docking
- efficient returns logistics(transport in reusable LU, repacking, ect.)
- sustainable solutions
- intelligent packaging (few lost space but secure, avoiding theft / mis-use)
- and finally: all processes for transport or for picking
  must be "travel way-optimized" either for man or for machine

Figure 4: Requirements in food retail business

Each requirement has a strong impact on Materials management as well as on Handling Systems:

Shorter delivery cycles. This needs faster processes with shorter lead times and "Travel way optimized transports".

Increasing assortment, more categories and doubling of part numbers.

That needs more efficiency in warehousing and distribution:

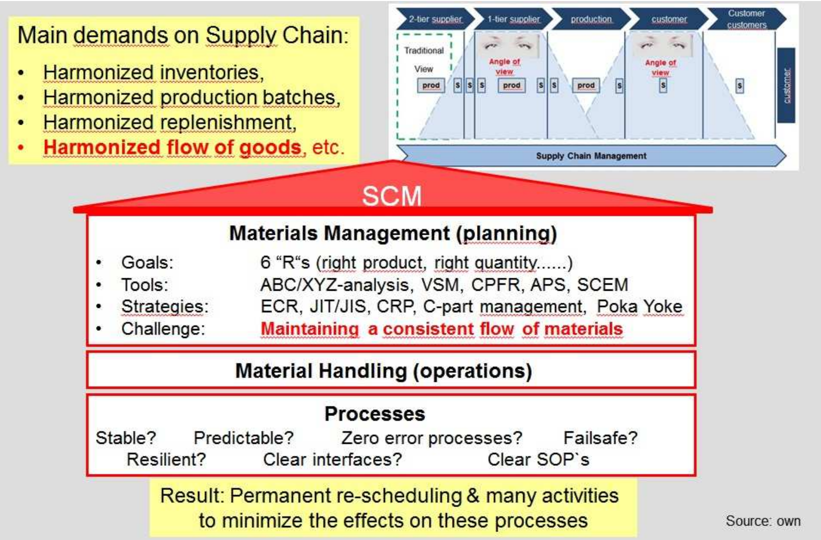
- The main goals are reduced inventories and lead times. This will be enabled by strategies like cross docking, vendor managed inventory, etc.
- Sequence requirements, like optimized travel way in POS according to the individual store layout and structure of the categories or weight aspects (heavy before light). This needs more sortation and consolidation.
- Sustainability requirements influence very strong all parts of business. Therefore efficient return logistics and intelligent packaging is needed.
- Travel way optimization is a must, either for man or for machine.

The impact is in system design as well as in elements. Due to more and more volatile conditions in future the characteristics like flexibility, transparency, robustness, resilience will become challenging requirements even for MHS.

3. Task of materials management

3.1 Overview

The demands on supply chain are very easy to define and simple to tell: "Harmonized inventories, harmonized production batches, replenishment, etc…..". But materials management became very difficult. The challenge is "Maintaining a consistent flow of material".



To tackle the challenges many tools and strategies have been developed.

Figure 5 shows some important only.

Before we want to look to the characteristics of processes, we want to focus on tools and strategies first.

The goals of logistics in general are defined very easy by 6 "R"`s

Figure 5: Demand on Supply chain and materials management

The real goals of materials management are:

- To optimize processes in general
- To reduce inventories
- To reduce lead times
- To optimize replenishment
- To achieve more transparency in processes
- To enable a more precise forecast

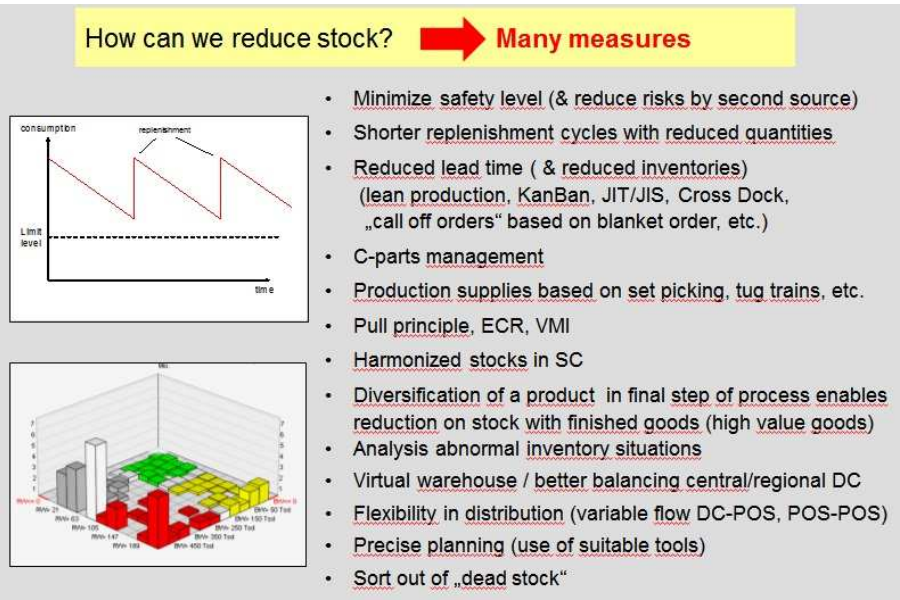
Within the following sub chapters some important tools are described only. This should give a small outlook how large and challenging the tasks of materials management are.

3.2 Tools & strategies to optimize processes – some examples

3.2.1. Strategies to reduce inventories and lead times

Concerning inventories there should be paid attention to 2 main aspects:

- According to the EOQ-diagram the inventories should be in balance between the savings in purchasing due to large scale effects and the costs of inventories (financing aspects, warehouse investment costs and additional operational cost like longer travel ways, etc.)
- The inventories should be in balance between replenishment lead time and consumption / demand. To be out of stock is never to accept. Therefore a minimum level of stock should always be available. Either in the own warehouse or in the warehouse of the suppliers. How large this reserve stock has to be, depends on the demand, no fluctuation or large fluctuations.) But in any way the reserve has to pay attention to unforeseeable situations.



Another essential requirement is the flexibility to react very fast to changes. This is possible only when the lead time of all processes will be reduced to a minimum-

Figure 6 gives an overview about the measures to reduce inventories

Figure 7 and 8 show 2 concepts which reduce inventories and lead time together.

Figure 6: Measures to reduce inventories

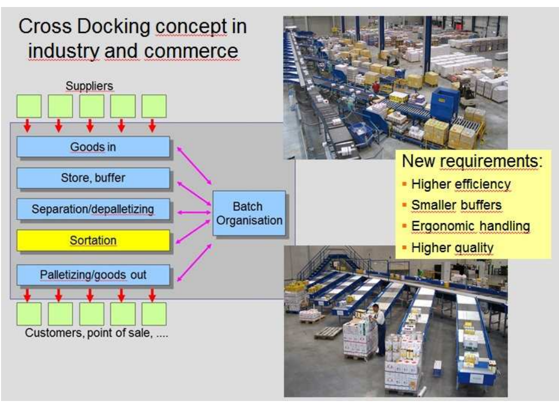


Figure 7: Cross docking

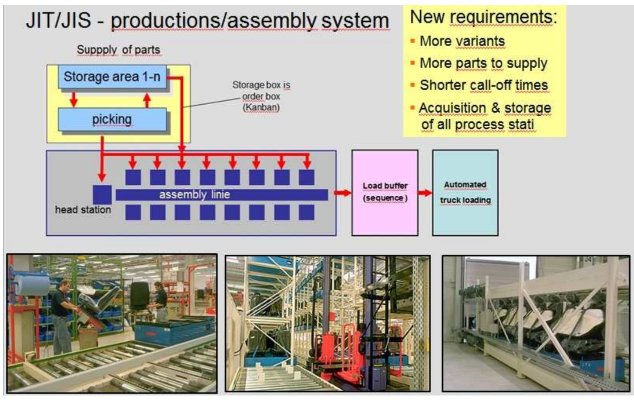


Figure 8: JIT / JIS

For both concepts the requirements are shown

3.2.2.Tool “Logistics Fingerprint” – (mSE solution)

This tool was developed by mSE, a company specialized for Supply Chain solutions. “Logistics fingerprint” is a tool which shows very clearly were inventories can be reduced. This tool is very mighty, because many parameters can be defined very easy.

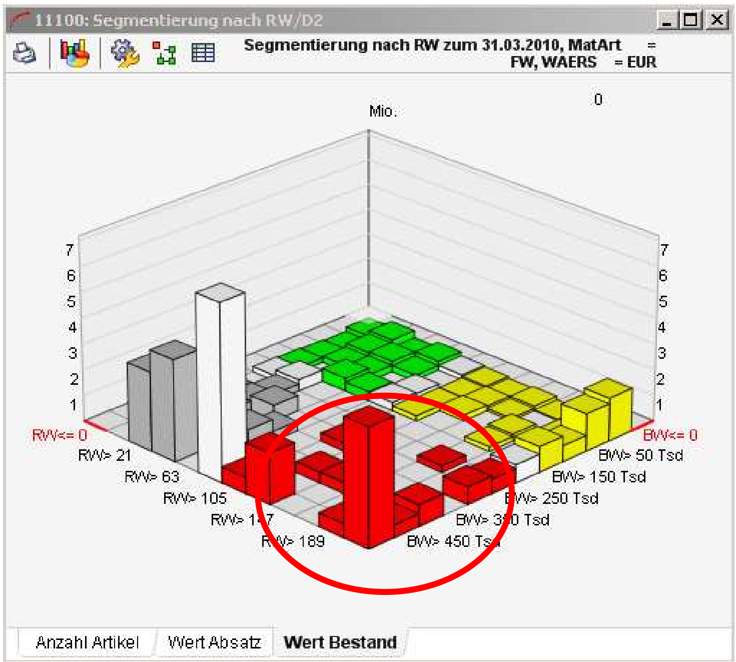


Figure 9: Analysis Tool – example 1

Figure 9 shows an often existing example. The article group with the characteristic **“Longest range and the most expensive articles”** have the highest inventory.

The analysis can be done by use of many different parameters. Figure 10 shows 2 examples.

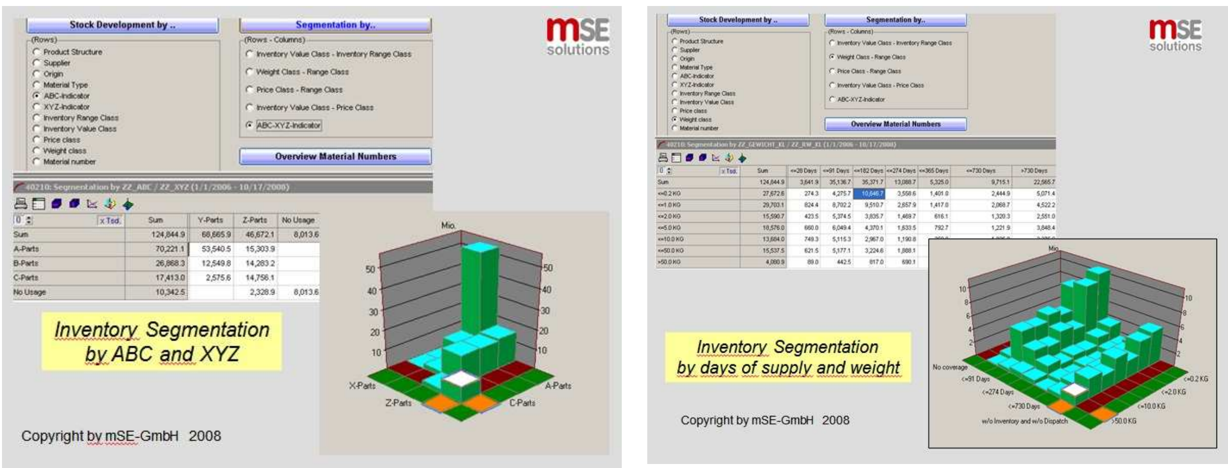


Figure 10: Analysis Tool – example 2 and 3

If someone studies fluctuating inventories in life time of SKU some abnormal inventory situations/large fluctuations will be detected.

The tool "Logistics Fingerprint" supports the analysis of abnormal situations and often quick wins are to earn.

Figure 11 show a couple of abnormal inventory situations in life time of a SKU

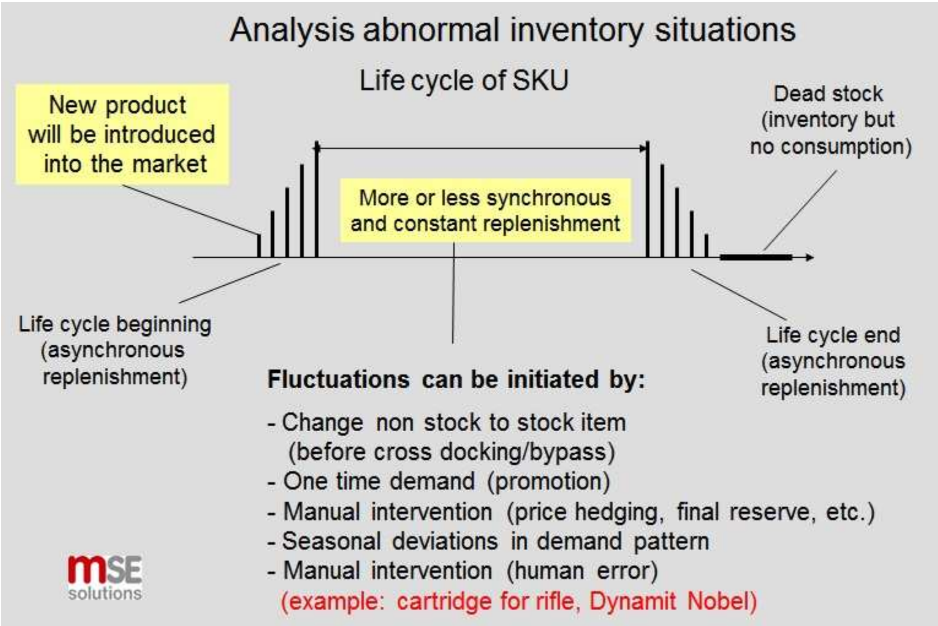


Figure 11: Reasons for large fluctuations

Sometimes human error is the reason. An example is given:

Due to input error in order planning operations produced too many items of a specific type. The result was a range of more than 400 years for this SKU

3.2.3.Tool “Value stream design”

The tool “Value stream design” is very powerful when you have to optimize your processes. A lot of symbols allow to design the processes in detail. Figure 12 gives an overview about the most used symbols. If one has specific processes with specific characteristics it is possible too to define specific symbols further.

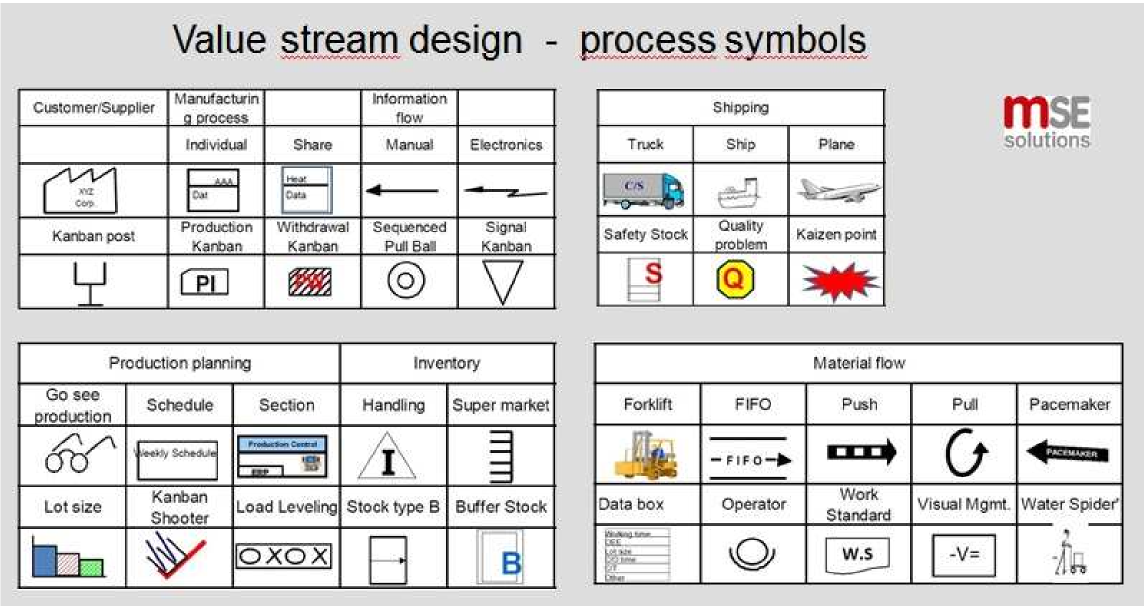


Figure 12: Value stream design - symbols

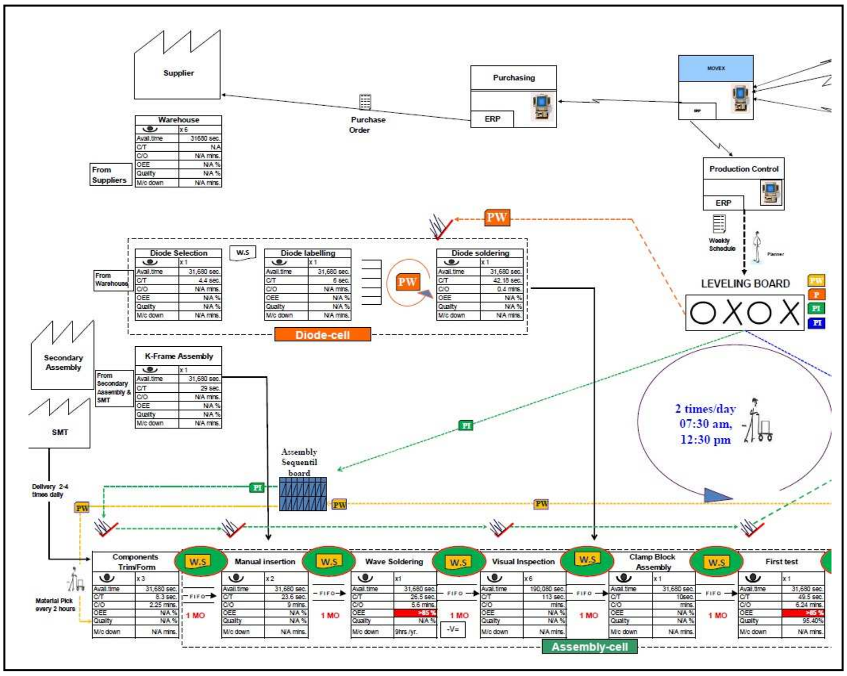


Figure 13: Value stream design – example for an application

After all processes are designed according this method, you can see very clearly, where waste of time (MUDA) is and where some processes can be put together, etc.

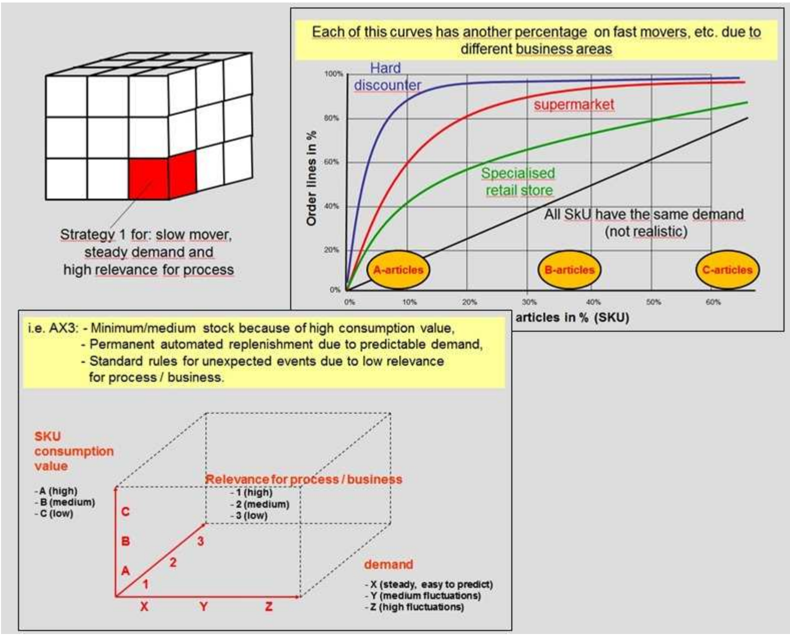
Figure 13 shows a part of the complete processes.

3.2.4. 3D-demand analysis and classification of strategies

One of the most important analysis in materials management is ABC-analysis (Pareto curve). Figure 14 shows in the upper right corner some Pareto curves for different business areas.

All SKU can be split in 3 groups: A, B, and C

- A-parts are important because the most turnover will be made with this SKU`s. Fast processes, highest quality and adherence to schedule is needed.
- C-parts are minor important for turnover but are the largest part in stock (volume, handling efforts and value). Therefore the logistics efforts have to be reduced/minimized



Advanced analysis methods combine different parameters to achieve a more precise and integrated view about demand situation and makes it is to define according strategies.

In the following the 3D- analysis method will be introduced and explained in detail. This method allows a 3-dimensional view and makes the selected strategies more transparent.

Figure 14: Advanced analysis tool

The 3 parameters (axes of 3D-model) are:

- ABC classification according turnover/consumption related to addressed SKU. ABC classification is split in mover classes (fast, medium, slow)
- XYZ classification follows the kind of demand / consumption (X continuous consumption, fluctuations are very seldom, Y fluctuations in consumption, mostly due to trend, like seasonal patterns, Z consumption is not at all continuous and not predictable
- Classification according to the importance for the company (supply risks, business strategy, etc.).The split can be as follows: 1= very important, large risks, 2= medium important……, 3= minimum important……)

With this 3D model and 3 classes per axe you can define maximum 27 different strategies. Different strategies are needed because the individual cubic elements need different treatment/priorities. An example is given:

AX3 is characterized by fast mover – predictable demand – minor important risks. X-parts have steady demand. The strategy can be adapted to the characteristics of this group.

3.2.5.C-parts Management

The parts which have to be purchased can be split in 3 groups:

- Group A: very expensive parts
- Group B: medium expensive parts
- Group C: low cost parts

The last group(C-parts) is often characterized by.

- Extreme low price
- Purchasing cost and materials management costs are higher than the value of the items
- Typical parts are fastening elements like, screw, nuts and washers
- Parts belong to the category “Bulk material”
- Inventory posting will not done, sometimes a reduced SKU master data is used

Classic C-parts Management use Kanban with 2 or more boxes of each SKU. The replenishment is started by worker.

Figure 15 shows the classical Kanban system including card

Figure 15: Classical Kanban System

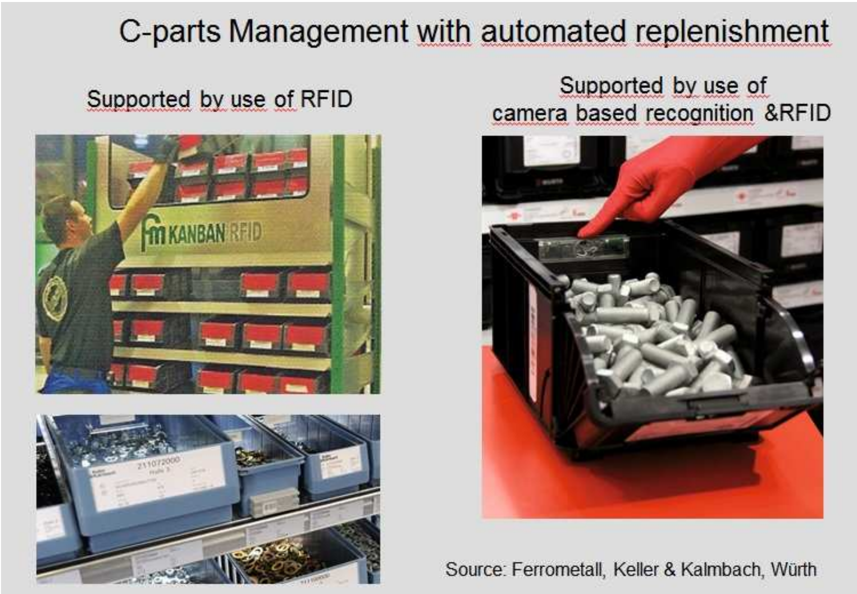
In this case the cards of the empty boxes will be collected, transported to the warehouse dispatcher and for each card a new full box will be provided.

This process needs a lot of time and error can be occur (lost card, etc.)

Today most applications use a barcode reader to scan the part number and start the replenishment process.

Very new are concepts which use RFID or other sensors to start replenishment fully automated.

Figure 16 shows some applications.



The main advantages of an automated replenishment are:

- Faster
- Less errors

If you have optimized the organizational aspects a lot of costs can be saved.

Figure 16: Advanced Kanban System

On the right side of the figure 16 the brand new System **"iBIN"** from company Würth can be seen. This system starts replenishment fully automated. On each box a control element is installed. A camera recognizes the filling degree of the box and can even count the items inside the box.

If there is very low demand 1 box only is needed only and this is an advantage if space is limited.

In this case the system "**KKL2in1**" from company Keller & Kalmbach is the right one.

Figure 17 shows the process steps.

Figure 17: One box concept.

3.3. Strategic management needs methods for comparison and benchmarking

If we have to decide between 2 solutions, we have to compare a lot of different aspects and it is not so easy to decide which solution is the better one. Naturally hard facts play always a large role but often it has to be paid attention to soft facts too.

Figure 18 and 19 show some methods how comparison is done.

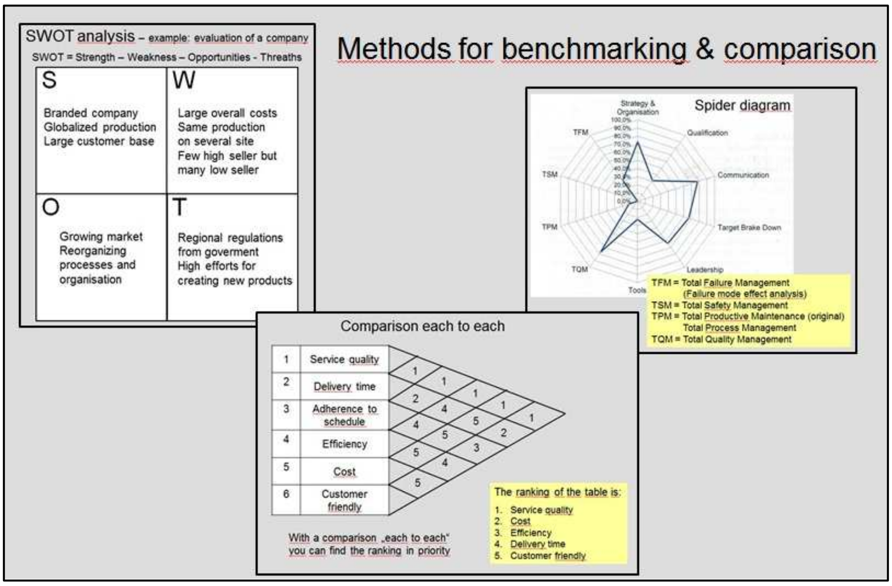


Figure 18: methods for comparison & benchmarking

Relation Score: strong = 5, none = 0; Weight Score: 1=less important, 3=very important		FMCG businesses meets sales goal	Performance of 3PL in operation	Information flows smoothly and accurat	Financial relationship	ECR-aspects	Operation flexibility	Score
Output		Y1	Y2	Y3	Y5	Y5	Y6	
Input	Weight	3	2	1	1	3	2	
X1	% of employees with IT training	0	1	5	0	3	1	18
X2	% of failed orders	5	5	0	1	3	3	41
X3	% of inform. exchange through IT	0	1	5	0	3	3	22
X4	% of information management assets used / production assets	1	3	5	1	3	0	24
X5	% of invoice receipts orders and payments generated via EDI	3	5	5	3	5	3	48
X6	% of orders scheduled to customer request	5	5	3	3	5	0	46
X7	% orders / lines received with correct shipping documents	5	5	3	3	5	0	46
X8	% product transferred without transaction errors	5	5	5	1	5	1	48
X9	Additional services price (priority transportation)	1	0	0	5	0	3	14
X10	Availability of IT equipment	1	1	5	0	3	1	21
X11	Contact points (number of 3PL people to contact)	1	0	3	0	5	1	23
X12	Effectiveness of delivery invoice methods	5	0	5	5	1	0	28
X13	3PL Mission Failure costs	1	5	3	1	3	0	26
X14	Fixed asset costs	0	0	1	0	3	1	12
X15	Goods safety	5	5	0	3	0	1	30

Figure 19: Cause – effects analysis.

The example of figure 19 show the output (Y1-Y6) regarding to the input (X1-X15).

3.4. General challenges how to predict the future

There are 2 main aspects why predicting future process results like lead time, etc. is so difficult:

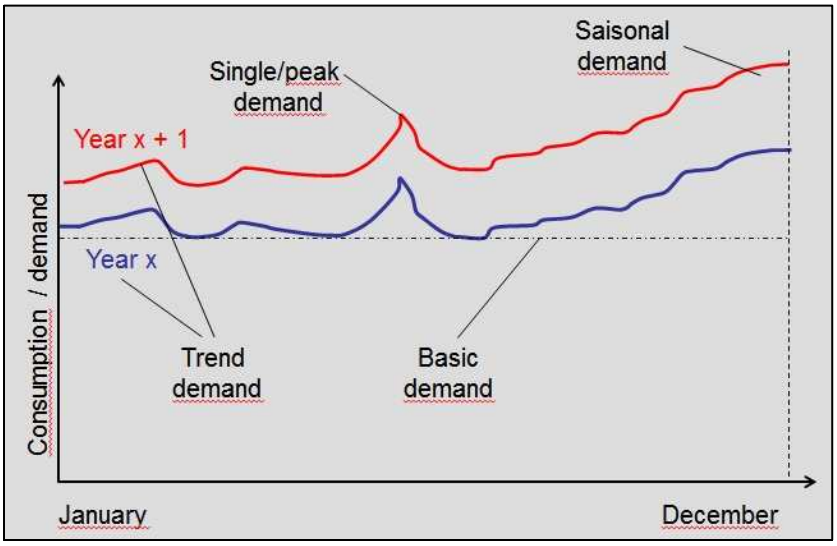
- Fluctuating demand
- Unforeseeable situations like break down of components, damaged items, poor quality, etc.

The following subchapter will show more transparency to the above aspects and how materials management can tackle these challenges.

3.4.1. Fluctuating demand

Tools for demand forecast analyze the history and try to define the demand very precisely. To forecast the demand very exactly, it is necessary to have available data for a couple of years (the more years the better). The data should be the real consumption data (true values) and the forecast data.

Figure 20 shows the consumption of year x and the following year.



This figure shows the 4 kind of demand:

- Basic demand
- Trend demand
- Saison demand
- Single/peak demand

Figure 20: Structure of demand

If forecast data are available, you can define the deviations. With statistical methods you can calculate the error and you can optimize the forecast for the next time period.

The errors can be defined as follows:

- **ME** Mean error
- **MAE** Mean absolute error
- **MPE** Mean percentage error
- **MAPE** Mean absolute percentage error
- **MASE** Mean absolute scaled error
- **RMSE** Root mean square error

The longer the life time of an SKU is the more data are available and the more forecast optimizing by error analysis is possible. Typically parts are spare parts

Unfortunately today many SKU have a short life time (textile, electronics, etc.)

To tackle this challenge some additional measures have to done. Figure 21 shows an example for efficient forecasting in textile business. The goal must be:

When life curve of a SKU ends stock must be zero

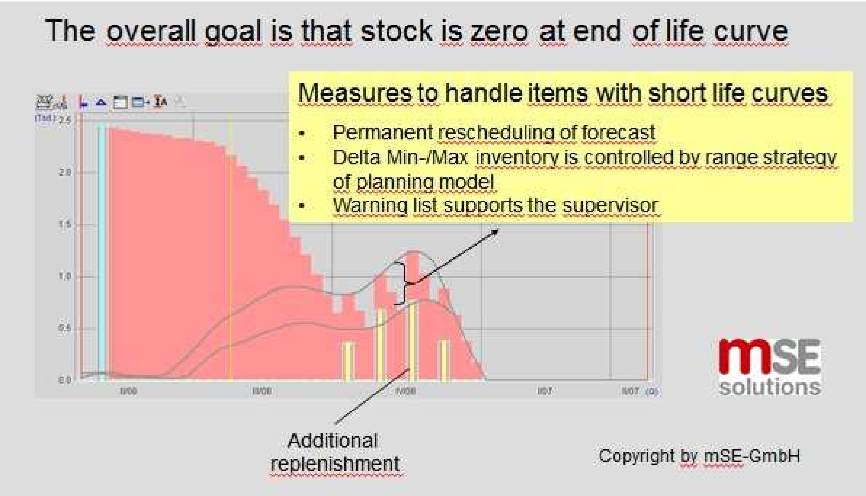


Figure 21: Measures to handle items with short life curves

3.4.2. Unforeseeable situations

Another major aspect of materials management is the planning of processes with a lot of unforeseeable situations. The more stable the processes are, the more efficient planning can be. Therefore we have to take a look at the processes in detail:

- Are they stable and predictable?
- Are the processes “Zero error processes”? , fail safe and resilient?
- Are the interfaces and SOP`s clear? (SOP is Standard operating procedures)

The conclusion is: “No”

The result of unstable processes is:

- Permanent re-scheduling / and
- Many activities to minimize the effects on these processes

Some examples can be given:

- Inaccurate inventories lead to extra costs and delays
- Instead of avoiding delays in putaway, we permanently try to optimize time slotting for truck unloading at goods in
- Often use paper based clearing instead of direct clearing

When we compare our Supply chain models with a building we would say: “The basement is not stable enough”

What do we need? We need a holistic approach and we have to improve our processes in detail.

The processes must be

- 100% precise,
- Permanent check of quality & “progress in processes”, is needed including direct clearing
- We need processes: 100% reliable, failsafe, highly flexible and resilient
- And we need unambiguousness of strategies and interfaces.

The result: Materials management will become easier, faster & more efficient

To improve the processes significantly, we have to bring in more intelligence and have to modify the characteristics
of material handling.

In the following chapters of this paper it will be shown how we the processes can be improved.

4. Characteristics of Material handling systems concerning system design

The life time of Material Handling Systems is often more than 20 years and including some retrofits the life time can be much longer. If we want to design systems which fulfill the increasing volatile demands and enable to reduce supply chain risks, etc., the system design has to have all characteristics which are shown on figure22.

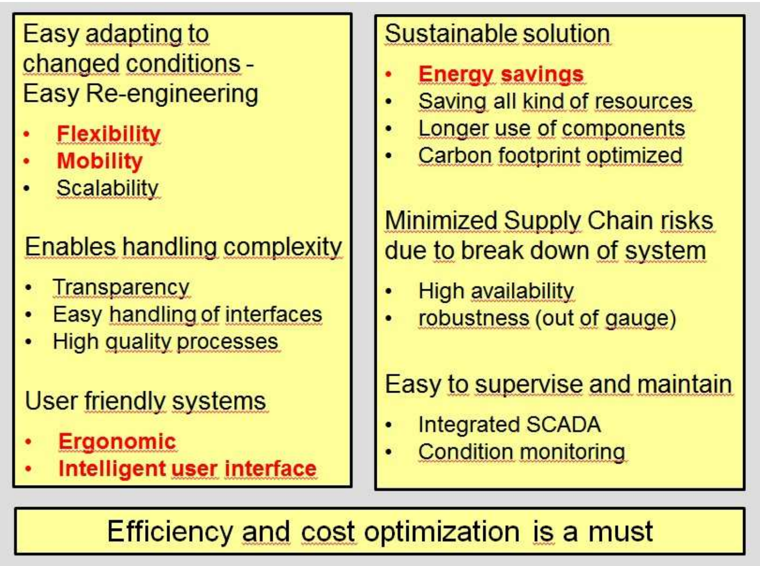


Figure 22: Most important characteristics of MHS

The characteristics which are highlighted by use of red color will be covered in detail in the following sub-chapters.

These characteristics are the most important ones to handle future challenges.

All these characteristics **"simplify processes".** This saves money and resources.

Naturally the basic goals "High efficiency & cost optimized must primarily be fulfilled.

4.1 Autonomous – mobile – flexible

These characteristics have a very high priority because these systems have a lot of advantages. The most important advantage is the flexibility concerning changed parameters like order structure and the flexibility concerning layout modifications. In former times manual based systems had these advantages only but manual based systems often cannot fulfill the increased requirements concerning quality, efficiency, etc.

Figure 23 shows the major advantages and the solutions how you can achieve these characteristics.

All this mentioned concepts are based on proven technologies.

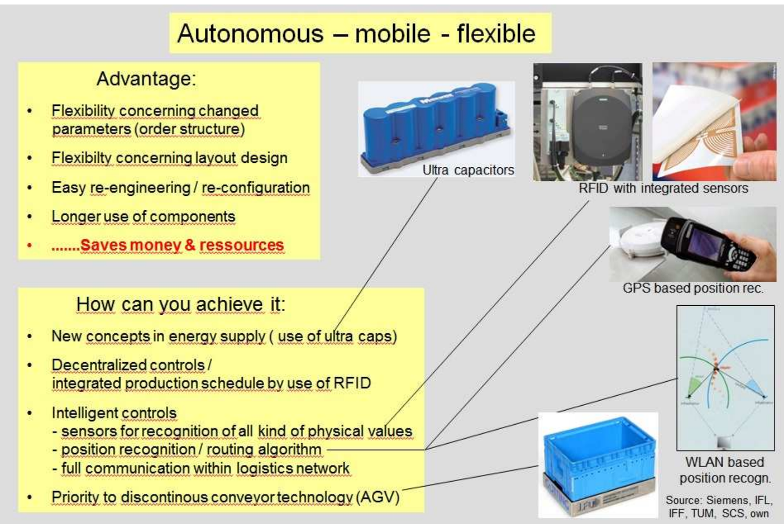


Figure 23: Characteristics: Autonomous – mobile - flexible

Naturally, ultra capacitors do not have the same capacity as classic power supply and lead batteries but with intelligent charging concepts this small disadvantage is avoidable. The new concept of energy supply allows transport and storing systems with excellent ratio of net/gross weight.

Intelligent controls with innovative components and sensors which are able to communicate like RFID and RTLS allow a more precise materials management. "Real Time Location finding System" helps to track containers and the load inside, and we always know the physical condition of our load.

AGV will enjoy something of a renaissance because discontinuous conveyor systems have a very high flexibility and allow concepts based on swarm intelligence. Further on there will be a large area for applications with continuous conveyor systems, for instance when high capacity is needed, etc.

4.2 Decentralized structure – self controlling

The above mentioned discontinuous working, vehicle based transport systems have to be equipped with intelligent hybrid sensors. These sensors allow the vehicle to recognize the environment. This helps to avoid collisions with other vehicles, other physical objects or people but tries always to use the shortest way to the point of destination. The vehicle reacts in the same way like a car plus driver.

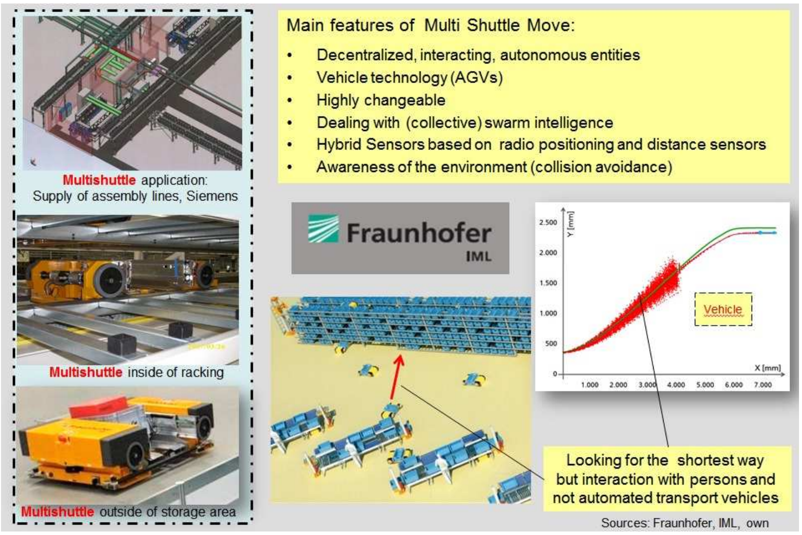


Figure 24: Application for "Self controlling" processes

The use of RFID allows the storing of all process data (schedule and results) either on product itself or on load unit. The integrated production schedule enables completely decentralized processes including collection of all kind of process results. This allows a more efficient decision making for the next process steps as it is now possible.

With this intelligence the vehicle can interact autonomous. Typically bottle necks from today`s production and logistics will be avoided.

Figure 24 shows on the left side applications in industry (Multi shuttle) and on the right hand side "Multi Shuttle **move**", developed by Fraunhofer IML, Dortmund.

The "Multi Shuttle move" has the above mentioned intelligence and in future these vehicles will react like an automotive car plus driver but in this case the driver is the controls.

Further on the controls of the "Shuttle move" communicate and decide together which shuttle will take over the next task. This intelligence can we define as "collective swarm intelligence".

4.3 Sustainable solution

The future will bring a lot of challenges for the living on our planet Earth. Besides demographic change, urban aspects in Mega-cities, saving energy as well as other resources will be a must for all business areas. Logistics is a business area with high consumption on energy and resources. Reduction of pollution is one of the largest challenges for global traffic.

According EU statistics logistics is responsible for 21% of all gas emissions in EU-27.

This volume is split in:
- 76% external transport (inbound & outbound logistics)
- 24% material handling & ware-housing

This figures show that sustainability is a must in logistics processes.

In material handling the focus must be more on energy saving, efficient use of resources and reducing waste.

There is a wide range of sustainable solutions and aspects in material handling. To go into detail this would exceed the scope of this paper. Therefore in this paper one has to focus on some major aspects.

Besides that it has to be referred to the book “Sustainable logistics”, issued by BVL in 2011. The author of this paper was part of the team of authors and has written the chapter “Retrofit of material handling systems to save energy and resources”

Figure 25 shows the main measures to create sustainable solutions in material handling systems.

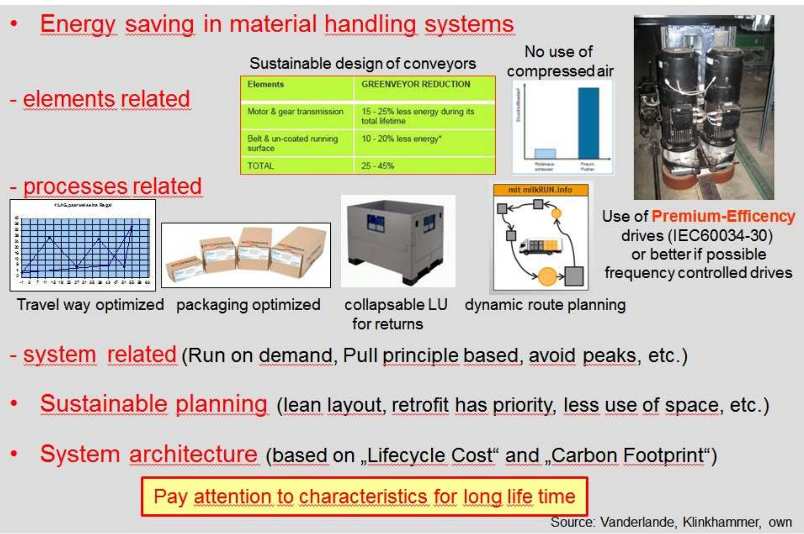


Figure 25: Sustainability is a need in material Handlings

The measures can mainly be split in 3 parts:
- Energy saving aspects
- Sustainable planning to optimize footprint, space, etc.
- System architecture to minimize lifecycle costs

The following shows the measures more in detail:

- **Energy saving aspects**
  - relating to components
  *(use of efficient electric motors, sustainable design of conveyors,
  avoid use of compressed air,
  use of inverter technology for charging of lead batteries
  for fork lift trucks, etc.)*
  - relating to processes
  *(optimized according travel way, filling factor of load units, minimized volume of warehouse
  optimized packaging, optimized shipping, route planning and reduced energy for IT-systems)*
  - relating to system design
  (Run on demand, avoid peaks, use of pull principle, use of intelligent software strategies)

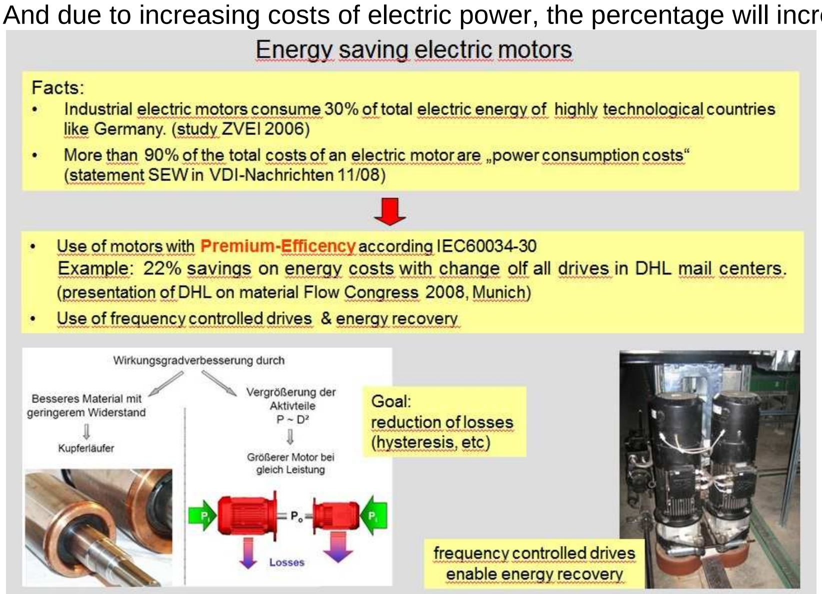
- **Sustainable planning**
  *(with the focus on a lean layout, planning based on performance figures according energy consumption,
  Simulation under consideration of sustainability parameters like energy consumption, consumption of foot
  print, priority to retrofit, re-use of components and upgrading of components, etc.)*

- **System architecture**
  (with the focus to „Lifecycle Cost", „Carbon Footprint" aspects and long lifetime of components)

One of the most important aspects relating to components is energy saving with efficient electric motors.

Figure 26 shows the advantages of this aspect and the main measures.

More than 90% of the total costs of an electric motor (life time based) are power consumption costs. And due to increasing costs of electric power, the percentage will increase in future.



The use of motors with "Premium Efficiency" saves a lot of energy like the example of DHL has shown.

Up from 01.01.2017 all new applications must use these energy saving motors.

Figure 26: Use of energy saving motors (source: SEW)

Premium efficiency motors are optimized for continuous operation. The electric/magnetic losses are reduced due to larger volume of rotor winding and materials with reduced reluctance.

Figure 27 show the different dimensions of a motor with the same capacity (left side) and the design of the rotor (right side)

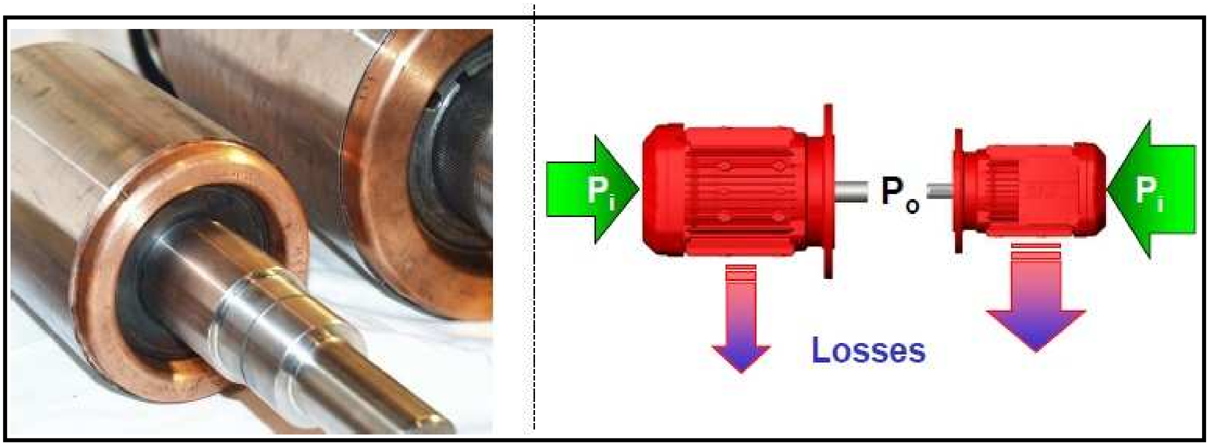


Figure 27: Disadvantages of energy saving motors (source: SEW)

Due to the larger diameter of the rotor, the moment of inertia is larger too. This means a small disadvantage in operation with permanent start-stop-mode.

Another important aspect is to save resources, like raw material, etc. Figure 28 shows the structure of CO^2-equivalents in value stream.

Extraction of raw material together with mechanical processes like master forming, re-shaping, cutting, material properties changing and joining are responsible for ca. 89% of CO^2-equivalents.

This shows the need of repair, retrofit and upgrading of components which have mal-functions or do not cover the latest trends.

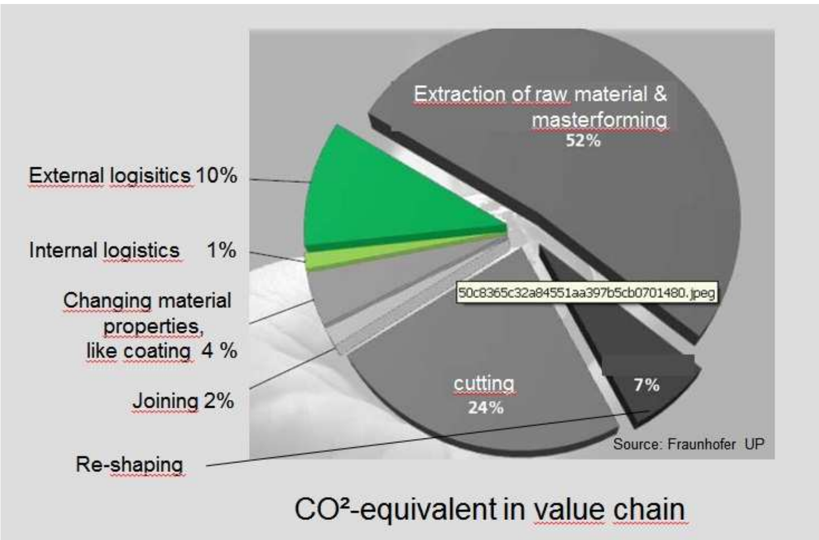


Figure 28: CO^2 - equivalent of value chain

4.4 Intelligent user interface

Intelligent user interfaces enable a high efficiency in operations together with a high achievable quality.

It is very clear that in future, more robots will be used for material handling processes, mainly for repetitive, dangerous and heavy works.

But it will take some time until a robot is able to have the same skills like human beings.

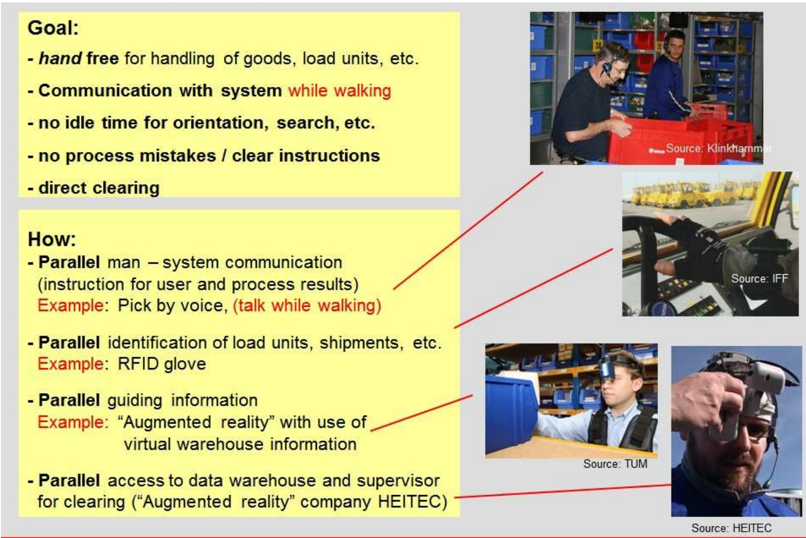


Figure 29: Intelligent user interface

Therefore workers will be needed for many processes like:

- Item picking where perfect dexterity is needed.
- Intuitive handling operations
- Clearing and supervising processes

Figure 29 shows the main goals of an intelligent user interface and the measures how you can achieve it.

One of the results is an increased capacity too. But the main aspects are the following:

- No process mistakes / clear instructions for workers
- Permanent check of quality & / "progress in processes"
- More information for precise decisions

Another aspect is that workers can do more than 1 activity in the same time:
- Pick to light allows "Talking and listening, while walking and handling "
- RFID gloves allow " identification while handling"

And a large advantage will be in future: the use of "Augmented Reality" in logistics, for planning and operations as well.

The following shows some examples where "Augmented Reality" supports the logistics tasks:

- The result of simulations become more accurate and shows the process steps in detail
- The workers like pickers get additional handling information to optimize the process (faster, higher quality, etc.)
- Trouble shooting becomes easier due to more information available

4.5 Highly ergonomic working conditions

There are 3 reasons why working conditions have to become more ergonomic:

- The needed capacities for handling activities like picking, increase
  (in former times picking capacities of 300 picks per hour were normal but now the common goal is 1.000 picks per hour, and this capacity should not be a peak capacity but a continuous capacity for several hours.)
- The higher age of working people
  (Consequences of higher age of working people are increasing health hazards.)
- And this is very important for improving the processes, “Ergonomic workplaces can reduce handling errors”

Before we show the measures we want to show the definition of ergonomics:

- Ergonomics is the science of characteristics / rules of human work
- Main goal of ergonomics is to create optimal conditions for workers suitable to the physics of human beings

The stressed body parts of working people in material handling are neck, shoulder, back and gluteal muscles. One of the most important aspects to pay attention to is the “RSI” (RSI is an abbreviation of „Repetitive Strain Injury“. The injury comes from continuous, repetitive single movements)

If we want to create working conditions free of health hazards we have to pay attention to body movement & position, muscle fatigue, mental fatigue, heart-/ circuit stress (statement TNO, a Dutch research organization)

There is a wide range of measures to avoid / reduce health hazards. Figure 30 shows the main measures.

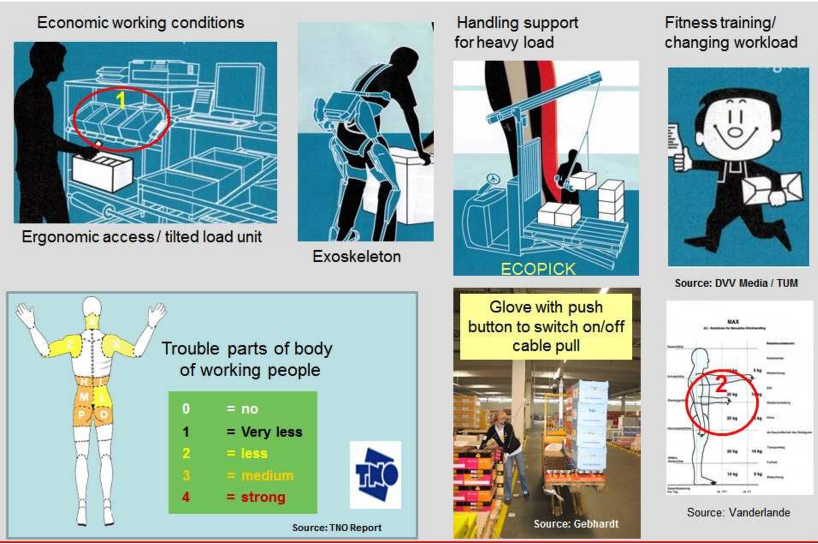


Figure 30: Measures to avoid / reduce health hazards

All the measures can be split in 4 categories:

- Ergonomic access to load
- Support the worker to be able to lift heavy loads (ECO-PICK, Exoskeleton, etc.)
- Changing work load, other processes
- Fitness training

A tool to optimize processes concerning ergonomic and speed aspect is MTM (method for time measurement.)

Figure 31 shows that it is very simple to design ergonomic workplaces:

- The example on left side of the figure uses a shifting technology and a working platform which can be raised and lowered according to the size of worker.
- The example on right side of the figure show a simple solution for picking heavy stacks of tiles. Pallet table and order pallet on forklift truck can be adapted to the optimum level according to the workers need.

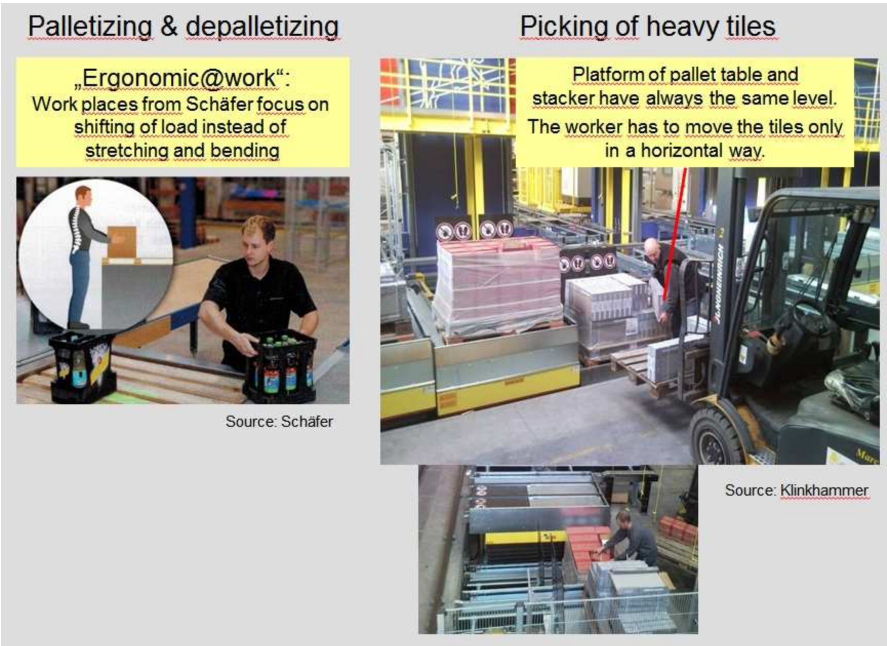


Figure 31: Simple design of ergonomic workplaces

5. Core/basic elements – overview of trends

The basic technologies in material handling are:

- Store
- Transport
- Sort
- Pick & Place

The most important tools / enablers for process optimizing are:

- Efficient identification
- IT-systems with intelligent strategies
- Integrated SCADA (Supervisory Control and Data Acquisition)
- Simulation with multipurpose use, high significance and benefits

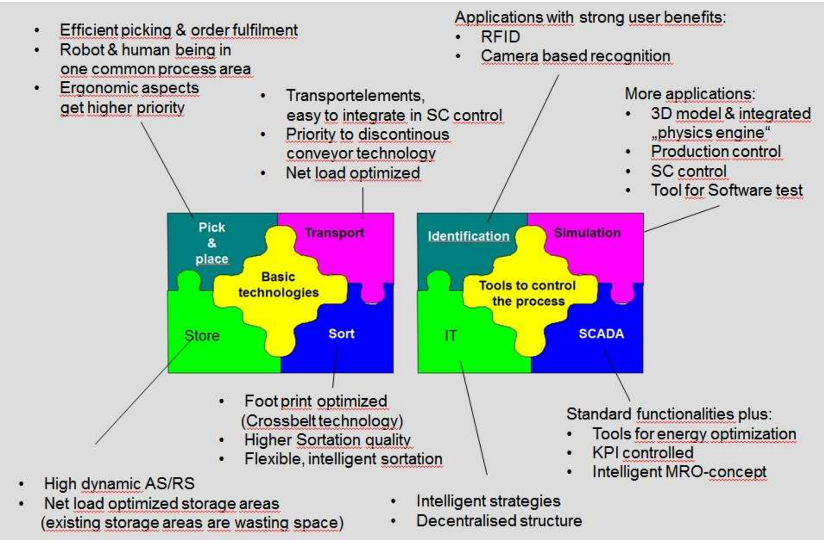


Figure 32: Core / basic elements

Material handling is a very innovative business area. Figure 32 shows the above mentioned technologies and tools including the major and latest trends / developments. And this overview is by fare not complete.

In chapter 6 some trends will be described in detail.

The selection of the shown aspect in the following chapter was based on the degree of supporting warehousing and materials management.

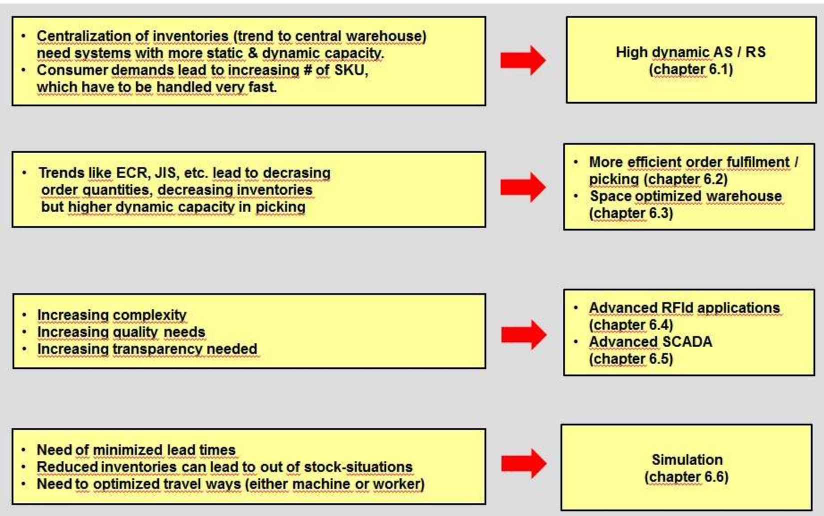


Figure 33 shows the selection criteria including the selected core elements.

Figure 33: Selection criteria and selected core elements

6. Most important trends in detail.

6.1 Highly dynamic AS/RS

The latest developments of AS/RS fulfill all the above mentioned requirements. One aspect was the development of new crane technologies and crane design like shuttle based systems. This technology allows dynamic capacities of 800 double cycles per hour for small parts (a standard mini load achieves ca. 200 dc/h).

A further important aspect is the huge power consumption of standard cranes. Therefore it was a strong need to improve the ratio net load to gross weight.

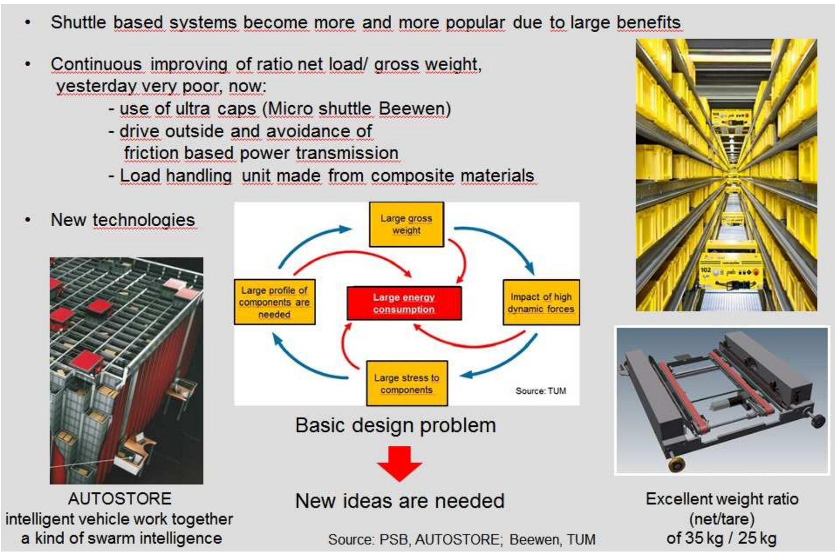


Figure 34: Measures for highly dynamic AS/RS

This was a very challenging task because the basic design problems are loop based impacts and amplifications:

- Large weight leads to high dynamic forces
- High dynamic forces lead to large stress of components
- Large stress of components stress leads to large profile of components
- Large profile of components leads to large gross weight

This loop based impacts lead to large energy consumption. A really fine example is a “Highbay” stacker crane: Net load: 1 ton
Gross weight: ca. 15 tons

Figure 34 shows the latest developments and how system engineers have solved the loop based problem. Furthermore this figure shows an example for an excellent weight ratio. The Micro Shuttle from Beewen is equipped with a new developed LHU (load handling unit. This LHU has a weight of 35 kg and is able to take loads up to 50 kg.

A total new design approach (AUTOSTORE) is shown too. The vehicles react with a kind of swarm intelligence.

6.2 Efficient order fulfillment / picking

Order fulfillment / picking is one of most important processes in warehousing and distribution. There are 2 main reasons for the importance:

- Picking is the most expensive process in a warehouse / distribution center.
- Pick errors influence directly the quality of follow-up processes or have a direct impact to the consumer`s satisfaction if the consumers get the wrong article, the wrong quantity or a damaged items.

Figure 35 show 2 aspects, the structure of handling costs in distribution centers (average value) and the time segments for picking. The mentioned values are related to a manual picking system.

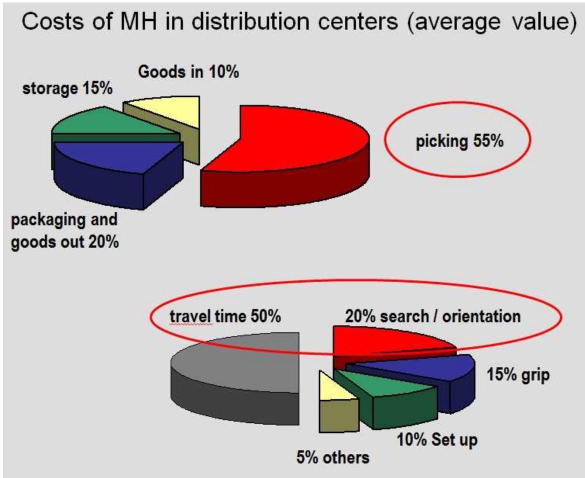


Figure 35: Importance of picking

Efficient technologies for order fulfillment and picking were the basis for fast processes together with high quality. Future oriented pick faces pay attention to ergonomics aspects as well as to the needed flexibility.

Some material handling companies offer picking systems which enables 1000 picks /h. Naturally this is possible only with small and light items, but this capacity can be achieved over a long time without health hazards for the picker.

Figure 36: Efficient picking system

Figure 36 show how it is able to achieve these capacities:

- Many order boxes and SKU boxes in direct access. This allows short grip times.
- Multi order access. This means 1 grip for a couple of orders which need the same SKU. Beforehand an intelligent batch planning is needed.

Figure 35 has shown that it is necessary to optimize more aspects than travel time and grip. It is important to optimize the user interface and it is necessary to reduce times for orientation, search and set-up. An optimized user interface pays attention to following aspects:

- Clear instructions what to do (pick to light or screen with multimedia info, etc.)
- Line of vision for information must be the line of arm movement.
- Automated order acknowledgement instead of pushing buttons (use of light grids)

The latest approach with a lot of success in USA is the order fulfillment concept of KIVA systems. This vehicle based concept was so interesting for Amazon that Amazon has overtaken the company.

6.3 Space & capacity optimized warehouse

Each warehouse consists of a couple of storage areas with more or less very stable and stiff construction/racking. Storage locations and load units are designed according to the needs of 20 years ago. The fast change in demands in past led to not efficient designed storage systems.

Figure 37 shows everyday life in warehousing. The table shows change in structure, problems and consequences/suggestions to solve the problem.

The main lack is “not efficient used space” and a more or less poor performance. You often can see a very poor degree of filling of boxes and mesh pallets.

Changes in structure	Problems	Consequences
SKU number increases	Many SKU are stored in 1 or 2 location only	• Can reduce performance • or balancing strategy needed
	2. storage area is needed	• Investment necessary • Consolidation necessary
Access per SKU increases	Higher performance necessary	Processes need longer, bottlenecks can occure or investment in automation
Grips per order line increase or/and additional work	Longer picking time, more pickers needed…	
Too many boxes with rest quantities	A lot of „air“ in store (not used space)	• Refilling/decanting • Strictly FIFO
Many SKU in wrong LU (LU is too large)	A lot of „air“ in store	• Use of smaller LU • Use of raster sets
Unbalanced work load due to order structure or order income	Some aisles / cranes are over loaded and others are idle	• Relocation necessary • Balancing strategies

Figure 37: Ever day life in warehousing

To avoid cost intensive investments in racking and infrastructure modifications it is better to implement intelligent IT-strategies.

The most important strategies are balancing strategies and sequence strategies.

Efficient use of space will be a very important sustainability aspect too.

Often a full pallet is too large but a box is too small. Therefore load units with medium volume become more and more popular. The most used load units for medium volume are:

- Half pallet (Düsseldorfer pallet)
- Quarter pallet / display pallet
- Big box

Figure38: Load units for medium volume

Figure 38 show some typical load units for this application

6.4 RFID applications with a lot of user benefits

Logistics needs “Identification Systems” for many reasons. The following list addresses the main aspects:

- Synchronization of processes, interfaces, etc.
- Failure- recognition and -avoiding within the process flow (quality)
- Tracking and tracing / tracing backwards to start of SC
- Identification number is an anchor point for set up after break down
- Security aspects
- Safety aspects (prevents confusions, allows precise decisions)
- Marketing aspects (authentication of products)

RFID is a new technology which will influence the logistics processes dramatically. This technology allows reduction of complexity in general (processes become leaner and often the number of process steps can be reduced).

RFID enables a lot of user benefits, like:

- Identification of items and load units for follow-up processes, i.e. transport processes, etc.
- Bulk recognition for goods in and goods out
- Stock taking in warehouses and retail stores
- Increased transparency, for example: Tracking & tracing functionality
- Decentralized controls (decentralized production schedule) including real time data acquisition of process results
- More secure processes due to sensor integration for intelligent data acquisition of physical conditions

Figure 39 shows different versions of RFID applications according to the main aspects loop structure and tagging principle.

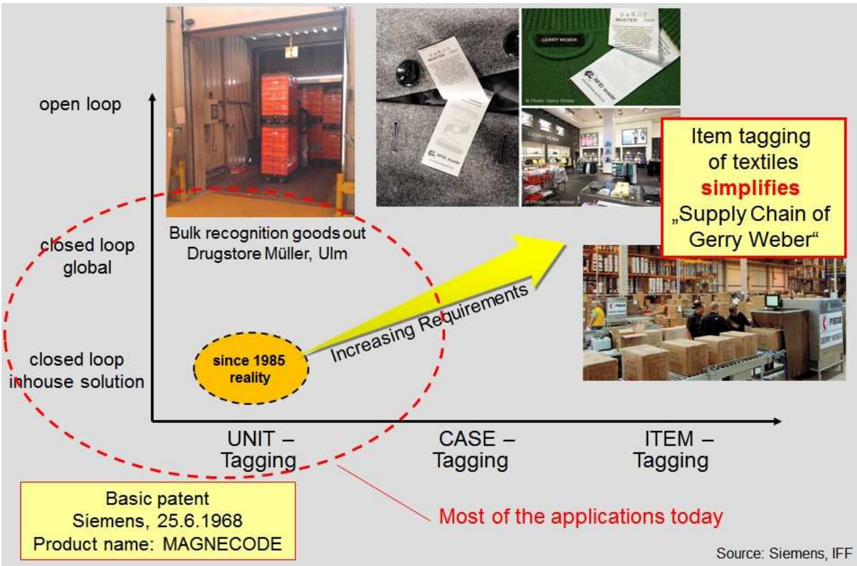


Figure 39: RFID will change logistics processes dramatically

Loop structure can be split according to:

- close loop in house
- closed loop global
- open loop

Tagging principle can be:

- Unit tagging
- Case tagging
- Item tagging

Most of the applications are characterized by Unit-tagging - close loop in house.

This application is used to control the boxes on a conveyor system. The boxes never leave the conveyor loop. The RFID tag is installed in the bottom of the box. At each divert possibility the RFID system reads the tag and according to the tag info the box will be diverted or not.

Figure 40 shows an application from 1989. This application was used for a very large system (Global spare part center, Daimler in Germersheim). More than 400.000 SKUs are stored and distributed in this whole warehouse.

The basic technology is not new. The first use of magnetic fields for identification was in 1968. Siemens developed the system MAGNECODE. With this technology it was able to control skid systems and Power & Free systems in the automotive industry.

The first large application "Item tagging – open loop" was the use of RFID in the supply chain of Gerry Weber, a German retailer in textile business.

On the figure can be seen:

- RFID tag woven in textile
- The bulk recognition of cartons from Asia with a tunnel reader *Figure 23: Use of RFID in 1989*
- Point of sale. RFID enable secure processes and easy stocktaking.

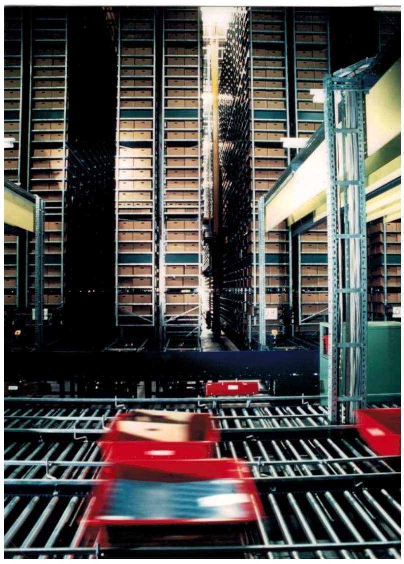


Figure 40: RFID application Daimler

Another very important task of RFID is the integration of material flow and information flow. The logistics institute of Munich, TUM FML developed such an application together with Jungheinrich a supplier of forklift trucks. (Figure 41)

While the fork is going into the pallet the pallet will be identified and the material handling system can check whether the truck driver had taken the right pallet.

If it is the right pallet the driver will receive a transport order for this pallet.

If it is not the right pallet, the driver receives a clearing order.

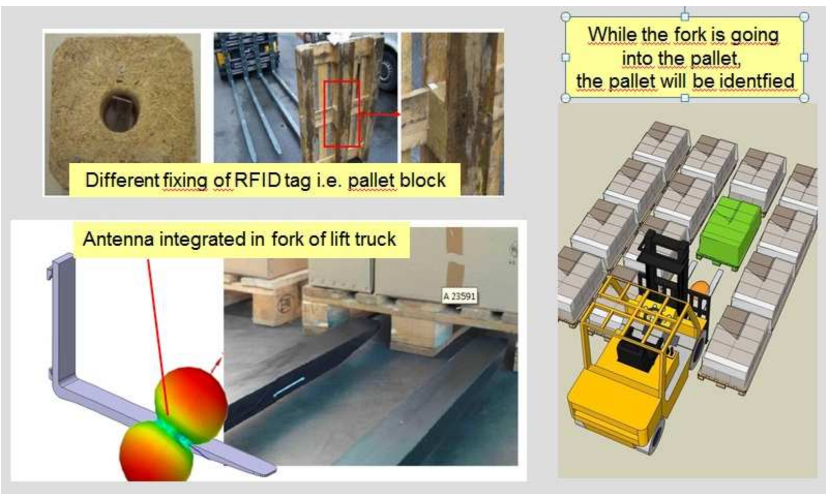


Figure 41: RFID application for integrated transports.

6.5 Future oriented SCADA

In the last years the control of supply chains became more and more complex. According to that Material handling systems became complex too.

User of MHS must be able to manage and to handle the system in an optimized manner. Sometimes user define fully automated MHS as "Logistics Machine"
Standard SCADA systems enable the user to handle the "logistics machine" efficiently:

- Quick overview of complete process (what happens how)
- Quick reaction in case of break down (what to do and how to do)
- Understandable system behavior (why reacts the system in this way)
- Clear documentation, especially for the programmed strategies
- Multi-media based information for nonverbal describable situations
- Ergonomic control room (to handle a lot of information parallel)
- Easy setting of new parameters to react on changed requirements

One of the most important aspects is the way how information is shown to the operator. To react to any change in process, the operator has to have a clear overview:

- What happened in past
- What are the topical results
- What are the goals for today/this shift/next time, etc.
- What are the topical KPI
- Is any process in a critical situation (traffic light system)
- How is the movement of KPI`s (stable, becomes better, becomes worse)

Figure 42 shows an example for very informative monitoring

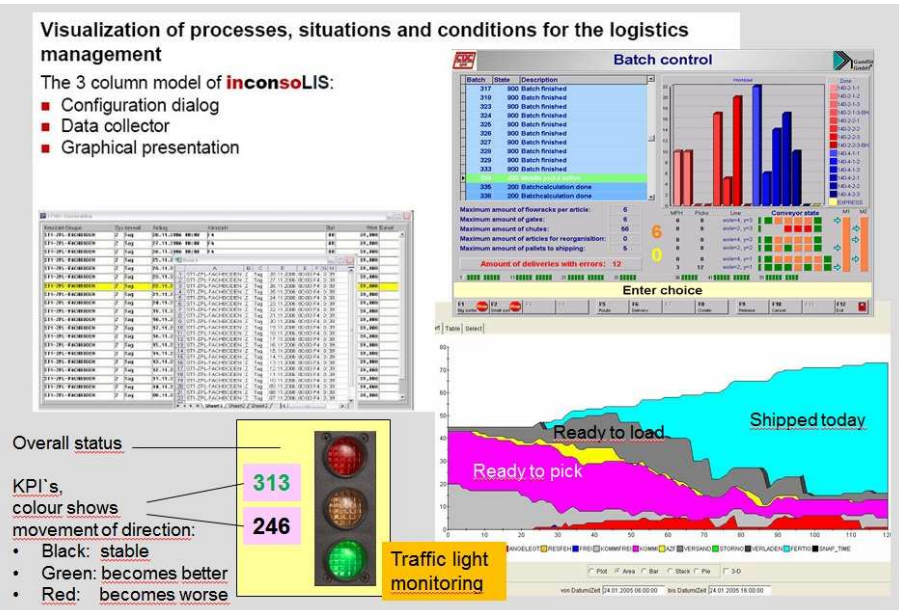


Figure 42: Visualization of processes, situations and conditions

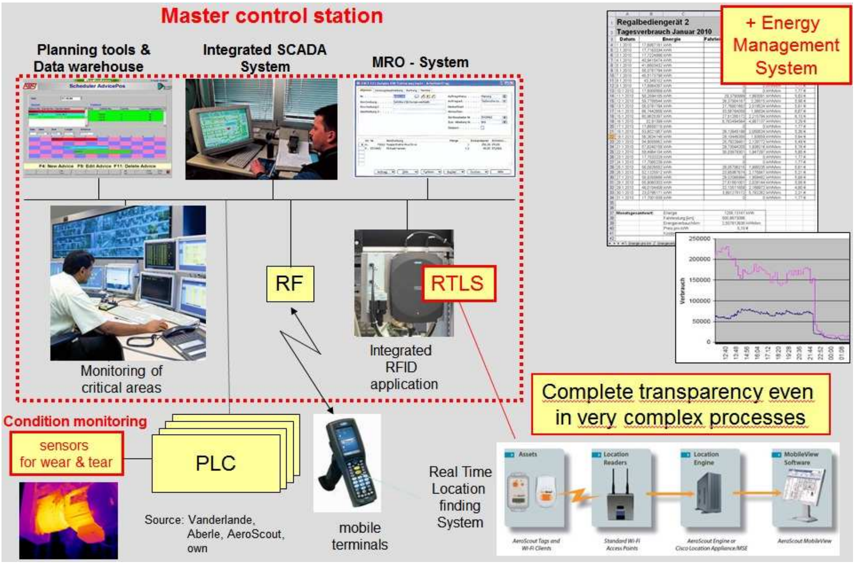
Especially the traffic light monitoring supports the management very strong:

- The traffic light gives an overall status about the process
- The colour of the KPI display shows the details about process stability, movement to become better or to become worse.

Integrated and future oriented SCADA systems have a larger functionality, like:

- Planning and scheduling tools
- Data warehouse for collecting KPI`s, etc.
- MRO-system
- Video system for monitoring all critical areas
- Energy management system
- Condition monitoring system

Figure 43 shows a master control station of a future oriented SCADA system.



is

Figure 43: Future oriented SCADA system.

The following examples show how the new versions of SCADA systems can increase efficiency:

Monitoring all critical areas:
If a jam occurs, the system shows on screen fully automated the area where the jam is. This allows the service people to react very fast and in the right way (organizing spare parts, specific tools, etc.)

Real Time Location Finding System
This system gives transparency about the status of each transport:

- Where is the load
- Is the load secure or has anyone opened the load unit (container, etc.)
- What are the physical conditions of the load (topical and in history)

Energy Management System
This system allows you to minimize the energy costs. The percentage of very expensive “High tariff” power can be reduced. And you can have a full transparency what the power consumption of a single process element is, i.e. the energy for a double cycle of a stacker crane

6.6 Advanced MRO-concept

One of the main reasons for often needed re-scheduling is a breakdown of components or system parts. Consequence of re-scheduling is inefficiency. To avoid breakdown to the utmost a couple of things have to be paid attention for:

- Proper MRO concept based on full service from system supplier and “Trouble shooting management”. This enables a maximum of availability. Preventive and cyclic maintenance play an important role.
- Rules how system has to be designed and operated. The more robust system design and product design is, the more some situations out of gauge will not lead to a jam or break down.
- Organization for quick elimination of breakdowns. It is very important to reduce the total break down time. Some measures are:

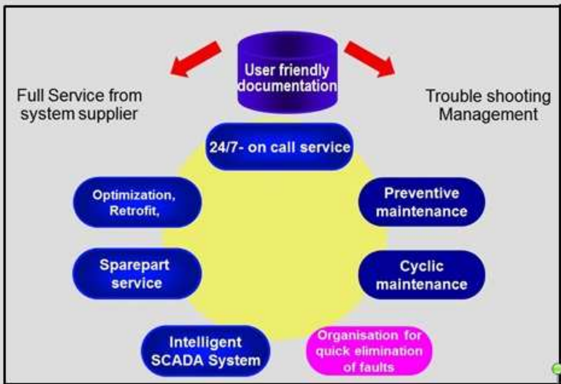
  - fast recognition what is the real reason/consequence of the break down

  - short travel way to the break down area

  - short repair time

The last aspects are a very important one, because nobody can take a look into future and knows when a breakdown arises. But it makes sense to be well prepared for this event. Some tools support the operator like FMEA or SCEM.

Figure 44 shows main measures regarding highly available processes.



Example: Design of conveyor system

Kind of break down	Measurement to avoid reduced availability
Break down of any element in general	Redundancy, back up-strategies, ie. other routings, etc.
Break down of mechanic components (valves, chaines, belts, etc.)	• No operation in the rated range (design: one grade higher) • Use of lifetime lubrification (no maintnance necessary)
Break down of electric components or disturbed functionality (breakdown motor, circuit breaker is triggered, dirty sensor, etc.)	• No operation in the rated range (design: one grade higher) • Avoid dirt-sensitive components • Design of protection measures (cover, etc.)
Break down due to misalignement (sensors, pressure of rollers, centering mechanism, etc.)	• installation of measures against misalignement (cover) • robust installation • walkways to cross conveyor lines for maintenance reasons
Break down due to load unit which are damaged or out of gauge	• No operation in the rated range (design: one grade higher) • Installation of check unit for incoming load units
Break down due to loads pot of specification	• Installation of check unit for incoming load
Break down due to operator reasons	• Training, training, training

Example FMEA worksheet

FMEA Ref.	Item / function	Potential failure mode	Potential cause(s) / mechanism	Mission Phase	Local effects of failure	Next higher assembly level effect	System Level End Effect	(P) Probability (estimate)	(S) Severity	Detection (Indications to Operator, Maintainer)	(D) Detection Dormancy Period	Risk Level P*S (+D)	Actions for further Investigation / evidence	Mitigation / Requirements
1.1.1	Brake Manifold Ref. Designator 2b, channel A	Internal Leakage from Channel A to B	a) O-ring Compression Set (Creep) failure b) surface damage during assembly	Landing	Decreased pressure to main brake hose	No Left Wheel Braking	Severely Reduced Aircraft deceleration on ground and side drift. Partial loss of runway position control. Risk of collision	(C) Moderate	(VI) Catastrophic (this is the worst case)	(1) Flight Computer and Maintenance Computer will indicate "Left Main Brake, Pressure Low"	Built-In Test interval is 1 minute	Unacceptable	Check Dormancy Period and probability of failure	Require redundant independent brake hydraulic channels and/or Require redundant sealing and Classify O-ring as Critical Part Class 1

Source: Vanderlande, Wikipedia, own

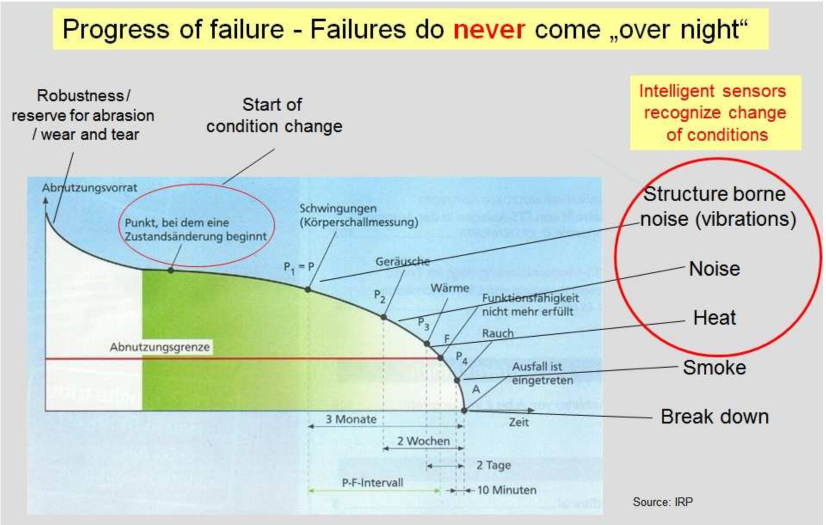
Figure 44: Measures for highly available processes.

The advantage of these tools is that one has to think about all the possible breakdown situations and measures to avoid it or to reduce it to a minimum.

If this reflecting is done in a very early stage (design phase) a lot of trouble in operations can be avoided.

A brand new system is the “Condition Monitoring System”. This system helps to recognize a breakdown of system components which might approach shortly. Condition monitoring allows reacting on time without any stop of processes.

This system uses sensors which recognize change of conditions far before people can recognize it with human senses.



Typical sensors are:

- Sensors for vibrations
- Sensors for noise
- Thermal imaging camera

The above mentioned sensors were very expensive and therefore the applications were limited to expensive elements too.
But meanwhile the sensors become more and more cheaper. And this enables us to install theses sensors in conveyor systems.

Figure 45: Progress of failure

Figure 45 shows the typical development of breakdowns. The start of condition change is in the very late stage of a product life. An example will be given: an electric motor has an average lifetime of 15.000 operating hours. If a condition monitoring system is used, the maximum of a product life is usable.

But pay always attention:

– a break down never come “overnight”

- If you notice “heat” the break down is very near.

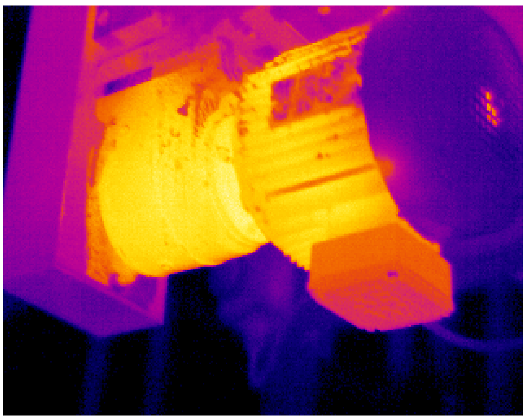


Figure 46 shows a motor with a gear. The photo was taken by a thermal imaging camera. As you can see the bearing will break in near future, because it is very hot inside. From outside you will not be able to see this with human eyes.

Figure 46: Application with thermal imaging camera

6.7 Simulation

The above mentioned logistics requirements resulted in very complex business cases/business models with a high variety of parameters and rules. To handle this complexity, consultants, system designers and operators need an efficient tool. Simulation is an ideal tool to support everyone, to design systems, to understand the way of working of the "logistics machine**"** and with that you can generate a lot of benefits and reduce the "return on invest"- time.

Simulation can have a lot of positive results for the design of the system/solution, but only if some basic rules are correctly followed. The most necessary rules are

- Detailed definition of strategies,
- Simulation must be done on time,
- Pay attention to peak data.

For a long time, simulation was a tool for consultants and designers only. With this tool you could find in an early stage of a project, what the real system capacity is and what the major bottlenecks are, etc.

Figure 47 shows the use of simulation in the classical way and some advanced applications.

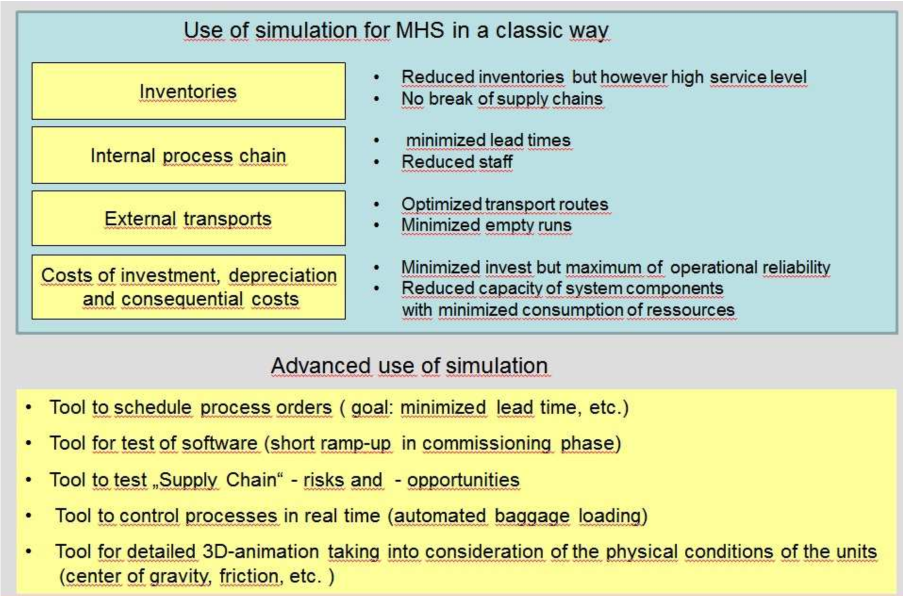


Figure 47: Use of simulation in MHS

Typical questions for a classical simulation in material handling are:

- Can we achieve the required capacity with reducing the number of cranes, buffer lanes, etc.?
- Which strategies are the most efficient ones?
- What is the lead time? (min., average, max.)
- How many workers do we need for the required capacity?
- Where the buffer areas should be located?

Within the last 5 years simulation became a very powerful tool. Developments in hardware and software enabled advanced applications with a lot of benefits to the user.

One application for advanced use of simulation will be given:

"Simulation as tool to define the right sequence of orders"

This tool is designed for use in a control center and supports the supervisor to control the process.
In this case simulation is an additional tool to SCADA to increase the capacity of the system.

Figure 48 shows how simulation is integrated in a planning tool.

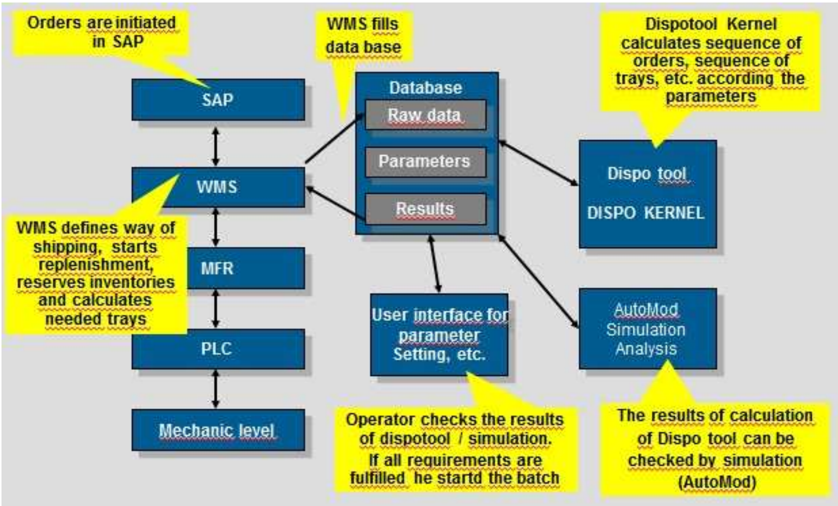


Figure 48: Simulation based planning tool

The Warehouse Management System defines all needed resources and the simulation tool calculates the needed sequence of order starts.

The result is:

- Full use of all resources
- shipping of all orders within the required time
- Jams will be avoided

This planning tool enables cost optimized system configurations shown in figure 31.

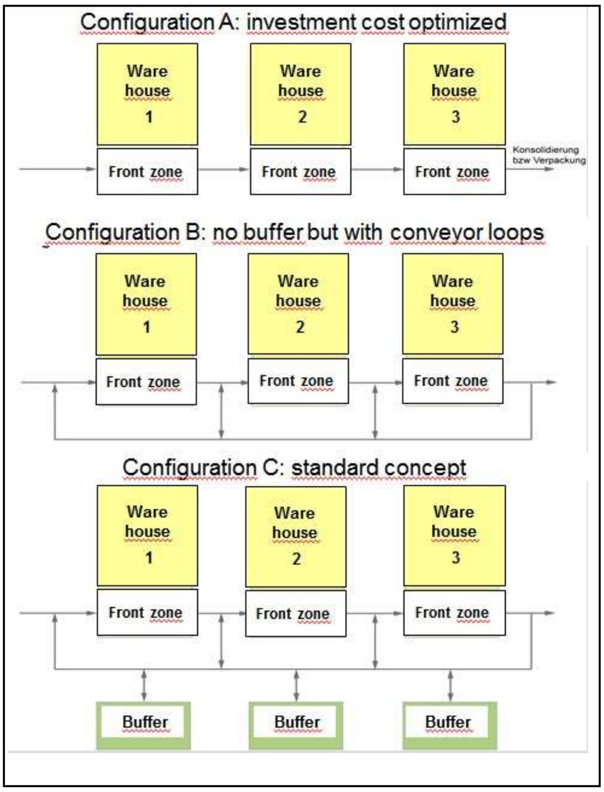


Figure 49 shows 3 versions of system design.

Configuration A is optimized concerning investment costs (no buffers, minimum of conveyor lines).

With simulation only, the design capacity will be achieved.

Figure 49: System configuration

7 Summary and outlook

The developments and applications have shown that intelligent material handling systems will be a strong enabler to handle future challenges in operation.

Concerning supply chain aspects we can summarize:

- Tools for optimized materials management are necessary further on
- Intelligent material handling is a holistic approach and reduces mainly complexity, resources and overall costs.

But in any case there will be some design rules which are always “up to date”:

- Keep it as simple as possible
- Lean material flow is always a challenge
- Added values / USP`s to customer / user are a must
- Efforts for more quality costs money but it is always worth to do
- New innovations come up permanently

This paper has shown many developments which are about to be launched into the market. But many developments are in the pipeline of logistics institutes and producers of material handling systems. Figure 50 shows some of them.

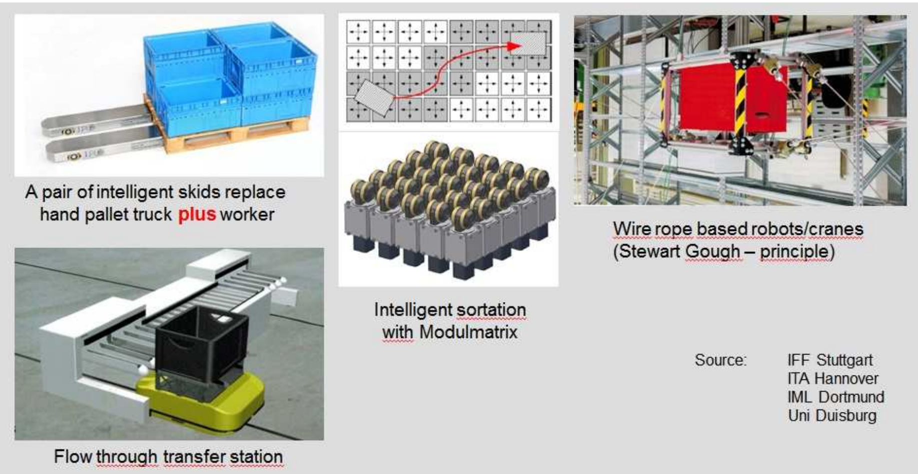


Figure 50: Research and development activities of some logistics institutes

Intelligent material handling like it is shown in this paper is part of **“Industry 4.0”.**

Industry 4.0 is: **“Integration of mechatronics, IT, global communication and augmented reality”**

The conclusion is:

- Intelligent Material handling systems are fit for future and enable more efficient supply chains.
- Automated solutions will have all characteristics to become much more efficient than manual systems. Therefore fully automated systems will increase strongly.
- Industry 4.0 will help European production and logistics companies to compete with Asia´s power and to have success in the global struggle.

8 Abbreviations

AGV	Automated guided vehicle
APS	Advanced planning system
AS/RS	Automated storage and retrieval system
BVL	German logistics association (Bundesvereinigung Logistik)
CPFR	Collaboration Planning Forecasting & replenishment
CRP	Continuous replenishment program
DC	Distribution center
ECR	Efficient consumer response
FMEA	Failure Mode and effects analysis
IT	Information technology
JIT/JIS	Just in time / Just in sequence
KPI	Key performance indicator
LHU	Load handling unit
LU	Load unit
MFR/MFC	Material flow controller
MH	Material Handling
MHS	Material handling system
MRO	Maintenance repair & overhaul
MTM	Methods for time measurement
PLC	Programmable language controller
POS	Point of sale
Poka Joke	Japanese term for mistake-proofing
RF	Radio frequency
RFID	Radio frequency identification
RTLS	Real time location finding system
RSI	Repetitive strain injury
SC	Supply chain
SCM	Supply chain management
SCADA	Supervisory control and data acquisition
SCEM	Supply chain event management
SKU	Stock keeping unit
SOP	Standard operation procedure
USP	Unique selling point
VAS	value added services
VMI	Vendor managed inventory
VSM	value stream mapping
WLAN	Wireless local area network
WMS	Warehouse Management System

9 Used literature

9.1 Literature issued by the author:

Karl-Heinz Dullinger, Leitfaden der Logistik, 1999
Karl-Heinz Dullinger, Material handling volume 1, 2003
Karl-Heinz Dullinger, Material handling volume 2, 2008
Karl-Heinz Dullinger, BVL congress volume, chapter „Intralogistik im Wandel“, 2008
Karl-Heinz Dullinger, WSL Poznan, Poland , congress volume „Simulation in der Logistik“, 2008
Karl-Heinz Dullinger, Huss Verlag, paper „Logistik Retrofitting“, 2009
Karl-Heinz Dullinger, BVL book, Sustainable logistics, chapter “Energy saving in internal logistics”, 2011

9.2 Literature from logistics institutes & universities

Fraunhofer Institutes: IML, Dortmund / IFF, Magdeburg / SCS, Nürnberg

Logistics institutes in universities: TUM-FML, München / IFL, Stuttgart / IRP, Ilmenau / ITA Hannover / Duisburg

9.3 Literature from companies involved in logistics business

Aberle	Aeroscout	Autostore		
Beewen				
Chep				
Dematic	DHL	DVV Media		
Förch	Ferrometall			
Gebhart	Gerry Weber			
Inconso				
Heitec				
Keller & Kalmbach	Klinkhammer	Kiva systems		
Lear Seating				
Müller				
PSB	Pepperl & Fuchs			
Rotho				
Schäfer	SEW	Siemens	Sandoz	Simplan
TNO				
Vanderlande Industries				
Witron	Walmart	Würth		

Vita Karl-Heinz Dullinger

Education:
Dipl. Ing. (FH), discipline Electrical Engineering

Professional experience: 40 years in logistics

- 23 years SIEMENS, 3 years Head of logistics
- 13 years Vanderlande Industries, CEO Germany
- 01.April. 2008: Foundation of Consulting company **LSCC**
- lecturer at different universities and logistics institutes

- Air Traffic Management	SRH Hamm
- Consumer Logistics & SCM	UNI Nuremberg
- International Logistics	UNI Nuremberg
- Material Handling	TUM-Asia, GIST Singapore
- Material Handling	Jacobs International University Bremen

Experience in logistics: Consulting, IT-programming, Project Management and General Contractor Business

Main business areas: Automotive industry, B2C, Consumer logistics, Inplant logistics, Airports(Baggage & Cargo) and Express & Courier business

Activities in logistics associations
- 1997-2009: Member of the board of DGFL and BVL (German logistics association)
- 1985-2009: Member of the board of VDI (German engineers association, department logistics)
- 1985-today: Member in work groups for logistics guidelines

Author of books and articles

Lecturer and speaker in Germany and abroad as well
(more than 80 speeches on congresses and forums)