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INTRODUCTION OF DEMO3D INTO THE SCIENTIFIC EDUCATION OF MATERIAL HANDLING

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Abstract: Using of advanced machines and methods requires highly educated engineers, who gain their basic knowledge at universities. In the aspect of material handling, the Institute of Logistics of the University of Miskolc (LOG) is one of the leading education centres in Hungary, so its teaching materials, methods and devices have significant effects to the knowledge of future logistic engineers. In this paper, we describe the state of the art of planning of material handling and the education structure of LOG. Main objective of this paper is to present developing possibilities of the scientific education of LOG with some help of the Institute of Engineering Logistics of TU Graz (ITL) in the frame of project UMi-TWINN. One of the most important results of the project is the application of the Demo3D software for the education of material handling. The developed examples, videos, sheets and other documentations are directly usable in the teaching curricula of different courses of LOG.
Keywords: planning of material handling, scientific education, Demo3D, simulation

1. INTRODUCTION

Nowadays, material handling processes are much more complex than some years ago, and they have very important role in every field of the industry. Handling processes use advanced, automated machines; planning and operation of the handling machines requires effective computer methods.

To use advanced machines and methods we need highly educated engineers, who gain their basic knowledge at universities. In the aspect of material handling, the Institute of Logistics of the University of Miskolc is one of the leading education centres in Hungary, so its teaching materials, methods and devices have significant effects to the knowledge of future logistic engineers.

In this paper we describe the state of the art of planning of material handling and the education structure and courses of LOG. After it, we present the developing possibilities of the scientific education of LOG by the help of the Institute of Engineering Logistics of TU Graz in the frame of project UMi-TWINN.

2. PLANNING OF MATERIAL HANDLING

Material handling is an activity for short moving of materials, semi-finished units, finished products or units, without any changing of the goods [1]. Material handling equipment is a special machine used for the realization of given material handling tasks. Application of a single handling machine in effective, advanced production processes is not considerable, in generally a materials handling system has to be applied.

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Material handling system means a group of machines which have to be used together to realize the related material handling tasks. The design and operation processes of material handling systems are much more complicated than single equipment, because they integrate the characterisations of the individual machines. Through the integration the parameters of the different machines can be changed, their effects can be more intensive or weaker, in certain cases some new characterisation can be appeared. Besides them there are some special material handling tasks which can be solved only in systems (for example: waiting phase of a handling machine).

During the planning of material handling systems we are looking for handling machines for complex material handling tasks and synchronizing their operation. The solution can be task-based or system-based (Figure 1).

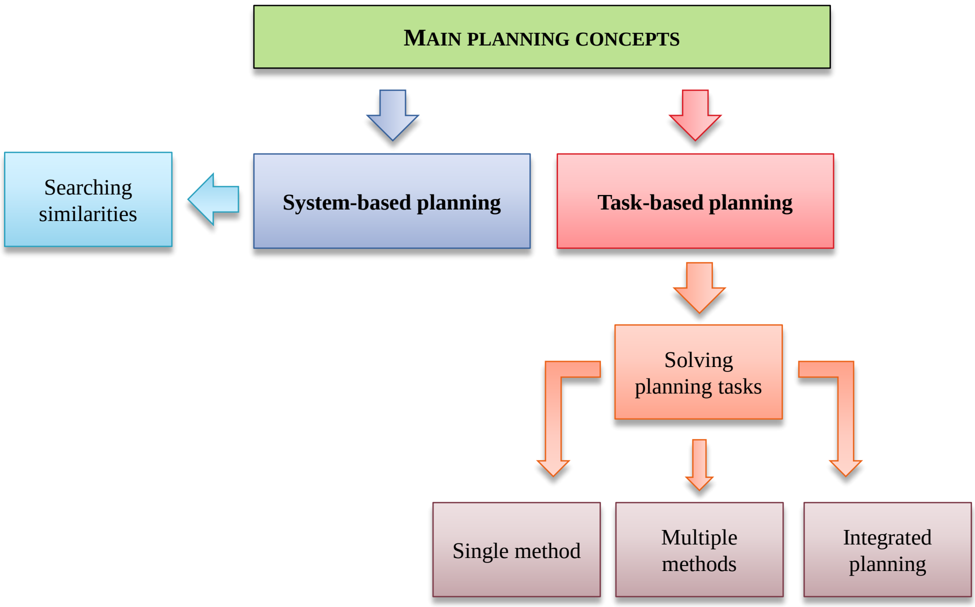


Figure 1. Planning concepts for material handling

In system-based approach, we analyze the whole system and look for a similar existing one to apply its handling solutions to our system [2]. Similarity of the system can be found in objects, handling tasks, technology or handling devices. During the planning process, we are searching in a special database for a similar system-structure and trying to adapt its handling solutions. To realize this planning concept, we need a special database, which are built on certain system types [3]. Typical application of this approach is the duplication of production processes, which is used by multinational companies to multiply their production [4].

In task-based approach, we realize the planning with the use of different individual planning tasks. Main advantage of it is the using of material-flow parameters, which enables exact, mathematically described calculations. This approach is much better published and used in the practice, but the application in complex systems is not so easy. Main problems of this approach are the large number of planning tasks, their complexity and the iterative solution process (Figure 2), which result three different application cases in practice: single-task planning, multiple-task planning and integrated planning process [5].

During single-task planning we can solve only one planning task (e. g. [6]) in any kind of system. The complexity of the solution method depends on the scale of the handling system. Multiple-task planning means the solving of a group of planning tasks, where usually the methods for the single-task are used, but this concept is basically more complex for any system [7]. Integrated planning tries to solve all the planning tasks in one process, but because of the large number of tasks and the iterative procedure it is usable only for simple handling systems [8].

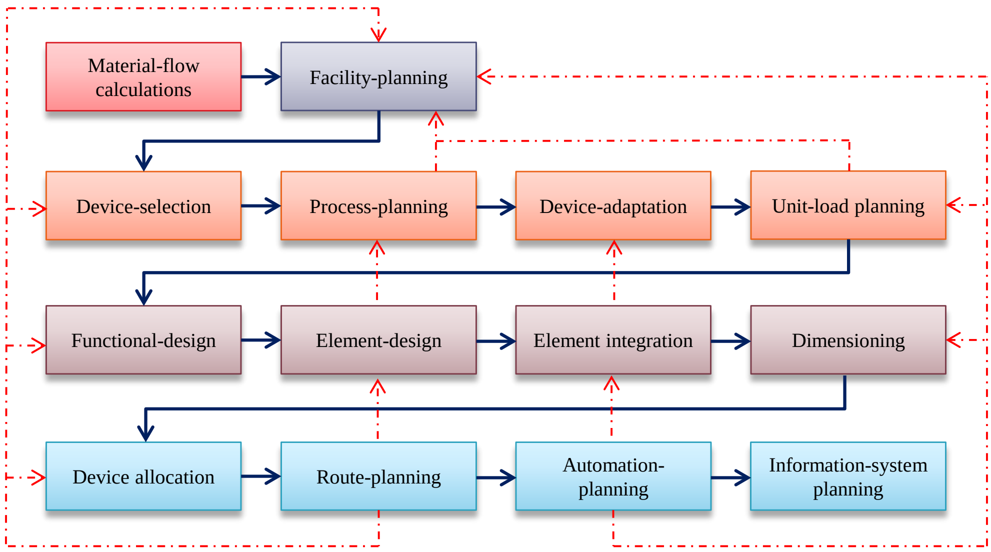


Figure 2. Structure and steps of integrated planning

Because of the complexity of the production system and the planning processes, there is no chance to make generally usable method for the planning of handling systems. Integrated design processes give the best device for the planning, but their very complex characterization makes the application too hard. There are different initiatives to solve these problems using different methods [5], but non-of them resulted general solution so far.

Another aspect of the planning process is the solution concept which can be analytic, knowledge based and hybrid methods [9].

Analytic methods use mathematical formulas related to given objective function to find optimal handling equipment based on material handling parameters [10]. Knowledge based methods use special database of practical experts which includes their knowledge about material handling equipment, and look for results by the comparison of the material flow and handling device parameters [11]. Hybrid methods use knowledge-based procedures and analytic formulas together to select optimal materials handling solution combining their characteristics [12].

Advanced methods for planning of material handling machines and processes use different computer software in the practice, so the applied IT techniques influence the available solutions.

3. COMPUTER METHODS IN PLANNING PROCESSES

Because of the large differences of material handling systems and the complexity of handling tasks, there is no universal solution for planning of material handling processes. In most cases, engineers use the task based approach but only for single tasks or for small group of tasks.

In certain cases, if the planning problem is simple and the tasks can be easily solved, designers are able to give solutions based on their experiences. If it is possible to reduce the complexity level of large planning process, it can also help to find easy and quick solutions. In other cases, planning process is usually complex and complicated, so it requires sufficient practice and application of advanced methods and computer software. Most important characterisations of advanced planning solutions are focusing on given task-groups, using advanced computer methods and the integration of different planning solutions.

Because there is no universal planning method, the applied computer devices have to be suited to the analysed handling tasks, so many different methods and software are applied during the planning process. In advanced planning processes, applicable computer methods can be sorted into different categories based on their characterisations and application fields:

- CAD methods
- Knowledge based systems
- Simulation methods
- Virtual reality solutions
- Optimisation methods

3.1. CAD methods

Computer Aided Design methods (CAD) are computer devices which help designers and engineers in their planning and design activities. CAD methods used in the advanced industrial and scientific processes are 2D and 3D planning software [13].

Main application fields of CAD methods are the design and development of machine elements, production units, industrial products and other parts and elements. There are many CAD methods in the industry which have been effectively applied from decades in engineering (AutoCAD [14], CATIA [15], CadKey [16], etc.).

CAD software is mainly applied in planning process of material handling for the design of machine elements and units of handling equipment and their building structures. Besides some of them are suitable to model and demonstrate complete handling equipment.

3.2. Knowledge based systems

Knowledge Based Systems (KBS) are computer programs which use Artificial Intelligence (AI) techniques to solve complex problems based on specific experiences of human experts. Knowledge Based Engineering (KBE) is a technology able to merge the capabilities of conventional Knowledge Based Systems with computer aided analysis and design systems (CAE and CAD systems) [17]. KBE systems enable to insert the result of the knowledge based calculation procedure directly into the design process of machine elements using special software solutions.

For the realisation of KBE systems three different solutions were published in the international literature [18]:

- Augmented CAD systems with KBE
- Full KBE systems and
- Linked KBE/CAD solutions

Augmented CAD systems with KBE are found in many different CAD environments and have different scopes of operation [19]. Main principle of this concept is that the KBS solution has to be integrated into the CAD environment. Well known commercial products are Knowledge Ware within CATIA and Knowledge Fusion within NX [20].

Full KBE systems are object oriented highly advanced generic and super ordinated software programs which apply captured knowledge to design processes by using different visualization tools [21]. The systems must drive the way of design automatically by using various validation rules and should not criticize pre-generated results leading towards engineering process automation. An investment into a full KBE system is nowadays only seen in automotive and aeronautic sectors [22].

Linked KBE/CAD solutions means a new approach, in which existing KBE and CAD solutions are linked by special software. The basic idea behind this concept lies in using separated system elements for knowledge capture and use as well as geometry representation. In its most basic form the two core elements can be a calculation scheme implemented in a capable software tool and a parametric CAD model. In order to combine them to a full featured application they are bidirectional interconnected to each other via a specific interface [7].

What KBE means within Material Handling Equipment Design (MHED) is best described in [23]. The first is to specify input parameters in form of rules and constraints classes for KBE in MHED. Some fuzzy criteria such as shape design, leading to customer acceptance or not, and system integration are relevant as well as the “harder” facts concerning manufacturing and costs, which can be formulated within rules much more easy. As every MHE is determined by the demands of throughput (in tons or pieces per hour) it is necessary, to define throughput as the major input parameter [23].

3.3. Simulation methods

Simulation is a device to model real processes and evaluate their states, changings and other process elements [24]. Simulation methods usually applicable for modelling of given processes, however they can be adapted for different similar process variations setting their parameters in.

Types and characterisations of simulation processes are depend on the applied modelling. Calculation schemes, environment and parameters are taken into account. Based on the large variation of methods a huge number of simulation software had been developed during the last decades.

There are also several simulation methods used for the material handling and logistic processes, modelling different elements of the handling procedure (e. g. [25]).

The main application field of simulation software in material handling is the modelling of operation and taking the effects of stochastic changing parameters into consideration. They have smaller influence during the planning process of material handling, but they have importance in previous analysis of the designed machines and systems.

The most often used simulation methods in material handling are PlantSimulation [26], FlexSim [27], ExtendSim [28], Enterprise Dynamics [29], etc.

3.4. Virtual reality solutions

There are different definitions for virtual reality (VR) [30], but in the aspect of the planning of material handling we can define virtual reality solutions as devices for presentation of simulated 3D objects and their environment. In practice, VR solutions can be used for planning or teaching of handling processes.

For planning purposes we can apply simulation software to present and simulate the operation of handling machines and systems, or 3D CAD software to design their building elements, so they are suitable to demonstrate and analyse the application and operation problems of material handling machines [31].

3.5. Optimisation methods

Optimisation is a new and effective technique to find the best solution for a given task or process. During the optimisation process we create different variations and analyse their efficiency to find an optimal solution. The increasing of the computing capacities and calculation speed of the computers resulted many new methods and algorithms in the practice (e. g. [32]), but this device mainly suit for increasing the operation efficiency, application in the planning process is not so frequent.

4.USE OF DEMO3D ® FOR LOGISTICS PLANNING

Within logistics planning, there is a trend towards shortened planning cycles with improved planning quality using high-end digital planning methods. A specific approach for digital validation of planning results is so-called "virtual reality". Using these solutions within the system planning process it is possible to animate logistics systems within 3D representations in a realistic manner. The resulting virtual reality models create a high level of understanding of the plant. Design alternatives can be evaluated interactively and the system can be viewed from any angle with virtual “walk through”. The use of virtual reality solutions thus leads to a more efficient planning process and is increasing the planning quality [30], [31].

Classic scope for the use of virtual reality environments is detected in the area of sales and layout planning. Also for scientific teaching in the field of intralogistics, the use of virtual reality environments seem appropriate. Design and functionality of modern intralogistics systems are complex for purely theoretical knowledge transfer in teaching [33]. With the application of 3D animated realistic models, students get a better understanding of intralogistics equipment and plants. Specific characteristics of the logistics systems are in focus:

- design, layout, structure and components of logistics plants,
- functionality, strategies and mode of operation of logistics equipment,
- technical and performance parameters of technical devices.

4.1. Software Solution Demo3D ®

The software tool Demo3D ® provides a user-friendly and interactive virtual reality environment for the animation of logistics facilities. The software provides comprehensive layout planning, animation and presentation capabilities for logistics and planning processes.

The representation of material flows and device movements is close to reality. Physical properties such as gravity, friction and much more are considered. In addition, the user can decide whether he wants to present plants on detailed level of light barriers and drives or rather on a more abstract level [31].

4.2. Usage of Demop3D ® in practice

There is a variety of predefined elements available from libraries for modeling the 3D layouts. The elements can be adapted with numerous parameters. This affects both, the design as well as the function of the elements. Based on the integrated snap function used for creating the model layout, executable models are created automatically. If necessary, the models are adjustable in terms of material flow control (based on JavaScript or ladder logic).

The following element libraries are particularly supported [31]:

- Conveyor technology (continuous and discontinuous conveyor)
- Warehouse technology (automatic high-bay warehouses, manual warehouses)
- Industrial trucks (forklifts, automated guided vehicles)
- Load handling (robot, palletizing)
- Sorter (shoe sorter, tilt tray sorter)

In addition to use standard elements, the software also offers the opportunity to develop separate parameterized components (which can be stored in new libraries). For demonstration, a "walk through" for the animated plant is defined. For illustrative purposes, the software offers further functionality such as video recording with arbitrary camera angle.

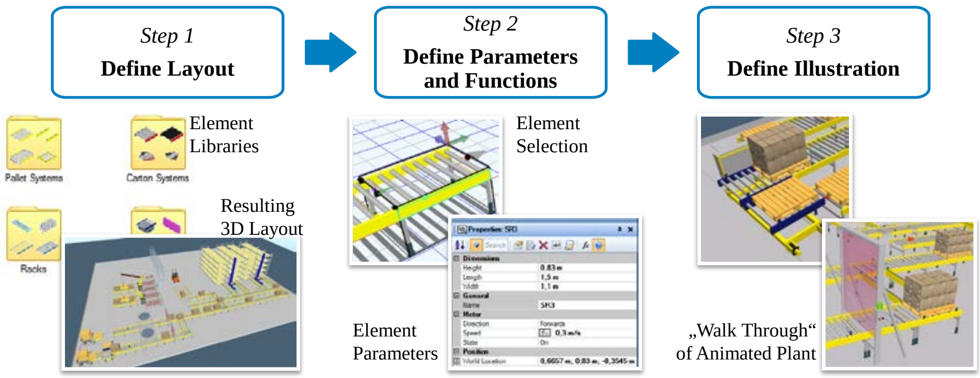


Figure 3. Process steps of defining "Virtual Reality" animated plant model with software Demo3D ®

5. Application of software Demo3D ® in scientific education of material handling

At the University of Miskolc the Institute of Logistics deals with the education of material handling and logistics. The institute has activities on different faculties, in different education fields and specializations (Figure 4). Material handling courses are taught in seven education fields and three different levels (BSc., MSc., PhD.).

Most of the courses (Material handling machines, Material handling machines and systems and Equipment used in logistics) contain the principles and basic information related to handling methods and devices. Most important objective of these courses is to present the structure, operation and characterisation of handling machines for students.

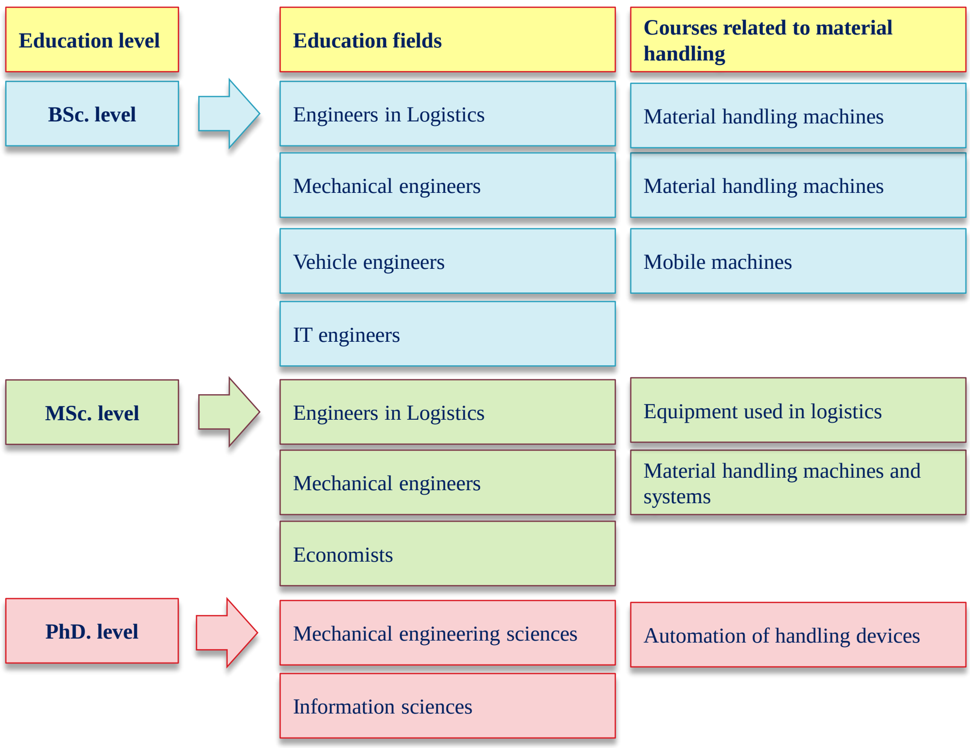


Figure 4. Education structure of LOG

5.1. Education related to material handling

Curricula of the main courses contains similar thematic which involves the topics presented on Table I. It can be seen, that the first 5 main topics is the same for all main courses, only the half of the topics are different for the individual subjects.

The first 5 topics contain basic knowledge about material handling and the teaching of them determines the basement for the further studies. It is important that students attended on these courses get sufficient, advanced and understandable knowledge about material handling.

LOG (and its ancestors) is dealing with the education and research related to material handling from 60 years, so the knowledge which is used to develop curricula for the subjects is proved and suitable. Staff of the Institute uses advanced devices to present the planning methods and demonstrate the operation of different machines.

There are two important deficiencies in the education of material handling, one of them is the involving of newest research results into the curricula, other one is the application of new and effective computer devices and software.

Reacting to the first problem, we started a new H2020 project in 2016 (UMi-TWINN), which targeted, among others, to increase the scientific excellence and research capability of the University of Miskolc in the field of logistics. During the project duration, staff of LOG met the researchers of their two high quality scientific project partners (TU Graz, and Fraunhofer IFF) to see their advanced research activities and results. As a result of the UMi-TWINN project the staff of LOG involved many new and advanced research results into the education materials of the University of Miskolc.

Table I.

Main thematic topics of material handling courses of LOG

Topics	Material handling machines	Material handling machines and systems	Equipment used in logistics
1.	*Introduction into the material handling*	*Introduction into the material handling*	*Introduction into the material handling*
2.	*Principles of material handling*	*Principles of material handling*	*Principles of material handling*
3.	*Material handling machines and their elements*	*Material handling machines and their elements*	*Material handling machines and their elements*
4.	*Material handling systems*	*Material handling systems*	*Material handling systems*
5.	*Planning of material handling*	*Planning of material handling*	*Planning of material handling*
6.	*Planning of transport paths*	*Material flow calculations*	*Automation of material handling*
7.	*Planning of mobile material handling machines*	*Equipment selection*	*Automatic handling machines*
8.	*Planning of conveyor systems*	*Process planning*	*Automated handling systems*
9.	*Dynamical characteristics of handling machines*	*Storing systems*	*Maintenance of handling machines*
10.	-	*Automation of material handling*	*Reliability of handling machines*

Related to the second deficiency, we can state that the education materials of LOG contains computer methods and software, however they cannot be used for material handling machines. During the project, staff of ITL presented their computer devices to the Hungarian partners, and University of Miskolc decided to make an education development related to material handling courses using knowledge and devices of the Austrian partner.

5.2. Application of Demo3D ® in the education

As the education of LOG is dealing mainly with the structure and operation of handling machines, it was obvious to use a 3D virtual reality method for the development. Related to Table I, main application possibilities of these methods are

- visualisation of handling machines,
- drawing structural elements and their relations,
- demonstrate the operation of machines,
- simulate the operation and structure of handling systems,
- demonstrate the effects of influencing parameters of machines, etc.

Suited to the advantages of it, we used software Demo3D ® to realize the above mentioned tasks. There are many handling machines and solutions in the industry, so at first we selected some important and usually used machine and system versions to present the process and its applicability: conveyors, transfer cars, load lifters, AGV systems, LHD, sorter systems, etc.

To apply Demo3D ® in handling systems, we need to create a transformation procedure, which involves the determination of device parameters, application environment, process steps and details. Main steps of the application procedure are:

1. Definition of the machine/system
2. Description of the structure/elements
3. Description of the operation principles/theories
4. Determination of the industrial environment/application parameters
5. Implementation in Demo3D ®

First step of the procedure is the definition of the machine (or the system), which has to be suited to the handling task you need to realize. Functions, operations (at machines) or tasks of system elements have to be defined during this process step.

Next task is the description of the structure of machines or system elements and the selection of building elements and applicable solutions. For the realization of this step we can use predefined machine elements or connections, or we can build new, specific solutions.

After the description of machine or system details, we can determine the operation parameters of actual solutions, where we can use mathematical principles and theories described in the related literature.

In the knowledge of required mathematical formulas, we can take the effects of industrial environment and application parameters into consideration. In this step, we can fit the machine or system to the real requirement.

Last step of the application procedure is the implementation of the machine or system variation in Demo3D ®. As a result of the procedure we have got a 3D simulation about the machine or the system which can be analysed, observed and tested in simulated operation environment.

5.3. Application scenario

Demonstrating the development procedure we applied it to a complex roller conveyor system, which is used in an industrial environment.

During the definition of the handling system (Figure 5), we selected only roller conveyor elements and palette (box) handling operations.

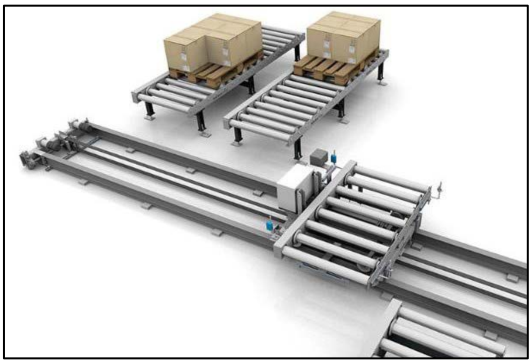
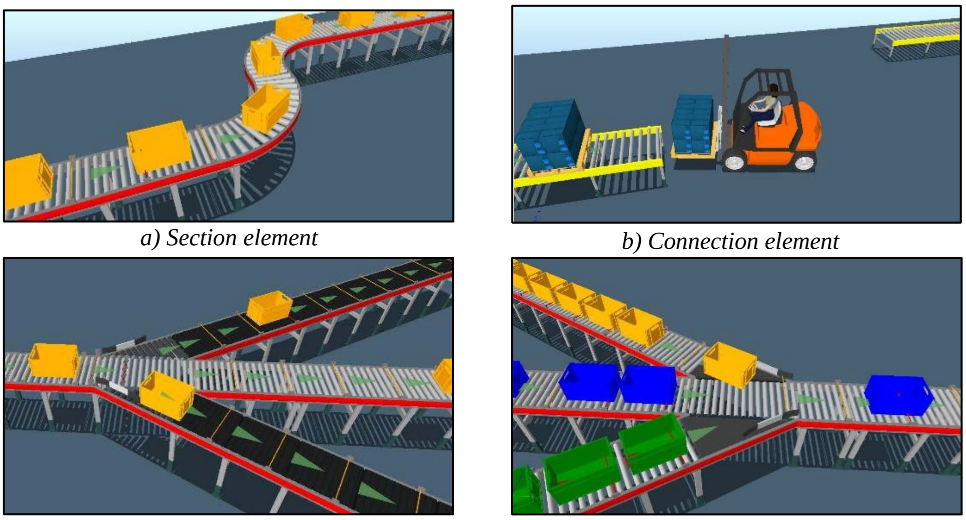


Figure 5. Example for a roller conveyor system

For the transportation of palettes and boxes we can use different section elements, which are defined on Figure 6 (Demo3D ® elements).



a) Section element *b) Connection element*

c) Branching element *d) Merge element*

Figure 6. Example for structural elements of roller conveyors

Taking the scientific aspect of the operation into account, we defined the next characteristics for the system:

- floor bound,
- consists of a frame (wheels and drive) and a lifting device,
- mostly used as palette conveyors,
- connects different conveyor systems,
- choice of the lifting device depends on the bordering conveyor system (roller track, chain conveyor, etc.).

For the calculation of handling parameters we used the education books of ITL (e. g. [34], [35]).

In the aspect of industrial environment and application parameters we applied the next data (Kardex Mlog):

- function: horizontal transport of loads, load lifting with chain- or roller conveyor or telescopic fork
- output: 180 units/h
- load carrier: palettes, lattice boxes
- load weight: 1200 kg/lifting device
- driving speed: max. 4 m/s

As a result of our procedure, the implementation in software Demo3D ® can be seen in Figure 7 (a simple machine) and 8 (a complex system).

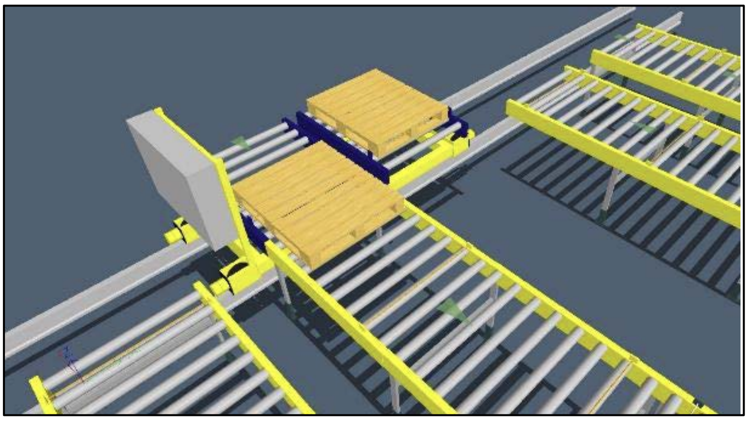


Figure 7. Realization of the machine in Demo3D ®

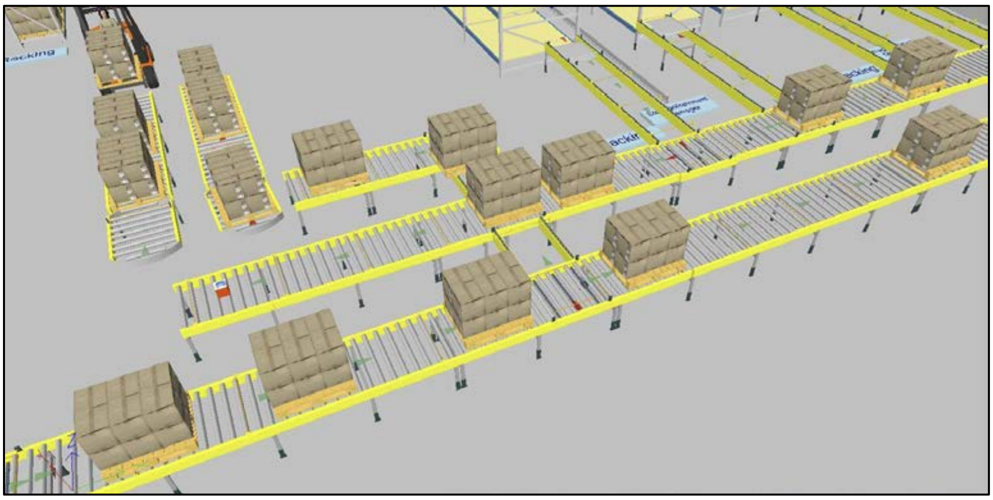


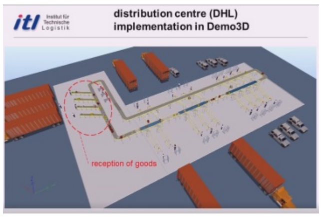
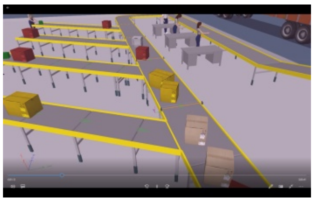
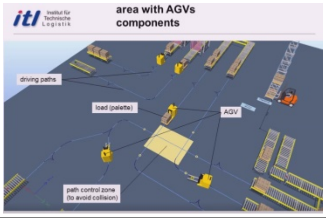
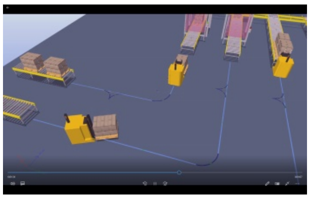
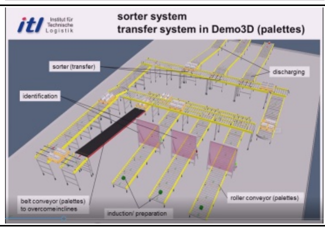
Figure 8. Realization of a complex system in Demo3D ®

5.4. Application possibilities and advantages

As a result of the project UMi-TWINN we developed numerous virtual reality models and animated 3D videos based on best practice studies of logistics industries (Figure 9).

The created logistics systems include:

- warehouse system of a distribution center,
- goods receipt and goods shipment area of a manufacturing company,
- sorting technologies within a parcel distribution center, etc.

<table>
<tr><th>No.</th><th>System type</th><th>System structure</th><th>Demo3D ® simulation</th></tr>
<tr><td>1.</td><td>Distribution center</td><td>
</td><td></td></tr>
<tr><td>2.</td><td>AGV transport</td><td>
</td><td></td></tr>
<tr><td>3.</td><td>Palette sorter system</td><td>
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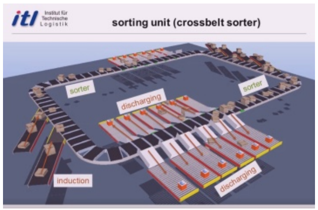
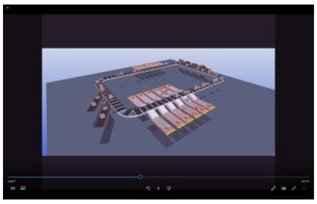
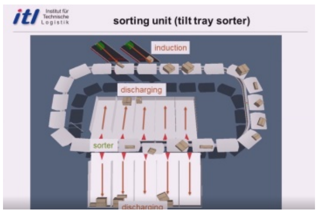
<tr><td>4.</td><td>Crossbelt sorter system</td><td>
</td><td></td></tr>
<tr><td>5.</td><td>Tilt tray sorter system</td><td>
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Figure 9. Elements of the developed materials

The documents created are an important contribution to support the teaching about intralogistics devices and plants both on LOG and on ITL. The results are also available to students on an internet platform for free download.

The most important application field of the developed videos and sheets is the scientific education of material handling and logistics. They are applied directly in three different courses (see Table I), as a part of the curricula: material handling machines and their elements, material handling systems, planning of material handling and automation of material handling.

Main advantages of these materials to show realistic machines and systems, and the effects of changings in any parameters can be directly presented.

Another application of the developed curricula is the direct use of a computer software in the planning process of material handling. Studying the software and its use can help to understand the planning and operation procedure of individual machines and systems.

6. SUMMARY

Scientific education of material handling requires the application of advanced, effective methods. Unfortunately, during the last decades, the University of Miskolc suffered some deficiencies in the teaching of handling machines.

By the help of the project UMi-TWINN, LOG of the University of Miskolc got a chance to develop its teaching materials and devices related to handling machines. During the project, staff of the Institute met the researchers of the TU Graz, and Fraunhofer IFF to see their advanced research activities and results.

Among others, the staff of ITL presented their computer devices to the Hungarian partner. One of the most important result of the project was the application of software Demo3D ® for the education of material handling. The developed examples, videos, sheets and other documentations are directly usable in the teaching curricula of different courses of LOG.

The software Demo3D is not a general solution for planning of material handling machines and processes, but it can help to present the operation of the machines and to demonstrate the effects of the changing of handling parameters, which is very important for the education.

After this starting step, next phase can be the application of software Demo3D ® in other handling processes and planning procedures (e. g. planning of total material flow within a production procedure), which can be used in other logistic courses (e. g. Logistic systems) of LOG.

Another direction of this research process can be the implementation of this software in the research activities of the Institute, which requires further cooperation between the ITL and LOG.

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