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Digital factory – theory and practice

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1. Introduction

The digital economy represents the pervasive use of IT (hardware, software, applications and telecommunications) in all aspects of the economy, including internal operations of organizations (business, government and non-profit); transactions between organizations; and transactions between individuals, acting both as consumers and citizens, and organizations (Atkinson et al. 2007).

Future production environment will require holonic approach of integration of information technologies (IT) into production area. On one side it is represented through IT applications in a real machinery and equipment. On the other side IT has to be employed in the design of production systems as well.

IT has been the key factor responsible for reversing the 20-year productivity slowdown from the mid-1970s to the mid-1990s and in driving today's robust productivity growth (Atkinson et al. 2007).

Any year automotive exhibitions show new models, merry-go-round of innovations turns faster and faster. Original Equipment Manufacturers (OEMs) introduce any 2 to 3 months new models which very often requires changes of production processes. Extremely short innovation cycles and products customisation significantly change all industries. The innovation is successful only in case, that it is quickly launched on market. The collaboration of single partners is very important not only in product development but in production planning and control too. There exists a lot of chaos and supplementary costs by the launching of new products. These supplementary costs often reach millions of Euros (*Jovane.F.;Westkamper,E. & Williams,D., 2009*).

Digital Factory is the phenomenon having its background in computer aided and computer integrated technologies and advanced virtual reality technologies. This phenomenon became very important mainly at the beginning of 21.Century.

The continually changing conditions of global markets combined with customer behaviour changes brought strong requirements for current producers e.g.: short time to markets, high quality, low cost, short production throughput times, etc. All these changes demand quick response with high orders fulfilment security (Barczik,R., 2003).

Current markets and customer's environment require from designers of manufacturing systems the utilisation of new advanced approaches and tools in the design of future manufacturing systems. Digital Factory seems to be one of the most appropriate approaches to fulfil this task offering all required functions e.g.: central database, digital models, integrated data management, modelling and simulation functions, visualisation through virtual reality etc. Virtual reality became a common tool used in Digital Factory environment. Digital Factory creates the environment for digital innovation of any part of production systems, e.g. products, processes and resources (Furmann, R. & Krajčovič, M., 2009).

The European researchers consider the future factories as products. These products are socio-economic systems, and are very difficult to design and to run and that is why a special attention to their development has to be paid. The competitiveness in future production will be provided by such production systems in particular. The effort of current research in Europe is focused into design of highly productive, flexible, effective and safe factories. To fulfil all above mentioned requirements the designers of future factories will have to apply quite new approaches and techniques e.g. Digital Factory concept. Therefore it is the goal of EU researchers to develop visionary approaches of organizing and realizing the future production *(*Jovane.F.;Westkamper,E. & Williams,D., 2009*)*.

Any change, even the smallest one, brings risk. The change has to be realised by real people who make mistakes. The dynamic development currently undergoes in the companies running business in the HighTech sphere by the application of Digital Factory systems. Some years ago the University of Žilina has started to build such complex Digital Factory system (Gregor,M. et al., 2006). The Digital Factory system utilises 3D digital models of real objects. DMUs (Digital Mock Ups) have firstly begun to be used in the sphere of products design and analysis. They are starting to be used in the sphere of complex production systems or even of whole factories (for instance in automotive industry). Such digital models are called **FMUs – Factory Mock Ups**, i.e. digital models of factories.

2. Digital Factory

Virtual Reality is a computer technology, which supported by hardware and software, enables to create virtual models of objective reality and use them for the generation of perceive feelings of people.
Virtual Reality technologies are possible to use for design of 3D spatial models as well as for 3D modelling and examination of properties of real objects (Medvecký, Š. et al., 2007). On the other side Virtual Reality enables to create „real" spatial environment, in which the man can conduct required activities. The possibilities for development of Virtual Reality technologies are tremendous and they still grow.

Digital Factory entitles the virtual environment for the lifecycle design of manufacturing processes and manufacturing systems using simulation and virtual reality technologies to optimize performance, productivity, timing, costs and ergonomics (Gregor,M. & Medvecky,S., 2010). There exists a comprehensive source of materials defining and describing Digital Factory, e.g.: (Kühn,W., 2006a), (Kühn,W., 2006b), (VDI 4499, 2008),(Zäh,M.F.;Fusch.T. & Patron,C., 2003).

Digital Factory environment uses 3D digital models (DMUs) and associated information for visualizing, modelling, and simulating production processes and production systems with the target of effective and productive real production within resource constraints. It enables to design, analyse and predict the future behaviour of designed production systems supported by computer simulation. Computer simulation plays very important role in the study of behaviour of real and artificial systems, almost in any scientific area (Plinta, D., 2001).

Digital Factory (DF) represents a virtual picture of a real production. It is the environment integrated by computer and information technologies, in which the reality is replaced by virtual computer models. Such virtual solutions enable to verify all conflict situations before real implementation of factories and to design optimised solutions (Furmann,R., 2007).

Product Lifecycle Management (PLM) is a business strategy supporting companies in product data sharing, and leveraging of corporate knowledge for the development of products for their lifecycle. PLM enables to operate and manage the entire network of all players (enterprise, suppliers, customers) as a single entity (Mleczko,J., 2008). Nowadays, the need for “Scientific Management” as proposed by Taylor has been extended to smart Product Life Cycle Management (Coze at. All. 2009).

Different types of software are linked in PLM solutions, which control different parts of the manufacturing cycle. Computer Aided Design (CAD) systems define what will be produced. Computer Aided Engineering (CAE) defines production processes and systems required for product´s production. Computer Aided Manufacturing (CAM) and Manufacturing Process Management (MPM) define how it is to be built. ERP answers when and where it is built. Manufacturing Execution System (MES) provides shop floor control and simultaneously manufacturing feedback (Garetti,M.;Macchi,M. & Terzi,S., 2007). The storing of information digitally aids communication, but also removes human error from the design and manufacture process. Computer Integrated Manufacturing (CIM) and Product Data Management (PDM) were recently replaced by term Digital Manufacturing (DM) which currently is conceptually very close to Digital Factory (Gregor,M. et al., 2006).

Digital Factory represents integration chain between CAD systems and ERP solutions, as it is shown in Figure 1.

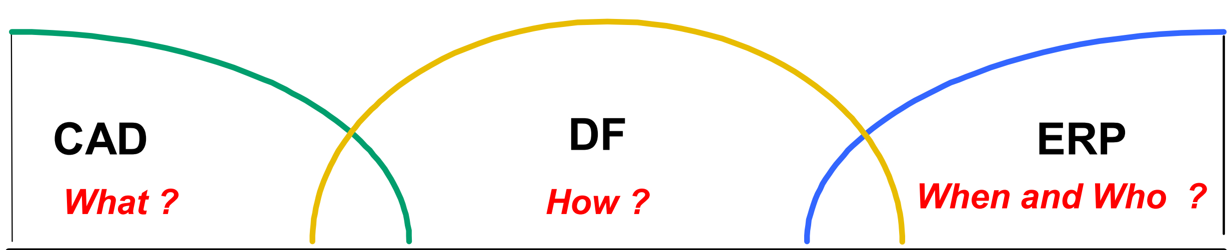

Fig. 1. Integration of Information Systems in Production (Delmia,2010)

One of very important properties of Digital Factory is the vision to realize process planning and product development with parallel utilisation of common data. It is very important to gain all required data only one time and then to manage them with the uniform data control, so that all software systems will be able to utilize it. The integration is one of the main conditions for the implementation of Digital Factory.

Digital Factory integrates three main elements (Delmia, 2010):
- **digital product**, with its static and dynamic properties,
- **digital production planning** and
- **digital production**, with the possibility of utilisation of planning data for enterprise processes effectiveness growth.

2.1 Key Enterprise Processes
Digital Factory concept prioritizes the six most significant areas, according to their influence on production process flow. Any area covers the set of tools which all together integrate the whole production process, from product design to its production (Gregor,M. et al., 2006):
- **product design systems** (including modelling and simulation),
- **process planning systems** (process and production plans, assembly plans, welding plans, tools, jigs, work standardization, value analysis, cost analysis, etc.),
- **production process detail and validation systems** (NC production process simulation, assembly, inspection, maintenance, production operations etc.). The utilisation of process plans, graphs and special BOMs which offer clear view about relationships between processes and resources already in conceptual design phase,
- **production engineering systems** (complex production scenarios, layout, industrial engineering, time analysis, ergonomics analysis, design and analysis of production and assembly systems, loading of machines, determination and optimisation of workers loading, etc.),
- **production planning and control systems** (ERP planning systems, scheduling, pull control, levelled production, mixed production, etc.),
- **automation and process control systems** (automatic generation of control programmes for control and monitoring of automated production systems, PLC, industrial robots, etc.)

2.2 Digital Factory Implementation Methodology
Rough procedure of Digital Factory implementation is as follows (Gregor,M. et al., 2006):
- Definition of total standards and production principles for entire planning operations, creation of primitives and customer databases,
- First data collection and organisation with the utilisation of data management system. All responsible persons have direct access to the data, its addition, inspection and changes,
- In this phase, Digital Factory system improves co-ordination and synchronisation of individual processes throughout their “networking” supported by workflow management system,
- In the fourth phase, Digital Factory system takes automatically some routine and checking activities, which are very time consuming in common systems. Implemented system insures high quality of all outputs.

2.3 Digital Factory Application Area

Digital Factory is appropriate mainly as a support for the batch manufacturing of highly sophisticated products, their planning, simulation and optimisation. Its main current application area is automotive industry, mechanical engineering industry, aerospace and ship building industry as well as electronics and consumer goods industries (Bohusova,B., 2009). 3D digital model of products (DMU) creates currently basic object for the work in digital manufacturing environment. There exists possibility to optimise products, processes and production systems even during the development phase with the utilisation of 3D visualisation and modelling techniques. Such solution brings time to market reduction and significant cost reduction (Durajova,M. et. al., 2006).

Cutting process simulation enables generation of real NC-part programmes for chosen production machines. The visualisation of machines and operational handling processes enables to reveal shortages in design of machines and to realise changes, remove errors and increase their effectiveness before real utilisation (Acél,P; Gregor,M. & Hrdliczka,V., 1993).

The system for the design of shop floor 3D layouts and generation of 3D models of production halls is missing in current Digital Factory solutions. It is possible to create the 3D model of production hall directly in CAD systems. Such solution is advantageous by new layouts or by new production systems designs. But, production halls do exists, in majority of real cases. By such conditions, it is often more effective to create 3D model of production hall with the utilisation of Reverse Engineering technologies and 3D scanners (Macus,P. & Durajova,M., 2006).

The material flow simulation enables to optimise the movement of material, to reduce inventories and to support value added activities in internal logistics chain (Štefanik,A. & Gregor,M., 2004).

The subsystems for effective ergonomics analysis utilise international standards as NIOSH, RULA, etc., which enable right planning and verification of man-machine interactions on the single workplaces (Helander, M., 1995).
The highest level of analysis represents computer simulation of production and robotics systems which enables optimisation of material, information, value and financial flows in the factory (Škorík,P., 2009).

2.4 Digital Factory at the University of Žilina

Since years the University of Zilina in co-operation with the Central European Institute of Technology have been developing own Digital Factory concept. The developed solution is used in education and research of Digital Factory. The developed Digital Factory concept structure is shown in Fig. 2.

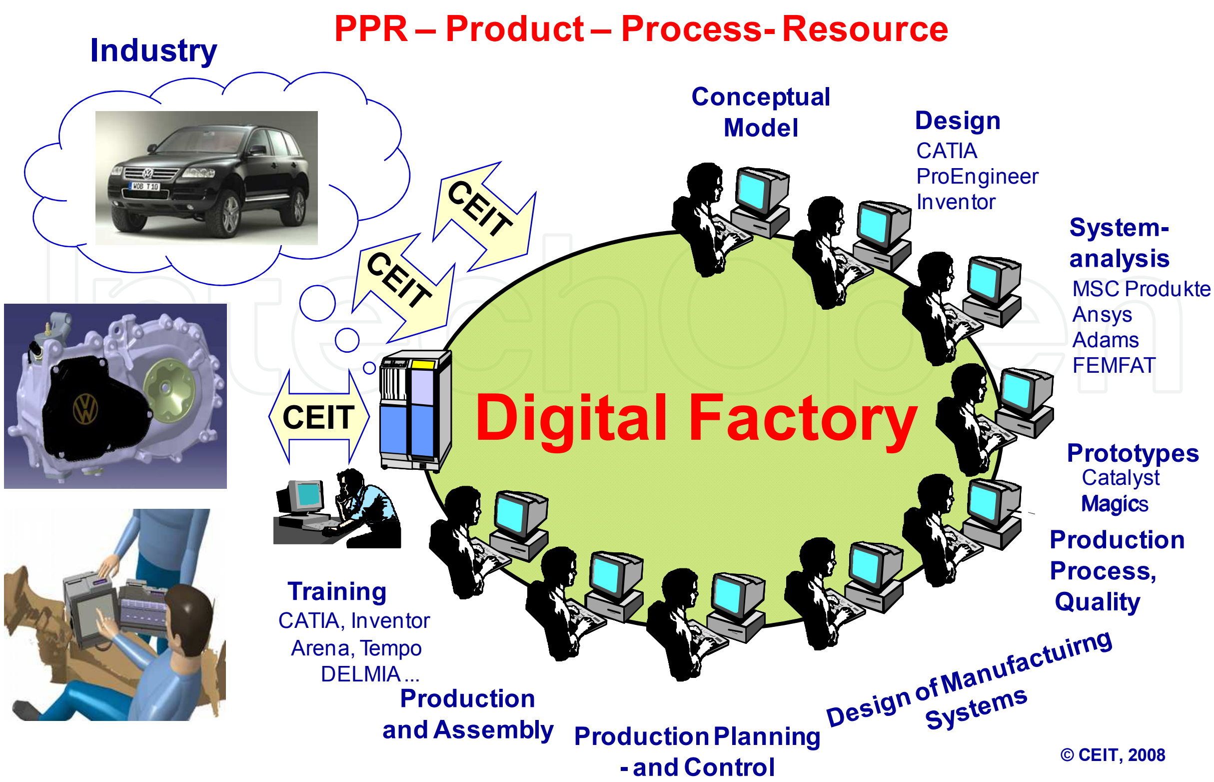

Fig. 2. Digital Factory Concept Built at the University of Žilina

The new developed Digital Factory concept increases the borders of current Digital Factory solutions. It endeavours to integrate activities conducted by designers, technologists, designers of manufacturing systems, planners, etc. It simultaneously tries to increase the offer of individual existing modules. The concept design goes from theoretical studies as well as practical experience gained in automotive and electronics industries in Slovakia (Gregor,M. & Medvecky,S., 2010).

3. Simulation and Emulation Production Environment

As a part of Digital Factory concept, a comprehensive holistic solution for the design and testing of new production systems is currently being developed, known as ZIMS - Zilina Intelligent Manufacturing System (Gregor, M.; Medvecký, S. & Mičieta, B., 2010). ZIMS represents a mixed virtual and real environment which enables to design and develop advanced intelligent solutions for industry. Figure 3 shows picture of current ZIMS state. It integrates many enterprise areas like: product design, Rapid Prototyping, product properties simulation and testing, new technology design, layout design and optimization, material flow optimization, handling, production control, ergonomics, simulation, etc. The computer simulation plays a central role in ZIMS concept, beginning from product design up to manufacturing processes simulation. Such simulation environment is known as Enterprise Simulation Management (Coze at. all. 2009).

Fig. 3. ZIMS – Innovative Environment (Gregor, M.; Medvecký, S. & Mičieta, B., 2010)

4. Chosen Examples from Research and Industry

The following part presents the chosen results of the research studies conducted in co-operation with the industrial OEM producers. As the results of research projects showed the Digital Factory solutions can save billions of Euros in industry.

The creative thinking methods became very popular in the design of new products. The methods of creative problems solution based on contradictions, like "general methodologies": TRIZ, WOIS, CREAX, DIVA, etc., are very often used by the design of new products (Medvecký, Š. et al., 2007).

The following example shows the application of Rapid Prototyping and Vacuum Casting technologies to the development and production of gear boxes.

The technologies of Rapid Prototyping are appropriate especially in case the company has to offer a quick response to the customer requirements on innovation. The automotive industry requires fast response to customer requirements. The following example shows the results of long term scientific co-operation between the University of Žilina and company VW Slovakia in the application of Rapid Prototyping and Vacuum Casting technologies by the development and production of gear boxes (Hrcek,S., 2005), (Hrcek,S. et al., 2006), .

The DMU model (DMU) of given gearbox was created by Reverse Engineering technologies (Minolta 3D Laser Scanner VI 900). Figure 4 shows the real VW Gearbox and its scanned clouds of point's model.

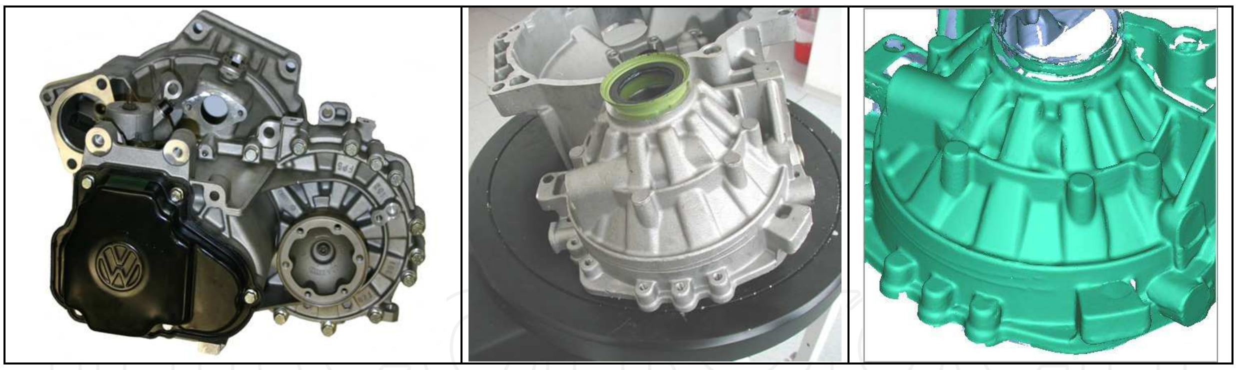

Fig. 4. Real VW Gearbox & Its Scan (Gregor,M.&Medvecky,S.,2010)

The 3D model of real gearbox was generated in Catia and FDM (Fused Deposition Modelling) prototype was produced through Rapid Prototyping (see Figure 5).

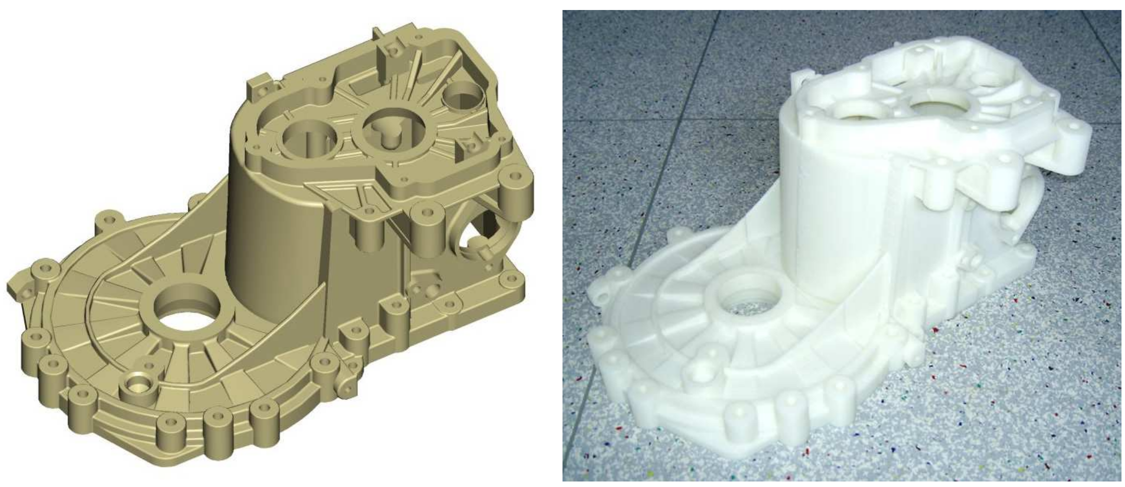

Fig. 5. 3D Model in Catia and FDM Prototype (Hrcek,S., et.al., 2006)

4.1 3D Laser Scanning for Quick Digitization of Real Objects

Mainly classical approaches are being used for digitisation and geometric analyses of the existing production systems. Information about the real state of the production system is, in case of complex production systems, obtained using the measuring tape, or laser measurers. Using such approach makes digitization of the whole enterprise extremely time-demanding and expensive. It is also a potential source of waste, inaccuracies and errors. It is much faster, much more effective and qualitatively better to create the 3D models of the existing production systems using the 3D laser scanners. These make possible to transform the existing, real 3D word, into its exact 3D digital copy which correctly reproduces the exact geometry of the recorded space and can simply be used for any computer analyses, in a matter of a few moments.

Thus obtained 3D digital model (so-called master model) can be used in all designer professions; it can be used by analysts as well as by the factory's management. Using the internet it is possible to share such model from anywhere worldwide. Its accessibility makes it easier to eliminate errors. Designers from all over the world can simultaneously work on new projects without any need to travel on to the spot and manually do all the measurements required before they start to design.

Extensive research is currently underway, all over the world, in the sphere of utilising the digital methods for digitization, modelling, analysing, simulation, recording and presenting of real objects (Durajova,M. at. al., 2006), (Macus,P. & Durajova,M., 2006), (Montorio,M. & Taisch,M., 2007a), (Montorio,M. & Taisch,M., 2007b) .

The sphere of creating, modelling and storing 3D digitalized virtual models of real objects is one of the most significant spheres, which are able to radically influence the effectiveness of producers. Research and development in this High-Tech sphere is technically and financially demanding. The most significant automotive and electronics companies are well aware of the permanent need to innovate their products, which is why they release a new model every 2-3 months. Innovation can only be successful if it is swiftly put on the market. To fulfil the requirement to shorten the whole production cycle of a product from its design to delivering it to the customer keeping the costs as low as possible is the most important prerequisite of success of every enterprise. The launch of a new product is always connected with the initial chaos, which increases the realisation costs behindhand.

The system for the creation of 3D production layouts and the generation of DMUs of production halls or FMUs is what Digital Factory solutions miss today. It is principally possible to design the DMU of production halls and production layouts using the direct CAD system approach. Such solution is convenient when designing new production systems. However, the more frequent case is that the production halls do already exist. That is the reason why it is often more effective to create production hall DMU using the Reverse Engineering technologies (e.g. 3D laser scanning.).
Reverse Engineering is the step needed to take to be able to achieve high efficiency and accuracy of digitization, not only considering the existing equipment, but also when the production layout themselves come into question. It opens up new opportunities to realize virtual designing. Creation of 3D-DMU of large objects using the 3D scanning is, at the moment, the joining link between virtual reality and real virtuality.

The 3D laser scanning (3D-LS) is one of the Reverse Engineering technologies which are usually used for the digitization of real objects. The digitization through 3D laser scanning represents one of the most productive and effective ways of how to get the high quality 3D digital models of current production systems. Those technologies enable simultaneously the transformation of current real worlds into their 3D clouds of points copies which represents their spatial geometry. Such 3D models are very useful for the analysis of current production systems. The 3D-LS technologies became a part of the Digital Factory technologies. Their advantage lays in the simplicity and a huge potential of cost and time savings by the development of 3D models of current objects.

Following statistics are known in a project practice of big project companies (Gregor,M. & Medvecky,S., 2010):
€ 100 mil. investment requested
€ 10 mil. increased costs because of lower transparency and about
€ 1 mil. additional costs and time because of lower transparency, clashes, organization problems and mistakes in suggestions.

Based on a research by 3D laser scanners users were achieved following costs savings (Gregor,M. & Medvecky,S., 2010):

- € 3-4 millions trough the virtual reality.
  According to the research by customer's consistent application of 3D factory it can save 30-40 % additional costs and time in projects.
- Complex 3D data are basis for detection and elimination of clash causes. It can be saved up to 2 % of investment costs by investment in to factories by using detection and elimination clash causes.
- Created and complex 3D DMU allows accurate, quick, easy and effective change management. Time in this case is featured, so these planning and management systems are also marked as 3D-CAD-Planning tools (also marked 4D). The utilization of automatic scanning based on ahead set plan allows quicker to obtain a new and real 3D DMU. The planning system on the other side allows with one click to realize changes in integrated form, which were in the past solved by groups of specialists in months.

The chosen Reverse Engineering technologies were tested in the framework of co-operation of the University of Žilina and Thyssen Krupp – PSL and Whirlpool companies. Figure 6 shows the DMU model of handling device developed using 3D laser scanning and modelling in Catia.

a) Clouds of Point Model b) Transfer in CAD c) 3D Digital Model

Fig. 6. DMU Model of Handling Device

The 3D virtual models of production halls were developed using 3D laser scanning (Faro LS 880 HE) and modelling in Bentley HLS. The following example shows the result of production halls DMUs development through 3D laser scanning and modelling, including detailed energy networks and transportation systems (Figure 7).

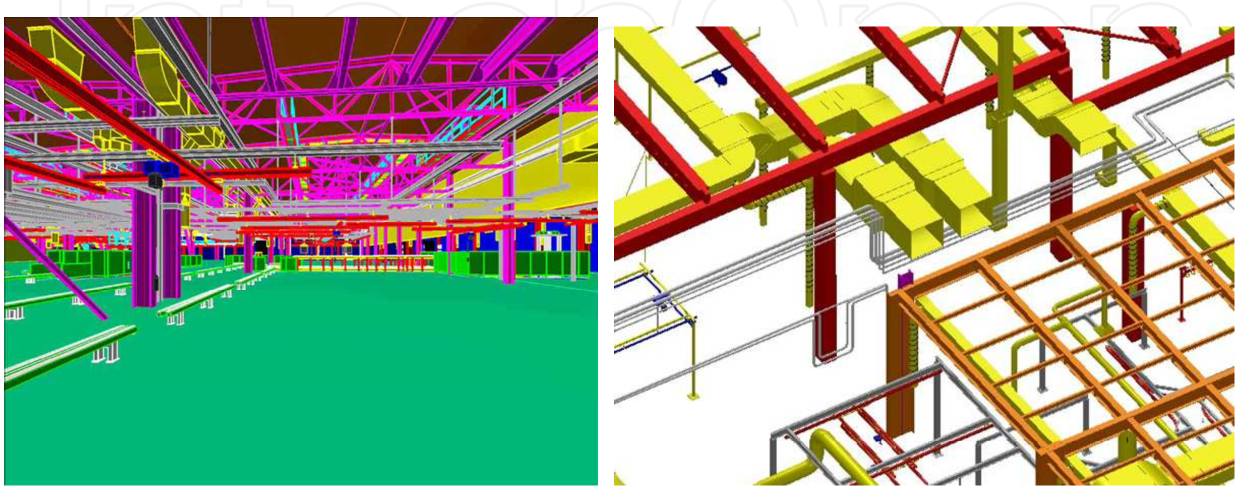

Fig. 7. DMUs of Production Hall – VW Slovakia

The designer of manufacturing systems can use the existing 2D production hall model and to develop new 3D digital model in CAD system. It is often advantageous to generate the 3D model on the basis of existing 2D model platform. A comprehensive research was done, in co-operation with Thyssen Krupp – PSL, in which the complex digital cycle was conducted. After 3D model of production hall was Developed in Bentley HLS system, based on 3D laser scans, all objects (e.g. production hall, machine tools, handling devices, etc.) were integrated into 3D model and through this approach the comprehensive DMU was developed. Then the new assembly concept with optimized material flow was developed. Consequently 3D simulation model of complex production system was developed and used by optimization of control of the designed production system. The final solution represents a comprehensive model and the research on this area continues. Figure 8 shows the part of FMU of Thyssen Krupp – PSL factory.

Fig. 8. DMU Model of Manufacturing and Assembly – Thyssen Krupp-PSL

4.2 The Development of an Assembly Line Digital Model

The University of Zilina has conducted several research studies in industry focused on Digital Factory solutions. The DMU model of a real gearbox was developed using Reverse Engineering technology (3D laser scanning), in the framework of co-operation in research with VW Slovakia. The developed gearbox DMU was used for the development of the digital model of the entire gearboxes assembly line. Figure 9 shows the real VW gearbox and its digital model (DMU).

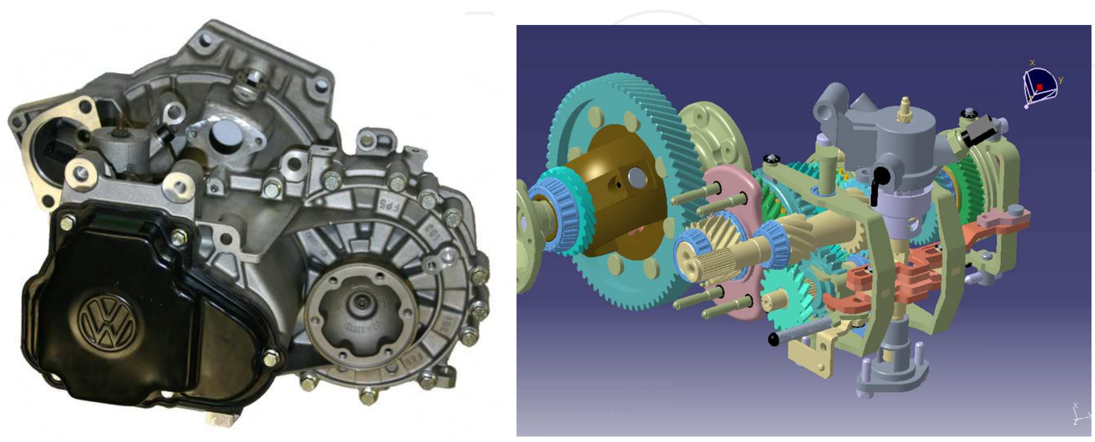
Fig. 9. Real Versus Virtual VW Gearbox (Gregor,M.&Medvecky,S.,2010)

Based on the gearbox DMU and a real assembly system a set of DMUs of VW production workplaces and transportation equipments was developed (see Figure 10).

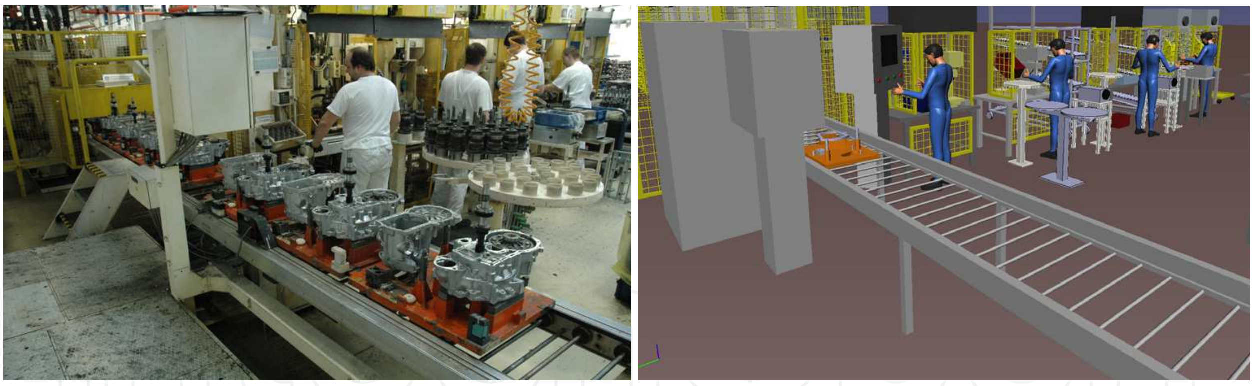

Fig. 10. DMUs of Assembly Workplace (Gregor,M.&Medvecky,S.,2010)

The design of workplaces was especially checked by ergonomics analysis whereas manikin concept of Delmia V5 Human was used. The final solution of designed workplaces was tested through the static simulation / animation (see Figure 11).

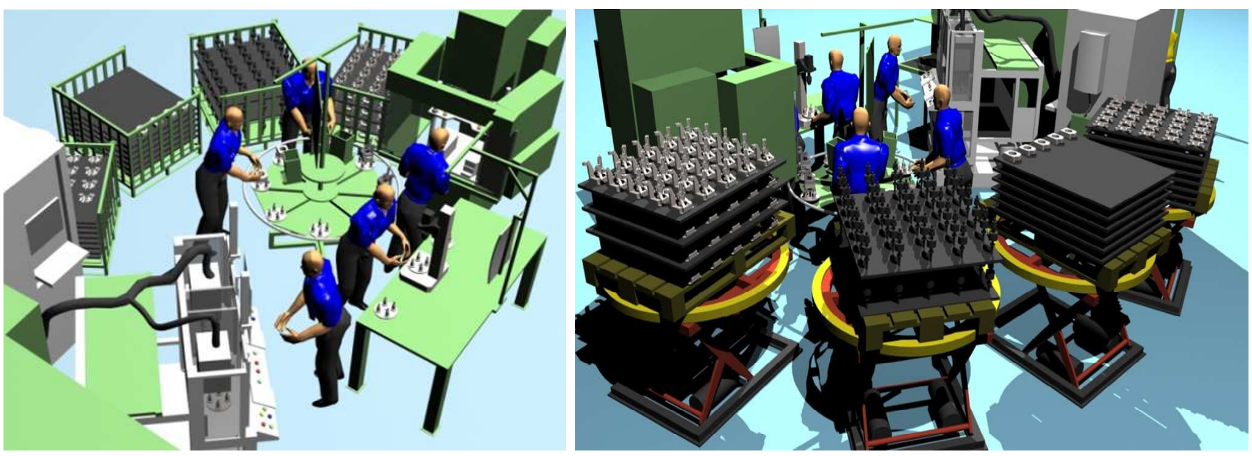

Fig. 11. Static Digital Model of Assembly Line – Askoll Slovakia

The static virtual model of a given gearbox assembly line was developed through integration of individual DMUs into manufacturing system scene. The dynamics of the real assembly system was checked in the 3D simulation environment Quest. The set of simulation experiments was conducted with the developed simulation model which showed bottlenecks stations and the possibilities for performance improvement of gearbox assembly line. Afterwards an FMU of the whole assembly line for gearboxes assembly in VW Slovakia was developed. This FMU represents the complex digital model of the entire VW assembly line. The final solution is shown in Figure 12.

4.3 Simulation and Emulation System

Central European Institute of Technology (CEIT) has long time been developing the simulation-emulation software platform ELLA, based on digital models of control system hardware and software elements supported by virtual reality environment. ELLA consists of many subsystems, e.g.: monitoring and control system WATCH for mobile vehicles control, modular production system, pattern recognition subsystem, quality control system with laser measurement and control units, etc. Figure 13 shows the framework of ELLA simulation & emulation environment.

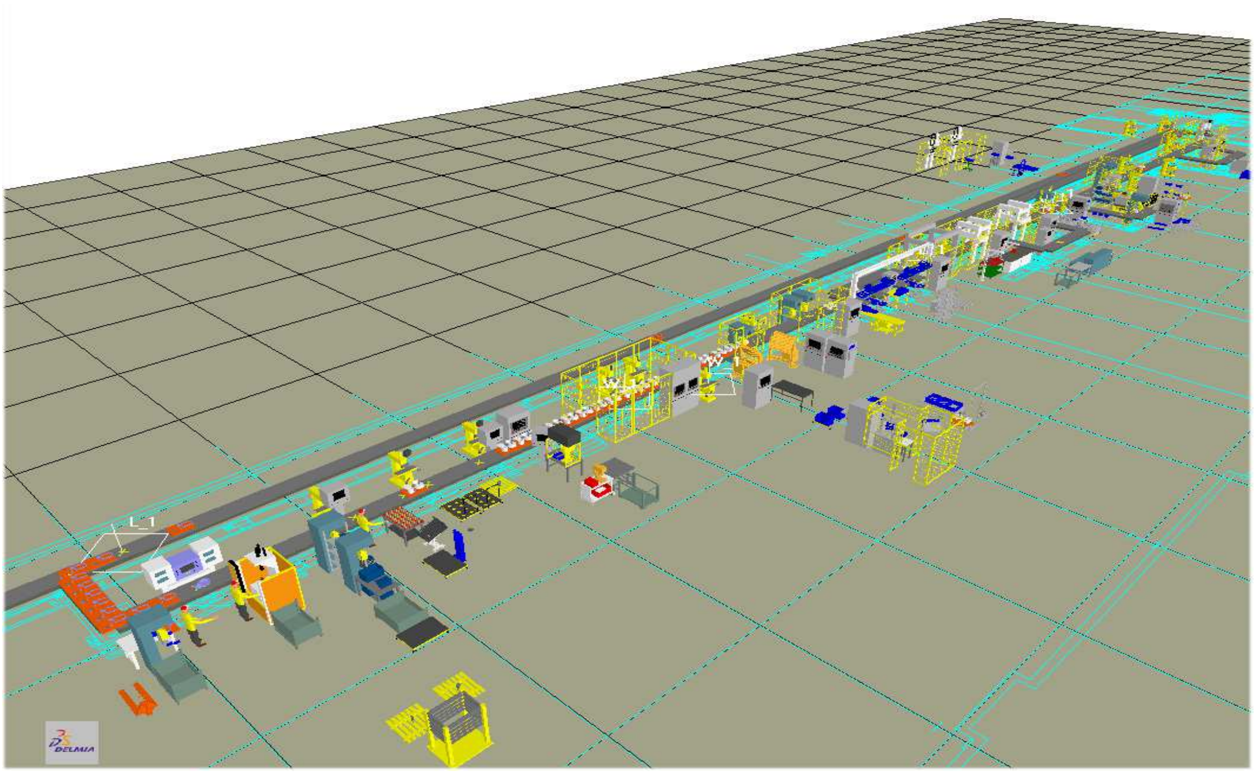

Fig. 12. VW Slovakia – FMU of Gearbox Assembly Line (Gregor,M.&Medvecky,S.,2010)

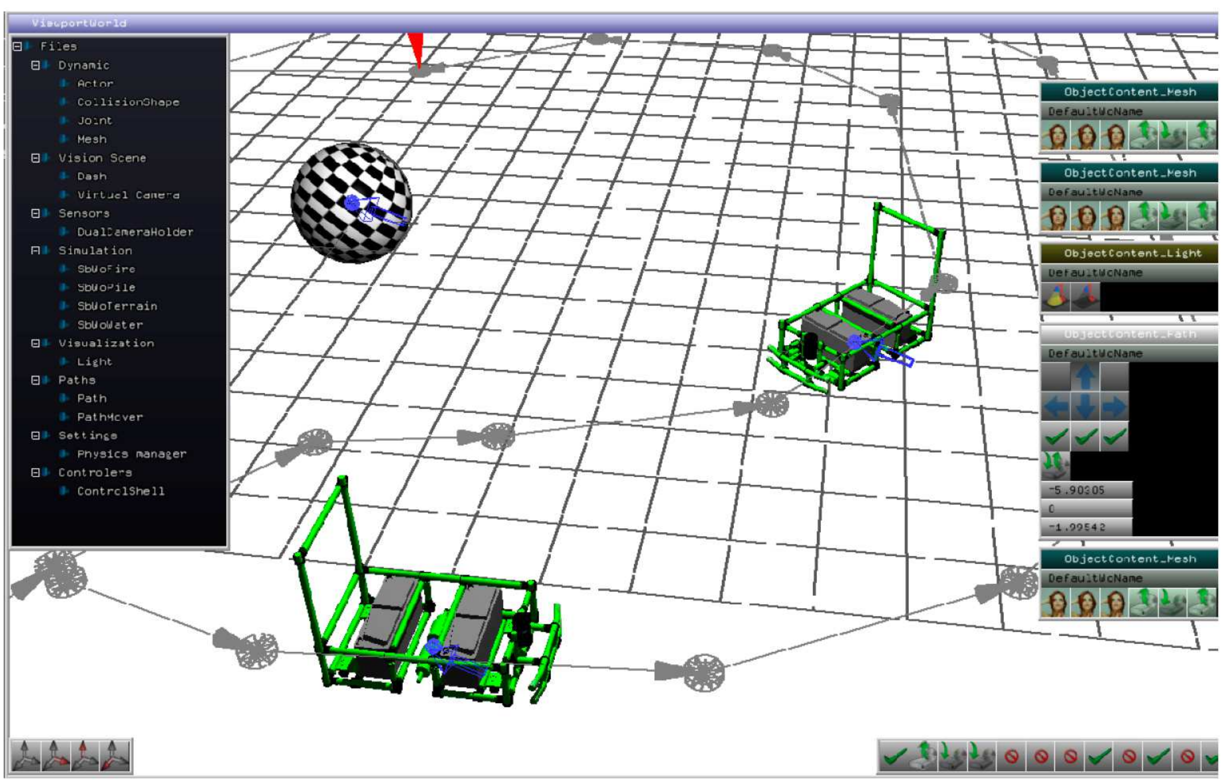

Fig. 13. ELLA – Simulation & Emulation Frontend Platform (Michulek, T., 2010)

Material transportation and handling system belongs among the most decisive parts of effective production systems (Matuszek, J., 2000). Future production systems will require Intelligent Automatic Handling System (IAHS) equipped with industrial robots, autonomous mobile robotic systems, etc. Recent development on this area showed the growing interest in AGVs (Automated Guided Vehicles). There exists a plenty of solutions for automatic transportation and handling of material in production, e.g.: inductive AGVs, through magnetic type controlled AGVs, radio frequency controlled AGVs, mechanically (hanged systems) controlled AGVs, AGVs with artificial intelligent control, etc.

CEIT has developed the platform of low cost AGV solutions for automotive and electronics industries which has been successfully implemented in VW and is currently in testing phase in Continental and Whirlpool factories (see Figure 14). The robotic platform control system was fully developed and tested in ELLA environment.

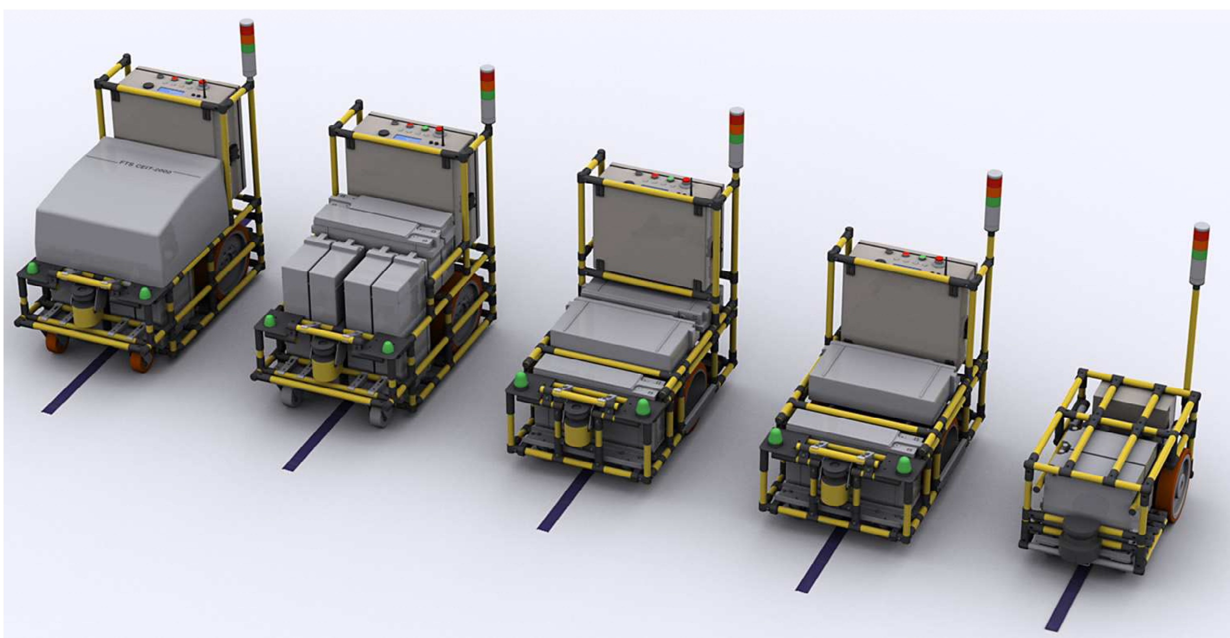

Fig. 14. AGV Platform - For Automatic Material Handling

4.4 Simulation of Chosen AGV Control Strategies

The basic principle of simulation (Figure 15) resides in a simplified representation of a real (conceptual) system, which we are interested in (simulation target). The analyst does, after verification and validation of a simulation model, a set of simulation experiments. The experimentation with simulation model, aided by a computer, allows examining the variants of system's behaviour in a longer time period and in assumed conditions. New knowledge gained through such simulation experimenting is used for the optimization of a real (conceptual) system.

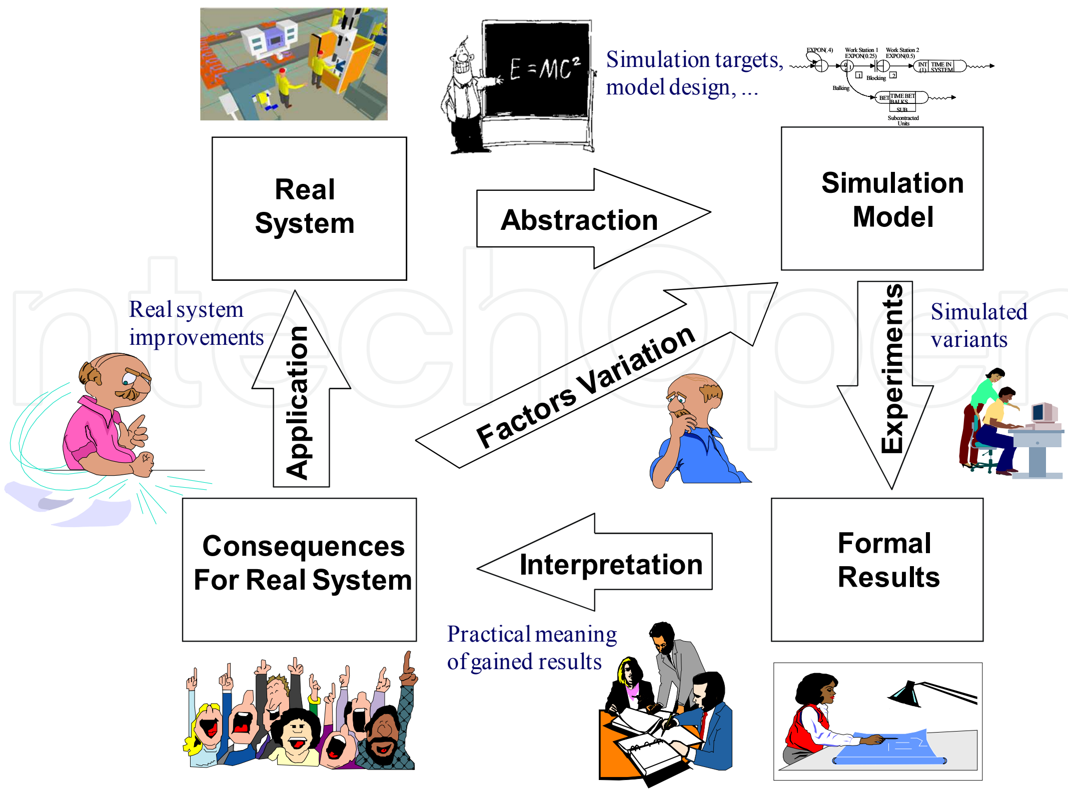

Fig. 15. Basic Principle of Computer Simulation

Simulation is a proven tool for the analysis of dynamic systems. The optimization, especially using Genetic Algorithms and evolutionary approaches, became part of simulation systems. There exists abundance of literature about simulation and optimization, e.g.: (Law,A.M. & Kelton,W.D., 1991), (Košturiak, J. & Gregor M., 1995), (Gregor,M. & Kosturiak,J., 1997), (Hromada,J., 2005), (Škorik,P. et al., 2009).

Chosen AGV control strategies were simulated in ELLA simulation and emulation environment (e.g., FIFO order selection, order selection from the nearest stations, higher priority of the orders in the production, etc.). The simulation project (Gregor at. all. 1997) was chosen as a test case for testing of validity of ELLA environment. Figure 16 shows a FMS layout with machines, conveyor, handling robotic workplace, and remote storage area and transportation tracks.

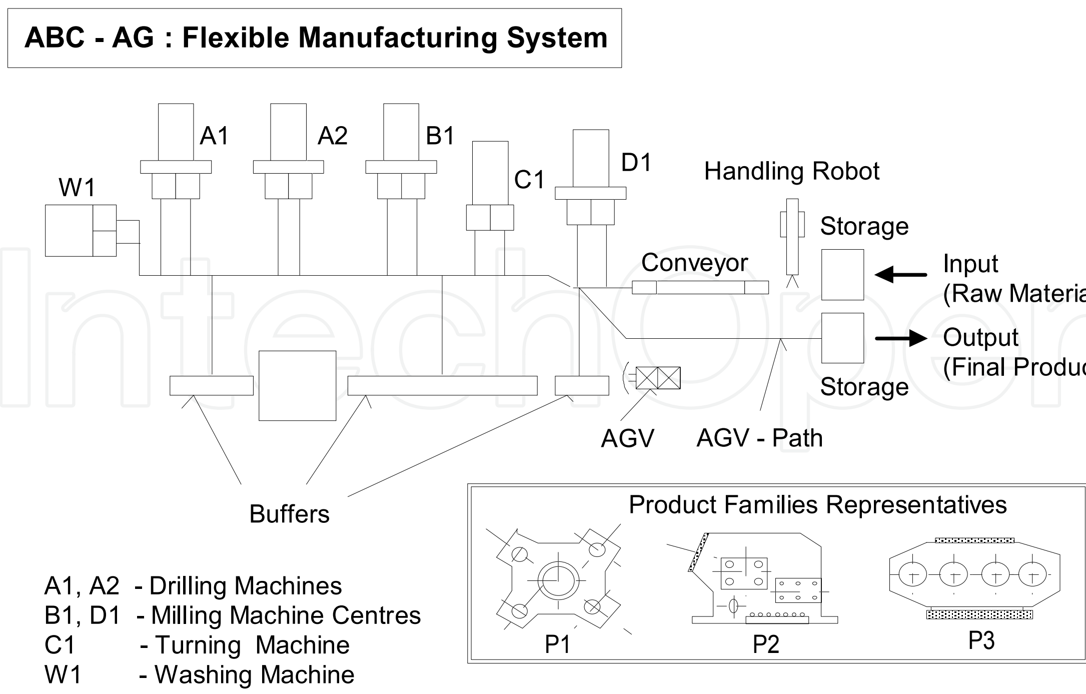

Fig. 16. Flexible Manufacturing System Layout (Gregor,M.&Kosturiak,J.,1997)

Following simulation variants were analysed by computer simulation:

Variant 1 - AGV control strategy, FIFO order selection, capacity of I/O buffer on the station – D1

Variant 2 - AGV control strategy, FIFO order selection, capacity of I /O buffer on the station – C1

Variant 3 - AGV control strategy, FIFO order selection, capacity of I / O buffer on the station – B1

Variant 4 - AGV control strategy, FIFO order selection, capacity of I / O buffer on the station – A2

Variant 5 - AGV control strategy, FIFO, capacity of I / O buffer on the station – A1

Variant 6 - AGV control strategy, order selection from the nearest station, capacity of I / O buffer on the station – A1

Variant 7 - AGV control strategy, order selection from the station with the most parts, capacity of I / O buffer on the station – B1

Variant 8 - AGV control strategy, FIFO, capacity of I / O buffer at the workplaces –A1, B1

Variant 9 - AGV control strategy, random order selection, capacity of I/O buffer at the workplaces – A1, B1

Variant 10 - AGV control strategy, random order selection, capacity of I/O buffer at the workplaces – A1, C1

Variant 11 - AGV control strategy, highest station priority, capacity of I/O buffer at the workplaces – B1, C1

Variant 12 - AGV control strategy, selection from the nearest station, capacity of I/O buffer on the workplaces - B1, C1

The results of simulation are shown in Figure 17. Figure 18 shows the progress of Work in Process (WIP) inventory in relation to the production throughput and order average throughput time.

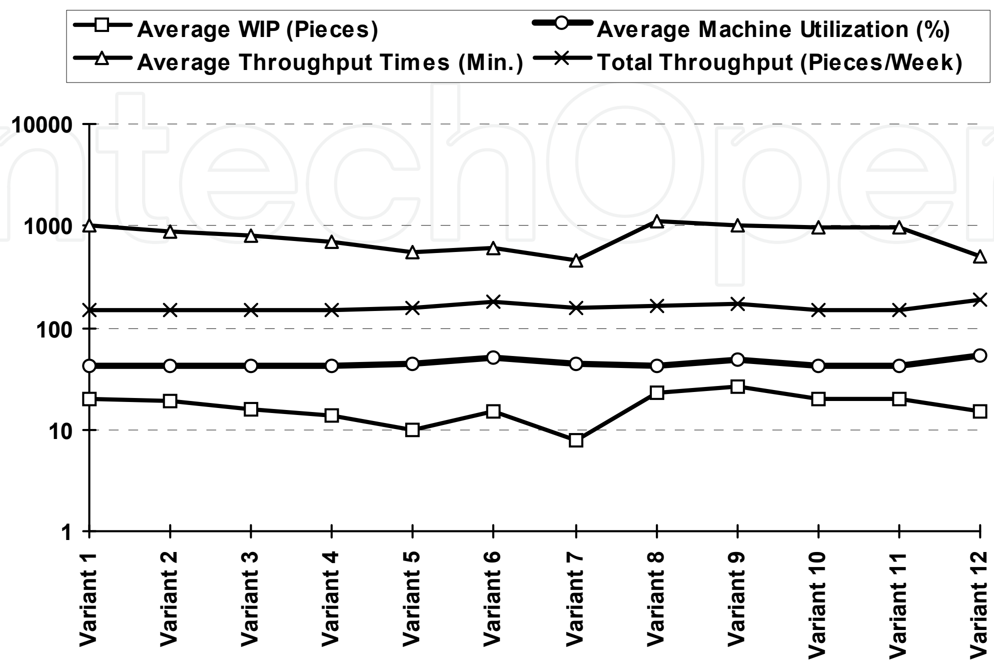

Fig. 17. Simulation Results - Chosen AGV Control Strategies

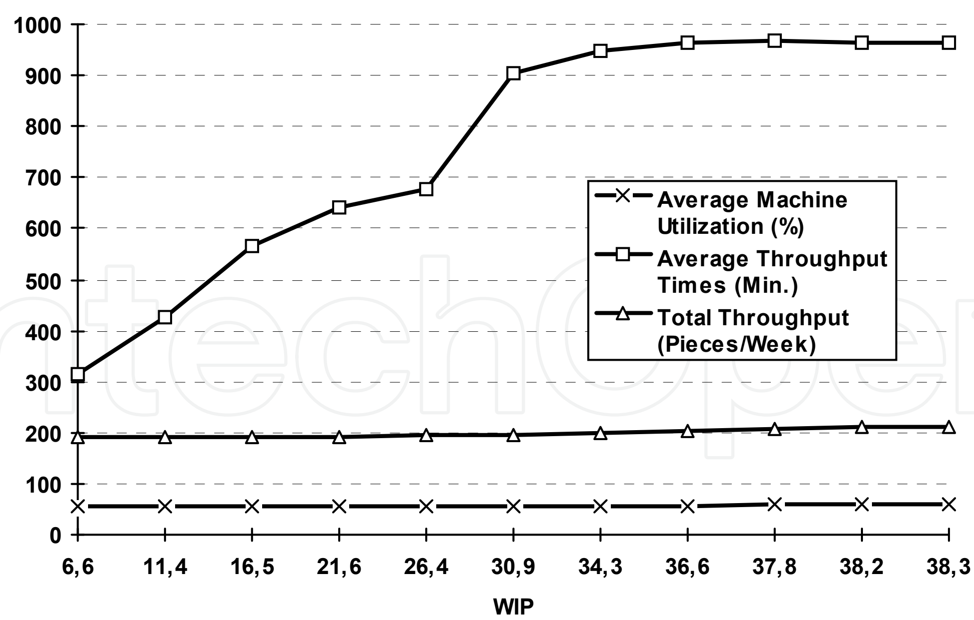

Fig. 18. Relationship between WIP and the System Performance (2 AGVs)

The simulation helped to find out the appropriate control strategy and thus it supported the optimization of performance of analysed production system.

5. Advantages, Restrictions and Benefits of Digital Factory Solutions

Digital Factory implementation results directly in economic as well as production indicators improvement. Any slight saving realised in design and planning phase can bring huge cost reduction in production operation phase. Thanks to this, the payback period of investment in Digital Factory is very short.

Digital Factory advantages (Gregor,M. et al., 2006):

- reduction of the entrepreneurial risk by the introduction of a new production,
- processes verification before start of production,
- possibility of virtual „visit" of production halls,
- validation of designed production concept,
- optimisation of production equipment allocation,
- reduction in required area,
- bottlenecks and collisions analysis
- fast changes,
- better utilization of existing resources,
- machines and equipment off line programming saving time and resources,
- reduction or full elimination of prototypes,
- ergonomics analyses, etc.

Digital Factory enables to test and reveal all possible production problems and shortages before start of production. It enables to eliminate errors in the production line, human or mechanical. Figure 19 shows the main advantages of Digital Factory solutions, e.g. shortening of time to market and significant reduction of lifecycle costs.

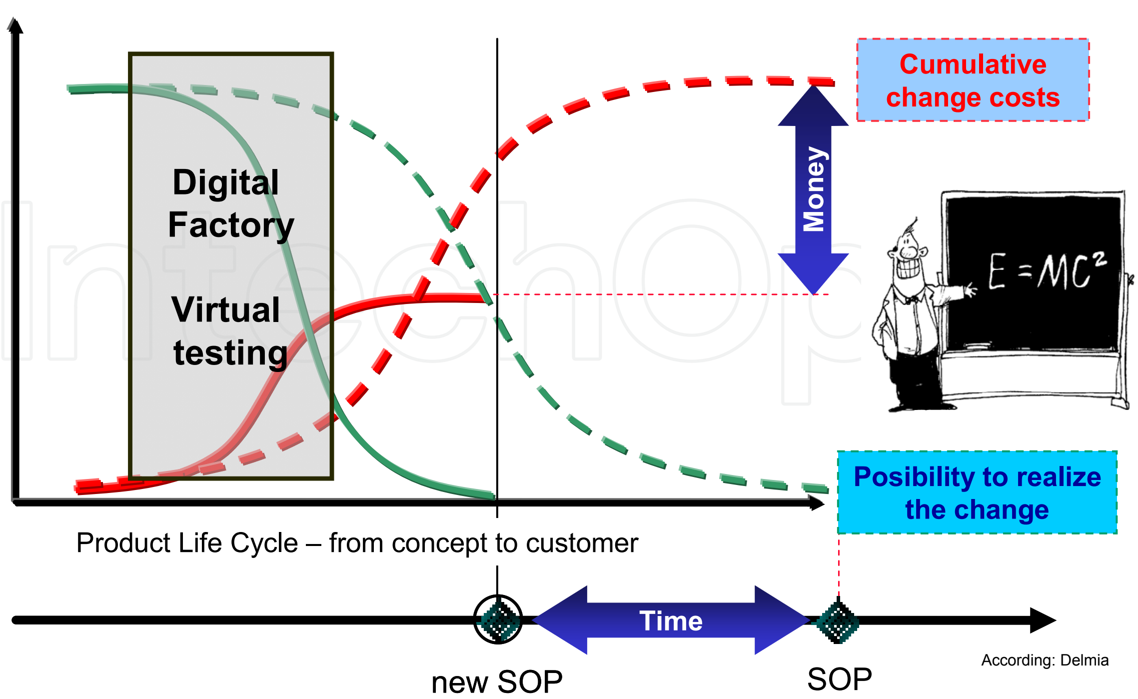

Fig. 19. Digital Factory Advantages (Delmia, 2010)

The highest potentials for high quality and low costs of products are in product development and production planning phases. The statistics show that product design and production planning influence about 80 % of production costs (Gregor, M. et al., 2006).

Digital Factory enables product launching time reduction up to 25 - 50 %. Estimated cost savings are supposed from 15 to 25 %. According to some studies done in industry, using digital manufacturing techniques, twice the amount of design iterations can be processed in 25 percent of the time.

The current production equipment is often inflexible by quick changes. That is why the designers of such equipment are looking for new solutions (automatic reconfiguration of production machines) with fully automated control systems, which will be able to find optimized production process and parameters after production task definition.

According to CIM data (CIM data, 2003), Digital Factory enables to achieve following financial savings:

- Cost savings by assets reduction about 10 %
- Area savings by layout optimisation about 25 %
- Cost savings by better utilisation of resources about 30 %
- Cost savings by material flows optimisation about 35 %
- Reduction in number of machines, tools, workplaces about 40 %
- Total cost reduction about 13 %,
- Production volumes growth about 15 %,
- Time to market reduction about 30 %.

6. Future Research

The future research will be focused on development and integration of Digital Factory technologies enabling synergies effects of such holistic solution. This environment will require a new IT framework which is currently under development in the EU funded research project – Virtual Factory Framework (VFF).

A significant research area is mobile robotics systems. The methods of Artificial Intelligence are under development for application in the development of control of autonomous, low cost, mobile robotics systems. The speech and pattern recognition are developed for the control of mobile robotic systems. Special simulation and emulation environment, supported by virtual reality, is under development. It will be used for the design and development of advanced mobile intelligent robotics solutions. This system uses evolutionary methods e.g. Genetic Algorithms and Artificial Neural Networks for the optimization of complex industrial control problems. Simulation meta-modelling represents one of especially important area of further research in approximated production control. The researchers developed new approach for automated generation of specified meta-models classes which is now under testing in industry.

The digitization of real objects, through 3D laser scanning, represents another very important area for the future research. The objectives on this area are focused into generation of savings by the digitization of real objects in industry. Digital Mock Ups obtained through digitization will be used by the optimization of current manufacturing systems. The part of research on this area is the development of augmented virtual reality based system for 3D layout planning and optimization.

The main target of researchers of the University of Zilina is, in co-operation with other EU scientists, to contribute to the development of Intelligent Manufacturing Systems.

7. Conclusions

The future outlook shows that next generation products can benefit from digital manufacturing. Any type of process elements are stored so that as modifications are made at any stage of product development, they are made to the entire design and manufacturing process.

The global business environment requires high flexibility of advanced manufacturing systems. Future manufacturing systems will be designed with new approach using simulation and emulation in the framework of Digital Factory. Such solution will enable designers to develop manufacturing systems which will be able to work effectively during their lifecycle.

Current research requires a huge investment. The common intention of the University of Žilina and the Central European Institute of Technology is the development of fully integrated system for the design of advanced production systems with its main focus on automotive and electronics industries. Such system should enable to bring new technologies into industry as well as into education. This solution will support the education of future designers, designers of manufacturing systems, technologists and managers.

The University of Zilina educates students in their creativity and ability to design competitive products and production systems with the application of advanced information technologies.

ZIMS is developed as new environment integrating all important subsystems in a holistic research and development system for design of advanced production systems. Simulation and emulation systems became a significant part of the design and control of manufacturing system. ZIMS development, based on recent research, supported by virtual reality and immersive technologies, presents a quite new direction in Digital Factory research. This innovative solution is fully available to the students, researchers and professors of the University of Zilina. It is used by the development of Learning University concept – new innovative learning system where professors and their students solve together applied research projects for industry.

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This book pilots the reader into the future. The first three chapters introduce new materials and material processing methods. Then five chapters present innovative new design directions and solutions. The main section of the book contains ten chapters organized around problems and methods of manufacturing and technology, from cutting process optimisation through maintenance and control to the Digital Factory. The last two chapters deal with information and energy, as the foundations of a prospering economy.

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