MSc Program
Engineering Management

CONTINUING EDUCATION CENTER

AUTONOMY IN LOGISTICS
WITH RESPECTIVE TO INDUSTRY 4.0

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
Em.O.Univ.Prof. Dipl.-Ing. Dr.h.c.mult. Dr.techn. Peter Kopacek

Martin Feldmann

Vienna, April 2017

Affidavit

I, **MARTIN FELDMANN**, hereby declare

1. that I am the sole author of the present Master's Thesis, "AUTONOMY IN LOGISTICS WITH RESPECTIVE TO INDUSTRY 4.0", 80 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and

2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, April, 2017 ________________________________

Signature

TABLE OF CONTENTS

ABSTRACT

This master thesis reflects actual and upcoming trends attributed to production logistical processes, interacting in a digitized environment.

It displays the vision of autonomy, describes the demand on processes and introduces specific and innovation-oriented approaches to logistical solutions. Complex systems are exposed to many variables. Promising developments in new technologies imply possibilities and options for use in various practices. Novel methodological capabilities that enable more efficient operations, enhanced manufacturing depth, individually personalized products and the entrance into new markets sometimes request the revision of conventional applied techniques which become gradually limited. The ambience about Industry 4.0 provides possibilities and calls for necessities. In combination with Cloud Computing, the fourth trendsetting revolution is taking over in multiple lines of business which respond and adapt to the changing market conditions. Always looking for improvement, sustainability and profitability the design of the new generation knows no stereotypical paradigms and is internationally considered to be groundbreaking. Market-opening measures plus its financial and economic considerations have predominated so far, sometimes neglecting the resultant social consequences. But with the addition that this fact generally tends to become a meaningful subject since the role and importance of the employee is constantly changing.

How to evaluate a possible approach and how to manage promising tools are further topics which will be explained in the following Chapters. This thesis can help smaller-sized companies for getting an overview of upcoming developments and serves as a tool for technical and economic decisions. Another ambition is to propose possibilities and alternatives towards the digitization of production logistical processes by considering the role of the employee.

1 INTRODUCTION

Since the year 2005, the German government has been promoting research into fundamental aspects of cyber-physical systems and funded a collaborative research platform based on the national roadmap for embedded systems. Acatech, the German Academy of Science and Engineering published a strategic research agenda and created the German term “Industrie 4.0”. The result was defined by new strategies where an industrial process reacts autonomously and self-organized to the greatest possible extent because of using information technology in networking systems. Science and Industry Research Union describes Industry 4.0 as follows. Meaning the technical integration of cyber-physical systems in production and logistic by using the internet of things and their related services within industrial processes. Including their resulting consequences for value creation, business models, downstream services and work organization (Acatech 2011).

This paradigm shift is built on a basis where intelligent systems are totally integrated and cross-linked within an exceptional comprehensive production environment. The value chain is influenced by different factors like human labor, machines, facilities, logistical touch points, power provider, the consumer and the product itself (Reichl & Wolf 2001: 1888). All these elements are communicating and cooperating directly with each other. Therefore, the entire supply chain should be adaptive and controlled under a common framework to exploit synergies that haven´t been accessible before. Logistic in this respect, is one component with increasing importance as numerous service activities add value to the product (Freitag et al. 2004: 23). In context to above mentioned scenery the main questions are related to detect and locate the borderline between the physical and virtual transition and how these changes are influencing management processes. Furthermore, the meaning of new implementations related to restructuring measures is gaining increasing importance. It represents new challenges which require adequate supporting tools and methods to assess and clarify each individual situation. In fact, the working environment is influenced and exposed to changes, not least because of robotics and automation. The situation for employees and current ways of job and task related duties will adapt, also because of increasing collaboration with robots without any need of safety distances. The critical attitude of humans in context with the labor market trend makes the situation even more complicated and requires effective mitigating measures and coordinating mechanisms prior the event of a crisis based on the principles of Industry 4.0. Hence appropriate to take a closer look at this faded but meaningful subject in following Chapter 2.3 and 3.1. Integrated artificial intelligence in a cyber-physical system could be applied in daily life and will considerably become commonplace in smart factories to fulfill any upcoming deviant requirement. The control and planning of logistic related processes is facing more and more complexity. Certain decentralized advanced techniques, possessing both sensing and actuation capabilities will be developed by using adequate tools and designing methods. Another indispensable prerequisite for a flexible and effective use of Industry 4.0 is mainly related to data security and data protection. Above mentioned future changes will be realized in next time not least because enterprises expect a quantum leap in productivity, efficiency, flexibility and of course competitive advantage through the intelligent network of production relevant components. All reflecting to product customization which is described as the prioritized benefit for the B2B (Business to Business) and B2C (Business to Consumer) - Client. Not only large-scale enterprises will encounter this trend reversal but also small and medium-sized companies should cope to keep up with the economical movement.

2 FORMULATION OF SITUATION

The world has been changed over the last centuries by means of three industrial revolutions. Beginning mechanization and the invention of the first steam engine with separate condenser and rotary motion by James Watt initiated water and steam driven production facilities in the end of the 18^{th} century which changed the lifestyle of individuals. Away from agriculture, as the basis of life to developing cities where farmers became industrial workers. Thereafter, commercial use of electric energy replaced steam power within work-shared mass production lines in the beginning of the 20^{th} century. Rising importance of electric and chemical routines were creating unparalleled reference sectors. Conveyor systems used in slaughterhouses around Chicago served as the basis for Henry T. Ford´s invention by using assembly line conveyors to produce the Ford “T-Model”.

The third revolution follows in 1970 through the implementation of Electronics and Information Technology for further automation in production. This technology has been founded by Konrad Zuse. His and the world's first programmable computer named “Z3” was presented to the public in the city of Berlin in the year 1941. IT–processing systems have undergone a substantial boom over the last 70 years, also because of “Moore´s-Law” which inspired semiconductor companies to double the performance every second year. Respectively to its computing, storage and communication power the personal computer found its integration in many applications. The fourth revolution has already begun to emerge but this is only the beginning of Industry 4.0. It was already foreseeable that life would be even faster and more intense as global networking had created new general conditions. Mobility and virtual networks are making our world smaller, more transparent and faster than ever. It might be reasonably assumed that this fact is bearing both positive and negative effects on economy and society. Going further, life in fifty or even hundred years is still a blank sheet of paper and who dares to prophesy how we work, drive, live and love in distant future? On the contrary the prognosis for the nearest future is less transparent and adequately specified. In other words, the sheet of paper is amended to become at least a first draft (Feichtenberger 2016: 28). The visions and trends in divergent views are not infrequently drivers in the scholarship and research, in the economy and further in art and literature. Whatever the decision taken, the mobility in private and business lines will remain a decisive and crucial factor in any scenario. People´s possibility for being mobile and flexible quite frankly has brought enormous benefits for humanity. From then until now our industrialized world is programed on road and personal motorized transportation as seen all over the globe. More than 100 years of experience in the automotive industry, highly eventful times in shipping, rail, bus, truck and air traffic have created unprecedented ways to aggregate and combine content from different sources. The next decades will introduce intelligent roads and autonomous hovering vehicles, maneuvering in a congestion-free and eco-friendly manner (Feichtenberger 2016: 28). From this perspective, production and logistics are constantly adapting to an extent which has been evolved quickly in its dynamic history where each branch of industry contributes greatly to national economies by three principle reasons (Cassiman & Golovko 2007: 2), Productivity, Innovation and Export. From the vantage point of the present it can be assumed that productivity changes since working becomes smarter rather than harder. Innovation enables intelligent products and the global market, a wide range of business potential. The offensive begins with going-international, which represents the expansion of the export rate. However commendable and laudable the purpose behind, the future will tell to what extent above mentioned principles remain unchanged.

2.1 Working Environment Development

Subsequently the Internet of Things (IoT) already found and will continuously find its way to production 4.0. IoT in what may follow could easily stand for Internet of Thoughts where then all one's intents and wishes can be detected and stored, completely independently processed and if applicable executed or fulfilled (Zhang 2013: 223). Another description of a totally connected world calls it “IoX” which stands for Internet of everything, as our life becomes fully connected and virtual dependent. Current situation in production logistics is driven by dynamic and complex events. Internet economy, individualized customer orientation in a worldwide market shoot the number of e-commerce companies upwards and boosted the overall sales volume in online marketplaces (Scholz-Reiter et al. 2004: 1). From the logistical aspect, a simultaneous vaporization of payloads and increase of shipment frequency as well as higher transport volume has approached in this sector (Kuhn & Hellingrath 2002: 19). Those developments usually require novel planning-control methods and infrastructure expansions. Both are mostly related to new investments and limited to possibilities. Autonomous logistic processes can be nearly exclusively operated in a decentralized way of control in the form of a heterarchical organizational structure as widely ramified and distributed value chains complicate the supply of relevant data to only one central entity (Goldammer 2006: 11). The achievement of logistics performance figures shall be improved in an apparent way. In the first instance a sharp distinction between autonomous acting and conventionally managed processes must be drawn. With the objective to develop decentralized and heterarchical structures in contrast to existing measures. After verifying any new method, it seems appropriate to prove which process is more effective and profitable (Scholz-Reiter et al. 2004: 2).

2.2 Digital Industry

Decision functions in a smart manner are bearing huge potential and subsequently further integrated features. The decision-making responsibility is shifted to the logistic object itself. In this context of autonomous control, logistic objects are defined as material items or immaterial items (Windt et al. 2007: 572). Series of production parts, turning or milling machines, conveyors, gates, pallets and skids are classified as material items whereas a production or purchase order belongs to immaterial objects. If this two–tier model is equipped with RFID for identifying, GPS for locating and with appropriate software, an autonomous system can be formed (Böse & Lampe 2005: 62), where the workpiece communicates with tooling equipment, the market with the production, the production with suppliers and finally the machine itself communicates over the heads of the human beings (Reichl & Wolf 2001: 1888). This Cyber-Physical System uses process data and enables a tight connection between real-life condition and virtual computer systems (Lee & Seshia 2011: 12). IoT in combination with Big Data already found and will continuously find its way to a digitized environment which, by the way, has been formerly referred as the "Second Machine Age" in the American region.

Customer personalization down to lot size one is another task and condition in a rapidly changing market. Ongoing adaptions due to new technologies require the understanding of complex correlations. In line with the text above, one major focus within a cyber-physical process lies on the resources which should be used in a sustainable manner where energy consumption is reduced to a minimum and materials applied in an optimal efficient way (Bauernhansl et al. 2014: 16).

Divergent prognosis and statements from the industry and research come to the consensual assumption that smart and lean business models can and must contribute to the success of a company.

Figure 1, explains a possible future scenario for implementation of industry 4.0.

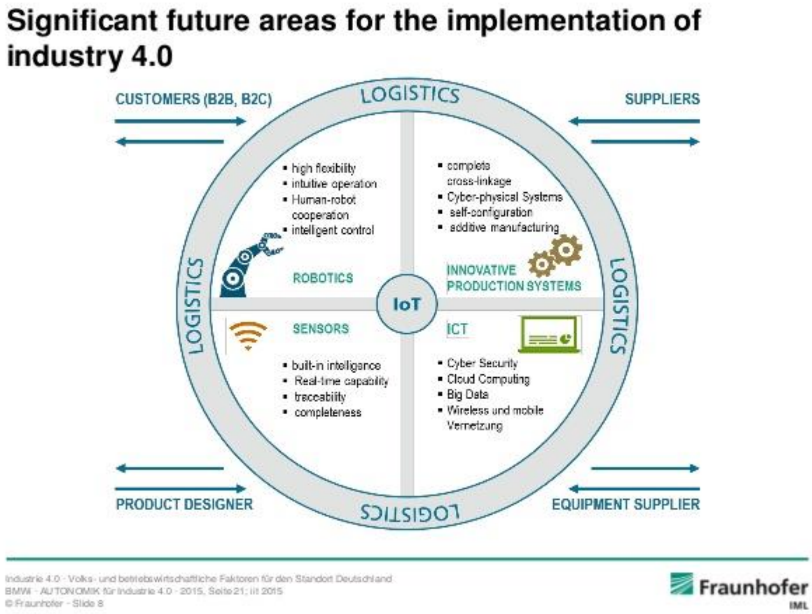

Fig. 1, Significant future areas for the implementation of industry 4.0 [1]

2.3 The Role of Employees

Human labor in the traditional sense has undergone a transformation in its concept and might become obsolete in wide fields of production because of automation. One factor here is that the simplest duties in workplaces having disappeared in our society. The performance gap between employed people is heavily increasing in such a way, that differences in salaries and wages payments for some people´s work is either enormously paid while others would in fact be more productive if they were not participating in the labor market at all. All digitization and related substantial social consequences to human beings can´t be properly predicted as of now but could be based on a fact since the requirements in education are changing tremendously quick. It is conceivable that just one learnt profession might not be sufficient to meet labor market demands and expectations, although the emphasis does vary somewhat because of the different business areas' own unique conditions. In general, it can be assumed that either a widespread or the combination with a targeted and specifically deep education and training on the job will be a significant success factor for companies and employees (Lorenz et al. 2015, IG Metall.de 2017). A general debate concentrates on topics comparing the effects and differences of automated work and human labor regarding societal impacts due to tax and contribution payments. Similarly, people assumingly fear an increase in unemployment because of robotics and automatization (Kögel et al. 2017). The risk of unemployment caused by technology can lead to a financial impoverishment of people and households as well as social impoverishment through the loss of work as a declared personal living content. One question thus arises as to why robots do not pay taxes, when compared to a person who performs the same task under compulsory taxation. This difference, with the intention to cover public expenditure, could cause a fundamental social injustice and seems to be further economically inefficient from the perspective of the public. Apart from that a future model might consider both types of value creation as to the continued existence of a welfare state. To alleviate social-regression effects, an assured basic income might become part of our future lifestyle (Kögel et al. 2017). From employee´s perspective, interpretative action tasks and meaningful goals in the working environment might be a considerable approach for a sustainable workplace. Broad qualified workforce and the statement, right people in the right positon, are well known themes in industry. Together with internal career progression the trail is blazed for the economic development of industry 4.0 in enterprises. It becomes more and more visible that a disruptive change of our economy and it´s real value output ratio goes far beyond of just a local technical optimization (Wolter et al. 2015). Therefore, everyone is affected to a certain degree. Either directly or indirectly in the role of beneficiary, originator and bystander of such a development. However, we can expect at least two potential effects which induce either high level of insecurity, especially in the context of employees and their tasks or a huge chance for those how keep up correctly positioned (Felser 2015). Scientific references to the work environment have been provided by Frey and Osborne, among others, and will be described in the following Chapter 3.1, below.

3 DESCRIPTION OF PRODUCTION LOGISTICAL ASPECTS

3.1 The Impact of Future Technologies

The employee´s diversity in this respect has been described in a study by Frey and Osborne, saying that up to fifty percent of jobs will disappear because of the digital trend reversal. Numbers of routine tasks can be easily automated but occupations that involve complex perception and social intelligence tasks are unlikely to be substituted by computer capital over the next decade. Those task characteristics can be described in form of a probability function. Figure below serves as a workable approach. It exemplifies different occupations, related degrees of susceptibility and how the probability of computerization might vary as a function of bottleneck variables (Frey & Osborne 2013: 27).

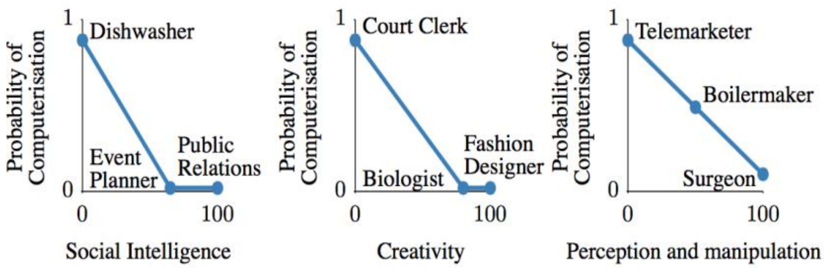

FIGURE I. A sketch of how the probability of computerisation might vary as a function of bottleneck variables.

Fig. 2a, A sketch of bottleneck variables [2]

In continuation, Frey and Osborne explain nine variables describing attributes derived from a survey conducted by the O-NET resource center, as shown in figure 2b. Respondents are given multiple scales with “importance” and “level” as the predominant pair. Relying on the level-rating which corresponds to specific examples about the capabilities required of computer-controlled equipment to perform the tasks of an occupation. For instance, in relation to the attribute “Manual Dexterity”, low level corresponds to e.g. “Screw a light bulb into a light socket”. Medium level is exemplified by “Pack fruits in crates as quickly as possible” and high level is described as “Perform open-heart surgery with surgical instruments”. This indicates a possible level of “Manual Dexterity” which a computer-controlled equipment would require to perform a specific task in an occupation. An exception is the “Cramped work space” variable, which measures the frequency of unstructured work (Frey & Osborne 2013. 31).

TABLE I. O∗NET variables that serve as indicators of bottlenecks to computerisation.

Computerisation bottleneck	O∗NET Variable	O∗NET Description
Perception and Manipulation	Finger Dexterity	The ability to make precisely coordinated movements of the fingers of one or both hands to grasp, manipulate, or assemble very small objects.
	Manual Dexterity	The ability to quickly move your hand, your hand together with your arm, or your two hands to grasp, manipulate, or assemble objects.
	Cramped Work Space, Awkward Positions	How often does this job require working in cramped work spaces that requires getting into awkward positions?
Creative Intelligence	Originality	The ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem.
	Fine Arts	Knowledge of theory and techniques required to compose, produce, and perform works of music, dance, visual arts, drama, and sculpture.
Social Intelligence	Social Perceptiveness	Being aware of others' reactions and understanding why they react as they do.
	Negotiation	Bringing others together and trying to reconcile differences.
	Persuasion	Persuading others to change their minds or behavior.
	Assisting and Caring for Others	Providing personal assistance, medical attention, emotional support, or other personal care to others such as coworkers, customers, or patients.

Fig. 2b, O*NET variables [3]

To classify a potential automatable event, Frey and Osborne developed a classification method based on 702 occupations. By examining the accuracy of subjective assessments an algorithm provides the label probability given a previously unseen vector of variables. Above plotted O-NET variables supply a complete dataset of 702 “feature vectors” (Frey & Osborne 2013: 32).

Discriminant probability function:

(1.) $$P(y* = 1 \mid f*) = \frac{1}{1+\exp(-f*)}$$

$$P(y* = 0 \mid f*) = 1 - P(y* = 1 \mid f*)$$

For $f* > 0, y* = 1$ is more probable than $y* = 0$

Three different models are tested for the discriminant function using the best performing for further analysis. Firstly, logistic (or logit) regression, which adopts a linear model for $f, f(x) = w^{\top} x$, where the unknown weights are often inferred by maximizing their probability considering the training data. This simple model necessarily implies a simple monotonic relationship between features and the probability of the class taking a particular value. Richer models are provided by Gaussian Process (GP) classifiers (Rasmussen and Williams 2006). Such classifiers model the latent function f with a Gaussian process, a non-parametric probability distribution over functions which is defined as a distribution over the functions $f : X \to \mathbb{R}$ such that the distribution over the possible function values on any finite subset of X $(such\ as\ X)$ is multivariate Gaussian.

For a function $f(x)$, the prior distribution over its values $\underline{f}$ on a subset $\underline{x} \subset X$ are completely specified by a covariance matrix K.

(2.) $$p(\underline{f} \mid K) = N(\underline{f};\ \underline{0}, K) = \frac{1}{\sqrt{det\ 2\pi K}}\ exp\left(-\frac{1}{2}\ \underline{f}^{\top}\ K^{-1}\ \underline{f}\right)$$

The covariance matrix is generated by a covariance function $\kappa : X \times X \to \mathbb{R}$ that is, $K = \kappa(X, X)$. The GP model is expressed by the choice of κ, considering the exponentiated quadratic (squared exponential) and rational quadratic. Note that we have chosen a zero-mean function, encoding the assumption that $P(y* = 1) = \frac{1}{2}$ sufficiently far from training data. Given training data D, we use the GP to make predictions about the function values $f*$ at input $\underline{x}*$. With this information, the predictive equations are as follows (Frey & Osborne 2013: 33):

(3.) $$p\,(f* \mid \underline{x}*, D) = N\,(f*; m(f* \mid \underline{x}*, D), V(f* \mid \underline{x}*, D))$$

(4.) $$m(f* \mid \underline{x}*, D) = K(\underline{x}*, X)\, K(X, X)^{-1}\, \underline{y}$$

(5.) $$V\,(f* \mid \underline{x}*, D) = K(\underline{x}*, x*) - K(\underline{x}*, X)\, K(X, X)^{-1}\, K(X, \underline{x}*)$$

(6) $$P(z* = 1 \mid f*) = \frac{1}{1 + exp(-f*)}$$

3.2 Autonomy in Logistical Processes

Autonomous control and collaboration requires a dissociation from conventionally managed logistic items as intelligent objects can interact, process, render and execute decisions with other sub-systems because of an own decentralized target system. Different levels of autonomy can characterize and assign the specific task to different layers of work in an enterprise (Windt et al. 2007: 572). The progressing automation of logistical processes, particularly when it comes to warehousing, classification, packaging and shipping, makes processes faster and more reliable. These enhancements were accompanied by new warehouse technologies, e.g. RF Scanners, with pick-by-light/ -vision/ -voice/ -point/ -RFID and RFID labeling, shown in figure 3a, b, c (Swisslog 2017). Order-picking is the most labor-intensive activity in many warehouses. Each time an item is put down, means that it must be picked up again sometime later which is double handling. Travel can be reduced by carefully appointed put-away procedures (Bartholdi & Hackman 2014: 24).

Fig. 3a, Pick-by-Vision [4]

Fig. 3b, Pick-by-Light [5]

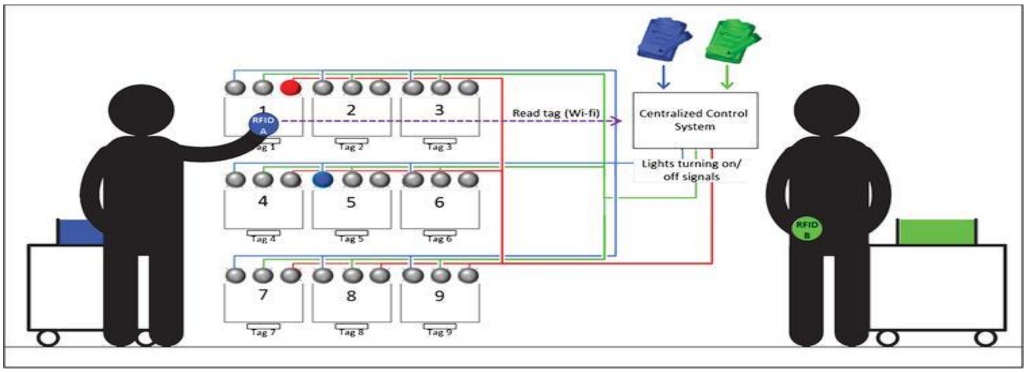

Fig. 3c, Pick-by-RFID [6]

Material savings and cycle time reduction are decisive economy factors which can be further improved by quick and error-free imaging of signals, the reading capability of various document formats, a very low validation rate and automatic assigning to the respective practices. More frequent automatic type change and the parameterization that comes with the production of smaller batches relieves employees from their workload. Intuitive handling guarantees short times of implementation and includes developing production technology that is tailored to the market volume and that also facilitates the performance of these activities. Further findings on agent-based reconfigurability in the conversion of a customer order into the product and its technical adaptation to unplanned deviations in earlier production steps are described by Pantförder (Pantförder et al. 2014: 145). In accordance with Rohpol´s description, different layers of work can be classified in organization and management, information and control methods and in material flow and logistics where each layer comprises a sub-system of information, decision and execution (Rohpol 2009: 101). Figure 3d, presents the assignment of the characteristics to the system layers, their correlations and decision making ability (Windt et al. 2007: 575).

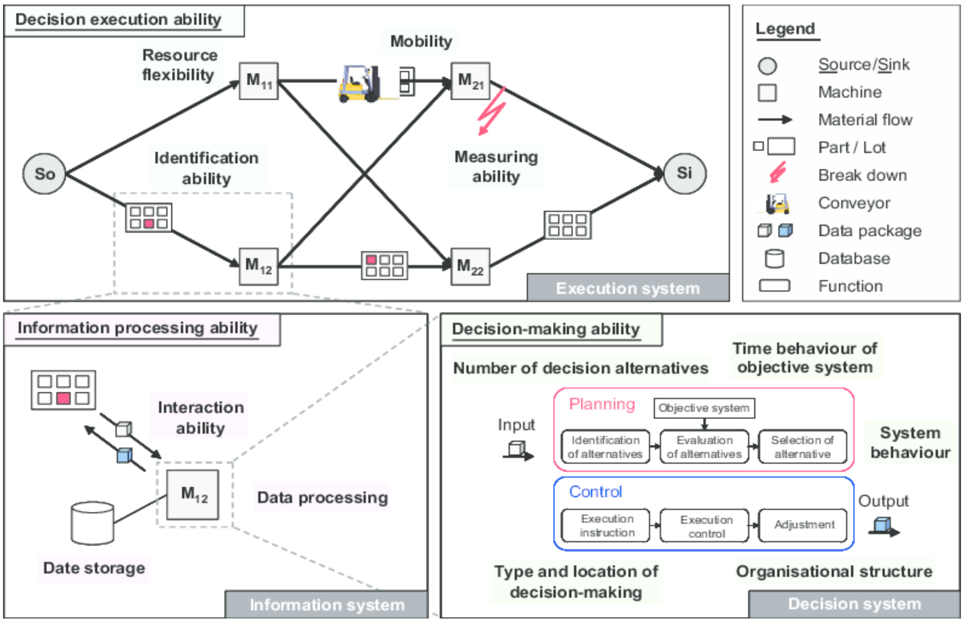

Fig. 3d, System layers and criteria of autonomous control [7]

The decision functions in an autonomous controlled production which contain planning and control tasks are shifted to the individual object and enable logistic items to create own checks and corrections and hence their progression (Windt et al. 2007: 575). A decentralized objective system includes the identification and evaluation of the best rated alternatives. The catalogue of criteria, developed and applied on a job - shop scenario comprises several points that are required for increasing the level of autonomy in a logistic system (Windt et al. 2007: 575). Based on figure 3d, an autonomously controlled production logistics scenario involves three systems and their related criteria, as listed below:

1. *Criteria of Information system:*
   - Decentralized data processing: a machine "M_{12}" processes the sensor data and informs other logistic objects about its breakdown.
   - Coordination of other parts: a part can determine the machining sequence of the complete lot.
   - Decentralized data storage: each part contains its relevant order data.
2. *Criteria of Decision system:*
   - Rule-based decision making: parts render their own decisions by using appropriate decision rules, e.g. choose machine with lowest utilization.
   - Decision alternatives: parts can choose the next stage of production.
   - Dynamic local objective system: adaption of the objective system of machine "M_{22}" because of the breakdown of machine "M_{21}", e.g. low-stock, high utilization.
3. *Criteria of Execution system:*
   - Flexible Processing: parts can identify their position and call for a conveyor.
   - Identifiable Objects: Conveyors can identify parts.
   - Measuring Ability: the assembling machine recognizes its breakdown via sensors.

Complex and customized manufacturing requires high level of collaboration between production and logistics in a flexible production system. One applied method for solving the complexity of workflows can be the use of e.g. a Colored Petri Net (CP-nets or CPN´s) which is a graphical language for constructing models of concurrent systems for analyzing their properties.
CPN tools have been developed et al. at Aarhus University, Denmark since the year 2000. Per description of the Department of Computer Science, CP-nets are a supplement to existing modelling languages and methodologies and can be used together with these or integrated into them. Typical application domains are communication protocols, data networks, distributed algorithms, embedded systems, business processes, workflows, manufacturing systems, and multi-agent systems. CPN models

are used to model and specify the behavior of concurrent and distributed systems. An interactive simulation provides a way to “walk through” a CPN model, investigating different scenarios in detail and checking whether the model works as expected. CP-nets include a concept of time that makes it possible to capture the time taken by events in the system. This means that CP-nets can be applied to simulation-based performance analysis, where performance measures such as delays, throughput, and queue lengths in the system are investigated (Jensen, 2010).

3.3 First Approaches towards Logistics 4.0

Some of the advantages in actual and upcoming trends which have become noticeable in logistics can be found e.g. in the Trend Radar Report by DHL.

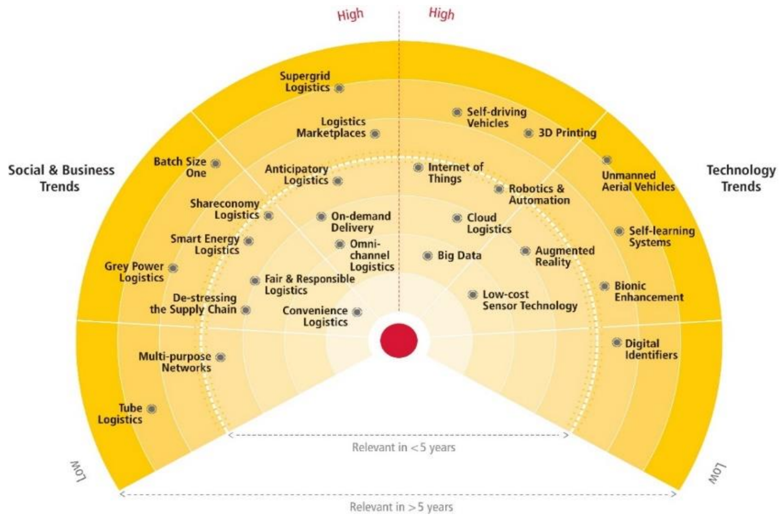

Fig. 4a, Trend radar [8]

A broad selection of technologies is guiding distributed systems with decentralized control paradigms towards logistics 4.0. The intelligence of distributed multi-agent systems in real world applications induce the reversal in logistical processes. Communication technology, miniaturized embedded systems and semantic information integration is shaping the future of transportation (Jeschke 2014: 4).

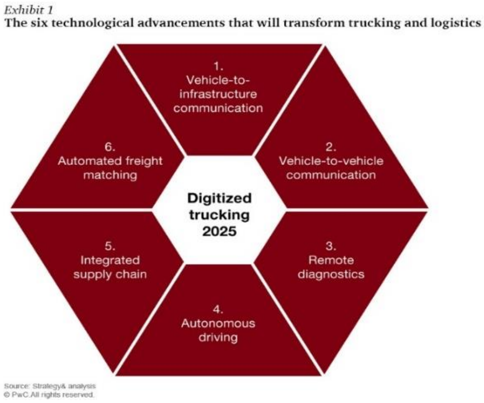

Fig. 4b, Technological advancements [9]

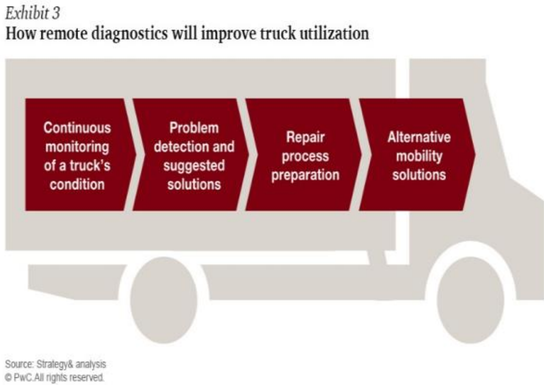

Fig. 4c, Remote diagnostics [10]

Beginning with cloud-based applications and technical upgrades on existing vehicles, the strategy continues with fully autonomous vehicles, delivery by drone systems and robot-, truck-platooning. The trend proceeds in form of autonomous swarm technology for intralogistical processing in warehousing or the creation of rail bound capsules for transportation of goods and persons (Jeschke 2014: 25). Current opportunities which can be implemented in the transportation process are seen in form of informational data transfer and communication between: human-operated vehicles and aircrafts, self-driving vehicles, freight items, customers and the head office. Figure 4b, c, show a possibility for truck improvements in the short term.
Considering the growing e- commerce business, a possibility for solving the challenges within the cost-intensive last mile connectivity can be improved and realized e.g. by following ways, shown in figure 4d, e, below. Related insights covering this topic could be observed, et al. in the published book “City Distribution and Urban Freight Transport: Multiple Perspectives” by Macharis & Melo, 2011.

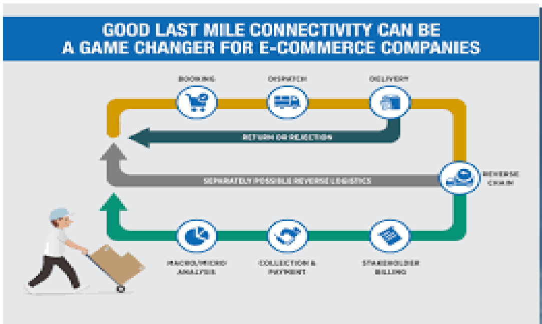

Fig. 4d, Last mile connectivity [11]

Fig. 4e, Drone transport [12]

Fig. 4f, Cargo Capsules [13]

Fig. 4g, Robot mail delivery [14]

3.4 Analysis on Central - European Market

Boston Consulting Group (BCG) demonstrates the variety of ways in which manufacturers will use new technologies for value creation and promises hundreds of thousands new employment opportunities by Industry 4.0. A special focus on the development in Germany with respect to the labor market trend is explained in figure 5a, below. This prognosis most likely expects a workforce growth also in logistics. Whereby this base-case scenario defines the greatest potential benefits in terms of growth in Information Technology, Analytics and Research & Development.

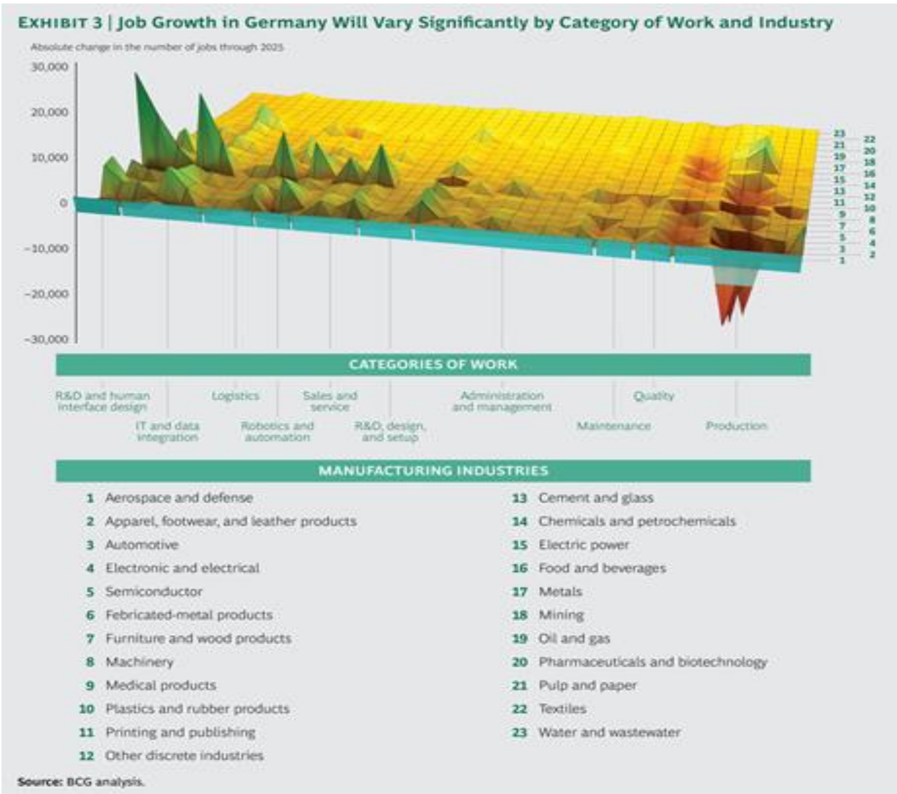

Fig. 5a, Prognosis of job growth in Germany [15]

As expressed in figure 5b, the statistical model by BCG describes the differences between Germany and the United States. It predicts the needs to adaption, the challenges and its possible achievements related to the implementation of industry 4.0-measures and concepts.

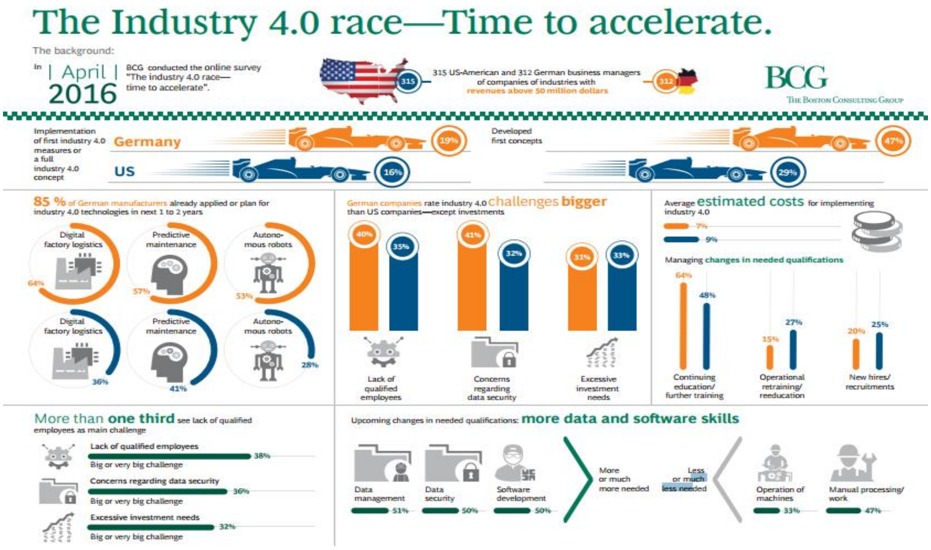

Fig. 5b. Comparison between Germany and U.S. [16]

Forecasts by Fraunhofer SAO, inter alia deal with subjects focused on the humanization of workplaces and the collaboration between humans and machines. Improved health and social conditions enhance employee's productivity. Fraunhofer experts determine key figures with one consent. The potential change and growth due to new technologies will influence the German economy in following ways, as plotted in figure 5c. The McKinsey Global Institute, figure 5d, observed the European digitization potential and compared the results to the U.S. market. When comparing two regions, it became apparent that only a small percentage of digitization was captured yet.

Fig. 5c, Prognosis on Germany [17]

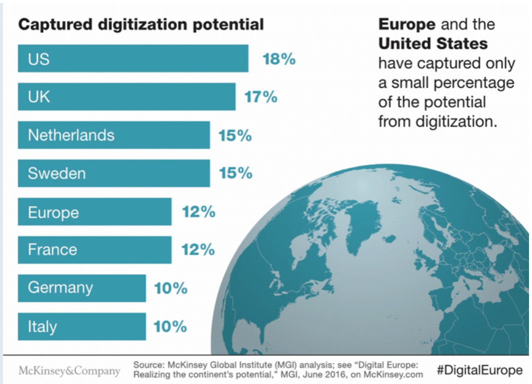

Fig. 5d, Prognosis on Europe and U.S. [18]

3.5 Information and Communication Technology (ICT) in Production Logistics

Enterprises are exposed to uncertain and rapidly changing business conditions. Often forced to change their traditional operational and organizational management style which tends to be replaced by integrated ICT-systems for pushing the speed and fluidity of physical and informational flows on different process levels. But also, to make the communication among organizations more efficient and capture the firm´s competitive advantage. The flow of information has been recognized alongside the importance of material flow in the logistics channel (Dawe 1994: 229). Product identification is realized by using information and integrated circuit technologies such as Radio Frequency Identification (RFID) (Kumar et al. 2006: 57), wireless based data networks, radio data transmission or barcode reading. Digital image and pattern recognition, Near Field Communication (NFC) are further common concepts for implementation (Twist 2005: 226, Choy et al. 2007: 19). Any of those techniques create large amounts of data which means that data collection and data exchange are critical for information management and control. Better and more accurate data acquisition in logistics field, such as optical scanning, the electronic pen notepads, voice recognition and robotics help firms to perform properly regarding the customers' needs (Lin 2006: 257, Dawe 1994: 230). This may only succeed by using Big Data to recognize patterns and analyze trends where algorithms enable ongoing optimizations in process modules. The McKinsey Global Institute et al. defines big data as large pools of data that can be captured, communicated, aggregated, stored, and analyzed (McKinsey 2011). Big data is remarkably diverse in terms of sources, data types, and entities. Accordingly, the concept of Big Data-Analytics refers to newly developed methods for analyzing large and complex data volumes. Advanced analytics assist companies to discover new customer segments, identify best suppliers, associate products of affinity and understand sales seasonality. Analytic databases and big data analysis can be used, so that users can make intelligent decisions as they embrace analytic procedures (Russom 2011: 5). In any event, an intelligent system is capable to act and control itself meaning that an item design it´s input-, throughput and output profile as an anticipative or reactive answer to changing constraints of environmental parameters (Freitag et al. 2004: 23).

Concurrently, the published concept by Robert Metcalfe (Metcalf´s Law 1980) implies, that the gain of a communication system will grow with the square as the number of participants increase. The more connected, also across company-boundaries, the stronger is the value increase and the higher is the ability to compete. A decentral -organized logistic and supply chain for example, contributes towards flexibility which is increasingly regarded as a core competence of today´s logistic. Flexible autonomous reaction on concept changes, high global transparency and automation could positively affect the rather negatively connoted cost causation of logistic workflows in the product manufacturing process (Günthner & Hompel 2010: 15). Major intralogistical coordinating functions which monitor and manage the internal delivery flow or any movement of goods from storage to dispatch is potentially influenced by cyber-physical systems, with its further potential to affect the the value adding in a positive and constructive manner (Arnold et al. 2008: 36). In this regard, the reference for potential savings in intralogistical processes has been discovered and characterized by Taiichi Ohno (Ohno 1988) who designed and implemented the Toyota Production System (TPS) already in the early 1970´s.

He combined principles and methods which increased the production flexibility, saved costs by lowering warehouse capacities and by avoiding prodigality in any process. Lean production was and is still a most favorable management solution. The basis of Ohno's TPS is the Kanban system which transforms a "PUSH" into a "PULL" system, which was further defined by Hopp and Spearman in the following description: *"A pull production system is one that explicitly limits the amount of work in process that can be in the system whereas a push production system is one that has no explicit limit on the amount of work in process that can be in the system"* (Hopp & Spearman 2004). The success of TPS offers also in today´s companies the possibility of cost reduction up to 70 percent. Reducing material stocks and throughput time leads to a 25 percent higher productivity compared to other production systems (Dickmann 2009: 19). An ICT system needs unified standardized interfaces or special technical features to encrypt and adjust the signals during the integration of sensors and machines in a CPS which is one prerequisite for bringing the results on a satisfactory level. At the same time, by using cross–company platforms also mean that the unprecedented pervasion of ITC bears risks around companies' data protection and data security. This explains, why to consider new security concepts and architectures to safeguard Cyber-Physical Production Systems (CPPS) and their communication connections (Broy 2010: 19). When further talking about ICT, it needs a mutual common understanding of joint business models, networked services or the integration of value adding chains for all markets and parties involved. Therefore, the methodical approach should be also consolidated and standardized (Sontow 2016). Summarizing the impact of ICT on transportation procedures, the report by Crowley stated three general parameters which are influencing (Crowley 1998: 547):

1. the nature of goods being transported, because of increasing data content,
2. the transport firm itself, because of new management and control tools and
3. the entire supply chain, because ICT has improved and redefined the role of freight transportation.

3.6 Cyber - Physical System (CPS)

The term Cyber - Physical System (CPS) was characterized by Edward Ashford Lee and Sanjit A. Seshia in the year 2006. The research of invisible embedded computer systems and the vision of ubiquitous computing by Mark Weiser already started in 1991 with his article *"The Computer of the 21st Century – The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.."* (Weiser 1991).

Lee describes the CPS as follows: *"Cyber–physical systems (CPS) are integrations of computation and physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa"* (Lee 2008).

CPS comprises a variety of used mobile and embedded devices combining computer technical and physical aspects together with sensor and actor technology (Broy 2006: 72). Smartphones, tablets, other wearables but also automotive On-Board Diagnosis (OBD), GPS–navigation plus traffic guidance or RFID-, NFC-systems enable the dialogue and connection to mobile cyber-physical systems (Finkenzeller 2015: 625).

Via sensors, a CPS can detect a defined physical status. This readout will be forwarded and processed in a format to be used for web-based network services. Actors, in turn can then directly influence a process by initiating physical actions. Meaning that the real and virtual environment merge to form a cyberspace including techniques of ubiquitous and pervasive computing (Fleisch et al. 2003: 29). In its early stages CPS technology mostly exists for certain and specified requirements, often regarding to system prerequisites during the installation, operation and maintenance processes. Nowadays embedded systems affect nearly everything and everyone. Some of the examples of recurrent fields of application are listed below (SIT Fraunhofer 2016):

- *Avionics and Air Cargo Transportation:*

Airplanes and other transport systems depend on information technology to realize functions such as fly-by-wire or the interlocking control. One trend in the air cargo sector describes the term Cyber-Physical Aviation which characterizes a merger plan of standardized interfaces on physical and control processes. Within an air transport system, the developer, manufacturer, operator and customer can communicate and interact continuously with each other. Localized transformation processes can be enabled via data receiving over the interface between aircraft, respectively its shipment and the cargo agents. Therefore, all components and handling devices will possess its own intelligence and communication capability which provides digital, discrete and real-time continuous information flow over wireless technologies. Advantageous for high flexibility and the prevention of bottlenecks as decisions and reorganizational steps can be taken just in time on a reliable information basis (God & Wittke 2016).

- *Automotive:*

Information technology is an integral part of modern vehicles and encompasses safety critical functions like automatic braking, driver assistance functions up to fully autonomous vehicles. All these applications run on a distributed Electronics and Electrical (E/E) architecture and often consists of hundreds of programmable Electronic Control Units (ECU´s) that are interconnected with each other and the environment to facilitate new functions for increasing safety and efficiency as well as for information and entertainment.

- *Healthcare:*

Electronic devices used for medical treatment, diagnostic investigation and minimal invasive surgery help patients in all stages of their illness and can support medical examinations through data analysis for efficient decision making. Active and passive user input such as smart feedback system or biosensors assist when patients require long-term therapies or when delivering treatment results, both in hospital or at home by remotely monitoring the vital values.

- *Smart Grid and Smart Home:*

Comprehensive networks and optimal network utilization guarantees a continuous energy flow to the user. In view of renewable energies, smart meters and other devices will manage and facilitate an efficient and reliable electrical power supply. For instance, smart homes but also production cells will be connected and remotely controlled. Automatic evaluated time setting can start and stop devices and machines to enhance efficient use of electricity with respect to network utilization, living quality and safety. A high-level view of a cyber-physical analytics platform with self-learning capabilities is illustrated in figure 6a, below. Including different physical aspects for selection and consideration of the respective cyber-physical platform (Kao et al. 2014: 98).

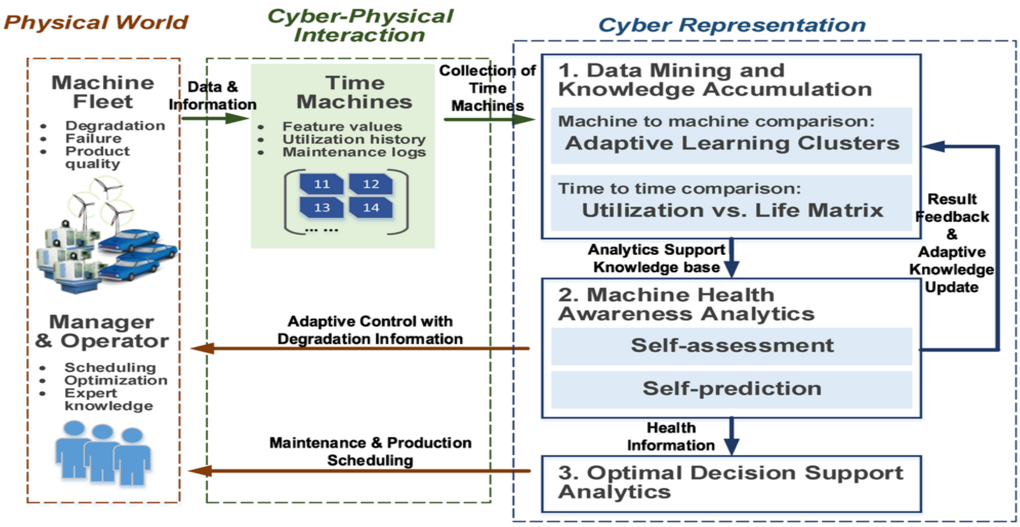

Fig. 6a, Cyber - Physical interaction [19]

A weighty ascertainment by leading researchers declare CPS as the fundamental basis of autonomy in production logistics. In addition, the correct understanding of autonomous control is important and explained in the following way:

"Autonomous Control describes processes of decentralized decision – making in heterarchical structures. It presumes interacting elements in non – deterministic systems, which possess the capability and possibility to render decisions independently. The objective is the achievement of increased robustness and positive emergence of the total system due to distributed and flexible coping with dynamics and complexity. Autonomous control in logistics systems is characterized by the ability of logistic objects to process information, to render and to execute decisions on their own" (Hülsmann & Windt 2007: 573).

While plant wide automation-techniques include the technical process and its dynamical behavior, the CPS starts upon that point where sensors and actuators are applied and deliver discrete binary data flow. CPS further reaches far beyond the borders of Enterprise Resource Planning (ERP) and integrate divergent standards form different sources over the internet. That step of overarching networking is per statements from the industry only partially realized and limited to the highest levels of Manufacturing Execution Systems (MES) (Broy 2010: 23). In fact, companies still use a plurality of intercommunicating software and IT-systems coincidently because of limited interconnectivity due to differing semantic properties which prohibit data integration in Supply Chain Management (Stadtler 2005). The observed heterogeneity is one of the most challenging and important factors during the implementation of cyber-physical systems in any real-life application (Sztipanovits et al. 2012). On the other hand, the pervasive use of security critical and privacy sensitive data turns these systems into attractive targets for all kind of software attacks (e.g. Viruses and Trojans) and hardware attacks (e.g. side channel attacks) that may have serious consequences on the individual's privacy, life and property. In this context, great efforts have been provided by e.g. SIT Fraunhofer, that exercises intensive research on security and data protection and their communication channels.

It might be with this aim in view often an overstraining agony for the end user who is firstly exposed to cyber-attacks of fraudulent background and secondly recurrent unable to protect himself. Specific embedded features like real time capability, physical accessibility and related resource constraints under which these services have ceased functioning may only be realized with the implementation of appropriate safety precautions which should be developed and implemented already in the earliest design phase. Manufacturers are now taking enhanced security measures of entire networks, platforms and the application itself into their consideration. But also within the architectural and technological level in the platform security area by using hardware based solutions as originally certified and approved components are applied to guarantee an impeccable function (SIT Fraunhofer 2016). New technologies in regenerative production of energy, like solar and wind power expedite the development in this sector. Storage of energy, energy recuperation by electricity from waste heat, energy harvesting and the use of super capacitors contribute their share to efficiency. Redox flow batteries (RFB) represent one class of electrochemical energy storage devices. High efficient and long lasting batteries which can scale the power independent of the battery capacity because of storing the electrolytic energy in external tanks. Mobile container cells could be placed at many locations wherever electric power is produced, buffered or drawn. Realized combinations of green plants with attached Redox Flow Battery technologies are promising a major step towards eco-friendly autonomy in areas using electricity, also remotely independent from the power network (Alotto et al. 2014). Another CPS example in the energy sector shows the assumingly system change in future. Not a single central power plant provides energy but a multiple number of decentralized providers are configuring an interlinked system, as shown in figure 6b.

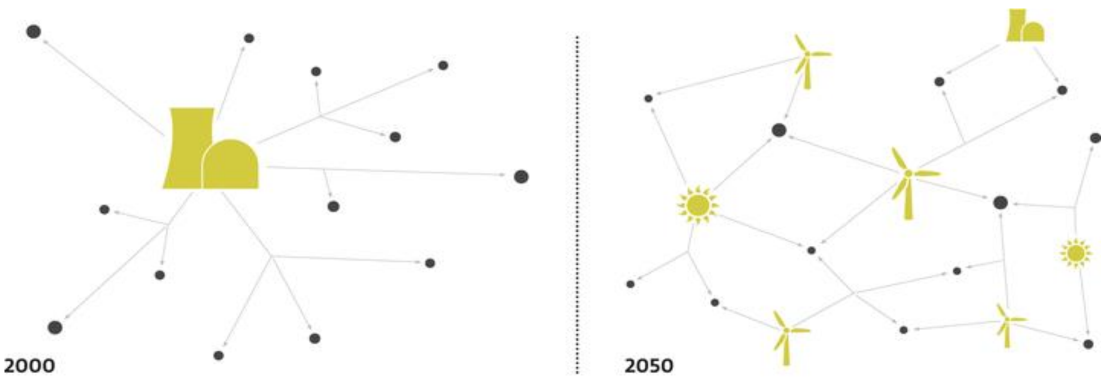

Fig. 6b, System change through decentralization [20]

In generally it should be noted that the principles of embedded systems in close connection with CPS´s possess versatile and promising attempts and represent the foundation for anything becoming entitled “Smart”. Manfred Broy reported, that all these themes are closely connected to the overall aim of totally mastering Cyber-Physical Systems in view of quality, cost and time-to-market movements (Broy 2006). When designing a CPS for different machine systems in industrial environment, it is most of the time problematical to attain the highest levels immediately, since this process includes different levels of technical implementations. An overview of a hierarchical architecture for CPS value proposition is shown in figure 6c below, which focuses on how to enable physical machines to utilize data and information from the lowest connection and data-to-information level upwards to its highest level through adding advanced analytical and resilient functions (Kao et al. 2014: 96).

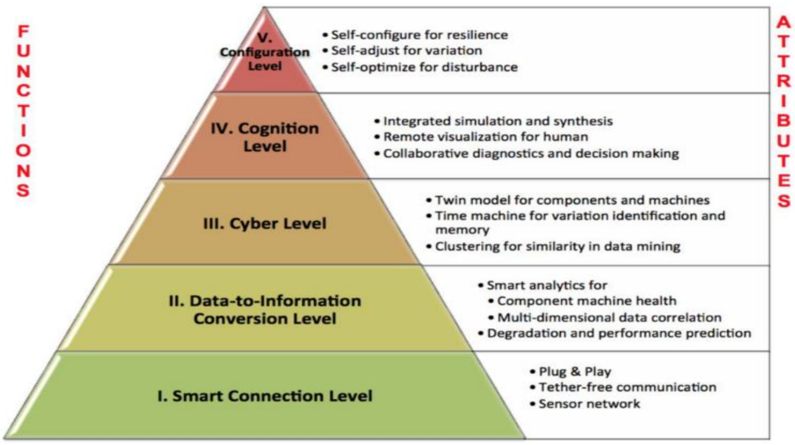

Fig. 6c, CPS value proposition [21]

3.7 Economic Reasons Underlying the Merger of Complementary Products: Enterprise Resource Planning (ERP) and Manufacturing Execution System (MES)

ERP usually comprises software solutions in cross-functional business administration processes with the aim to control uniformly and evaluate data obtained at the enterprise level. It can manage and synchronize data between remote databases and across platforms both inside and outside the firm which makes it a prominent tool for controlling and steering actions. Departments like finance and controlling, distribution, logistics and human resources can be selected and discretionarily controlled (Gunson & De Blasis 2001: 13).

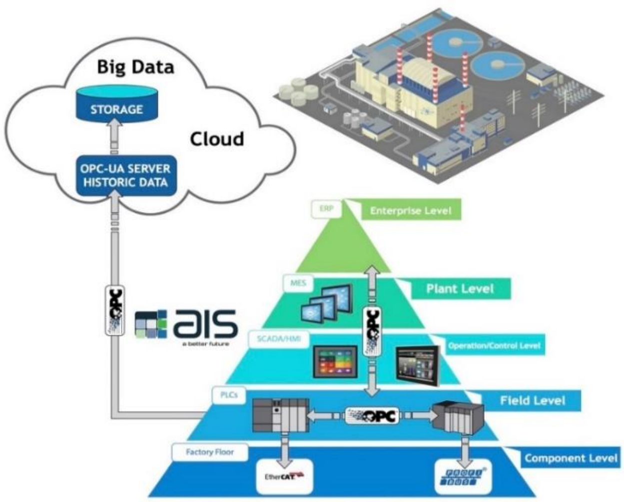

Fig. 7a, Extended automation pyramid [22]

MES represents a steering and controlling system but with the focus on the production and its current Work In Progress (WIP). It dispatches dates, stock levels of components and raw materials. This plant-level system serves to attain and preserve an overview about the condition of reconfigurable production (Koren 2010). It displays real time manufacturing information of latest data received from machines, robots and employees. The objective is to shorten cycle times and increase the throughput capacity (Bauernhansl et al. 2014: 27). A logical consequence in the ICT context might be the combined usage of ERP and MES that are designed to optimize business workflows and enhance production processes (Bauernhansl et al. 2014: 26).

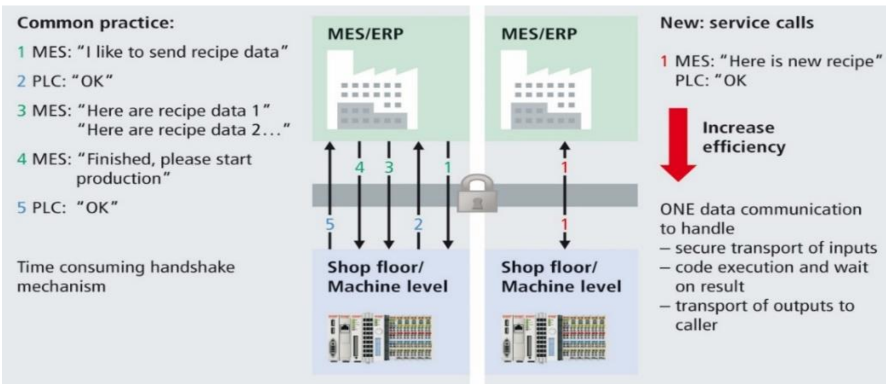

Fig. 7b, MES and ERP future change [23]

The benefit for the user at the control console is not only the ability for a proactive contribution but also to ensure cost efficient production and prompt delivery of quality products. With digitized production, the structure of the conventional automation pyramid will be altered and transformed to a newly designed network, as shown in figure 7c, below.

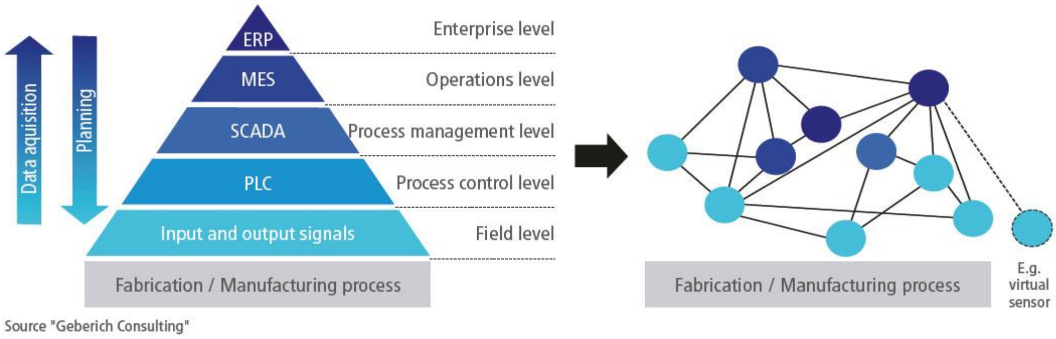

Fig. 7c, Pyramid transformation process [24]

Generally, it can be noted that *Automation has been divided into three levels:*

1. The level of Automation itself,
2. MES–level,
3. and the ERP-level.

Within these three levels, divergent planning and execution processes take place. Certainly, it can be observed that the management would most appreciate if all levels are permeably designed to ensure a simultaneous vertical and horizontal flow of information (Bauernhansl et al. 2014: 26). That requires standardized interfaces which might become the bottleneck in an unequal highly integrated system. However, the classical pyramid will be amended in a way where the function of an individual component will be capsuled and provided within the structure of a service oriented net. Additional focus is put on the archiving of task management data but also on the lifecycle of the product and on production technologies.
Meaning that a product and its related production technology, which is probably based on a joint platform, must be (Eigner & Stelzer 2009: 10):

1. designed, developed, optimized, evaluated,
2. produced and placed on market, sold,
3. used, “to be serviced”
4. and recycled or scrapped.

Above described cycle of four major categories applies to the entire manufacturing factory which is also designed, engineered, maintained and optimized over a certain lifespan.

For the sake of completeness, it is worth mentioning that companies e.g. like Siemens are additionally integrating the Product-Life-Cycle Management (PLM) function in its software, as shown in figure 7d.

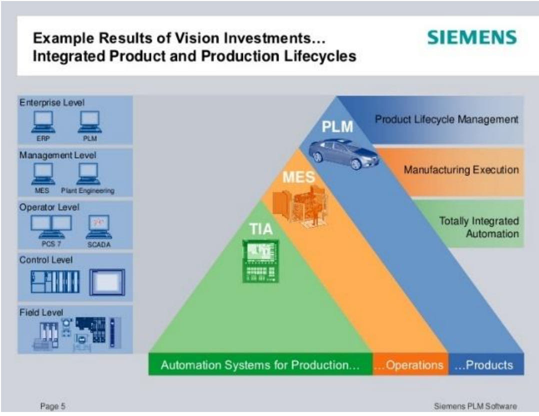

Fig. 7d, Siemens PLM Software [25]

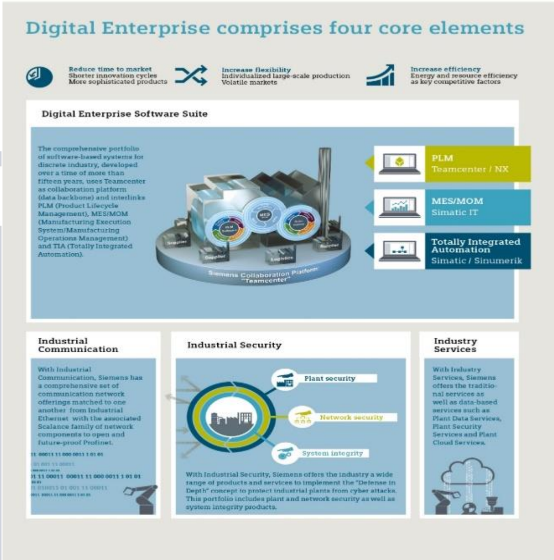

Fig. 7e, Siemens Platform [26]

Siemens announced the four core elements in a digital company, as shown in figure 7e, and serves the market with a variety of tailored solutions. It highlights the collaboration platform and hence the importance of connecting holistic data sources within the companies' network. The logistics service industry is going to rethink the meaning of ERP and MES combinations in their processes (Industrie-Informatik 2014).

3.8 Total Integration of Digital Data in Production Logistics

At present, many companies are in an aqueous phase to interpret and handle the theme Logistic 4.0. Firms are locating that topic somewhere in between marketing and future trend. By following two major marks like comprehensive digitization of physical items and the principles of decentralization, the main idea of using data as a value driver with its capability to develop new market strategies or to transform existing ones to revised ones can be permeably achieved (Bauernhansl et al. 2014: 12). One reason for Small and Medium Sized Enterprises (SME´s) for adapting to the changing market demand is to get in closer proximity to the customer. More responsibility is given to related divisions respectively for their own freedom of action.

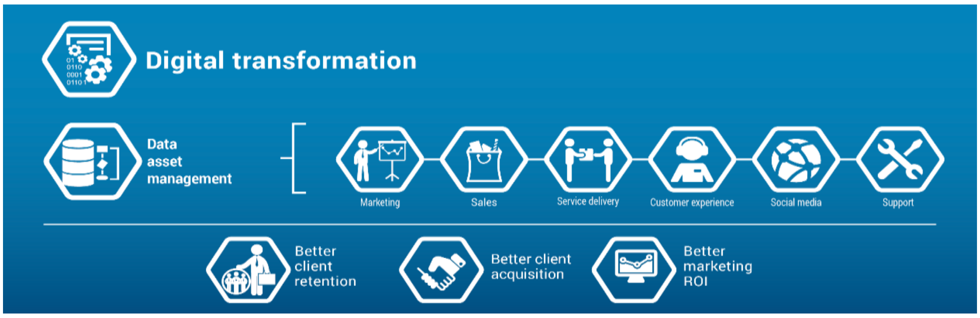

Fig. 8a, Digital transformation [27]

Responsibility, in this context is very important to obtain. To make this term explicit and more precise, an illuminating insight may be gathered by U.S. Admiral Hyman G. Rickover´s statement:

"Responsibility is a unique concept; it can only reside and inhere within a single individual. You may delegate it but it is still with you. You may share it with others but your portion is not diminished. You many disclaim it but you cannot divest yourself of it. Even if you do not recognize it or admit its presence, you cannot escape it. If the responsibility is rightfully yours, no evasion or ignorance or passing the blame can shift the burden to someone else." (Rickover 1932).

More of such thoughts and principles of defect preventing methods during implementations are based on the published book "The Zero Defects Option-How To Get Your People To Do Things Right" by the Author Dave Crosby (Crosby 2008). Agreed targets like high level of service and short delivery times elated SME´s to intensify the cooperation with customers to ensure or to achieve greater customer satisfaction and enhanced customer loyalty. SME´s in general are characterized by its flexibility, clear delimitation of tasks, flat hierarchies and its tendency to environmental awareness. These conditions are rated as a useful advantage to improve competitiveness, reduce macroeconomic imbalances and enhance labor market performance (BMWi 2015). Digital transformation can be understood as the consistent interlink between economic sectors, all actors of partnership and its adaption to the changing condition in digital economy. Figure 8b, explains possible steps and states of digitization.

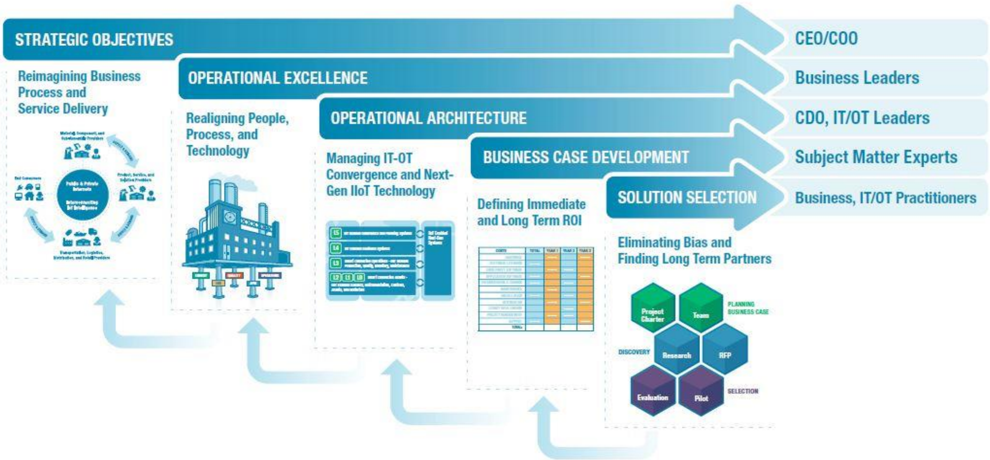

Fig. 8b, Transformation process [28]

Areas of production, logistic, transportation, agriculture and livestock farming belong to the central strategic field of action and should be put in relation to further *Sub-divisions which enable the transformation process (Berger 2015):*

- The degree of "e-Maturity" in an enterprise defines the digital mentality and its level of sensitivity to the subject of digital implementations applied. Besides the usual mentioned potential for enhancing efficiency, measures are also required within in-house optimization and the use of previously unused opportunities. For evaluating such possibilities, a firm should increase the level of e-maturity and their confidence in the digital environment. More important steps in that direction can be realized by a better penetration of digital solutions and a correct understanding of how the competition rules to the area of digital markets are changing in order to optimize business relations and to realize new chances.
- Common standards which are regulated, implemented and coordinated in a strong global infrastructure ensure future competitiveness through the existing industrial expertise. Standards and data exchange platforms are only effective if they can be used comprehensively and secure. A full-coverage broad band supply is the backbone for comprehensive and secure linking of data. The consistent service quality for business-critical applications and governmental advancement programs possess the potential for creating strategic alliances.

The "Four Levers of Digital Transformation" act as the core function in this progress which consists of Automation, Digital Data, Connectivity and Digital Customer Connectivity (Berger 2015).

Innovative enabler technologies and propositions serve the core competency in form of supporting columns, as shown in figure 8c, below.

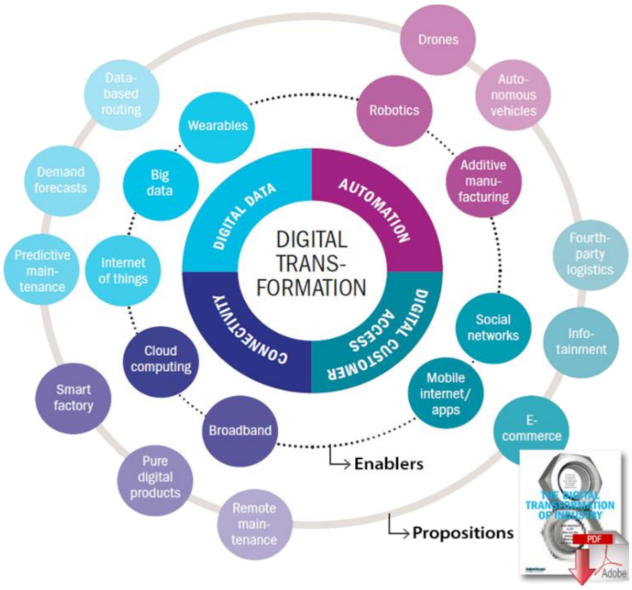

Fig. 8c, Four levers of digital transformation [29]

Recognizing the mentioned tool range of new digital technological proposals and initiatives, several different business models will be successful in the turnaround but others will get obsolete based loosely on the meaning of Joseph Alois Schumpeter´s permanent process of "Creative Destruction" (Schumpeter 1912). A possible approach by Unity Consulting and the MAN Group gives insights in terms of the development steps with respective to six logistical subdomains. The figure 8d below, gives an overview of the increasing level of digitization, starting with the entire supply chain down to intralogistics and line feeding.

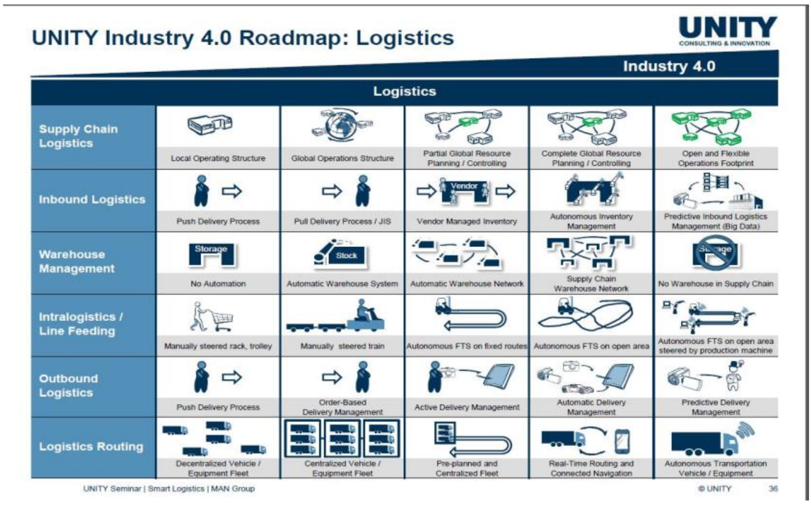

Fig. 8d, Roadmap Logistics 4.0 [30]

Placing ambient structures in a modern networking IT structure, established in the past years, made it possible to achieve certain diagnosis capabilities, especially in the process industry. Related research projects in this field were quite rare so far but undergo a change also because of projects financed by the European Union. One example is the “Res-Com project” with its focus on conserving resources through the optimal generation of embedded sensor–actuator system technology (Res-Com 2011). In the field of approaching Industry 4.0 through Big Data and CPS the highly interesting “Bitkom-report” explains by case studies the related challenges and methods (Bitkom 2014). Along with such projects, it leads to the consequence for describing harmonized standards relevant for target topics. Reflecting to Collaborative Production Management (CPM), a standard is provided by the Advisory Research Council (ARC) along with an integral use of the ISA standards, e.g. ARC ISA S95 referring to MES and IT/-ERP linkages.

The “NAMUR-Container” by the Standards Committee for Measurement and Control in the Chemical Industry, deals with regulatory that concerns the integration architecture and coupling of PLC´s (control via process program) and CAE´s (Computer Aided Engineering) (Scherwietes 2013). The data transfer is handled over a neutral data interface container which transforms heterogenous data to the Namur-structure.

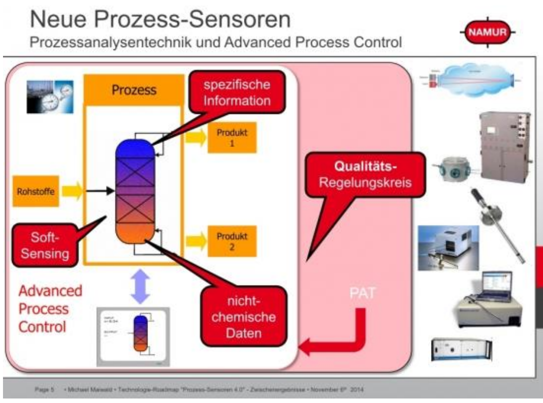

Fig. 8e, NAMUR process control [31]

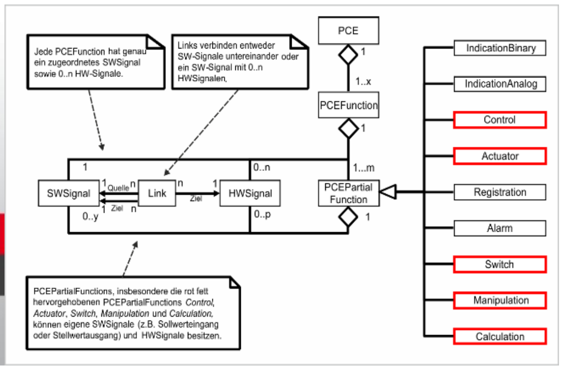

Fig. 8f, NAMUR-Container [32]

Additional helpful and instructive brochures, specified findings, case studies and further describing literature related to digital transformation was published et.al. by the Austrian Federal Ministry of Transportation, Innovation and Technology (BMVIT 2015) in cooperation with the Austrian Research Promotion Agency FFG within the scope of the program “Production of the future, presenting a catalogue to digital transformation through Industry 4.0 and novel business models”.

3.9 Logistic in Consolidation with a Cyber – Physical System

Besides all, it should be kept in consideration that the core competency of logistics still lies therein to transport goods, persons or information from point A to point B. Logistic further involves the design and use of logistic systems and the control of its processes to ensure the supply of objects available in line with the requirements. The term Logistic comes from Logic, respectively meaning to follow mathematical or symbolic strategies. In the 19th century it gained ground in the military for structuring and control of the troops and replenishment (Arnold et al. 2008: 3).
Until the 1960s the significance of logistics in industrial companies was quite low. With the description of “Supply Chain Logistics Management” by Donald Bowersox, logistics experienced an upturn (Bowersox et al. 1965). Companies attracted logistics not only in warehousing and transportation of material goods but as a general instrument and a cross-sectional role in the company which begins with the logging of the order and does not end until the labels are glued, goods properly packed and dispatched. The analytical model by Werner Delfmann explains a deeper meaning and analyzes logistic as a collaborative economic system which can be graphically segmented to show the economic, ecologic and social derivatives of logistic ordering cycles (Delfmann 2010: 172). An older but vivid depiction defined logistic with the “seven R´s”, as shown in figure 9a (Plowman 1964).

Fig. 9a, 7 R´s of logistics – interwoven with data [33]

Lean production methods, mainly initiated by the Toyota Production System, together with Kanban and eKanban, brought a continuous rise of prosperity to companies in the last years (Ohno 1988). Previous logistic systems were designed for a lean and more integrated process, which in turn resulted in a notable increase by reaching the limits of its actual capabilities. Because of the reduction of material stocks and intermediate storage facilities the lean production can sometimes hardly respond to the currently changing and fluctuating market demands (Erlach 2007: 117). Today's buyers' market consequently requires a review of items in stock or a from the demand decoupled supply method of materials because of the uncertain placing of orders (Dickmann 2009: 19). There would seem to be a need for the development of a specific system which comprises both logistic and cyber-physical aspects including the adaptions towards a structural alignment considering actual changes and future expectations. Logistic characterizes a logistic system, a special kind of a system which deals with transport and storage processes of objects (Pfohl 2010: 3). In turn a Cyber-Physical Logistics System (CPLS) is a specialization of a logistic system which describes the systems boundary and parameters, its elements and the relation between a CPS and logistics (Veigt et al. 2013: 15). A CPLS pursues economical, ecological and social objectives and concretizes logistic elements while referencing a relation between the flow of data and goods. The connection to production is indirectly available through networking and is the reference to the value chain where a CPLS defines itself by performing logistical duties. One informative disclosure in this context can be the early publication by Birgit Vogel-Heuser who describes a possible draft in the following way. The feedstock for this new kind of logistic system is a Production CPS (ProCPS) combined with the implementation of all relevant value enhancing elements from the supply chain. The resultant findings by Vogel-Heuser, in its basic meaning was called a self-controlling CPS-Logistic (Vogel-Heuser et al. 2012: 15). A generally recognized definition was not unified so far. The literature describes the cyber-physical logistic system in form of a merging togetherness using the existing definitions of CPS and Logistics in parallel (Veigt et al. 2013: 15). As mentioned in the previous section the research on CPLS is still under exploration. However, procedural models are, if available a decisive success factor and aid in CPLS development and problem solving. Applied development techniques are based

on Scholz-Reiter´s findings who designed ALEM, the Autonomous Logistics Engineering Methodology. By using an innovative modelling method, the researchers could determine the creation of autonomous logistic processes (ALEM–P), a modelling notation (ALEM–N) and a software tool (ALEM–T) (Scholz-Reiter et al. 2009: 4). At IFA–the Institute of Production Systems and Logistics, Leibniz University of Hannover, several logistic models, considering fundamental, organizational and logistic laws of industrial production have been developed.
In this context, a recent example which applies a derivation of a combined model was published by Kai-Frederic Seitza and Peter Nyhuis. Describing current trends in employment, new learning approaches, the impact of knowledge aging, Big Data, the concept of learning factories related to the upcoming changes in logistics, production planning and control, this article covers important topics which have been proven to be of particular use (Seitza & Nyhuis 2015: 94).

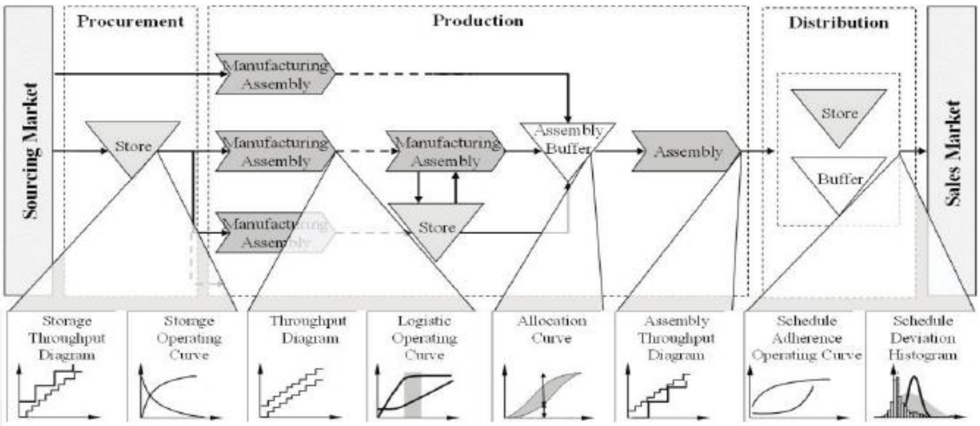

Fig. 9b, Overview of Logistics model [34]

As can be seen in the logistics model, figure 9b above, the flow of data and goods is channeled inter-divisionally. Any inconsistent database or submittal of erroneous information may create an opaque situation. According to the study conducted by Schuh in 2013, production data feedback is currently submitted in written and not digital form in 60% of small and medium sized enterprises and in 30% of large firms (Schuh & Stich 2013). This kind of circumstance hence leads to faulty results and makes it almost impossible to efficiently monitor a production process. Another finding implied that some enterprises lack the required capacity, expertise and knowledge about both production logistic methods and the occurrences within logistics (Schuh & Stich 2013). CPLS´s offer significant potential for compiling real-time data and allow operational production processes, optimally organized in terms of cost and logistic. With the support of big data analysis, the data required for monitoring the progress is derived from the total data volume and continually disposable, also for order processing and order throughput. Figure 9c, explains the control loop in the CPLS model and draws conclusions for the production planning and control to improve the performance of the entire system (Seitza & Nyhuis 2015: 95).

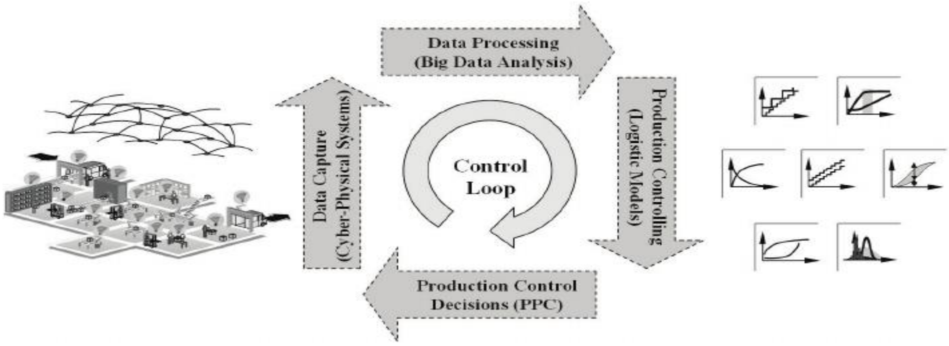

Fig. 9c, Control Loop in CPS [35]

3.10 Artificial Intelligence (AI)

Artificial intelligence is not exclusively a primarily demanding assignment about smart factories but also in areas which were handled with analytical or rule based methods before. Applied methods are mostly divided into two broad categories. Knowledge based systems and computational intelligence which includes neural networks, fuzzy systems and evolutionary computing. Copying the human brain is the target!

Neural Networks (NNs) are based on brain research and being found in real brains. The biological central nervous system consists of a network of neurons, where all are connected to each other and each neuron with up to ~10000 other neurons. The McCulloch–Pitts-Neuron was appointed in the year 1943. Warren McCulloch and Walter Pitts described a neuron by logical threshold element to examine whether the measures by Alan Turing have had effects on computable functions or not.

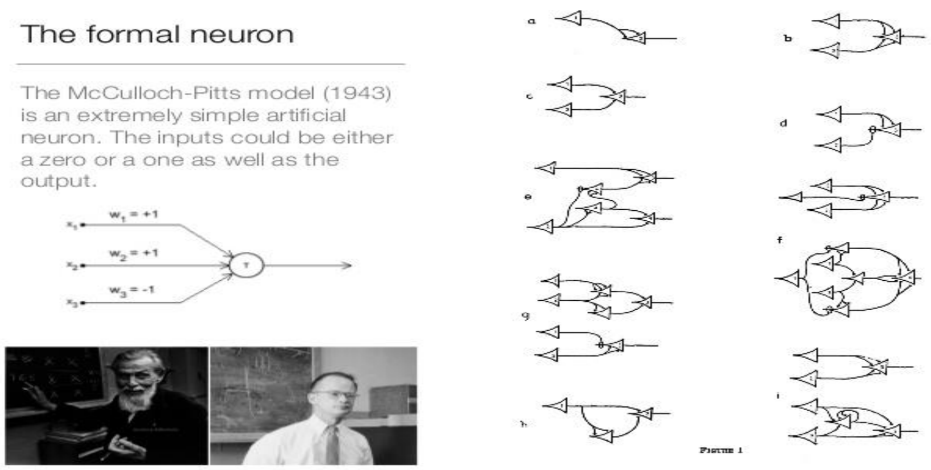

Fig. 10a, McCulloch – Pitts Neuron [36]

Figure 10a, shows a set of synapses (i.e. connections) which brings in activations from other neurons. A processing unit add up the inputs and then applies a non-linear activation function (i.e. squashing/ transfer/ threshold function). An output line transmits the result to other neurons. The Equation for the output out of a McCulloch-Pitts neuron as a function of its *"**n**"* inputs is illustrated below (McCulloch Pitts 1943):

$$out = \mathrm{sgn}\left(\sum_{i=1}^{n} in_i - \theta\right)$$

$$out \;=\; 1 \quad \text{if} \;\; \sum_{k=1}^{n} in_k \geq \theta \qquad\qquad out \;=\; 0 \quad \text{if} \;\; \sum_{k=1}^{n} in_k < \theta$$

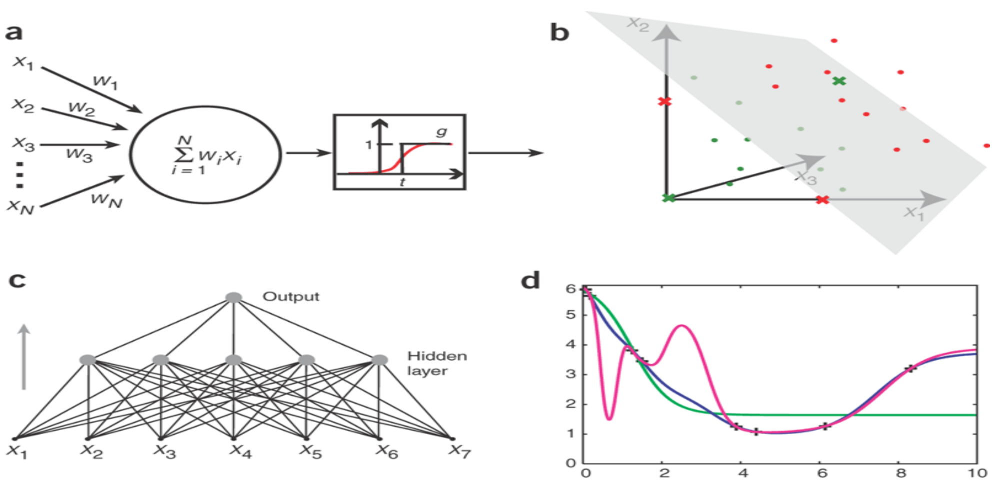

Fig. 10b, McCulloch – Pitts Neuron [37]

Figure 10b (Source: www.nature.com) explains the McCulloch Pitts model as follows:

(a): Graphical representation of the McCulloch-Pitts model neuron or threshold unit. The threshold unit receives input from N other units or external sources, numbered from 1 to N. Input i is called x_i and the associated weight is called w_i. The total input to a unit is the weighted sum over all inputs,

$\Sigma^N_{i=1} W_i X_i = W_1 X_1 + W_2 X_2 + \ldots + W_N X_N$. If this were below a threshold t, the output of the unit would be 1 and 0 otherwise. Thus, the output can be expressed as $g(\Sigma^N_{i=1} W_i X_i - t)$, where g is the step function, which is 0 when the argument is negative and 1 when the argument is nonnegative (the actual value at zero is unimportant; here, we chose 1). The so-called transfer function, g, can also be a continuous sigmoid as illustrated by the red curve.

(b): Linear separability. In three dimensions, a threshold unit can classify points that can be separated by a plane. Each dot represents input values $x_1, \ x_2 \ and \ x_3$ to a threshold unit. Green dots correspond to data points of class 0 and red dots to class 1. The green and red crosses illustrate the 'exclusive or' function—it is not possible to find a plane (or a line in the $x_1, \ x_2$ plane) that separates the green dots from the red dots.

(c): Feed-forward network. The network shown takes seven inputs, has five units in the hidden layer and one output. It is said to be a two-layer network because the input layer does not perform any computations and is not counted.

(d): Over-fitting. The eight points shown by plusses lie on a parabola (apart from a bit of 'experimental' noise). They were used to train three different neural networks. The networks all take an x value as input (one input) and are trained with a y value as desired output. As expected, a network with just one hidden unit (green) does not do a very good job. A network with 10 hidden units (blue) approximates the underlying function remarkably well. The last network with 20 hidden units (purple) over-fit the data; the training points are learned perfectly, but for some of the intermediate regions the network is overly creative.

Artificial Neural Networks (ANN´s) are networks of Artificial Neurons, and hence constitute crude approximations to parts of real brains. They may be physical devices or simulated on conventional computers (Faussett et al. 1994). From a practical point of view, an ANN can be seen as a parallel computational system consisting of many simple processing elements connected in a specific way to perform a particular task. One published detailed description in this context explains this topic as follows:

"Artificial Neural Networks (ANN) simulate the biological functioning of the brain and are a technical concept for problem solving and planning at the same time. ANN is further an information processing system which consists of a set of processing units (nodes) which simulate neurons and are interconnected via a set of "weights" (analogous to synaptic connections in the nervous system) in a way which allows signals to travel through the network in parallel. The nodes (neurons) are simple computing elements. They accumulate input from other neurons by means of a weighted sum. If a certain threshold is reached the neuron sends information to all other connected neurons otherwise it remains quiescent. One major difference compared with traditional statistical or rule-based systems is the learning aptitude of an ANN. At the very beginning of a training process an ANN contains no explicit information. Then many cases with a known outcome are presented to the system and the weights of the inter-neuronal connections are changed by a training algorithm designed to minimize the total error of the system. A trained network has extracted rules that are represented by the matrix of the weights between the neurons. This feature is called generalization and allows the ANN to predict cases that have never been presented to the system before. Artificial neural networks have shown to be useful predicting various events. Especially complex, non-linear, and time depending relationships can be modelled and forecasted. Furthermore, an ANN can be used when the influencing variables on a certain event are not exactly known as it is the case in financial or weather forecasts" (Traeger et al. 2003).

Fundamentals of Neural Networks, architectures, algorithms, and applications by Laurene Fausett, 1994 serve with more fundamental equations, as listed below (Faussett et al. 1994):

- When talking about ordered sets of related numbers,
  they are called ***vectors***, e.g.

  $x = (x_1, x_2, x_3, \ldots, x_n)$, $y = (y_1, y_2, y_3, \ldots, y_m)$

- The components x_i can be added up to give a ***scalar*** (number), e.g.

  $s = x_1 + x_2 + x_3 + \ldots + x_n$ = SUM (i, n, x_i)

- Two vectors of the same length may be ***added*** to give another vector, e.g.

  $z = x + y = (x_1 + y_1, x_2 + y_2, \ldots, x_n + y_n)$

- Two vectors of the same length may be ***multiplied*** to give a scalar, e.g.

  $p = x.y = x_1.y_1 + x.y_2 + \ldots + x_n.y_n$ = SUM (i, N, $x_i y_i$)

Per given statements, currently it´s possible to copy about one percent of the human brain capacity, even though this development is growing exponentially. However, per description of experts the next generation of AI will get more adaptive, self - learning and intuitive. Chipmakers like e.g. Intel announced “Exascale”-computing by 2018 to 2020. Meaning that a supercomputer is capable to perform at least one ex-aflops, which is a thousand petaflops or a quintillion, 10^{18}, floating point operations per second. Either way, trying to imagine that the ~23.000.000.000 Neurons of the human brain can be imitated by AI in future, this scenario could explain the enormous potential of this technology. One major difference still exists, humans may detect a degree of genetic similarity by making decisions based on the degree to which someone else physically resembles (Platek et al. 2009).
By going further, what will happen if the artificial capacity can be multiplied by “x”-numbers? Singularity, meaning that the human itself will get obsolete seems to move a bit further out but will be a fundamental theorem in future life.

3.11 Robots on the Rise - Robotics in Logistics

As robotics became a daily occurrence in widely spread applications and not only within the automotive industry, we are situated in the starting phase of a new epoch which seems to be a big step towards future life. How can the development of robotics in logistic be described over the last years? Structural company changes were triggered by the implementation of ERP and MES. Together with the automation of processes this change could be realized because of the technological progress since 2007. Per industrial statements there is neither a unitary system standard for the interconnectivity within Industry 4.0 fixed, nor uniformly rules agreed yet. But the usage of IT and automated items will be most probably further amended which again encourage companies to invest in such systems. A published report by the Bremer Institute for Production und Logistik (BIBA), gave a comprehensive insight into the current situation of the German logistics area. Based on application-oriented industrial research & development, BIBA describes the increasing demand and potential of Human–Machine interaction in logistical routines. As part of the RoboScan–survey, German companies were polled about the collaboration with machines and its technical feasibility where roughly 70 percent of all respondents were considering the use of autonomous technology as a promising alternative (RoboScan 2014). The most important factors evaluated, were loaded on speed and flexibility, occupational safety, acceptance and development of new technologies and its interaction. Ongoing market trends like the growing internationalization calls for adaptions in the process. It can be specified that beside above mentioned facts, the recorded trends in logistics show an increase in the concentration process and a decrease in procedures for obtaining a net reduction in outsourcing logistical services to contract-logistics provider. BCG published a prognosis on labor cost savings from adaption of advanced industrial robots, as shown in figure 11a.

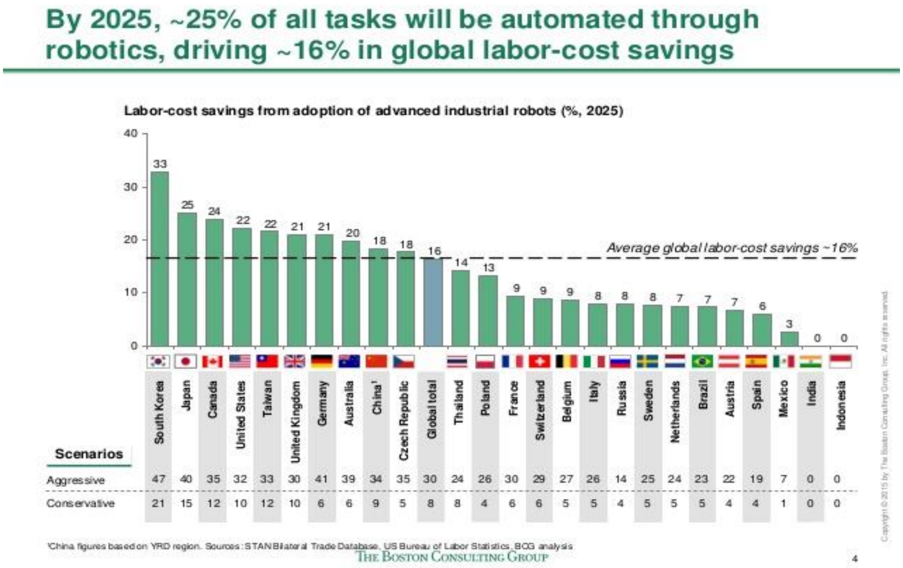

Fig. 11a, Prognosis on labor cost savings [38]

The robot itself plays therefore a key role in any line of business. Whereas until recent years, robots have been implemented in automotive and production for high piece numbers under difficult environmental conditions where they perform and carry out predefined iterative tasks quite independently. The range of today´s applications reaches much further. Besides the most commonly known function in the areas of automated welding, grinding, handling, assembling, painting, packaging the pursuit of activities below and above the water line directs to emerging newer applications in healthcare, biotechnology, banking, intralogistics and material flow up to commercial service robotics which forms the basis of the concepts for everyday work and efficiency in industrial and assistance robotics (Echelmeyer et al. 2008).
Specific algorithms, intelligent sensors and smart designs including modern procedures for geometric modelling and image–producing which are creating live views of the robot's surrounding are further developed. Equipped with e.g. surveillance cameras and sensors for distance measuring, the systems accuracy improves and gets empowered for handling uncertain circumstances. Humans and robots collaborate without the need of preventive safety clearances anymore and open many new opportunities in direct, autonomous or flexible cooperation. A newly developed term named Cobot, meaning the Collaborative Robot is describing this special category which serves the human worker in special subranges or situations during the production process (Rohde et al. 2015). It deserves mention here that the world’s first Cobot was

sold by the company Universal Robots and installed in December 2008 at Linatex, a Danish supplier of plastics and rubber for industrial applications. The market for Cobots in the year 2016, had an annual growth of 50% and is now the fastest growing segment of industrial robotics, per given statement of universal-robots.com, 2017. Available technical robot options and steps towards networking databases has been discussed and provided by e.g. the company KUKA. A German industrial robot manufacturer who generated a turnover of ~ 2,9 billion Euros in the fiscal year 2016 (Kuka 2017). Their statement to the industrial vision is clear and will be explained in the following lines. The KUKA research collaboration comprises partnerships with universities, companies and institutes with expertise in machine and installation automation. The collaborative aim is to develop groundbreaking products through pioneering research and patented innovations. One out of such products is the “KUKA Mobile Robotic iiwa” (KMR iiwa), an optional–mobile, light weighted robot which assists and reacts sensitively and compliantly to changes, figure 11b, c.

Fig. 11b, KMR iiwa 1 [39]

Fig. 11c, KMR iiwa 2 [40]

Sensitively in that way means that this apparatus can perform e.g. a calibration process without the need of additional external sensors. This is realized by using embedded joint-momentum sensor technology which provides the dose of sensitivity. That intelligent industrial work assistant (iiwa) bears utmost precision due to its omnidirectional wheel technology and can navigate freely and by remote, facilitated by navigation solution software. The positioning accuracy of the vehicle is ± 1.0 mm. Laser scanners attached to the lower mobile platform determine risk of collision and initiate countermeasures. To ensure a steady supply of energy, the built-in accumulator can be recharged in loading stations, autonomously over floor charging contacts (Kuka 2017).

This new generation of extreme lightweight robots, manufactured on an integrated mechatronic basis leads towards robot arms which deliver the same load carrying capacity as the classical reference but weighs 10 to 20 times less. The improved design allows a freely configurable elastic behavior and data retention. Bearing clearance and irregular motion are compensated which was achieved by joint–torque control where the torque signal is used for reducing the effects of joint friction as well as to damp vibrations related to the joint compliance. Also in high speed motion this type can detect and avoid collisions with objects in the vicinity. By using haptic perception and leading-by-the-hand, the intuitive programming and handling concept is a preferable option as this facilitates the utilization (Albu - Schäffer et al. 2007).

Figures 11d, 11e below, explain practical examples in the automotive industry where the "iiwa" is applied in the assembly line of e.g. BMW´s bevel gearboxes and e.g. in the assembly line of a Ford Fiesta, installing shock absorbers. The situations show the perfect Human-Robot Collaboration mode (HRC-mode).

Fig. 11d, BMW Bevel Gear Assembly [41]

Fig. 11e, FORD Fiesta Assembly [42]

The assisted operator is placed in a system, surrounded by intelligent products and machines delivering huge amount of data. Autonomous transport systems acting as smart load carriers forwarding objects directly controlled out of the cloud according the plug and produce principle. For the human operator, it is important to fulfill the exact working task. Therefore, a situation-dependent filtering mechanism is required for delivering on time information to the entities and items involved. Individual docking of dialog windows and toolbars allow the user interface to be adjusted to the task at hand. Versatile data derived from sensors and IT sources in the company, respectively for link and order tracking must be processed and properly channeled within an all-embracing concept (Gorecky et al. 2014). Central importance in this conglomerate is dedicated to the individual Human Machine Interface (HMI). Commencing with remote controls towards practical mobile tablet computers which can be incorporated into the network via wireless connecting possibilities. Equipped with various features and applications, camera and high processing power it can be used as the ideal support for monitoring and controlling of various systems. A combination with Virtual and Augmented Reality (VR/AR) therefore is another option applied in e.g. production planning, designing process and in training of maintenance activities (Gorecky et al. 2012).

Fig. 11f, AR in maintenance [43]

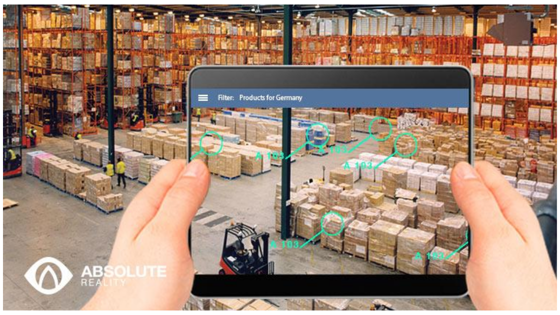

Fig. 11g, AR in warehousing [44]

Above figures 11f, g, explain possibilities for the field use of a tablet computer in combination with Augmented Reality application for maintenance and warehouse purpose. Figure 11f, visualizes the example of an electric crane drive malfunction in any part of the system disconnecting the faulty drive. The service specialist will be provided with essential information and receives valuable time saving suggestions for fact finding and troubleshooting. Fed by the internal database the specific relevant information can be used for assembly, commissioning, maintenance and repair of a system in accordance with current standards in force.
Research on Brain Machine Interfaces (BMI) has experienced an impressive growth since the original demonstration that electrical activity generated by arrangements of cortical neurons can be used directly to control a robotic manipulator. In clinical studies BMI´s can translate raw neuronal signals into motor commands that reproduce human movements like e.g. arm reaching and hand grasping in artificial actuators (Lebedev et al. 2007: 537). A fully implantable biocompatible interface between a human and an adaptive mechanism enables actions that can be controlled directly by brain-derived signals. With the aid of real-time computational algorithms, a method for two-way communication capability can be established. Neuroscientists at

the University of Geneva (UNIGE), Switzerland, published a novel optical brain-machine interface which allows bidirectional communication with the brain by resorting to modern imaging and optical stimulation tools. The method is described as follows: *"So far a robotic arm is controlled by neuronal activity recorded with optical imaging (red laser) and the position of the arm is fed back to the brain via optical micro stimulation (blue laser). These findings, published in the scientific journal "Neuron", offer an innovative alternative to the classical electrode approach by stimulating neural activity in the cortex of the brain"* (Huber 2017).

All mentioned approaches for driving the industry to the next revolution require investments, financial decisions, expert knowledge and advice to take sustainable decisions or to conduct certain activities. Decision making in this respect and the need for suitable managerial actions for dealing with the risk makes it therefore necessary to implement appropriate tools or measures. An exemplary model for innovative and successful solutions in the logistics sector, respectively around contract logistics was realized by the company DB Schenker with the construction of a new distribution center in Arlandastad, Sweden. This newly designed warehouse is covering a total surface of 10000 square meters and was built for a joint venture with Lekmer.com, the biggest e-commerce toy retailer in whole Scandinavia. 6000 square meters are exclusively reserved for autonomous robots where highly innovative networks perform handling of goods and packaging activities. DB Schenker´s strategy towards Logistic 4.0 was improved with the implementation of Carry Pick, an autonomous storage technology.

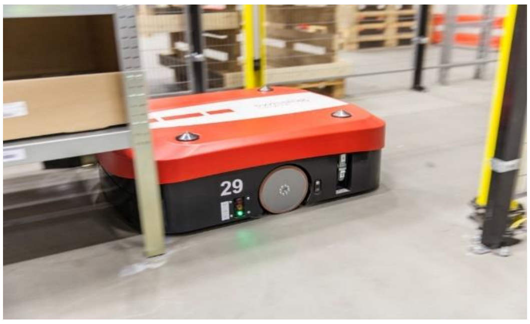

Fig. 11h, Carry pick 1 [45]

Fig. 11i, Carry pick 2 [46]

This online order system can execute one or more activities like conveying, order-picking, sorting and handling. The embedded return system simplifies the dispatch of goods returned. About 60 robots and 1.550 shelves maintain a product range of

35.000 diverse articles. An average of 40.000 orders can be distributed and shipped per day. DB Schenker stated an increase in productivity by 60 percent, because of this technology (DB Schenker, Swisslog 2017).

3.12 Innovative Personal Protective Equipment

Apart from standardized personal protective-equipment towards lifting aids and exoskeletons which can be worn on the body or integrated into clothes are gradually being offered in the market and represent new possibilities. Wearable devices and systems that can be used for several applications such as e.g. the Chairless Chair for improved ergonomics, in automotive production plants. A carbon-fiber construction for employees in the assembly line, as shown in figure 12a, supports the ergonomic action and promotes the working condition (Audi Mediacenter 2017). Exoskeletons are used e.g. for lifting or loading activities of heavy parts as they can increase the human force and helps to avoid postural defects, figure 12b.

Fig. 12a, AUDI Chairless chair [47]

Fig. 12b, Exoskeleton [48]

Technically highly developed exoskeletons are capable of learning and offer possibilities for customizing. The configurations can be personalized per the individual needs of each employee over an internet platform.

Fraunhofer IGD Rostock, has developed methods to determine current motion patterns of a user by means of acceleration sensors mounted on the user's body. Based on scientific knowledge, companies respond by implementing such advantageous working aids and show responsibility for the employees' health and wellbeing, possibly encouraging employment into old age.

4 DESCRIPTION OF MANAGEMENT METHODS

4.1 Stage Gate Method

This Idea-to-Launch method is a widely-spread process model for driving innovation and product development to final market launch. Cooper has seen and described this demand for the New Product-Development and -Innovation (NPD, NPI) process, with attention to those steps that have been merely or not observed formerly (Cooper 1990). Stage-Gate was originally developed from research that modeled how game winner act and what they do in common to be of success. Contrary, it happens that business projects missed the target and failed to perform. A closer evaluation illustrates that many projects were pestered by missing steps and activities, inadequate quality of execution, poor organizational design and leadership, uncertain data and missed timelines. Cooper explained, that technological development projects need tailored processes and applied his method, respectively a Stage-Gate-Playbook to overcome above mentioned difficulties. Stage-Gate is a system or process comparable to a manuscript for guiding a soccer team, which maps out the needs and directives to be transposed by each team member, especially within medium to high risk projects where the Return on Investment (ROI) could hardly be estimated at the beginning (Cooper 1990). However, it should be kept in consideration not to follow the mentioned playbook-directives to strictly, as all possible activities in Stage-Gate should be interpreted as evergreen-open guide lines, which acclaims the implementation of many best practices and methods. Misinterpretation of this idea led projects into the road to ruin (Cooper 1990).

Based on a project progression, it is concluded that a decision gate is linked to every single project stage, to evaluate and taking fundamental business decisions. That point which influences the future of the downstream stage is clearly focused on resource planning and strives to identify best opportunities at the earliest time possible. Available solutions are well spotted in leaner adapted gates, including governing methods such as “gates with teeth” as well as ways to deal with bureaucracy. The managerial arbitration in a gate review meeting is mainly achieved by one out of four possible conditions, as shown in figure 13a.

The decision is not only determined by parameters such as required by the customer but because of the calculated basis of realistic assessments:

Four possible occasions of choice:

1. GO to next phase, stage.
2. REMAIN in the current stage.
3. Put on HOLD and review.
4. STOP or KILL the project.

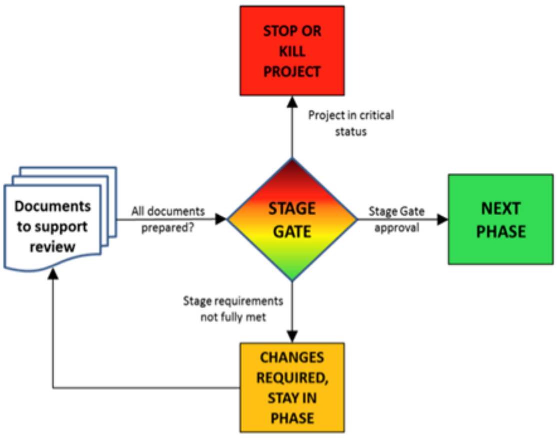

Fig. 13a, Decision Gate [49]

Basically, Stage-Gate is about "Killing Projects" at a specified time point. But doing this wisely, could be declared as an avoidance of cost traps and could be a core competency of a successful organization. Based on Robert G. Coopers article it could be understood that this method is a business process and not a research and development, or marketing process.

Further, Stage-Gate is NOT:

- a functional phased review process, but built for speed where stages are cross-functional and not dominated by a single functional area,
- a bureaucratic system. The objective is a systematic, streamlined process, not a locked, bureaucratic one.
- a rigid lock-step process full of rules, regulations, mandatory procedures, and ''thou-shalt'' that every project should follow regardless of the circumstances.

Based on Coopers article it could be understood in the following way: *"If above mentioned points describe your process, no wonder people try to avoid or circumvent it!"* (Cooper 1990).

The main significant positive effects of Stage-Gate (Cooper 2008):

- "Susceptibility to trouble", finding facts which had no, or little consideration in previous development processes.
- Better focus on priorities, information finding and prognosis.

- An efficient, lean and rapid system. Parallel process phase out with high speed, trans - sectoral structures where decisions and tasks are made team-wise where every member takes responsibility.
- Creating products with competitive advantage.

Figure 13b below, shows an application model of an actual updated 5-stage, 5-gate-idea-to-launch system with agile methods applied, in each of the stages.

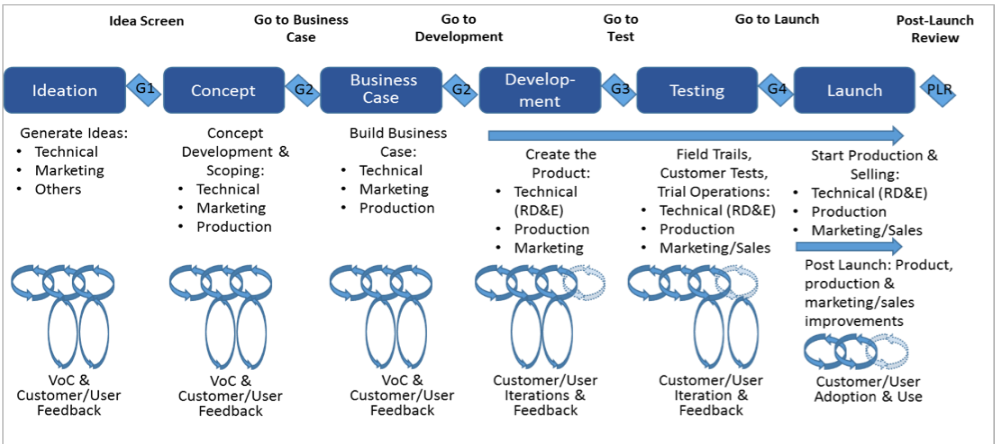

Figure 3:The integrated Agile-Stage-Gate hybrid model – a typical 5-stage, 5-gate Stage-Gate idea-to-launch system, with Agile built into each of the stages (Source: Cooper & Sommer, *IMM*, 2016; footnote 6)

Fig. 13b, Agile Stage Gate hybrid model [50].

4.2 Logistic - Oriented Value Stream Analysis

One of the greatest benefit in smart environments seems to be the optimization of the entire value adding chain instead of increasing just one step. Related to logistic services it can be said that the value adding is not accomplished solely by the transport of goods. Next to transport, handling and storage the logistics provider must perform reactive and consumer oriented. For this purpose, they offer a wide range of premium services like e.g. shipment tracking, quality control, reparation, return shipment, complaint handling, repackaging, sorting and assembling. Fundamentally it´s considerable that value added services will be handled differently in small and medium sized enterprises than in global companies in the forwarding sector. Capital costs and scope differ, however the suppliers for the industry must adapt and implement solutions to enable the linkage. Within the flow of items the integrated premium services or added-value services are mostly invisible at first glance for the customers (Klenk & Knössl 2010: 5). These additional actions exceed the basic service and enhances the value of the handled object and the entire service. Value creation and the avoidance of wasting money is the target. Lean methodology has approached together with supportive analyzing tools. The logistic-oriented value stream analysis is such a tool which is based on the conventional value stream analyses but with the focus on logistical processes. Production and logistic processes can be graphically plotted by using methods like e.g. "SCOR-Supply Chain Operations Reference", "SysML-System Modelling Language" or "BPM-Business Process Model" (Klenk & Knössl 2010: 8). At the same time, it offers the opportunity for localizing the lean categories, waste and value-add, even in a complex manufacturing process. The logistic-oriented value stream analyses would have the advantage to implement logistical procedures and the detection of their waste and value adding points. That approach is based on the perspective that logistical actions add a service value to the object rather than waste (Klenk & Knössl 2010: 7). Figure 14, describes the differences between current and future-state value stream analysis, referring to above mentioned facts.

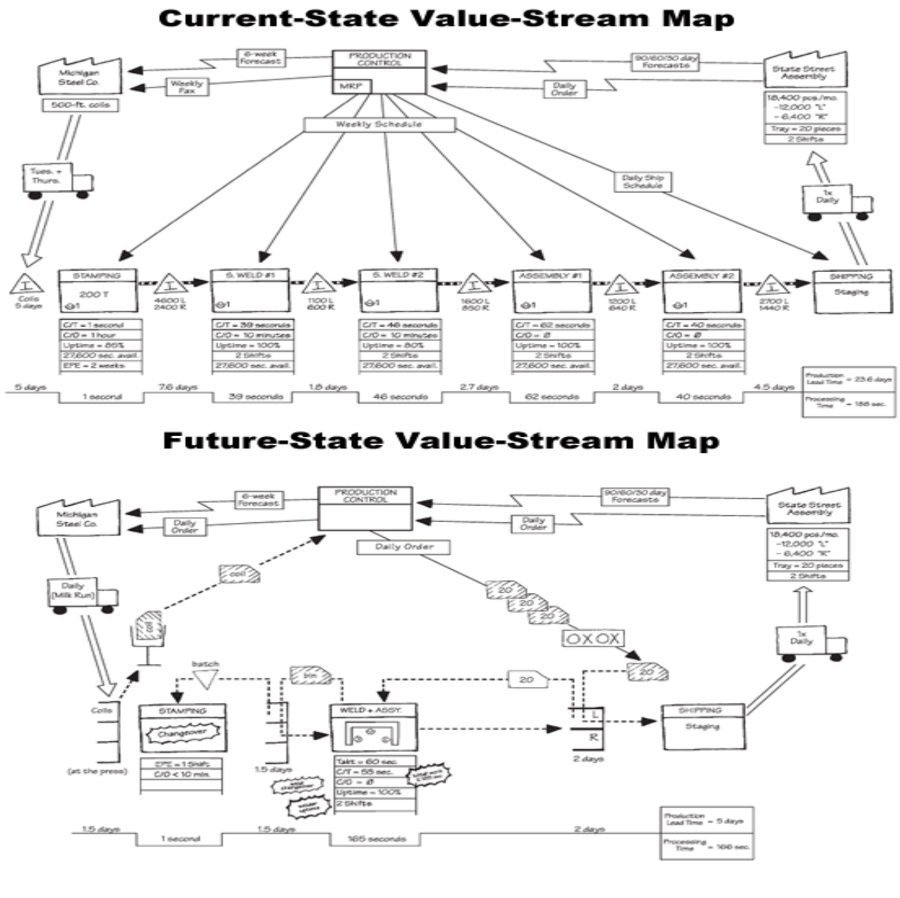

Fig. 14, Value stream mapping [51]

4.3 Activity Based Costing (ABC) Principle

The ABC principle is an applicable method, suitable in different parts within job-order costing. The core idea of ABC lies in finding out real facts by measuring the cost and performance of activities, resources, and cost objects whilst the opposite approach through full cost pricing is most of time seen as traditional cost calculation using a predetermined "overall"-overhead rate which disperses the costs equally over products in proportion to whatever base is used (Cooper & Kaplan 1988). Turney (1996), defined ABC as a method of measuring the cost and performance of activities and cost objects. It assigns costs of resources and then allocates costs based on their required activities, measure and rate. In 1985, Miller and Vollmann effectuated a reversal of the economic trend by reviewing the standard costing system with the published article "The hidden factory". Figure 15, gives an overview of contradictory effects of labor cost calculation at that time (Miller & Vollmann 1985).

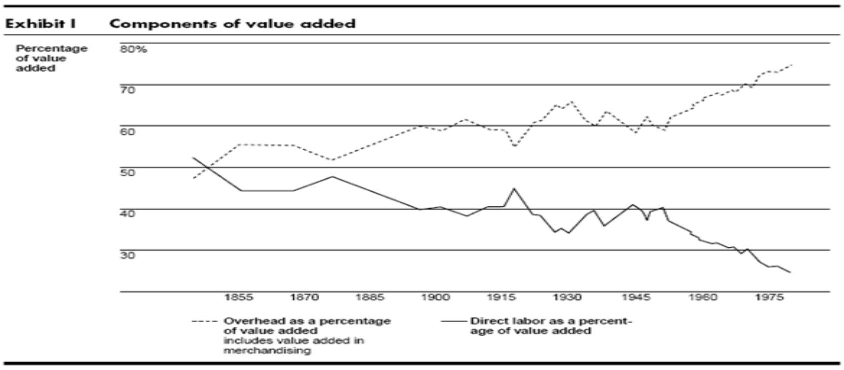

Fig. 15, Components of value added [52]

In some process situations, the roots of costs are not obviously directly related to the product itself or in other words not seen in the correct relation. This occurs also in the logistical sector where managers and consumers misinterpret the supply chain itself as a cost factor instead of a value adding process (Cooper & Kaplan 1992). The consequence is distortion and inaccurateness of product cost statement. Therefore, ABC attempts to correct these distortions by more accurately assigning overhead costs to product. ABC is dealing with source of errors especially in the field of fixed overhead. Critical view is often spent on rewarding surcharge calculation. With reference, to figure 14a, experts argue that direct labor hours might be an incorrect indicator for product cost causation because of increasing automation in production. Per published articles this criticism seems to happen also nowadays since the basis for calculation in some instances is still direct labor. Furthermore, taking into consideration that standardized calculation of upstream and downstream service sectors like order disposition, production planning and control, warehousing and transportation were also evaluated through modes of full cost accounting.

The following steps show variances on differing methods:

1. Plant wide predetermined rate: Easy, uniform, but distorted information, conceivably arbitrary these days.
2. Departmental predetermined rate: May not correctly assign overhead costs in situations where a company has a wide range of products and complex overhead costs. Overhead may be caused by variety of factors such as range of products, number of required setups, etc.
3. Both plant wide and departmental allocation rely exclusively on allocation bases such as direct labor hours and machine hours that are highly correlated with the volume of production.
4. Activity based rate: Focused on cause/ effect relation. Improves the accuracy of product cost, helps managers to understand the nature of overhead costs and helps target areas for improvement through benchmarking and other techniques.

Not only applicable in traditional production, ABC-implementation becomes more and more attractive in many other business areas like in logistics, insurance, banking sector, supply chain management and public administration which reflects the flexibility and company specific application of this methodology. However, certain caution should be exercised by implementing ABC, especially on money-saving at the wrong place. Attention should be put on “penny hunting” and the importance of e. g. customer relation and employees-satisfaction.

Activities are grouped into a four-level hierarchy:

1. Unit level 2. Product level 3. Batch level 4. Facility level

A variety of activities in ABC causing consumption of overhead resources could be also found in:

- Setup, Admission, Maintenance, Inspection
- Scheduling, Billing, Ordering of materials

Guideline for implementing and executing ABC in a beneficial way:

1. Project preparation (clarification of targets, teambuilding)
2. Scope and boundaries of study (ABC in departments/whole company)
3. Definition of primary process
4. Evaluation analysis of activities (appraisal interviews, observing, fact finding)
5. Activities catalog
6. Sub-process identification and description
7. Cost driver identification, description and definition
8. Allocation of costs and resources
9. Process - cost - rate calculation
10. Results should be transmitted to responsible employees and the management. Discussion meeting.
11. Action planning

Advantages of ABC:	*Disadvantages of ABC:*
• Overhead costs are becoming transparent	• High start-up costs, expedient at overhead with high cost volume
• Allocation – effect, - "fair according to the input involved" assignment to overhead	• High project outlay at continuous execution of ABC
• Complexity – effect, complex products consisting of higher demand of cost causing activities compared to simple products	• Implementation could lead to staff opposition, due to task analysis

5 DESCRIPTION OF THE RESULTS

As the past has shown, there will be neither one prescribed holistic solution nor a unique future concept for solving upcoming challenges within the rapid development towards a comprehensive Industry 4.0. Nevertheless, the achievements and benefits arising from the technical progress and the enormous growth in knowledge for digital transformation offers international opportunities for business development. It opens new perspectives and individual preferences in terms of managing and controlling the business and its value drivers. The methods described in Chapter 4 may at first glance represent a kind of traditional technology, originally designed for conventional management methods. However, compared to novel IT options these attributes still have the possibility to overlook and control the most important key figures, also in engineering management as these methods can be used to support the evaluation of proposals and decisions on the solution of upcoming change measures. These affordable methods in its basic application could assist small and medium-sized logistic firms to experience a clear overview of the current business situation in order to detect and eliminate possible weaknesses in the internal process. Another solution might be the integration of ABC in ambient controlling instruments, like into balanced scorecard, whereby the logistic-oriented value stream analysis clearly identifies the allocation of losses in accordance with the causative principles. In combination with further described novel options a manager could estimate and control forthcoming investments and lead the company with success.

One possible technical and economically reasonable alternative can be realized with the aid of the Research Cluster “Smart Logistic” at RWTH Aachen, which illustrates in an experimental and conceptual way how logistic partners may apply ICT in their individual projects by experiencing and researching complex interrelations. The specific industrial logistic situation can be modeled in the innovation lab and developed to an applicable tailored solution (RWTH Aachen). A further concept on the theme “Common Framework (CF) for ICT in Transport Logistics” by Frank Knoors, (Logit Systems 2011), is paying attention to SME´s and how they can take part in a digital supply chain, as illustrated in Figure 16a. The Common Framework should leave companies as much freedom as possible to organize activities and designing business processes. Hence, the focus is on interaction between the different domains, or roles belonging to the domains. After careful considerations, the areas covered by e-freight, intelligent cargo, supply chain security, and cooperative systems providing the scope for the framework (Logit Systems 2011).

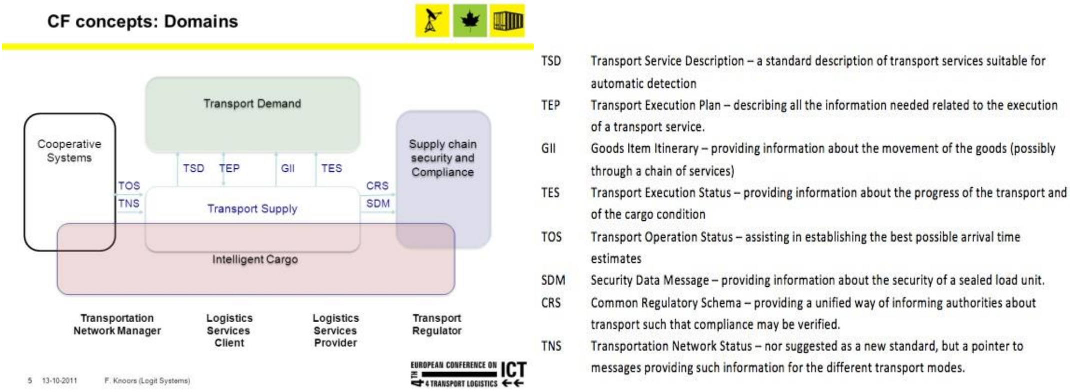

Fig. 16a, CF Concept [53]

Another promising approach for SME´s when shifting a logistical adaption to the level of digitized Cloud technology could be realized by the "Virtual Fort Knox Strategy" (Holtewert et al. 2013: 528). As an interface between physical production and the digital world which transmits "XaaS-Everything as a Service"-principles from Cloud Computing into the production environment is putting forward the idea of "MaaS-Manufacturing as a Service". This architecture, developed by Fraunhofer - IPA and Hewlett Packard, enables a connection between a CPS and the Cloud Service over so called integration services. Via this integration service interface the corresponding cyber-physical logistic data will be processed and transferred over the web to the cloud where the software of the manufacturing service bus evaluates the results and combines them in an aggregated service document. Cloud computing implies almost unlimited and instantaneously availability of computing power, which is an essential parameter to ensure the integration in flexible production plants (Bauernhansl et al. 2014: 27). Published figure below describes "A Timed Colored Petri Net, Simulation-Based, Self-Adaptive Collaboration Method for Production-Logistics Systems".

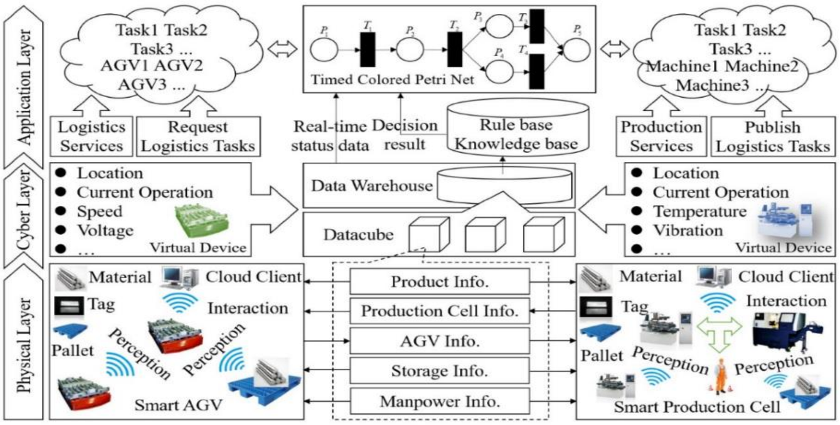

Fig. 16b, Time Colored Petri Net [54]

The authors describe this specific logistic CPN approach in the following way.
With the widespread use of Internet of Things technology in manufacturing, a great amount of real-time and multi-source manufacturing data and logistics data is created, that can be used to perform production-logistics collaboration. The method combines the schedule of token sequences in the Timed Colored Petri net with real-time status of key production and logistics equipment. The key equipment is made "smart" to actively publish or request logistics tasks. An integrated framework based on a cloud service platform is introduced to provide the basis for self-adaptive collaboration of production-logistics systems. A simulation experiment is conducted by using colored Petri nets (CPN) Tools to validate the performance and applicability of the proposed method. Computational experiments demonstrate that the proposed method outperforms the event-driven method in terms of reductions of waiting time, makespan, and electricity consumption. This proposed method is also applicable to other manufacturing systems to implement production-logistics collaboration (Guo et al. 2017).
Under any circumstance or condition the logistics service industry finds itself having to rethink its situation in terms of applied production control systems. Replacing the conventional automation pyramid through low rising informational structures could enable a modern and Advanced Process Control (APC). A logical consequence in the ICT context might be the combined usage of Enterprise Resource Planning and Manufacturing Execution Systems that are designed to optimize business workflows and enhance production processes. All these structures are constantly becoming more efficient and will be applied in areas where they haven't been used before. Hence well

equipped with high processing power, increasing battery life and considerable storage resources the embedded computer platforms have an enormous potential for many application areas as a multitude of communication interfaces often provide important control and assisting functions.

If a company intends to invest in robotics, a promising solution for the decision maker, might be a Robot investment tool which is available e.g. from the Danish Technological Institute. This tool is especially developed for strengthening the competitiveness of small and medium sized manufacturing enterprises and is set up to bring cognitive robotics from vision to reality as a part of the "SMErobotics-project", funded by the European Union, 7th Framework program. Shown in figure 11h, 11i, below.

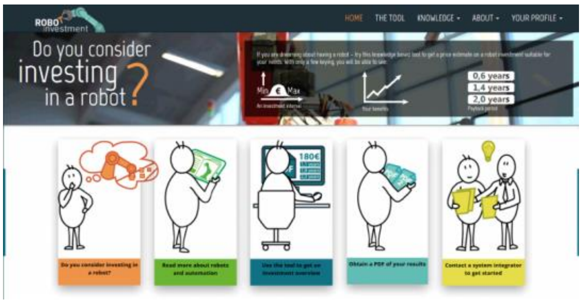

Fig. 16c, Robotinvestment tool [55]

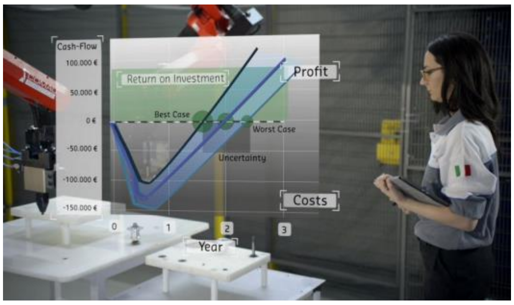

Fig. 16d, Financial statement [56]

This knowledge based online tool is designed to consider criteria's and application potentials with the aim to get an investment overview on a robotic solution suitable for the company's needs. This platform is based on information transfer and on specific expert advice. Rapid processing functions and convenient accessibility characterizes this homepage. A direct link to potential customers and suppliers in the respective line of automation business can be established and may be of use. Technical wise, the new generation of automation gains possibilities in several fields of the supply chain. Regarding the social trends, which are successively characterized by increasing robotics and automation can be determined as follows. By envisioning one possible scenario, where the robot is the digital counterpart of a working person in solving job related tasks during working hours it may happen in future that this robot becomes the private assistant during leisure time. If that´s the case, Frey and Osborne´s conclusions out of Chapter 3.1 may be considered!

6 CONCLUSION AND OUTLOOK

In contrast to prior management techniques a theoretical and methodical approach should be consolidated and standardized, starting from go–to-market ideas and methods for requirement analysis reaching towards the implementation of adequate payment and invoicing models. Novel data services, all-encompassing networking and marketing in tandem with electronic customer interfaces could overstrain existing business models. Hence the time is ripe for change and at the same time, companies have decided to examine their competences and abilities with respective to future market demands. Adaptive measures in automation and production logistics along with cooperative actions aim to enhance the degree of digital maturity for recognizing new possibilities to develop strategies and products that are sought after in the market. Connected intelligent controls for high-precision manufacturing and low-resource utilization enable intralogistical processes for rapid plant reconfiguration to respond to the customized product and the tight delivery schedule. Integrated environments for modelling, simulation, optimization, presentation and virtual production are tools that lead to ICT systems interwoven with all kinds of materials and objects. This concept of ultra-efficiency in the entire chain of value creation may possess the capability to lead firms away from the fractal to the smart factory. Cyber-physical systems will lay the groundwork for all time-dependent fields of intricacy. Progressive development of autonomous intelligent systems includes and combine information from different sources and may pave the way to the emerging production paradigm, shaped by novel manufacturing methods in combination with bespoke digital services. The stress is on the complexity of autonomy and decentralization of systems. Certainly, implemented cyber-physical systems play an important role in decentralized decision making. It enables and regulates the next stage of heterarchical systems autonomy. The granularity of decentralization, the sizing of the elements and its ability for interaction is defined by the complexity of the entire surrounding.

Our rich but increasingly endangered planet calls for actions towards a turnaround in energy policy. One possible solution may be found in a systematic concept for restructuring factories to become eco-friendly. This item comprises not only the factory but also the full spectrum of the company's effective range, its products and the comprehensive range of services. Further meaning that the supply chain and social responsibility for environmental protection already starts in an early phase of any project or draft. Apart from management directives for such a project, the infrastructural condition for a successful execution should also comprise governmental regulations to enforce energy projects and green technologies. It can be specified that the recorded trends in logistics show an increase in the concentration process and a decrease in procedures for obtaining a net reduction in outsourcing. Focus is put on value creation through service packages according the client's need. Current delivery times and delivery methods were adapting to meet high customer satisfaction. Parcel shipment of all sorts of sizes are numerically increasing, the lot sizes are shrinking down to one as the conditions in a growing internet market pushes the customer's expectation for immediate service and delivery action. Autonomous Transportation methods are within fingertip reach. Self-driving trucks will gradually replace existing ones including the drivers. Drones will be used for the quick delivery of goods in crowded cities, merely serving as a cost efficient last-mile transporter. Digital development is promising potential changes and not only in intralogistics. Warehouse robotics, the synchronization of processes and smart engineering of logistic solutions require creative ideas already from the beginning. Digital transformation should be firstly recognized as a product and secondly as a service. Therefore, processing technology plays a central role in this cross-functional relation and is a decisive commercial success factor. Real time communication and the omnidirectional flow of information between items, systems and humans are essential for responding to the amended market demands. The evidence suggests that this tight connectivity is likely leading to a steep increase of the firm´s transparency. At the same time, continuous knowledge will be available to everyone which again draws attention to the urgent need for analyses and improvement about data protection and data security in compliance with regulatory requirements. This process requires a harmonized coherent regulatory framework and a clear and focused policy initiative to improve the competitiveness of the European Industry. Particular attention will be given to the integration of measures to reduce working capital and to increase the business activity that uses new supply instruments. The modern value-generating production paradigm might be interpreted as more performance for the same amount of money. Meaning on the other hand that prior performance is becoming cheaper, which could engage too costly technical solutions as of today, for the use in near future. It can be noted that networking architectures, transfer formats, error detection and diagnosis with the aid of Big Data and Data Mining algorithms find completely new ways to conduct several businesses. Above explained approach further possess the ability to answer matters of smart factories and why they would be successful in the world market. Apparently, it emerges that different approaches are not a panacea as investments must be calculated legally and sustainably sourced. Social obligations should be considered on the way to smart industries. The central role of the human being, related to job assignments is going to be revised. Particularly within state-of-the-art technologies where embedded networks supply human beings with recommendations for action. The person in the center of a process is able to evaluate the data and enforce final decisions based on strategy. Ultimately, the human operator is the responsible and designated operational entity who channels the decisions taken in a purposive and situational manner. If the human, as a competent conductor of production resources will be phased out of the box, a major consequence could be the loss of innovation and further development. The experience with the deserted factory has shown that such a circumstance is successful in least cases. The general policy objective should be ideally achieved through a win-win situation for everyone. The conservation of the environment and natural resources should serve as basis for modifying and developing the guidelines. It seems unassailable that digitization will be subsuming an increasing share of current occupations. By my personal guess, future oriented technologies bear huge potential for improving our world. The crucial point still lies therein how such an instrument will be applied as with any violent invention a careful and respectful approach must be chosen to achieve the best possible and socially acceptable values. At any time in any event we should be able to freely decide if and when an emergency stop must be initiated.

BIBLIOGRAPHY:

Acatech 2011

Acatech (2011): Cyber-Physical Systems - Innovationsmotor für Mobilität, Gesundheit, Energie und Produktion. Proceedings of acatech Position, 2011, Springer Verlag, Heidelberg, DOI 10.1007/ 978-3-642-27567-8

Albu - Schäffer et al. 2007

Albu - Schäffer A. / Ott C. / Hirzinger G. (2007): A unified passivity based
control framework for position, torque and impedance control of flexible joint robots. Proceedings of The Int. Journal of Robotics Research, 2007, vol. 26, no. 1, pp. 23–39

Alotto et al. 2014

Alotto P. / Guarnieri M / Moro F. (2014): Redox flow batteries for the storage of renewable energy. Renewable and Sustainable Energy Reviews, Elsevier, 2014, Vol. 29, No. C, pages 325-335

Arnold et al. 2008

Arnold D./ Isermann H. / Kuhn A. / Tempelmeier H. / Furmans K. (2008): Handbuch Logistik, 3rd ed., Springer-Verlag, Berlin Heidelberg

Bartholdi & Hackman 2014

Bartholdi John J. / Hackman Steven T. (2014): Warehouse & Distribution Science. The Supply Chain and Logistics Institute School of Industrial and Systems Engineering, 2014, Georgia Institute of Technology, Atlanta

Bauernhansl et al. 2014

Bauernhansl T. / ten Hompel M. /·Vogel-Heuser B. (2014): Industrie 4.0 in Produktion, Automatisierung und Logistik. Springer Fachmedien Wiesbaden, pp. 16 -19

Berger 2015

Roland Berger Strategy Consultants / BDI Bundesverband der Deutschen Industrie (2015): Die Digitale Transformation der Industrie. 2015, Berlin,
http://bdi.eu/media/user_upload/Digitale_Transformation.pdf retrieved on December 06, 2016

Bitkom 2014

www.bitkom.org/Presse/Presseinformation/Digitalisierung-wird-die-Logistik-grundlegend-veraendern.html retrieved on December 07, 2016

BMVIT 2015

https://www.bmvit.gv.at/service/publikationen/innovation/mobilitaet/downloads/industrie_4_0.pdf, retrieved on December 12, 2016

BMWi 2015

Studie im Auftrag des Bundesministeriums für Wirtschaft und Energie (Bundes Ministerium für Wissenschaft), Studie „Erschließen der Potenziale der Anwendung von ‚Industrie 4.0' im Mittelstand" Juni 2015, http://www.zenit.de/fileadmin/Downloads/Studie_im_Auftrag_des_BMWi_Industrie_4.0_2015_agiplan_fraunhofer_iml_zenit_Langfassung.pdf, retrieved January 10, 2017

Bowersox et al. 1965

Bowersox J. D. / Closs J. D. / Cooper B. M. (2009): Supply Chain Logistics Management. 1st ed., 2009 by McGraw-Hill, New York

Böse & Lampe 2005

Böse F. / Lampe W. (2005): Adoption of RFID in logistics. Proceedings of IBIMA conference, Cairo 2005, pp. 62-65

Broy 2006:

Broy M. (2006): The ‚Grand Challenge' in Informatics: Engineering Software-Intensive Systems. Proceedings of IEEE Computer 39 (2006), pp. 72 – 80

Broy 2010

Broy M (2010): Cyber-Physical Systems. Innovation durch-Software-Intensive Eingebettete Systeme. Broy M (Hrsg), Proceedings of acatech diskutiert, 2010, Springer-Verlag, Heidelberg http://www.acatech.de/fileadmin/user_upload/Baumstruktur_nach_Website/Acatech/root/de/Publikationen/acatech_diskutiert/acatech_diskutiert_CPS_einseitig_oI.pdf retrieved on December 07, 2016

Cassiman & Golovko 2007

Cassiman B. / Golovko E. (2007): Innovation and the Export-Productivity Link. Proceedings of IESE Business School Working Paper No. 688. pp. 2-9

Choy et al. 2007

Choy. K / Lau H. / Kwok S. / Stuart C. (2007): Using radio frequency identification technology in distribution management: a case study on third-party logistics. International Journal of Manufacturing Technology and Management, 10 (1), Inderscience, Olney, pp. 19-32

Cooper 1990

Cooper, R. 1990. Stage-Gate Systems: A New Tool for Managing New Products. Proceedings of Business Horizons / May-June 1990 pp. 44-54

Cooper 2008

Cooper R. G. (2008): The Stage-Gate idea-to-launch process - Update: what's new and next-gen systems. Journal of Product Innovation Management 25 3 pp. 213 - 232

Cooper & Kaplan 1988

Cooper G. R. / Kaplan S. R. (1988): Measure Costs Right. Make the Right decisions. Proceedings of Harvard Business Review, 1988, pp. 96–103.

Cooper & Kaplan 1992

Cooper G. R. / Kaplan S. R. (1992): Activity-based systems: Measuring the costs of resource usage. Proceedings of Accounting Horizons 09 1992, pp. 1-13

Crosby 2008

Crosby D. (2008): The Zero Defects Option - How To Get Your People To Do Things Right. 1st ed., The Crosby Company, Boston

Crowley 1998

Crowley A. G. (1998): Virtual Logistics: Transport in the Marketspace. International Journal of Physical Distribution & Logistics Management, 28 (7) pp. 547-574

Dawe 1994

Dawe Richard L. (1994): An investigation of the pace and determination of information technology use in the manufacturing materials logistics system. Journal of Business Logistics, 15 (1), Wiley-Blackwell, Chichester, pp. 229-250

DB Schenker 2017

http://www.dbschenker.at/log-at-de/news-media/news/10736360/20160201-ecommercelogistik.html?start=0&itemsPerPage=20, retrieved on January 03, 2017

Delfmann 2010

Delfmann W. (2010): Logistische Segmentierung, Ein modellanalytischer Ansatz zur Gestaltung logistischer Auftragszyklen. Gabler, Springer, Wiesbaden, DOI 10.1007/978-3-663-14788-6_8

Dickmann 2009

Dickmann P. (2009): Schlanker Materialfluss mit Lean Production, Kanban und Innovationen. 2nd ed., Springer-Verlag Berlin Heidelberg, DOI 10.1007/978-3-540-79515-5, pp. 19, 24-25, 146-148, 163, 230-231, 406

Echelmeyer 2008

Echelmeyer W. / Kirchheim A. / Wellbrock E. (2008): Robotics-logistics: Challenges for automation of logistic processes. Proceedings of Automation and Logistics, ICAL 2008

Eigner & Stelzer 2009

Eigner M. / Stelzer R. (2009): Product Lifecycle Management - Ein Leitfaden für Product Development und Life Cycle Management. 2nd ed., Springer, Berlin/Heidelberg, pp. 9-25

Erlach 2007

Erlach K. (2007): Wertstromdesign- Der Weg zur schlanken Fabrik. 2nd ed., Springer-Verlag Berlin Heidelberg

Felser 2015

Felser W. (2015): Der Mensch und die Arbeit in der Industrie 4.0. http://www.huffingtonpost.de/winfried-felser/hannover-messe-industrie-40-mensch-arbeit_b_7091736.html, retrieved on January 8, 2017

Feichtenberger 2016

Feichtenberger Andreas (2016): Morgenstunde. Ein Verkehrsbericht aus 2100. DC Magazin/Ausgabe5/2016/Technologie, Media Unit, Wien, pp. 028-030

Finkenzeller 2015

Finkenzeller K. (2015): RFID-Handbuch: Grundlagen und praktische Anwendungen von Transpondern und kontaktloser Chipkarten und NFC. 7. Auflage, Carl Hanser Verlag, München, DOI: 10.3139/9783446444393, pp. 9, 33-77, 625

Fleisch et al. 2003

Fleisch E. / Kickuth M. / Dierks M. (2003): Ubiquitous Computing: Auswirkungen auf die Industrie. Industrie Management 2004, 6, pp. 29-31

Fraunhofer 2016

SIT Fraunhofer 2016: The Fraunhofer Institute for Secure Information Technology SIT. www.sit.fraunhofer.de, www.sit.fraunhofer.de/de/cyberphysicalsystems, Fraunhofer IML, Fraunhofer IGD retrieved on December 02, 2016

Freitag et al. 2004

Freitag M. / Herzog O. / Scholz-Reiter B. (2004): Selbststeuerung logistischer Prozesse – Ein Paradigmenwechsel und seine Grenzen. GITO - Verlag, Berlin, pp. 1-5, pp. 23-27

Frey & Osborne 2013

Frey C. B. / Osborne M. A. (2013): Program on the Impacts of Future Technology. University of Oxford, Oxford, pp. 28-33

God & Wittke 2016

God R. / Wittke U. (2016): Cyber-physical Aviation. Ingenieurspiegel 1/2016, Institut für Flugzeug-Kabinensysteme, Technische Universität Hamburg-Harburg, www.tuhh.de/fks/pdf/IS_1_2016_God.pdf, retrieved on January 09, 2017

Goldammer 2003

Goldammer E. (2003): Heterarchie-Hierarchie: Zwei komplementäre Beschreibungskategorien. Proceedings of Vordenker, 2003, http://www.vordenker.de/heterarchy/a_heterarchie.pdf, retrieved on January 16, 2017

Gorecky et al. 2012

Gorecky D. / Campos R. / Meixner G. (2012): Seamless Augmented Reality Support On The Shopfloor, Based On Cyber-Physical-Systems. Proceedings of the 14th International Conference on Human-computer Interaction with Mobile Devices and Services (MobileHCI-12), September 21-24, San Francisco, CA, USA, ACM, 2012

Gunson & de Blasis 2001

Gunson J. / de Blasis Jean P. (2001): The Place and Key Success factors of Enterprise Resource Planning (ERP) in the New Paradigms of Business Management. Ecole des Hautes Etudes Commerciales, Universite de Geneve, faculte des SES, pp. 7-20

Guo et al. 2017:

Guo Z. / Zhang Y. / Zhao X. / Song X. (2017): A Timed Colored Petri Net Simulation-Based Self-Adaptive Collaboration Method for Production-Logistics Systems. Proceedings of Applied Science, 2017, 7, pp. 235-250, DOI 10.3390/app7030235

Günthner & Hompel 2010

Günthner W. / Hompel M. (2010): Internet der Dinge in der Intralogistik.
1st. ed., Springer-Verlag, Berlin, Heidelberg, pp. 15-21

Holtewert et al. 2013

Holtewert P. / Wutzke R. / Seidelmann J. / Bauernhansl T. (2013): Virtual Fort Knox - Federative, Secure and Cloud-based Platform for Manufacturing. Proceedings of CIRP 7, pp. 527-532, DOI 10.1016/j.procir.2013.06.027

Hopp & Spearman 2004

Hopp Wallace J. / Spearman Mark L. (2004): To Pull or Not to Pull: What Is the Question? Proceedings of Manufacturing & Service Operations Management 2004, Catonsville, pp.133-148, doi:10.1287/msom.1030.0028

Hülsmann & Windt 2007

Hülsmann M. Windt K. Freitag M. (2007): Understanding autonomous cooperation and control in logistics – the impact on management, information and communication and material flow. Springer, Heidelberg

IG Metall 2017

IG Metall.de, https://wap.igmetall.de/docs_Lernen_im_digitalen_Wandel_web_507d78fbd67e7168ade06052851d615e0ffe0732.pdf retrieved on January 7, 2017

Industrie – Informatik 2004

ERP vs. MES Oder warum ein ERP alleine nicht alle im Unternehmen glücklich mach, 05. November 2014, https://www.industrieinformatik.com/de/unternehmen/aktuelles/detail/industrie-informatik-erp-vs-mes.html retrieved on January 08, 2017

Jeschke 2014:

Jeschke S. (2014): Towards Logistic 4.0, Distributed Systems with Decentralized Control. Proceedings of Global Production Summit Lufthansa Cargo, June 2015, Faculty of Mechanical Engineering RWTH Aachen University. Pp. 4-25

Kao et al. 2014

Kao An H. / Jin W. / Siegel D. / Lee J. (2014): A Cyber Physical Interface for Automation Systems-Methodology and Examples. Machines ISSN 2075-1702 NSF I/UCRC for Intelligent Maintenance Systems, University of Cincinnati, pp. 96-98

Klenk & Knössl 2010

Klenk E. / Knössl T. (2010): Logistikorientierte Wertstromanalyse. Proceedings of Logistikseminar Erschließung von Produktivitätspotenzialen in der Logistik, Garching, 14.10.2010, fml -Lehrstuhl für Fördertechnik Materialfluss Logistik, Technische Universität München, pp. 2-28

Koren 2010

Koren Yoram (2010): The Global Manufacturing Revolution. Published by John Wiley (2010); New York, ISBN: 978-0-470-58377-7

Kögel et al. 2017

Kögel T. / Kohn M. / Wimmer T. (2017): Verarmt durch Industrie 4.0 die Gesellschaft? Ein Stimmungsbild. Wie cyber-physische Systeme die Arbeitswelt verändern. Springer Fachmedien, Wiesbaden

Kuhn & Hellingrath 2002

Kuhn, A. / Hellingrath H. (2002): Supply Chain Management – Optimierte Zusammenarbeit in der Wertschöpfungskette. Springer-Verlag, Berlin, pp. 12-35

Kuka 2017

www.kuka.com/de-at/produkte-leistungen/mobility/mobile-roboter/kmr-iiwa,
www.kuka.com/de-de/presse/news/2017/02/vorläufige-geschäftszahlen-2016,
retrieved on February 03, 2017

Kumar et al. 2006

Kumar S. / Soeren P. / Budin E. (2006): Impact of radio frequency identification technology on manufacturing and logistics: challenges and issues. International Journal of Manufacturing Technology and Management, 10 (1), Inderscience, Olney, pp. 57-60

Lebedev et al. 2007

Lebedev Mikhail A. / Nicolelis Miguel A. L. (2007): Brain–machine interfaces: past, present and future. Proceedings Trends Neuroscience, 2006; 29, pp. 536-546,
DOI 10.1016/j.tins.2006.07.004

Lee 2008

Lee Edward A. (2008): Cyber Physical Systems: Design Challenges. Technical report, University of California, Berkeley

Lee & Seshia 2011

Lee Edward A. / Seshia Sanjit A. (2011): Introduction to Embedded Systems - A Cyber-Physical Systems Approach, 1st ed., 1.08, University of California, Berkeley

Lin 2006

Lin Chieh-Yu (2006): Influencing Factors on the Innovation in Logistics Technologies for Logistics Service Providers in Taiwan, Journal of American Academy of Business, 9 (2), Cambridge, pp. 257-264

Lorenz et al. 2015

Lorenz M. / Rüßmann M. / Strack R. / Lasse Lueth K. / Bolle M. (2015): Man and Machine in Industry 4.0, How Will Technology Transform the Industrial Workforce Through 2025?.
https://www.bcgperspectives.com/content/articles/technology-business-transformation-engineered-products-infrastructure-man-machine-industry-4, retrieved on January 7, 2017

Macharis & Melo 2011

Macharis C. / Melo S. (2011): City Distribution and Urban Freight Transport: Multiple Perspectives. Nectar Series, Edward Elgar Publishing, Cheltenham, ISBN0857932756, 9780857932754, pp. 56-58

McKinsey 2011

McKinsey (2011): Big Data, The next frontier for innovation, competition and productivity. McKinsey Global Institute, San Francisco, p. 4
McKinsey Global Institute: (2012): Manufacturing the future: The next era of global growth and innovation. McKinsey Global Institute, New York

Miller & Vollmann 1985

Miller G. J. / Vollmann E.T. (1985): The hidden factory. Harvard Business Review, 63, 05, ISSN 0017 8012, pp. 142-150

Ohno 1988

Ohno T. (1988): Toyota Production System: Beyond Large-Scale Production.
March 1, 1988, Productivity Press, Tokyo, New York

Pantförder et al. 2014

Pantförder D. / Mayer F. / Diedrich C. / Göhner P. / Weyrich M. / Vogel-Heuser B. (2014): Agenten-basierte dynamische Rekonfiguration von vernetzten intelligenten Produktionsanlagen. Springer, Wiesbaden, pp 145-158

Pfohl 2010

Pfohl Christian H. (2010): Logistiksysteme. 8th ed., Springer, Berlin Heidelberg

Platek et al. 2009

Platek M. S. / Keenan P. J. / Shackelford K. T. (2009): Evolutionary Cognitive Neuroscience. The MIT Press, Cambridge, p. 139

Plowman 1964

Plowman Grosvenor E. (1964): Seven-Rights-Definition. Proceedings of Lectures on Elements of Business Logistics, 1964, Stanford University Press

Reichl & Wolf 2001

Reichl H. / Wolf J. (2001): Things that think. TU Berlin - Forschung aktuell, No. 49/Jahrgang 18, Berlin, pp. 1887-1898

Res-Com 2011

http://www.res-com-projekt.de/index.php/ueberblick_DE.html retrieved on December 08, 2016

RoboScan 2014

RoboScan'14, BIBA – Bremer Institut für Produktion und Logistik,
http://www.robotik-logistik.de/index.php?id=316&L=1&type=1, retrieved on January 17, 2017

Rohpol 2009

Rohpol G. (2009): Allgemeine Technologie, Eine Systemtheorie der Technik. 3., überarbeitete Auflage 2009, Universitätsverlag Karlsruhe, Karlsruhe

Russom 2011

Russom P. (2011): Big Data Analytics TDWI Best Practices Report. The Data Warehousing Institute), Media Inc., Renton, https://vivomente.com/wp-content/uploads/2016/04/big-data-analytics-white-paper.pdf, retrieved on January 20, 2017

Scherwietes 2013

Scherwietes T (2013) Standardisierter Datenaustausch zwischen CAE und PLS. Proceedings of Vortrag Namur Hauptsitzung 2013, Lahnstein

Scholz-Reiter et al. 2004

Scholz – Reiter B. / Windt K. / Freitag M. (2004): Autonomous Logistic Processes - New Demands and First Approaches. University of Bremen, Bremen, pp. 1-6

Scholz-Reiter et al. 2009

Scholz-Reiter B. / Hildebrandt T. / Kolditz J. (2009): Modellierung selbststeuernder produktionslogistischer Prozesse – die Modellierungsmethode ALEM. Planung und Steuerung produktionstechnischer Systeme, Universität Bremen, pp 4-5

Schuh & Stich 2013

Schuh G. / Stich V. (2013): Produktion am Standort Deutschland. Management-Summary, Aachen, 2013. ISBN: 978-9-943024-15-9

Seitza & Nyhuis 2015

Seitza Frederic K. / Nyhuis P. (2015): Cyber-Physical Production Systems Combined with Logistic Models – A Learning Factory Concept for an Improved Production Planning and Control. Proceedings of CIRP 32, 2015, 92-97, The 5th Conference on Learning Factories, pp. 94-95, Science Direct, DOI 10.1016/j.procir.2015.02.220

Sontow 2016

Sontow K. (2016): Interview mit Dr. Karsten Sontow für den IT & Business Newsletter, 2.6.2016, http://www.erp-area.com/2016/06/ retrieved on February 06, 2017

Stadtler 2005

Stadtler H. (2005): Supply chain management and advanced planning - basics, overview and challenges. European Journal of Operational Research, Volume 163, Issue 3, 16 June 2005, Elsevier, pp. 575–588

Swisslog 2017

http://www.swisslog.com/en/Solutions/WDS/Supporting-Picking-Technology retrieved on January 9, 2017

Sztipanovits et al. 2012

Sztipanovits J. / Koutsoukos X. / Karsai G. / Kottenstette N. / Antsaklis P. / Gupta V. / Goodwine B. / Baras J. / Wang S. (2012): Toward a science of cyber–physical system integration. Proceedings of IEEE 2012, pp. 29-44, DOI 10.1109/JPROC.2011. 2161529

Traeger et al. 2003

Traeger M. / Eberhart A. / Geldner G. / Morin A. M. / Putzke C. / Wulf H. / Eberhart L. J. H. (2003): Künstliche neuronale Netze. Theorie und Anwendungen in der Anästhesie. Proceedings of Anaesthesist 2003, Springer-Verlag, DOI 10.1007/s00101-003-0576-x© 2003

Twist 2005

Twist D. (2005): The impact of radio frequency identification on supply chain facilities. Journal of Facilities Management, 3 (3), Emerald Group Publishing Limited, Bingley, pp. 226- 240

UNIGE, Huber 2017

http://www.biopticsworld.com/articles/2017/02/optical-stimulation-provides-sensory-feedback-between-brains-and-artificial-limbs.html retrieved on February 26, 2017.

Veigt et al. 2013

Veigt M. / Labbe D. / Hribernik K. A. / Scholz-Reiter B. (2013): Entwicklung eines Cyber-Physischen Logistiksystems. Industrie Management (1), 2013, pp. 15-18

Vogel-Heuser et al. 2012

Vogel-Heuser B / Bayrak G / Frank U (2012): Forschungsfragen in „Produktionsautomatisierung der Zukunft. Proceedings of acatech Materialien Diskussionspapier für die acatech Projektgruppe „ProCPS – Production CPS", acatech München, p. 15

Vogel-Heuser B (2013): Herausforderungen und Anforderungen an CPS aus Sicht der Automatisierungstechnik, Automatisierungstechnik 61(10): 669–676. DOI 10.1524/auto.2013.0061T.

Windt et al. 2007

Windt K. / Böse F. / Philipp T. (2007): Autonomy in production logistics: Identification, characterisation and application. Robotics and Computer- Integrated Manufacturing 24, pp. 572-578, Science direct, DOI 10.1016/j.rcim.2007.07.008

Wolter et al. 2015

Wolter M. I. / Mönnig A. / Hummel M. / Schneemann C. / Weber E. / Zika G. / Helmrich R. / Maier T. / Neuber-Pohl C. (2015): Industrie 4.0 und die Folgen für Arbeitsmarkt und Wirtschaft., Proceedings of IAB-Forschungsbericht 08/2015

Zhang 2013

Zhang Yi (2013): The Study on the Governmental Tactics of Persuasion of Network Public Sentiment, Advances in Intelligent Systems Research, p. 223. DOI 10.2991/icpm.2013.41

LIST of FIGURES