Towards an Production Concept based on Internet Technologies

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Abstract: An important change in the environment of industrial firms is the diffusion of Internet Technologies in production processes. While traditional Production Concepts inevitably disregard this development, new Production Concepts arise that fundamentally consider the application of Internet Technologies on the shop floor. This paper provides a discussion of the consequences of Internet Technologies on production/operations management as well as of Production Concepts based on Internet Technologies. This discussion reveals major conceptual drawbacks on existing concepts concerning an intrafirm application. Thus, we introduce Web-based Manufacturing as a concept based on the consequent intrafirm application of Internet Technologies on the shop floor.

Keywords: E-Manufacturing, Web-based-Manufacturing, Production Concept, Manufacturing System Integration, Distributed Automation

1 Introduction

One of the most important changes in the technological and economic environment of industrial firms is the increasing diffusion and strongly increasing commercial use of the Internet in the last years. As the most important medium of the new information and communication technologies, it has also a high influence on manufacturing, because new technologies generally affect manufacturing processes in a very special manner (Lau 1998, pp. 150). Both, formal and empirical studies verified the significant increase in productivity of manufacturing processes by intraorganizational applications of modern information and communication technologies (Barua/Lee 2001, pp. 37).

Early applications of Internet Technologies were limited to single, unconnected solutions for distributed CAD systems or telecooperation. Now Internet Technologies may reach into automation and control level of every assembly line. Therefore, it is not surprising that applications of Internet Technologies in production processes on the shop floor increase and that automation technology suppliers combine Internet Technologies more and more to their products. While many traditional Production Concepts inevitably disregard this development, new Production Concepts arise that fundamentally consider the application of Internet Technologies on the shop floor.

2 Recent Advances in Industrial Applications of Internet Technologies

Usually the term Internet Technologies is understood in the context of the well-known Internet as the technological basis of a global information and communication network. Often there is no differentiation between company internal and external applications. Indeed, the WWW (World Wide Web) is the most popular and for almost everyone observable application of Internet Technologies. However, the term „Internet Technologies" does not prejudge an external relevance. The term Internet Technologies describes nothing but a family of technologies suitable for exchanging structured data by means of package-oriented transmissions on heterogeneous platforms, in particular protocols, programming languages, hardware, and software. They may be used for global, interfirm, as well as intrafirm communication and information purposes. Yet, the internal application of these technologies focuses on Intranets for office information systems. In future, the main intrafirm area of industrial applications for Internet Technologies is the shop floor or rather any production process (Blecker/Haber 2001, pp. 338).

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In particular, the networking of automation infrastructure and machine controls via Internet capable network technologies is very important. Fieldbuses are still dominating in production processes, e.g. the Profibus concept of Siemens. In future, Internet based systems will complement or even replace fieldbuses and other proprietary automation techniques. Since 1985, industrial firms use Ethernet networking on the shop floor. Due to new standards, Industrial Ethernet reduces the technological limits existing up to now to the applicability of Internet Technologies on the shop floor or even the replacement of fieldbuses. Industrial Ethernet is based on the relevant international standards (e.g. IEEE 802.3). It is adjusted to the specific environmental conditions in manufacturing, for example regarding to electromagnetic compatibility, shaking, moisture, and chemical resistance (Siemens 1999a, pp. 20). Today, Ethernet and Industrial Ethernet are already the de facto standards in manufacturing, e.g. in the automotive industry, process industry as well as in plant engineering (Siemens 1999b). Thus, we consider Ethernet and Industrial Ethernet as the general future network technology for production environments.

However, the technological improvement of Industrial Ethernet and/or Internet Technologies in general does not necessarily enable a total replacement of fieldbuses. On the one hand, some applications or existing machinery still needs an infrastructure based on fieldbuses. On the other hand, fieldbuses such as Profibus evolve towards a convergent, interconnective infrastructure, e.g. as Profinet. Hence, even where Ethernet can't replace fieldbuses, Internet Technologies connect the different lines together and transfer detailed data from the shop floor to the office et vice versa. Consequently, a comprehensive application of Internet Technologies enables the expansion of existing Intranets in office automation to all production processes, especially manufacturing. We call this the application of Internet Technologies „on the shop floor". The utilization of so-called enabling technologies, such as Web Services, Active Technologies, and Industrial Frameworks (based on .NET or Sun ONE), will support intelligent manufacturing automation technologies and a homogeneous network from office to manufacturing. Internet Technologies become a ubiquitous network respectively an omni-present information infrastructure in the complete industrial firm.

The interconnection of assembly lines as well as sharing detailed data with corporate Ethernet networks leads to a direct communication between Enterprise Resource Planning (ERP) respectively Production Planning and Control (PPC), Manufacturing Execution Systems (MES) and Automation Technologies in the sense of Enterprise Application Integration (EAI). Because of the resulting high availability of real-time data from shop floor equipment new (production) planning and control mechanisms as well as continuous information and communication structures between administrative and production systems arise. Furthermore, due to the evolution of the direct, IP supported networking on machinery level, we expect an increase of distributed services in production processes. This leads to a strong approximation of the traditional production and operation systems and the Internet Technologies. Industrial practice as well as technical and business literature describes this phenomenon as convergence of information and production systems (e.g. Blecker 2001, pp. 19). It describes in a simple understanding the uniting of functionally different technologies to a homogeneous service bundle, which enables the revision of traditional Production Concepts or even the development of new Production Concepts.

3 Emerging Issues of Internet Technologies in Production Concepts

3.1 State of the Art

While management research is still neglecting the usage of Internet Technologies in production, first approaches for an integration of information systems in production environments based on Internet Technologies can be observed in engineering since end of the 1990s. However, the emphasis is mostly on the coordination of decentralized units, for example distributed CAD systems

and telecooperation (Cheng/Pan/Harrison 2001, pp. 14). An intrafirm usage of Internet Technologies to support all industrial business processes even hardly occur.

The considerable advantages of Internet Technologies are uncontroversial for the technological infrastructure of information and communications in production processes. According to Atherton's (1999) idea *Java-based applications* support planning and control of all production processes. In this scenario Internet Technologies integrate the technical CAx-Systems with the economical ERP. This means, Java connects different technological environments and acts as gateway between automation technology and information technology. This scenario reminds of the already known basic idea of Computer Integrated Manufacturing (CIM). The application of Internet Technologies is set into the center of the consideration and extensive, heterogeneous functionalities are integrated in a homogeneous web-interface. Nevertheless, this attempt does not achieve new advantages vis-à-vis the CIM-concept or quite a new Production Concept. It only centers the attention to industrial applications of Internet Technologies. However, in the literature some self-contained Production Concepts exist, which more or less consider Internet Technologies in production processes. For the discussion of these concepts, we differentiate four criteria: 1. the guiding idea presented in the literature, 2. the aimed conditions of the production system, 3. (general) recommendations for achieving the aimed conditions and 4. the discussed instruments.

E-Manufacturing or Electronic Manufacturing are keywords, which are discussed recently in connection with terms like E-Commerce and E-Business. Main guiding ideas of E-Manufacturing are the control of the entire value chain with E-Technologies as a central task of industrial firms and a comprehensive optimization of the Supply Chain (Wildemann 2000, pp. 22). For realizing these ideas, E-Manufacturing aims the continuous alignment of manufacturing at the individual customer requests, high quality of products and low costs. E-Procurement, cooperative manufacturing operations in production networks, flexible and decentralized planning and control systems as well as a direct networking of decentralized production units are seen as a general framework, in which industrial firms has to operate. Therefore, sophisticated build-to-order concepts, the integration of customers and suppliers as well as the application of E-Technologies are recommended. Additionally, an integration of the dislocated information systems is required. The E-Manufacturing fills the different demands through the application of instruments such as Internet based PPC, a product data management / engineering data management (PDM/EDM) as well as newer CAx-Technologies. However, this is in our understanding not a new manufacturing concept, but only a relatively non-structured collection of approaches and technologies that focus on the application of so-called E-Technologies. It outlines only qualities of manufacturing in the E-Commerce.

The *Information-Based Manufacturing* shows a higher reference to production processes. This approach describes as guiding idea an information-dependent production, which is distributed about several enterprises. As aimed conditions, it refers a strong customer relationship, a high velocity of (re)actions, networking of decentralized production processes and synchronized demands (Shaw 2001, pp. 8). Similar to E-Manufacturing the Information-based Manufacturing recommends build-to-order concepts, supply chain coordination and an optimal information sharing. Therefore, exemplary instruments are an optimal synchronization of production factor appropriation and scheduling between the firm and their partners in the entire supply chain. Therefore, companies must have agent systems, decentralized planning and operation systems as well as integrated information and automation technologies in the dislocated production processes for the realization of Information-Based Manufacturing (e.g. Veeramani/Wang 2001, pp. 246). Thus, the commitment of Internet Technologies does not occur in an intraorganizational way, but mainly interorganizationally, for example based on WebEDI, or during the communication with the customers. The focus of the investigations differs obviously from our intraorganizational perspective.

Beavers examines manufacturing and the different production processes within his concept of the *e-Factory* and considers the necessary qualities of industrial firms. He formulates as guiding idea for the e-Factory, that it is an upright element of an electronic supply chain in E-Business and defines this approach as „a new, all-encompassing term for all of the electronic control, automation, and intelligent machines that occupy today's factory environment" (Beavers 2001, p. 14). Aimed conditions are a quickly reacting production system respectively low operation times, a high process orientation as well as the integration of the own enterprise into the supply chain. Therefore, additionally to the application of E-Technologies, Beavers recommends a cooperative production process in the network structures of a supply chain (Enterprise Extension) and a strong coordination between outsourcing and inhousing. Discussed instruments are electronic control systems for all automation technologies and an extensive application of information systems, e.g. ERP, Warehouse Management System and PDM/EDM. We share the fundamental opinion that modern information and communication technologies penetrate the production processes and pass the production up to the automation level as well as to the machine control. However, we criticize the delimitation of the e-Factory on electronic supply chains and/or the E-Business. On the one hand, we absolutely see a high application potential of Internet Technologies within industrial firms, which were not subjects of the E-Business up to now and would traverse a material production in the classical sense. On the other hand, Beavers apply with this consideration again a perspective, which is at least partially enterprise-external. However, it is more serious that Beavers writes generally about „electronic control", without a specification, e.g. on Internet Technologies. Therefore, the definition encloses almost all modern control mechanisms in manufacturing. Even NC, CNC or DNC machinery contains an electronic excitation and/or control. Thus, the definition is not selective enough and does not provide a suitable explanation of an Internet based Production Concept.

Positive approaches for the application of Internet Technologies in manufacturing are observable in engineering research. We have to point out that at the Fraunhofer-Institut for Factory Operation and Automation (http://www.iff.fhg.de/) Kuehnle et al. elaborated an approach of *Web-Integrated Manufacturing*. Web-Integrated Manufacturing follows the guiding idea of the general applicability of Internet Technologies in manufacturing, for example, agent based systems, Java, Jini and SOAP (e.g. Kuehnle/Klostermeyer/Lorentz 2001, pp. 463). Even the international research project „plant automation based on distributed systems" (http://www.pabadis.org/) uses this approach as theoretical basis. The project goal is the application of decentralized, distributed systems of the office communication within the machine control on the shop floor. This is supposed to lead to the aimed conditions, namely highly flexible, adaptive and simply reconfigurable production systems. Reconfigurable production systems combine the respective advantages of high-productive and high-flexible systems, because they may be adapted immediately regarding their structure, functionality, capacity as well as their inherent technology to changed demands. For the realization of this scenario, this approach recommends a distributed computing and distributed problem solving in automation on the shop floor. Therefore, the instruments of Web-Integrated Manufacturing focuses on decentralized agent system in manufacturing and embedded systems in automation technologies. Furthermore, these agent systems have to substitute occasionally existing Manufacturing Execution Systems (MES). However, up to now, the different projects analyze the Internet Technologies only as a basis of the Web-Integrated Manufacturing and examine their applications in technical systems. A definition of a Production Concept occurs just as little as a strategic substantiation.

Additionally Huang/Mak use the term *Web-Integrated Manufacturing* during the preparation of a special edition of the International Journal of Computer Integrated Manufacturing. Both Huang/Mak (2001a, pp. 3; 2001b, pp. 125) as also the other contributors to this journal only describe individual, dislocated applications based on Internet Technologies for the product design and manufacturing. Therefore, the main idea of this approach is the application of interorganizational CAx-technologies and CAD/CAM systems, e.g. for the distributed product design

(Chang/Pan/Harrison 2001, pp. 14). Aimed condition of Web-Integrated Manufacturing is a flexible, distributed production process between two ore more collaborates. Hence, the recommendations for realizing Web-Integrated Manufacturing are the development of interorganizational information systems for a dislocated product development, rapid prototyping, the application of automated production systems based on so-called Web-Applications. The authors discuss mainly CAx and CAD/CAM, quality function deployment and the integration of the dislocated intra- and interorganizational information systems in the sense of EAI as instruments. While Huang/Mak does not systematize the term Web-Integrated Manufacturing exactly, they define the term „Web Application“ as the essential element of Web-Integrated Manufacturing (Huang/Mak 2001a, p. 4). However, with this definition Web-Integrated Manufacturing is considered merely very generally as the application of Internet based technologies in the production and does not lead to any Production Concept.

The figure 1 shows a comparison between the different approaches related to Internet based Production Concepts following the discussed criteria. We can diagnose, that both scientific research and industrial practice impose the importance of the Internet Technologies for manufacturing. Nevertheless, we criticize that the individual island solutions as well as the first more comprehensive concepts concentrate primarily onto technical aspects.

Concept / Criteria	E-Production / E-Manufacturing	Information-Based Manufacturing	e-Factory	WIM (IFF / PABADIS)	WIM (IJCIM)
Guiding Idea	• production in e-commerce • optimization of the Supply Chain	• integration in Supply Chain Networks • distributed, information-dependent production	• production as vertical element of the Supply Chain in e-business	• decentralized, agent-based automation as technical reply to turbulent environments	• interorganizational CAD/CAM combined with Internet Technologies
Aimed Conditions	• customer focus • high quality • low costs	• customer focus • high velocity of (re)actions • networked production • synchronized demands	• process orientation • low operation time • production in an e-Supply Chain	• high flexibility • adaptive • reconfigurable subsystems	• flexible • interoperabel
Recommen-dations	• build-to-order • e-technologies • integration of customer & suppliers	• build-to-order • Supply Chain coordination • information sharing	• enterprise extension • outsourcing • inhousing • cooperative manu-facturing operations	• distributed computing • distributed automation	• high automation • dislocated product development • development of web-applications
Instruments	• e-procurement • decentralized CAx • decentralized production planning • PDM/EDM	• web-EDI • agent systems • decentralized production planning • Integration of IT and automation	• electronic machine control • business information systems, e.g. ERP, CRM, SCP • (e-)procurement	• agent systems • embedded systems • mobile code • reduction of MES-System	• CAx or CAD/CAM • quality function deployment • enterprise appli-cation integration

Figure 1: Comparision between different Production Concepts based on Internet Technologies

The most comprehensive approaches represent the Web-Integrated Manufacturing according to Huang/Mak (IJCIM) and the e-Factory. Nevertheless, we must consider that Web-Integrated Manufacturing is still guided too much by the main features of Computer Integrated Manufacturing. The authors take over these considerations too uncritically and introduce only single Internet Technologies into the production systems. Furthermore, at least terminologically we have to criticize the strong integration aspect that contradicts many approaches of the decentralization, for example the decentralized automation. The e-Factory uses an uncritical definition of the electronic control of the machines and plants as central basis. Furthermore, the approach of the e-Factory does not focus on the improvement of the internal production processes. Instead, Beavers recommend the participation in an optimized supply chain. The discussion above showed that almost all concepts share explicitly or implicitly the same underlying idea of the enterprise-external orientation. This means that they rather focus on cooperative production and/or supply chain perspectives. Figure 2 presents the different emphases of the described approaches related to an Internet Technology based Production Concept. For this purpose, we distinguish on the vertical axis between an interorganizational and an intraorganizational orientation of the concepts. On the horizontal axis, we differentiate between a technical and an economical focus of the underlying theories and approaches.

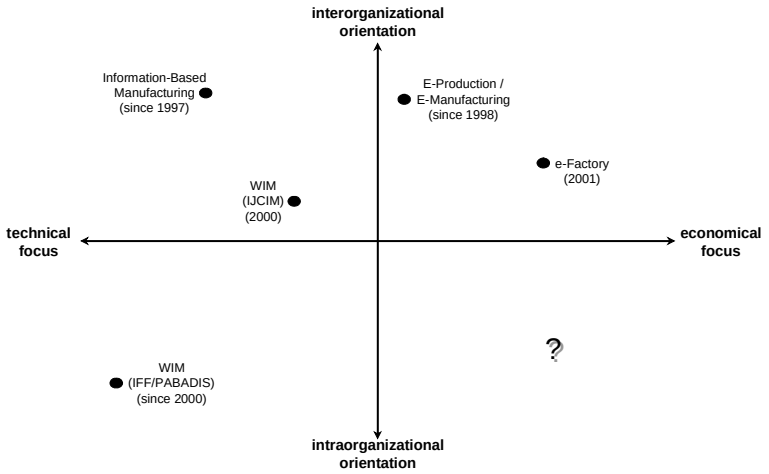

Figure 2: Focusses of different Production Concepts based on Internet Technologies

A more comprehensive concept of Internet Technologies applications in production processes has to focus a more consistent and continuous commitment of the Internet Technologies *in* industrial firms and has to deal with the current evolutions of the production technique as well as Production/Operations Management (POM). Mainly we expect that such a concept focus not only on the dislocated usage of the Internet Technologies as a communication media between a company and their partners, suppliers, and customers. Instead, it has to concentrate itself on the consequences of Internet Technologies for the shop floor, new options of the Internet Technologies in POM and their effects on the strategic and operative management of industrial firms. Such a concept is *Web-based Manufacturing*. It is based on the continuous and global application of multimedia Internet Technologies in the technical and managerial processes concerning industrial production and reaches from the office into the automation level.

3.2 Web-based Manufacturing as a new Internet Technology based Production Concept

We assume that it is generally necessary, to changeover from computer integrated to Internet based Production Concepts. Therefore, we will oppose important characteristics of these two philosophies.

An essential difference between these two philosophies is that CIM focuses on an integration of different, dislocated subsystems of the planning and operation of production processes. If we consider this integration as constitutive for Internet Technology based Production Concepts too, it is only a necessary, not a sufficient definition criterion. In particular, we regard the centralistic integration intended in former Production Concepts as technological and organizational obsolete. Internet based Production Concepts emphasize that the application of Internet Technologies on the shop floor represents an important basis of an economically successful production in future. Therefore, these concepts consider the application of Internet Technologies as focal component, not only integrating element. The intense application of Internet Technologies in the production processes and/or their combination with the automation technologies reduces the central coordination and control as well as the formerly forced heteronomy of the actors in production processes. Instead, decentralized coordination and operation mechanisms as well as an at least partial self-determination of the actors become possible. This means, that industrial firms can apply the already known concepts of the decentralized PPC as well as partially autonomous manufacturing technologies more effectively.

A further advantage of Internet Technology based Production Concepts is that they reduce the up to now rigid, but often inflexible infrastructures and the resulting high configuration intensity. The Internet based infrastructures will lead to flexible, easily reconfigurable production systems. Industrial firms acquire the advantage to approve unsolicited modifications in the production processes respectively the underlying structures on the shop floor, so that they will have a infra-

structure in the sense of „plug and produce“. Consequently, they will reduce hierarchical organization and coordination efforts too. In fact, the elements and actors of the production system receive own problem solution abilities and decentralized data storage through the application of Internet Technologies so that they are partially emancipated of central planning and control authorities. Additionally, it is conceivable, that firms have to give up their up to now effective process orientation in favor of an orientation to the occurring information and communication processes. The fig. 3 compares Computer-integrated and Internet-based Production Concepts.

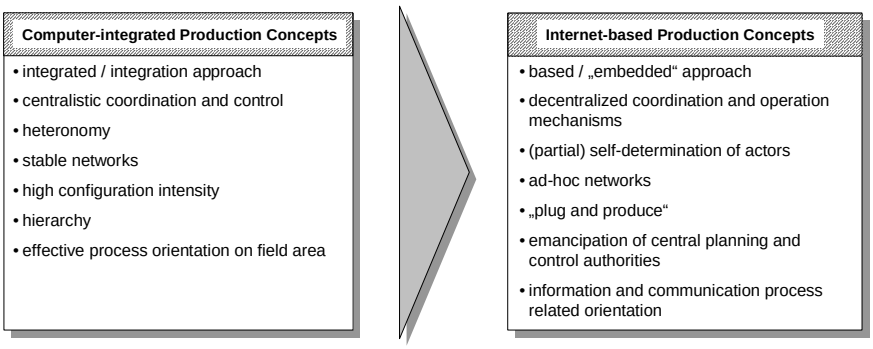

Figure 3: Computer-integrated vs. Internet-based Production Concepts

The concept of Web-based Manufacturing assumes the convergence of automation and information technologies, this means the solely enterprise-intern application of the Internet Technologies „on the shop floor“. Hence, Web-based Manufacturing is a technology driven Production Concept, which is based considerably on the new technologies. However, this does not mean that it is inevitable technology centered. Instead, this concept focuses on a rigorous perspective from business administration as well as production/operations management and concentrates on the up to now unused potentials of the Internet Technologies in production processes. Thus, we define:

> Web-based Manufacturing is an Internet Technology based Production Concept, that is an in theory well-founded guiding-idea, based on empirical knowledge where appropriate, on the organization, planning, control and evolution of production systems. It aims at easily reconfigurable, high flexible production systems based on the comprehensive application of Internet Technologies on the shop floor. Main goal is to achieve market- and resource oriented competitive advantages supported by the application of Internet Technology based technological and/or conceptual procedures and processes in a decentralized coordinated, according to informational criteria organized and ad-hoc structures forming production environment.

Production concepts strive ex definitione for an improvement of the competitive position in industrial firms based on an optimization of production processes (Blecker 2003). This very general goal is to be adapted for the Web-based Manufacturing according to the current basic conditions of the industrial production. In particular, we have to emphasize strongly increasing flexibility requests, for example due to the individualization of products, and the tendency to reduce the high automation in the production for the benefit of a so-called adaptive automation in flexible manufacturing systems. As a guiding-idea, the Web-based Manufacturing proposes a flexible, freely configurable production system. With that, we focus a high strategic importance of production and follow the projects arisen in the last 20 years that use the production as a success factor in competition. However, these projects mainly place the market-based view as conceptual basis. This means, these projects does not consider the asymmetric resource allocation between individual companies, although the resource allocation is decisive for the realizable variants of production systems. Hence, Web-based Manufacturing abolishes the one-sided analysis dominating up to now and considers the production processes as well as the applicable technologies as strategically relevant resources of the enterprises that lead to competitive advantages. As result, Web-based Manufacturing interprets the industrial production as a competitive weapon from a market-based as well as from a resource-based view.

Based on the above-elaborated definition and outlined elements we can derive and/or accentuate several qualities of Web-based Manufacturing here again:

- Web-based Manufacturing is an intraorganizational Production Concept that concentrates on internal production processes and not on dislocated processes between companies. However, it enables an interconnection between decentralized production units and/or the participation in production networks and virtual organization by the application of Internet Technologies too.
- Web-based Manufacturing concerns all fields and assignments of production, which are the design of the production system, the determination of the production program, production factor appropriation and scheduling as well as manufacturing operations (Blecker 2001, pp. 22).
- Web-based Manufacturing considers both technological tasks and functions, e.g. automation, as well as business administrative tasks and functions, e.g. PPC.
- The application of Internet Technologies in the Web-based Manufacturing is not only a device for the integration of dislocated processes and tasks, but also an important component respectively an essential organization element that achieves new qualities of the production system, for example the easy reconfigurability.
- The Web-based Manufacturing describes no „electronic“ production in the sense of the E-Manufacturing, but a concept of the physical production of goods.
- Web-based Manufacturing aims both strategic and operational goals.

Currently, the research on Web-based Manufacturing is a not yet completed „work in progress”. Nevertheless, we can already present first considerations to consequences of the Web-based Manufacturing for the intrafirm production processes and/or for the complete industrial firm.

4 Implications of an Internet Technology based Production Concept

Due to the dichotomic characteristics of production processes between technical and economical aspects, the implications of an Internet Technology based Production Concept differ between multiple, interdependent technical and economical effects. First, we have to emphasize, that almost all enterprises can use technology in general and particularly the highly standardized Internet Technologies. Neither from a market-based nor from a resource-based view the fundamental availability of these technologies represents a competitive advantage for the enterprises per se (Blecker 1999). Additionally, empirical research projects show that intended competitive advantages either never have been reached by information and communication technologies or have been caught up rapidly from other competitors (Boddy/Gunson 1996, pp. 244). Thus, statements, that the application of Internet Technologies would be the solution of all structural and strategic problems of industrial firms in production processes, are not only illusory but also fundamentally wrong. A successful technique application is only a necessary, not a sufficient condition for competitive advantages. Only *an optimal organizational implementation*, new concepts of the application of the Internet Technologies in production processes, and/or new Production Concepts based on the Internet Technologies are suitable for achieving sustainable advantages. The basis for economic success represents not the techniques themselves, but their organizational and strategic internalization as well as their optimal application (Bensaou/Earl 1996).

Yet, the *high efficiency effects* of Internet Technologies in manufacturing are undisputed. Firms mostly use cost aspects for the rating of efficiency effects. Due to the high importance and strong interdependence of the different effects, flexibility and time aspects of the usage of Internet Technologies must complement these criteria. Cost reductions primarily arise with the parameterization and configuration of the machines and plants through Internet Technologies. A homogeneous surface in the web browser and the possibility for measures from a single computer lead to a reduction of the equipping and standstill costs as well as an acceleration of the diagnosis. Furthermore, Frost & Sullivan (2000, p. 3-24) see considerable advantages in manufacturing

through the availability of real time data from the shop floor. These data enable a reduction of the process costs at a simultaneous increase of the product and process quality. However, flexibility and time effects of the Internet Technologies are more important than the cost effects.

Today, many studies show that a high automation is not appropriate anymore. Instead of this, companies try to achieve an optimal and/or an adapted automation with *high flexibility* simultaneously (Lay/Schirrmeister 2001, pp. 2). A reason for that is for example the inflexibility of highly automated systems that frequently leads to an incompatibility of the traditional automation techniques with new, modular Production Concepts. However, production-near Internet Technologies on the automation level allow a distributed automation (Siemens 2000) with a high flexibility. In the case of a consistent usage of sophisticated Internet Technologies, a combination of machines is possible in the sense of plug-and-produce, a kind of plug-and-play in automation. On the one hand, office information systems can be included; on the other hand, manufacturing machinery can be integrated up to individual sensors into this concept. A cooperation of different, up to now often independently of each other acting sections in the enterprise occurs. Frost & Sullivan (2000, p. 3-16) speak of that as a reunification of planning and control in all production processes.

We can say Internet Technologies eliminate the barriers of interoperability on the shop floor and in the office area. From the patchwork of integration prevailing up to now, new possibilities for the combination of separate systems arise due to the high interoperability and connectivity of the Internet Technologies. Thus, the *vertical integration* of the existing systems in industrial firms or even an EAI occurs because of the Web-based Manufacturing. Usefully for the Web-based Manufacturing is, that platform independent programming languages like Java allows applications, that access dislocated databases (e.g. component libraries, parts lists, capacity plans) and process the data interactively on local systems in manufacturing (e.g. MES, PPC). Concepts like Concurrent Engineering are achievable, because of the comprehensive use of information. In connection with XML, it is even possible to build up task and cooperation-oriented information systems. This allows complying with an old demand of the CAD/CAM-Integration: to exchange data between individual CAx-Systems or even to implement a common database.

> This shows the relevance of the Internet Technologies in the production management: they enable cost reduction as well as flexibility and time advantages through distributed information systems in manufacturing. These information systems enable continuous business processes from the managerial control level over the technical systems to the production or even to field level. The arising convergence of automation and information technique leads in this case to modularity on machinery and plant level. Through that, modular Production Concepts on the shop floor become possible and the fiction of Totally Integrated Manufacturing Systems seems to be attainable.

However, during the assessment of Internet Technologies we also have to consider the *potential risks*. Additionally to the original (software) implementation problems of Internet Technologies in production processes, these risks are the main obstacles and barriers to industrial applicability of Web-based Manufacturing. In many cases, an essential obstacle is the existing infrastructure on the shop floor. A receipt of fieldbuses is necessary if an investment protection and/or the further use of specialized machinery are required. Companies can solve this problem with gateways between the fieldbuses and the Internet Technologies (Cena/Valenzano/Vitturi 2001, pp. 41) or the application of convergent infrastructures. Big suppliers in the field of the automation technology have already offered corresponding solutions or even Internet-suitable fieldbus-systems like Profinet. It is more problematic that occasionally the Internet-Protocol is considered crucially from fundamental reasons in production environments, since it often does not correspond to the high demands on the data transfer. Nevertheless, a new version of the Internet Protocol (IPv6) defines qualities, which correspond to the demands in production environments. Thus, only security aspects can be problematic with the application of Internet Technologies in production. There is a risk that important machines and plants are exposed to sabotage and espionage attacks, e.g. by

hackers, viruses and trojans. In particular, this scenario is valid when customers and suppliers connect their systems to the new infrastructure on the shop floor directly, for example for the preparation of production processes in the mass customization. However, technical and/or organizational protection mechanisms already known from the office environment reduces the problems, e.g. cryptography, virus scanner, firewalls, and access controls.

In conclusion, we can state that considerable potentials for the improvement of the efficiency of the enterprises result from the application of Internet Technologies in production processes. Additionally we estimate the problems and disadvantages of the commitment as manageable. Nevertheless, we have to consider, that the effects of the usage of Internet Technologies in Web-based Manufacturing exceed the discussed effectiveness and efficiency effects. Improvements of traditional enterprise structures are not only with a new communication media conceivable. Furthermore, industrial firms may implement completely new, up to now impossible approaches and structures of production processes based on Internet Technologies. By now, it is impossible to predict completely the potential benefits of these modifications. However, due to the massive commitment of the Internet Technologies in manufacturing in future, some authors formulate the necessity of elementary modifications in the management thinking, especially in industrial firms (see crucially for this purpose Neumann 2002, p. 26).

5 Conclusion

Recapitulating, we point out, that Internet Technologies and the potential fields for their applications in production processes evolve very rapidly. Internet Technologies will replace in the next year's traditional fieldbuses more and more. Therefore, the intraorganizational application of Internet Technologies will be the generic networking infrastructure for production processes in future. Especially Web-based Manufacturing opens up to now unavailable options to the enterprises and creates sustainable competitive advantages.

From a *technical point of view*, the realization of Web-based Manufacturing is already possible without problems, as the high number of the practice-relevant projects and the implemented island solutions shows. The combinations of robotics and Internet Technologies are proved for a long time. Furthermore, the importance of Internet Technologies in the automation systems as a crucial basis for competitive advantages and new manufacturing concepts is at least in the engineering undisputed. Even *industrial practice* confirms the high potentials of Internet Technologies in production processes. Many firms recognized that the usage of Internet Technologies could contribute to an improvement of the competitive position and already build up first approaches of Internet based Production Concepts. From the point of view of *business administration,* a development of the already known approaches to a comprehensive concept of Web-based Manufacturing is necessary. Thus, the further research will concentrate on reducing the existing deficits with the consideration of the Internet Technologies in business administration and supplying a concept for a successful production based on the concept of Web-based Manufacturing.

References

Atherton, R. W. (1999): Moving Java to the Factory. *IEEE-Spectrum*, 35, 12, pp. 18 – 23.

Barua, A./Lee, B. (2001): The Information Technology Productivity Paradox Revisited: A Theoretical and Empirical Investigation in the Manufacturing Sector. In: Shaw, M. J. (Ed.): *Information-Based Manufacturing. Technology, Strategy and Industrial Applications*. Kluver, Boston et al., pp. 37 – 58.

Beavers, A. N. (2001): *Roadmap to the e-Factory*. Auerbach, Boca Raton et al.

Bensaou, M./Earl, M. (1996): Information *Technology in Japanese Firms: Are there Lessons for the West?*. INSEAD Working Paper 96/92/TM/ABA, Fontainebleau.

Blecker, Th. (1999): *Unternehmung ohne Grenzen — Konzepte, Strategien und Gestaltungsempfehlungen fuer das Strategische Management*. Gabler Verlag, Wiesbaden.

Blecker, Th. (2001): Wettbewerbsvorteile durch moderne Produktionskonzepte? In: Blecker, Th., Gemünden, H. G. (Ed.): *Innovatives Produktions- und Technologiemanagement. Festschrift für Bernd Kaluza*. Springer Verlag, Berlin et al., pp. 3 – 34.

Blecker, Th. (2003): Entwurf eines auf Internet-Technologien basierenden Produktionskonzepts. In: Wildemann, H. (Ed.): *Moderne Produktionskonzepte*. TCW-Verlag, Munich.

Blecker, Th./Haber, G. (2001): IP-basierte Geschäftsprozesse in Industrieunternehmen. In: Horster, P. (Ed.): *Elektronische Geschäftsprozesse. Grundlagen, Sicherheitsaspekte, Realisierungen, Anwendungen.* it – Verlag für Informationstechnik, Höhenkirchen, pp. 338 – 350.

Boddy, D./Gunson, N. (1996): *Organizations in the Network Age*. London — New York.

Cena, G./Valenzano, A./Vitturi, S. (2001): Integrating fieldbuses and factory intranets. *International Journal of Computer Integrated Manufacturing*, 14, 1, pp. 41 – 54.

Cheng, K./Pan, P. Y./Harrison, D. K. (2001): Web-based design and manufacturing support systems: implementation perspectives. *International Journal of Computer Integrated Manufacturing*, 14, 1, pp. 14 – 27.

Frost & Sullivan (2000): *The Industrial Internet*. Report 7275-10, Mountain View.

Huang, G.Q./Mak, K.L. (2001a): Web-integrated manufacturing: recent developments and emerging issues. *International Journal of Computer Integrated Manufacturing*, 14, 1, pp. 3 – 13.

Huang, G.Q./Mak, K.L. (2001b): Issues in the development and implementation of web applications for product design and manufacture. *International Journal of Computer Integrated Manufacturing*, 14, 1, pp. 125 – 135.

Kuehnle, H./Klostermeyer, A./Lorentz, K. (2001): A Paradigm Shift to Distributed Systems in Plant Automation. In: Fares Sebaaly, M. (Ed.): *The International NAISO Congress on Information Science Innovations ISI' 2001 (Dubai, 17th – 21st March) - Proceedings*, pp. 463 – 469.

Lau, H. (1998): The New Role of Intranet/Internet Technology for Manufacturing. *Engineering with Computers*, 14, 2, pp. 150 – 155.

Lay, G./Schirrmeister, E. (2001): *Sackgasse Hochautomatisierung? Praxis des Abbaus von Overengineering in der Produktion*. Fraunhofer Institute for Systems and Innovations Research, Results of the Production Innovation Research No. 22, Karlsruhe.

Neumann, G. (2002): Neue Medien und deren Einfluss auf die Betriebswirtschaft. *FAZ — Frankfurter Allgemeine Zeitung*, February 25 2002, p. 26.

Shaw, M. J. (2001): Information-Based Manufacturing with the Web. In: Shaw, M. J. (Ed.): Information-Based Manufacturing. Technology, Strategy and Industrial Applications, Kluver, Boston et al., pp. 7 – 21.

Siemens AG (1999a): *SIMATIC NET. Industrial Ethernet*, White Paper.

Siemens AG (1999b): *Informationstechnologie in der Automatisierungstechnik*, White Paper.

Siemens AG (2000): *Verteilte Automatisierung auf Basis Industrial Ethernet*, White Paper.

Veeramani, D./Wang, K. (2001): Performance Analysis of Auction-Based Distributed Shop-Floor Control Shemes from the Perspective of the Communication System. In: Shaw, M. J. (Ed.): *Information-Based Manufacturing. Technology, Strategy and Industrial Applications*, Kluver, Boston et al., S. 243 – 266.

Wildemann, H. (2000): Kernkompetenz-Management: Mit intelligenten Technologien Kunden binden. In: Wildemann, H. (Ed.): *Kernkompetenzen und E-Technologien*. TCW-Verlag, Munich, pp. 15 – 59.