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ScienceDirect

Procedia Manufacturing 3 (2015) 417 – 424

Procedia MANUFACTURING

6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015

Transforming to a hyper-connected society and economy – towards an "Industry 4.0"

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Abstract

Volatile markets and global and inter-industrial networks are creating a radically more dynamic market environment which calls for considerably greater on-demand flexibility in resource deployment. Today's businesses have to respond to evolving trends. As well as increasing flexibility, this also means taking action in two further areas, namely increasing transformability and responding to demographic change. Furthermore the global change towards a fully networked society is in progress, in Germany, in Europe, and of course in the United States – actually more or less all over the world. In this context one significant topic is the "Internet of things and services". The digital transformation changes business and private life likewise – in a radically and sustainable way. The economic potential is enormous. Topics related to the networking of the internet by far have the most economical potential worldwide. The world becomes more and more digital. This is the Big Business of the future. Digitally networked and data-intensive are the main attributes of a smarter production, the so called industry 4.0. But not only in technology many things are changing, humans and the society transforms, too. To achieve a positive influence on key performance indicators, organizational approaches to enterprise architecture should not be restricted to purely technical aspects but should instead put the focus firmly on employees. The study examines initial design approaches in the areas of qualifications, leadership and demography-resistant work architectures.

Peer-review under responsibility of AHFE Conference

Keywords: Business models; Demographic change; Digital transformation; Flexibility; Human behavior; Industry 4.0; Key performance indicator; Leadership; Production; Productivity; Qualifications; Technology; Transformability; Work architectures

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Peer-review under responsibility of AHFE Conference
doi:10.1016/j.promfg.2015.07.200

1. How globalized value creation poses a challenge to manufacturing

Just as they are today, rapidly growing markets will in future be located outside industrialized nations. But there is no way with currently technology to give everyone in the world the level of prosperity these nations enjoy. What is needed are completely new approaches for creating products and services that will enable comparable standards of prosperity in the future on a global scale while consuming radically fewer resources.

Manufacturing will also have to adapt to the increasing dynamism of sales markets and the radical challenges thrown up by the innovation process, particularly in regard to energy and resource efficiency and the increasing hybridization of products using mechatronics, software and services. New approaches are needed to accelerate the product creation process, optimize the transitions from product development to production, and ensure that the cost of manufacturing is competitive. The combination of customer-specific and technically sophisticated products and short innovation cycles forces companies to demonstrate a high degree of dynamism, transformability and customer orientation. The challenge is to find the right balance between optimum quality standards, the ability to deliver products quickly, and a competitive pricing strategy. The centralized process of order planning and scheduling which is still in use today is too sluggish and too costly to achieve this goal. As well as making turnaround times longer, it also requires considerable buffer stocks of materials and leads to significant waste. A strategy of customer-led lean production offers a far greater likelihood of success.

The increased international interconnectedness of companies and entire industries is leading to ever more intertwined dependencies and is intensifying developments in individual sectors of the economy both vertically and horizontally. One notable example is the coalescence of the finance sector and the real economy and the global effects of this amalgamation on the global manufacturing industry which were evident worldwide in the economic crisis that began in 2008. In Germany, a country in which more than one in every four euros is earned directly in manufacturing, the turnover index for manufacturing industries alone fell by almost 30 percent between October 2008 and January 2009. Business confidence, too, dropped by nearly 30 percent in the same period according to the business climate survey for the manufacturing industries conducted by the Munich-based Ifo Institute for Economic Research. A few months later both indicators bounced heavily back in the other direction. In total, these two spikes in the turnover index represented an unprecedented fluctuation of 56 percent over a 12 month period. These radical kinds of cyclical fluctuations in sales will occur more frequently in the future and will be compounded by seasonal, business-specific and product-specific fluctuation effects. The superposition of these effects will lead to unpredictable, volatile markets which will pose a significant challenge to companies' abilities to take a flexible approach towards costs and resources.

2. Flexibility is the key to competitiveness

Market volatility and long-term changes will require companies and their workforces to become more flexible. Even as a high-wage country, Germany is currently asserting itself successfully in a difficult market environment within a crisis-hit Europe while setting a series of new export records. Thanks to high-mix production combined with competitive delivery times, close proximity to the customer and above-average product and service quality, Germany's gross domestic product (GDP) rose almost 25 percent faster between 2009 and 2011 than in the rest of core Europe. One of the reasons for this is the fact that manufacturing is more deeply rooted in Germany than elsewhere. Germany is a manufacturing country. In 2011, German manufacturing companies posted sales of almost 1,750 billion euros. Representing more than 25 percent of German GDP and with almost 8 million employees, manufacturing is one of the key pillars of the German economy.

The volatility of sales markets is reflected in increasingly heavy fluctuations in orders, shorter order delivery times and a diminished ability to plan ahead. To remain competitive in the traditional senses of short delivery times, high productivity (or lowest possible costs) and optimum quality despite this shift in the underlying conditions, manufacturing companies are required to increase the flexibility of their machines and equipment, their material procurement (and their supply chain) and their personnel deployment strategies [1]. This latter aspect plays a key role, especially in traditional high wage countries. In a survey conducted by Fraunhofer IAO, almost 98 percent of the 661 participating companies stated that they consider flexibility in the deployment of their production workers

over the next five years to be very important. Over 72 percent anticipate that they will have to enhance the flexibility of their personnel deployment strategy at some point during the next five years [2].

The paradigm of capacity flexibility is seen as the key to successfully handling volatile market situations. The traditional goals of production planning and control – namely short delivery times and high delivery capabilities combined with minimal stocks and good utilization of available capacity – still apply. In fact the importance of short delivery times and rapid responses to customer requirements across the board will increase massively in the future, particularly for customer-specific products. This situation requires high flexibility for all manufacturing resources. For the personnel-intensive manufacturing arena, this means that flexible deployment of production workers will take on an increasingly important role alongside highly responsive supply chains and self-regulating material cycles based on lean principles. Over the past few years, a range of different tools designed to flexibly adjust personnel capacities have become firmly established in German industry. Flexible working times are already widespread and used by more than six out of ten German companies. As well as flexibility in regard to working time, other personnel-related levers that companies can use to carve out a successful position in fluctuating sales markets include content-related factors such as job rotation and multi-skilling, and spatial flexibility such as hiring out and secondment.

There seems to be no prospect of volatility diminishing in the future. On the contrary, the pressure to achieve highly productive resource deployment and minimal idle time is making it necessary to come up with new tools for strategically adjusting personnel flexibility in manufacturing environments. In the future, flexibility will need to be oriented toward the long term, systematically organized, and utilized in a targeted manner in order to balance out the full range of fluctuation effects that occur in volatile markets. The standardized notion of flexibility that is so often embedded in companies will no longer be sufficient in the future. Instead, business-specific flexibility strategies with individually selected and systematically scaled flexibility tools will become essential. In addition, a new set of rules for ultra-flexible manufacturing will need to be developed in collaboration with employees, and the resultant added value will need to be fairly compensated.

As a result of increasing links between leisure time and work and new forms of work, people now have greater expectations of being able to better dovetail their working time with their private life.

3. Transformability enables market-driven responses

“The term transformability stems from discussions on flexibility which have shown that the term flexibility is no longer adequate to meet current market requirements (‘Flexibility is not enough!’).” [3]

If flexibility is understood as a quality that is fundamentally intrinsic to a system, transformability refers to the capacity to make rapid and lasting changes to an existing system.

In other words, flexibility means utilizing existing areas of a system – for example rapidly adjusting the number of employees to cater to short-term fluctuations (“capacity flexibility”). In contrast, transformability refers to structural changes to the system, for example demand-driven changes to an assembly system including the machines and equipment, the material supply systems and the underlying work organization (from the individual workstation through U-shaped cells to the continuous flow line and back) [4]. This example also shows how transformability cannot simply be understood in the limited sense of technical equipment and resources. Above and beyond these purely technical considerations, it is people who act as the essential link in organizational initiatives and who therefore lie at the heart of approaches designed to provide transformable responses to fluctuations in variants and volumes.

4. Key performance indicators for competitiveness

Key performance indicators (KPIs) can help introduce and then consistently develop and optimize an organization’s ability to transform itself while simultaneously maintaining productivity in the three stipulated areas. In addition to financial KPIs, operational machine and equipment-related KPIs, and KPIs from business and customer perspectives, a number of other KPIs from the following areas play an important role, especially from an organizational standpoint.

One of the key indicators used to evaluate the performance of a company is sales productivity, in other words the sales per employee as an indication of a company's profitability and value creation. However, this metric does not tell us anything about the actual productivity of the value creation because it contains the price paid for the company's products or services but not the input required to create them. At 255,000 euros/employee, the federal state of Baden-Württemberg, for example, lies below the 2012 German average in the manufacturing industries of 293,000 euros/employee [5]. The basis for this and for long-term international competitiveness lies in unit labor costs and productivity. A slight increase has occurred in Germany in recent years. In comparison to other European countries, Germany lies in the upper range of unit labor costs while coevally exhibiting high productivity (Fig. 1).

These rather rough estimates of productivity are heavily influenced by indicators within a company. They have a key impact when it comes to taking targeted steps to optimize business processes.

On the one hand this involves process metrics such as turnaround times (production and order) as well as defect, failure and complaint rates, delivery reliability and delivery capabilities. What all these indicators have in common is that they represent not only productivity, but also the two additional dimensions in the triad of primary objectives, namely quality and time.

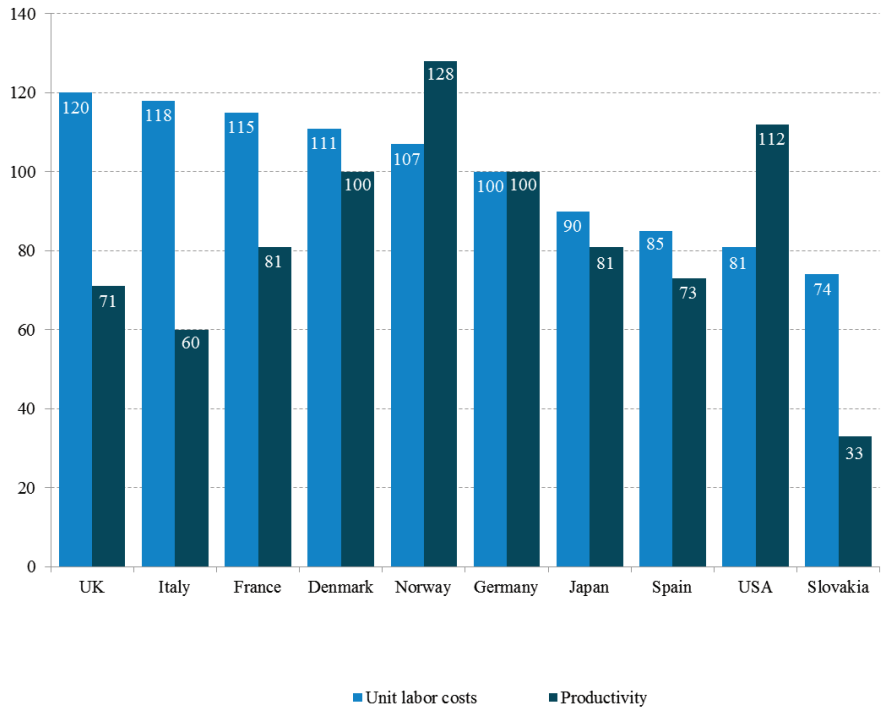

Fig. 1. International comparison of unit labor costs and productivity in the manufacturing industries in 2012 (in per cent), Germany = 100 [6].

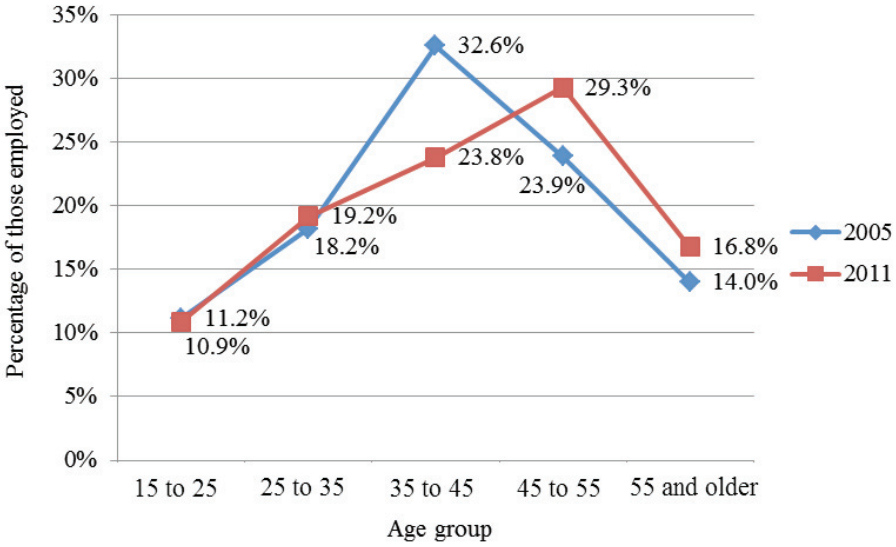

Fig. 2. Age distribution of employees in the mechanical engineering industry in Germany, comparison between 2005 and 2011 [9].

From the process perspective, a company's performance is primarily influenced by its equipment and its employees. While the former factor can be rated in terms of Overall Equipment Efficiency (OEE) as a standardized measure of equipment availability, human performance is considerably more difficult to define.

Indicators such as the number of workdays lost to illness, staff turnover rates, and age distribution can provide clues to working conditions, employee satisfaction and employee commitment. Germany-wide, the rate of sick leave absence (i.e. the percentage of stipulated work time missed due to illness) has stood at between three and four percent across all industries in the past few years with some minor differences between genders and isolated outliers in the traditional flu months of February and March 2013 (6 percent) [7].

Staff turnover rates as a measure of the percentage of employees who join and leave a company each year averaged 14 percent in Germany in 2013, around half the amount recorded in Russia (26.8 percent) but more than twice as high as the figure for the Netherlands (6.1 percent) [8]. A further KPI which has an effect in regard to a company's competitiveness is the age distribution of its employees. Over the next few years the age distribution is expected to rise, particularly in the manufacturing arena and especially in large companies. One clear example is the mechanical engineering industry: 23.8 percent of those employed in mechanical engineering in Germany were between 35 and 45 years old in 2011 as compared to 32.6 percent for the same age group in 2005 [9] (Fig. 2).

Similar developments are evident elsewhere, particularly in the German automotive industry where the maximum average age over the coming decade is expected to rise considerably. Daimler, for example, expects the average age of its employees to increase from today's figure of 43 years old to 47 by 2021 [10].

In light of demographic changes and the continuing importance of people in the manufacturing environment, KPIs that lean more towards the qualitative than the quantitative can provide a key indication of competitiveness. These include ergonomic assessments which can be conducted by means of self-assessment (e.g. Kobra [11]), expert evaluation (e.g. AAWS plus [12]) or through processing observational data using computers (REBA and REBA 9.0 [13]). Modern versions of this type of assessment encompass far more than just user-friendliness and typically include multiple other aspects such as psychological issues.

Numerous more holistic assessment methods are also used for the work environment, including the WAI (Work Ability Index [14]) and the Austrian IMPULS test designed to evaluate work-related stressors [15]. The common factor behind all these methods is that they provide a qualitative, process-oriented assessment of work which can deepen the understanding gained from purely quantitative methods.

In addition to successfully filling orders, achieving competitiveness in today's marketplace also requires superior skills in innovation and product creation processes. KPIs in this context include innovation performance and time to market. Both these metrics provide very rough indicators of factors that shape the performance of the company as a whole without actually directly influencing the process. These areas depend more on the motivation and commitment of employees. For that reason the best approach here is to design work environments and processes in a way that stimulates productivity and creativity.

5. Design approaches for selected aspects

Taking into consideration the current challenges facing Germany as a key industrial location and the basic levers of efficient value creation, the following sections aim to provide recommended design approaches for selected aspects. Reference is occasionally made to the German government's high-tech strategy project "Industry 4.0" which promotes computerization and networking of industrial business processes – particularly those in the manufacturing arena – and which is viewed as a key blueprint for the future, at least by large portions of the German research and business communities. (cf. [16], [2])

5.1. Qualifications for smart manufacturing environments

One development that is providing new opportunities to make manufacturing environments fit for the future within the context of Industry 4.0, particularly in a high-wage country such as Germany, is the introduction of cyber-physical systems (CPS). These involve the coordinated application of new sensor and actuator technologies which dovetail the real and virtual worlds into an Internet of Things, Data and Services within the context of smart factories. However, the development corridor of Industry 4.0 goes far beyond the purely technical aspects. The CPS-based manufacturing systems of the future need to be understood as highly interactive, socio-technical systems. The use of cyber-physical systems with intelligently networked objects in manufacturing will enable a new quality of flexible working in the future which will constitute tasks distributed in multiple dimensions of time, space and content.

Technological innovations remove the dependency on fixed workplaces and work schedules, thereby changing the nature of work both in manufacturing and in knowledge-intensive occupations. Technological innovations will continue to alter products and services and will therefore require workforces to continuously develop new knowledge and capabilities. Information and communications technologies (ICTs), which are yet to achieve their most revolutionary developments, have a key role to play in future work design strategies. From factories to offices, human-computer interaction is transforming into human-computer cooperation. All this will necessitate new qualifications for employees in manufacturing environments.

5.2. New principles of work and leadership

In the future, the goal should be to make employees and teams in CPS production systems into equal or, even better, leading decision-making authorities within the production process in line with the principles of Industry 4.0 and to organize the division of labor so that better decisions can be taken. This will open up new potential for employees by giving them a greater opportunity to regulate their own work but will also require more from them in terms of their own qualifications, particularly in the field of media and social skills (e.g. Enterprise 2.0).

In this context, social media can produce considerable transparency in regard to knowledge and skills within a company [17]. Outside the company techniques such as crowdsourcing can be used to incorporate end customers and suppliers in the product development process as well as creating a more direct, topic-based environment for exchanging ideas with customers and for maintaining relationships in a more continuous and sustainable way (cf. [18]). Social media enables employees to network autonomously across multiple hierarchical levels or even across multiple organizations. Particularly in environments with a high project and knowledge focus, social media offers the potential to reduce the transaction costs of knowledge acquisition, knowledge linking and the occasional incorporation of key knowledge holders in a project. It does this by removing the need for lengthy coordination processes and complex decision-making channels.

However, this gain in autonomy for individuals inevitably raises questions as to traditional tasks and the roles of hierarchies. It alters work by making it increasingly project-oriented, or indeed more network-oriented in the case of interorganizational tasks, since these are the kinds of structures that can facilitate delegative decision-making power and entrepreneurial freedom in an organizational context. Project and network orientation thereby form efficient mechanisms that make it possible to link knowledge, skills and resources in a dynamic environment in a manner that fosters successful task completion. This raises additional questions as to how companies can achieve stronger delegative decision-making discretion and entrepreneurial freedom while simultaneously appealing to employees' changing values in order to remain attractive as a potential employer. Networking and communication are therefore becoming increasingly significant for companies for both business and personnel-related reasons.

5.3. Demography-resistant work design

Demographic change and a new self-awareness among employees are shifting the balance of power in the business environment. In the future it will be perfectly normal to work in teams that are mixed according to age, gender, origin and attitudes/approaches. This could potentially unleash major improvements in creativity and productivity but also poses an increased risk of conflicts. The design of the interactions, the orchestration of diversity, will become one of the defining skills of successful leadership.

This development will not only lead to a significant shortage of skilled personnel but also, up until 2025, to a decline in the size of the working-age population [19]. In light of this development businesses will have to rethink their approach if they wish to have access to a sufficient number of qualified personnel in the future. This issue has already been raised by the Confederation of German Employer Organizations (BDA): "In light of demographic change and the growing demand for qualified personnel, the employment of older workers continues to be an important goal. This is the only way in which Germany can maintain its competitive edge in international markets and continue to build prosperity in the future." [20] Accordingly, the primary aim of politicians and industry should be to make a complete break with the previous strategy of replacing old employees with younger ones. Even though a process of reorientation is already evident in some companies, especially larger ones, it should be noted that there is still no personnel policy oriented toward older employees in the majority of companies, nor any sign of the appropriate tools to achieve such a policy (cf. for the chemical industry [21]).

This insufficient focus on older workers is also evident from the lack of consideration paid to the needs of older people in relation to work organization and (ergonomic) workplace design. Although 80 percent of companies run a workplace health promotion scheme [22], only 56 percent operate age-adapted, ageing-appropriate and needs-based work organization practices. These figures, however, merely show that these kinds of initiatives are being run by companies and do not provide any indication of either their quality or intensity.

The selected data clearly show that business workforces are "going grey" as a result of demographic developments ([23]) and that companies are not adequately prepared to deal with this issue ([24]); this is particularly true in regard to small and medium-sized enterprises (SMEs). This primarily requires a cultural shift within companies to increase the regard in which older employees are held, though it also requires the framework of a manufacturing policy incentive program which must be designed to develop practical concepts and approaches, and include a particular focus on SMEs.

6. Conclusions

The effects of across-the-board CPS deployment are expected to be revolutionary, and indeed commentators in Germany are already heralding the fourth Industrial Revolution. In a manufacturing environment this leads to near real-time transparency which makes the production control and management process radically more flexible. It will still be some time before this vision is fully realized, but mobile devices and social media are Industry 4.0 elements which are already set to have a big influence on the design of manufacturing work in the near future. In terms of organization, this throws up various challenges for companies, requiring them to find efficient structures and methods capable of achieving task-oriented networking of specialized knowledge carriers both within and outside the company while incurring minimal transaction costs for information and knowledge distribution.

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