A review of enterprise agility: Concepts, frameworks, and attributes

Bohdana Sherehiy, Waldemar Karwowski*, John K. Layer

Department of Industrial Engineering, Center for Industrial Ergonomics, University of Louisville, Lutz Hall, Room 445, Louisville, Kentucky 40292, USA

Abstract

Existing knowledge about agile manufacturing (AM) and an agile workforce was reviewed in order to extend the concept of agility to the whole enterprise. The frameworks that describe other elements of the enterprise besides manufacturing, or contain attributes that could be applied to all enterprise structures were also included into the review. The review identified a large number of papers related to the AM. However, there was little empirical research done on the agile workforce and agile organization. This review identified the global characteristics of agility which can be applied to all aspects of enterprise: flexibility, responsiveness, speed, culture of change, integration and low complexity, high quality and customized products, and mobilization of core competencies. The need for further research in order to empirically establish and validate the attributes and indices of the agile workforce and agile enterprise has also been discussed.
© 2007 Elsevier B.V. All rights reserved.

Keywords: Agility; Agile manufacturing; Agile workforce; Agile enterprise; Adaptive enterprise; Responsiveness; Change

1. Introduction

The problem of how organizations can successfully deal with unpredictable, dynamic, and constantly changing environments has been a prevailing topic both in industry and academia for a few decades. Many different solutions have been proposed: networking, reengineering, modular organizations, virtual corporations, high performing organizations, employee empowerment, flexible manufacturing, just-in-time (JIT), etc. Among proposals of how to deal with an uncertain and unpredictable environment, the three notions of "adaptive organization", "flexible organization", and "agile enterprise" are the most predominant and popular. There are many different approaches to define each of these terms and there is much confusion and ambiguity concerning definitions and components of each of these concepts. Some authors make a sharp differentiation between those concepts while others use them synonymously. However, in general all concepts were considered as possessing the ability to adjust and respond to change.

Research on how organizations cope with uncertainty and change using the term "adaptivity", investigated how the organization's form, structure, and degree of formalization influenced the ability to adapt (Burns and Stalker, 1961; Hage and Aiken, 1969; Hage and Dewar, 1973). In the 1980s, the research was more focused on the organizational flexibility. Reed and Blunsdon (1998) describe organizational flexibility *as an organization's capacity to adjust it's internal structures and processes in response to changes in the environment*. The review of research on flexibility by Volberda (1996) and De Toni and Tonchia (1998) show that most of the definitions of the flexible organization emphasize the ability to adapt and respond to change. In the beginning of the 1990s, the new solution for managing a dynamic and changing environment emerged—agility. According to Gunasekaran (1999), agile manufacturing (AM) is the *ability of surviving and prospering in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-defined products and services*. Kidd (1994) defined agility as *a rapid and proactive adaptation of enterprise elements to unexpected and unpredicted changes*. The creators of "agility" concept at the Iacocca Institute, of Lehigh University (USA) defined it as: "A manufacturing system with capabilities (hard and

---

*Corresponding author. Tel.: +1 502 852 7173; fax: +1 502 852 7397.
E-mail address: karwowski@louisville.edu (W. Karwowski).

soft technologies, human resources, educated management, information) to meet the rapidly changing needs of the marketplace (speed, flexibility, customers, competitors, suppliers, infrastructure, responsiveness)'' (Yusuf et al., 1999). Yusuf et al. (1999) proposed that agility is the successful application of competitive bases such as speed, flexibility, innovation, and quality by the means of the integration of reconfigurable resources and best practices of knowledge-rich environment to provide customer-driven products and services in a fast changing environment.

Despite the differences, all definitions of ''agility'' emphasize the speed and flexibility as the primary attributes of an agile organization (Gunasekaran, 1999; Sharifi and Zhang, 1999; Yusuf et al., 1999). An equally important attribute of agility is the effective response to change and uncertainty (Goldman et al., 1995; Kidd, 1994; Sharifi and Zhang, 2001). Some authors (Sharifi and Zhang, 1999) state that responding to change in proper ways and exploiting and taking advantages of changes are the main factors of agility. The next common component of published definitions of agility is a high quality and highly customized products (Gunasekaran, 1999; Kidd, 1994; Mccarty, 1993; Tsourveloudis and Valavanis, 2002).

As the brief overview of the agility definitions shows, this concept comprised both characteristics of adaptability and flexibility. It seems that these two terms represent the evolution of the idea of the organization or enterprise that is able to adjust. The agile enterprise/organization may represent the latest stage of development of this idea, which could combine all important notions from the adaptive and flexible organization concepts. Although, studies on agility utilize some ideas and practices related to the adaptive and flexible organization, many important developments on this topic from the organizational and management field were overlooked. In order to clarify the agility concept and to categorize the large diversity of strategies, techniques, and practices that are mentioned in the literature as components of agile enterprise need to have their origins investigated. In order to synthesize the agile enterprise concept, important knowledge related to managing the unpredictable and changing environment needs to be reviewed. Workforce adaptation and organizational flexibility that was conducted in such areas as industrial and organizational psychology or organizational development and behavior also is in need of review.

In this paper, the attempt was made to make an overview of the existing frameworks of AM and attributes of manufacturing, organizational, and workforce agility. For this overview, AM frameworks were selected that could be adapted or extended to the whole enterprise. Therefore, this review includes frameworks that encompass other elements and structures of the enterprise besides manufacturing, and contains attributes that could be used to describe not only manufacturing but also other enterprise structures. The literature on organizational flexibility and workforce adaptability was reviewed in order to select the ideas that could be utilized to create a comprehensive framework for agile enterprise. It was out of the scope of this paper to make a comprehensive review of all research and concepts related to the organizational flexibility or agility. The main goal was to identify the origins and theoretical background of some ideas implemented in the agile enterprise field in order to clarify the ambiguity of the concept, and categorize the large variety of concepts, strategies and practices described in the literature as a part of agility.

2. Adaptive and flexible organization

The idea of adaptive organization has originated from the contingency approach in organizational research. Contingency theories are classes of behavioral theory that state that there isn't one universal way of managing or organizing a company, and that the organizing style is dependent on the situational constraints of environment in which the company operates (Donaldson, 2001; Hatch, 1997; Vecchio, 2006). This view is based on the approach that treats organizations as open systems that have to interact with their environment in order to be successful. This in turn implies that organizations cannot be considered and analyzed in isolation of the environment. The main premise of the contingency theory is that organizational effectiveness can be achieved by fitting the characteristics of the organization to contingencies that reflect the situation of the organization (Donaldson, 2001). Thus, in order to maintain effectiveness, the organizations have to adapt over time to fit changing contingencies. The environment, organizational size, and organizational strategy are considered as main contingencies that shape the organization.

The investigation of the relationship between the characteristics of the environment and organizations determined two main types of the organizational design, structure, or form: mechanistic and organic (Burns and Stalker, 1961). The results showed that in relatively stable and predictable environments, the organizations tend to have a mechanistic design. This type of organization has highly hierarchical structure and formal management operation with centralized authority, large number of formal rules and procedures, precise division of labor, narrow span of control, and a formal means of coordination. The organizations that operate in the unstable, changing, and unpredictable environment usually have an organic design, which is less formal, less hierarchical, and less mechanistic. The organic design has a less precise division of labor, wider span of control, more decentralized authority, fewer rules and procedures, and more personal means of coordination. The main features of organic and mechanistic designs (Burns and Stalker, 1961; Hatch, 1997; Donaldson, 2001; Vecchio, 2006) are presented in Table 1.

The observation of an organization's operation in different environments showed (Burns and Stalker, 1961; Donaldson, 2001) that the hierarchical approach is most efficient in case of routine operation, and mechanistic

Table 1
Characteristics of the organic and mechanistic design

Mechanistic design	Organic design
Hierarchy of authority	Less adherence to authority and control
Hierarchical communication	Network communication
Centralized knowledge and control	Decentralized knowledge and control
Insistence on loyalty and obedience to organization	Loyalty and commitment to project or group
	High degree of flexibility and discretion
High degree of formality	Informal and personal coordination
Formal and impersonal coordination	Few rules and procedures
Many rules and procedures	Shared tasks
High tasks specialization	Employee contribution to a common tasks

design best fit stable environments with low rates of change. In such environments, the high-level management possess the appropriate amount of knowledge to make decisions and organize the work. In case of unstable and unpredictable environments, the high level management is not able to acquire all the needed information that changes with the environment, and the knowledge and decision making has to be distributed among lower hierarchical levels. Further research (Hage and Aiken, 1969; Hage and Dewar, 1973) supports the relationship between centralization and the formalization of organization with low task uncertainty. Hage and Dewar (1973) showed that the decentralized organization with low formalization and high complexity (trained worked with high expertise) leads to the higher innovation rates. It was concluded that organic design is more innovative, flexible, and more capable of adapting to change, thus it is appropriate for unstable and continuously changing environments.

First attempts to explain how organizations deal with the uncertain and complex environments were based on the concepts of requisite variety and isomorphism (Hatch, 1997; Vecchio, 2006). The law of requisite variety states that in order for one system to be able to deal with another system, the two systems must be of the same or greater complexity (Ashby, 1956). The different conditions and elements in organization's environment create a pressure for internal differentiation. Lawrence and Lorsch (1967) defined differentiation as the ''difference in the cognitive and emotional orientation among managers in different functional departments''. Internal differentiation allows different parts of organization to specialize in responding to different demands of the environment. In this way, internal differentiation increases the responsiveness of organization to different elements of the environment. Furthermore, the internal diversity of the organization has to fit the variety and complexity of the environment in order to successfully handle the environment (Ashby, 1956). This assumption is based on the notion of isomorphism which states that an organization matches and reflects the complexity of environment with internal

structures and systems (Hatch, 1997; Vecchio, 2006). Based on the above arguments it was concluded that the diversity provides the requisite variety which is conductive for organizational adaptivity because it allows the pursuit of multiple courses of action and quick changes from one course to another as the environment changes (Nonaka et al., 1996; Stewart et al., 2003).

According to Lawrence and Lorsch (1967), the increased internal organizational differentiation increases the need for appropriate integrating mechanisms, but the integration is harder to achieve as differentiation increases. Integration was defined as the ''quality of the state of collaboration that exists among departments that are required to achieve unity of effort by the demands of the environment'' (Lawrence and Lorsch, 1967). Further research by Lorsh and Allen (1973) showed that integration in a diversified company is required only where there is close interdependence between the firm's sub-units. The research of Weick (1982) revealed that organizational adaptability can be increased when a highly differentiated organization has a low level of integration. Weick (1982) argues that different business units may have to manage inconsistent demands from their specific environments (or aspects of environment) and the organization maintains greater flexibility if different sub-units will operate autonomously from each other. Brown and Eisenhard (1998) also showed that modular businesses with loose connections and a low level of coherency between them are most successful in achievement of adaptability in changing business environments.

Organizational flexibility is considered as the organization's ability to adjust it's internal structures and processes in response to changes in the environment (Reed and Blunsdon, 1998). Several different taxonomies of the organizational flexibility have been proposed in the literature. The most commonly used taxonomy distinguishes numerical, functional, and financial flexibility (Dastmalchian, 1993). The numerical flexibility responds to fluctuations in demand and output by altering the number of employees and hours of their work. This type of flexibility is achieved by employing part-time, temporary, short-term contract or by altering distribution of the working time. The functional flexibility is concerned with the content of the jobs and it involves changes in skills of workforce so they can undertake a wider range of tasks. Financial flexibility relates to the introduction of individualized pay systems, pay for performance, and profit sharing plans. The prevailing body of research on organizational flexibility was focused on the investigation of the numerical and financial aspects of flexibility and labor market flexibility (Dastmalchian and Blyton, 1998; Kalleberg, 2001).

The reviewed theories and research suggest that flexible and adaptive organizations are characterized by clarity of purpose and low levels of formal regulation in respect to job description, work schedules, and overall organizational policies. These organizations have fewer power differentials

(fewer titles, levels, status dimensions, etc.) and rely on teams to perform the task. The research concerning the contingency approach showed that organizations in uncertain environments should adopt an organic organizational form: few levels of hierarchy, informal and changing lines of authority, open and informal communication, loose boundaries among function and units, distributed decision making, and fluid role definitions (Lawrence and Lorsch, 1967; Ashby, 1956; Hatch, 1997; Vecchio, 2006). The organization associated with continuous change has authority tied to tasks rather than positions, shifts in authority as tasks shift, systems that are self-organizing rather than fixed, and ongoing redefinition of job descriptions (Weick and Quinn, 1999).

3. Conceptual frameworks of AM

Most of the literature on AM discusses only strategies and techniques. Few papers address the conceptualization and development of an integrated view of the agile enterprise concept. However, several AM frameworks based on the different definitions and approaches can be found in the literature. The review of some AM frameworks was made below in order to identify main elements and attributes of agile enterprise.

Goldman et al. (1995) developed four main strategic dimensions that underline the achievement of agile competitive capabilities. These authors suggest that each company can create a program of agility achievement based on the audit that relates the agility dimensions with current and future company operations. The proposed strategic dimensions of agility are: (1) enriching the customer; (2) cooperating to enhance competitiveness; (3) organizing to master changes; and (4) leveraging the impact of people and information. Enriching the customer means delivering value and solutions to the customer rather than products. In order to bring products to the market as rapidly and cost effectively as possible, it is necessary to utilize all existing resources regardless their location and cooperate internally and with other companies. Effective mastering of change requires flexible organizational structures that allows for rapid reconfiguration of the human and physical resources. According to Goldman et al. (1995), an agile competitive environment is where the people skills, knowledge, and experience are the main differentiators between the companies. Thus, continuous work force education and training are integral to an agile company's operations and represents an investment into future success.

According to Jackson and Johansson (2003), agility is not a goal in itself but the necessary means to maintain the competitiveness in the market characterized by uncertainty and change. Agility is based on several capabilities found in three main enterprise dimensions: manufacturing, product, and market dimensions. Jackson and Johansson (2003) divide agility capabilities into four main dimensions: (1) product-related change capabilities, (2) change competency

within operations, (3) internal and external co-operation, and (4) people, knowledge, and creativity. The first dimension is related to the product-related strategies and operation needed to respond to the change and uncertainty of the market. The change competency within operations concerned with competencies, methods, and tools required managing long- and short-term changes within the production system. Cooperation refers to the ability of enterprise departments to cooperate between each other and ability of whole enterprise to cooperate with suppliers and customers. The final dimension relates to the need to place knowledge and ability of employees as a basis of all actions dealing with the turbulent market changes.

Yusuf et al. (1999) identified competitive foundations of agility as follows: speed, flexibility, innovation, proactivity, quality, and profitability. Yusuf et al. (1999) claimed that proposed competitive foundations are the absolutely essential characteristics of AM that must be achieved in synergy. In this framework, Yusuf et al. (1999) distinguished three aspects of agility related to different levels of enterprise. Elemental agility refers to individual resources (people, machinery and management); micro-agility refers to the enterprise, and macro-agility to the inter-enterprise level. This framework includes four core concepts of AM: core competence management, virtual enterprise formation, capability for re-configuration, and knowledge-driven enterprise. Core competences are associated with the corporation's workforce and products that are identified at the individual and firm level. The enterprise core competences are derived from a corporate-wide learning process, integration of diverse skills and technologies, work organization, and capability for inter-organizational co-operation. The virtual enterprise is the integration of core competencies distributed among several organizations with a similar supply chain (Gunasekaran, 1999).

According to Yusuf et al. (1999), the development of a strategic architecture that presents a corporate wide map of core skills may allow the organization to make rapid changes in focus and afford reconfiguration of the business when the window of opportunity opens. Based on the review of literature, a list of attributes and practices that constitute the agile organization is proposed (see Table 2).

Among reviewed literature, the most holistic and concise framework was proposed by Sharifi et al. (2001). In this model, Sharifi et al. (2001) identified four main aspects of AM: (1) agility drivers, (2) strategic abilities, (3) agility providers, and (4) agility capabilities. The conceptual model describes the relationship between these four elements (See Fig. 1). The agility drivers represent characteristics of the external business environment in reference to the turbulence and unpredictability of the changes. According to the literature, the agility drivers would force a company to revise the current company's strategy, admit the need to become agile, and adopt an agility strategy. Strategic abilities such as responsiveness, competency, quickness, and flexibility are considered as main attributes of the agile organization that allow

Table 2
Attributes and practices of agile organization (Yusuf et al., 1999)

| Decision domain	Related attributes
Integration	Concurrent execution of activities
	Enterprise integration
	Information accessible to employees
Competence	Multi-venturing capabilities
	Developed business practice difficult to copy
Team building	Empowered individuals working in teams
	Cross functional teams
	Team across company borders
	Decentralized decision making
Technology	Technology awareness
	Leadership in the use of current technology
	Skill and knowledge enhancing technologies
Quality	Quality over product life
	Products with substantial value addition
	First time right design
	Short development cycle time
Change	Continuous improvement
	Culture of change
Partnership	Strategic relationship with customers
	Close relationship with suppliers
Market	New product introduction
	Customer driven innovations
	Customer satisfaction
	Response to market changes
Education	Learning organization
	Multi-skilled and flexible people
	Workforce skill upgrade
	Continuous training and development
Welfare	Employee satisfaction
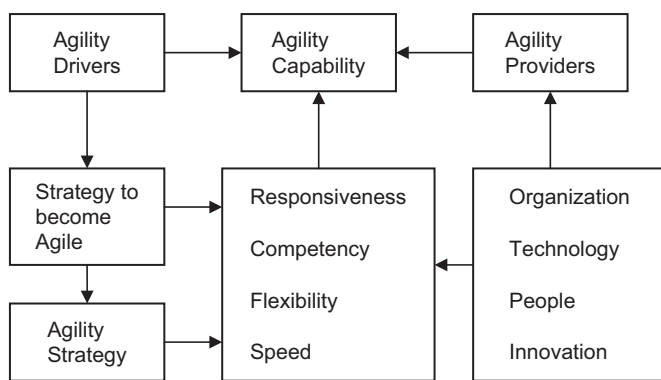
Fig. 1. A conceptual model for agile manufacturing proposed by Sharifi and Zhang (1999).

successful dealing with changes. The agility capabilities could be achieved by the means of agility providers. Agility providers can be derived from four manufacturing areas: organization, technology, people, and innovation. The authors also applied Kidd's (1994) argument that the agility can not be achieved without integration of these four areas.

The assessment of the company's agility level requires specific definition and description of the agility attributes. It should be noted, that especially in a modern dynamically changing environment, the companies will, and should differ in regards to the capabilities used to achieve and maintain agility. However, some general attributes still can be distinguished. Specific categories for each of the major agility capabilities proposed by Sharifi and Zhang (1999) are presented in the Table 3. In this model, responsiveness is considered as the ability to identify changes and respond quickly to them, reactively or proactively, and to recover from them. Competency is defined as an extensive set of abilities that provide a basis for productivity, efficiency, and effectiveness of a company's activities. Flexibility is an ability to process different products and achieve different objectives with the same facilities. Quickness is the ability to carry out tasks and operations in shortest possible time.

4. Measurement of agility

Several different approaches to agility measurement can be found in the literature. Some authors (Tsourveloudis and Valavanis, 2002; Yusuf and Adeleye, 2002; van Hoek et al., 2001) used an integrated agility index. The agility index was defined as combination of agile capabilities intensity levels. Also, the weighted index of the agility, where the intensity of each agility capability was weighed

Table 3
Agility capabilities as defined by Sharifi and Zhang (1999)

Agility capabilities

Responsiveness
- Sensing, perceiving and anticipating changes
- Immediate reaction to changes by effecting them into system
- Recovery from change

Competency
- Strategic vision
- Appropriate technology (hard and soft)
- Sufficient technological ability
- Product/services quality
- Cost effectiveness
- High rate of new products introduction
- Change management
- Knowledgeable, competent, an empowered people
- Operations efficiency and effectiveness (leanness)
- Cooperation internal and external
- Integration

Flexibility
- Product volume flexibility
- Product model/configuration flexibility
- Organization and organizational issues flexibility
- People flexibility

Quickness
- Quick new products time to market
- Products and services delivery quickness and timeliness
- Fast operation time

by it importance was proposed (Yang and Li, 2002). Another method of agility measurement (Ren et al., 2000) was based on analytical hierarchical process (AHP) methodology. In this approach, a pairwise comparison technique was used to evaluate the agile capabilities. The obtained comparisons between all possible pairs of capabilities were synthesized to derive overall agility score. Other authors (Lin et al., 2006a, b; Tsourveloudis and Valavanis, 2002) claimed that since agility indicators and definitions are imprecise and vague, the linguistic expressions and fuzzy logic are more relevant approaches to agility measurement. Arteta and Giachetti (2004) used complexity as a surrogate measure of this concept. Kidd (1994) stated that there are five performance measures of agility: cost of change, time to change, stability of change, scope of change, and frequency of change. These performances measures can be applied to almost every element of the company, which needs to be modified in response to turbulent business environment.

Tsourveloudis and Valavanis (2002) noted that the agility metrics is difficult to develop due to the multi-dimentionality and fuzziness of the agility concept. In order to solve this problem, Tsourveloudis and Valavanis (2002) proposed fuzzy logic knowledge-based framework that consists of four structures of AM: production, market, people, and information. The authors defined specific parameters and measures for each of the main structures (see Table 4). Production infrastructure is concerned with plant, processes, equipment, layout, and material handling and can be measured in terms of time and cost that are needed to respond to changes in production system. The

market infrastructure is focused on the external environment of the enterprise, including customer service and market feedback. Tsourveloudis and Valavanis (2002) proposed to measure this infrastructure by the ability of the enterprise to identify opportunities and the ability to deliver and enrich products and services. People infrastructure can be measured by the level of training and motivation of the personnel. Information infrastructure refers to information flow within and outside of organization, and can be measured by the ability to capture, manage, and share information related to the area of interest.

In order to measure agility, Ren et al. (2000) combined two theoretical frameworks into one four-level hierarchical model. The main objective,"agility" was placed at the highest level of the hierarchy. The main objective was divided into four main dimensions proposed by Goldman et al. (1995), which are enriching the customer, cooperation, mastering change and uncertainty, and leveraging the impact of people. The third level of hierarchy includes ten decision domains, and the fourth level consisted of 32 attributes. The ten decision domains and the related agility attributes were derived from framework proposed by Yusuf et al. (1999). In this approach, each of the hierarchy levels was evaluated by the paired comparison rankings. The comparison data was converted to relative weights and the final score of the agile company could be calculated.

Lin et al. (2006a) developed a fuzzy logic-based agility index for mass customization product manufacturing. Authors argued that mass customization is a production model that combines advantages of mass production with those of customized products. However, the proposed index is worthy of consideration since manufacturing or production agility and organizational agility was discussed. Lin et al. (2006b) identified three main agility capabilities: organizational management agility, product design agility, and product manufacturing agility. For each of these general capabilities, the three grade-specific criteria were proposed (see Table 5).

Arteta and Giachetti (2004) took a perspective that the primary dimension of agility is an ability of the enterprise to respond to a change. They noted that this common description of agility creates a problem with a priori definition of change. According to the authors, this is the main reason why most proposed metrics are backwards looking and cannot predict how the enterprise will react to change. Finally, Arteta and Giachetti (2004) suggested that using a surrogate measure of complexity that has an inverse relationship with agility, could solve this problem. As some authors (Dove, 2001) noted, the complexity of organization in transition needs to be reduced in order to deal with the transition. The complexity of system hinders the ability of the enterprise to quickly react to change by re-configuration of products, processes, or organization structure. Since, the less complex system is easier to change and more agile, the complexity of the system can be used as the measure of agility. Arteta and Giachetti (2004) argued that

Table 4
Measures of agility dimensions (Tsourveloudis and Valavanis, 2002)

1. Production infrastructure
- Setup or change over time
- Versatility (variety of operations machine/workstation can perform)
- Adjustability of machine
- Substitutability (ability to reschedule jobs)
- Operation commonality
- Variety of loads of material handling system
- Transfer speed
- Part variety
- Changeover effort
- Part commonality

2. Market infrastructure
- Reconfigurability of the product mix
- Modularity index (ease of adding new components)
- Expansion ability
- THE range of volume

3. People infrastructure
- Training level
- Job rotation

4. Information infrastructure
- Interoperability (level of standardization)
- networking

Table 5
Mass customization agility index (by Lin et al., 2002b)

I. Organizational management agility	Information management agility	• Enterprise information system quality • Network connection extensiveness • Information and network utilization rate
	Inter-organization cooperation	• Degree of cooperation with other enterprises • Application degree of VE
	Inter-organization cooperation	• Time needed for production process organization • Space needed for production process organization
	Institutional framework agility	• Institutional framework form • Team building speed
II. Product design agility	Availability of customer demands information	• Information access • Proportion of information processing time in products period
	Speed of products design	• The period product design • Proportion of design period in products period
	Product design flexibility	• Degree of product seriation • Degree of product structure similarity • Degree of part universalization
III. Product manufacturing agility	Re-configurability	• Integrated modular packaging unit • Supplement tool displacement • Displacement compatibility
	Manufacturing speed	• Production and technology preparation time • Period of manufacturing • Proportion of manufacturing period in product period
	Flexibility of manufacturing process	• Degree of equipment universalization • Degree of equipment scalability

the complexity and agility can be linked by the measurement of the business process complexity. In addition, the ease of change from the current system state to desired state could be evaluated.

5. Empirical research on agility

Most agility related publication is focused on the theoretical descriptions of agility and agility frameworks. Few of the developed frameworks and metrics were investigated in empirical research. For example, specific and quantitative metrics of agility developed by Tsourveloudis and Valavanis (2002) and Lin et al. (2006a, b) were not applied in empirical research. The comparative analysis of lean and AM by Yusuf and Adeleye (2002) did not give much attention to the development and description of the measures of agile capabilities assessed in the research. In this research, the agility was measured by the means of low cost, quality, speed, dependability, product variety, volume flexibility, and leadership in new technology products. The study by Yusuf and Adeleye (2002) found a larger number of significant correlations between competitive capabilities and performance measures for agile companies than for lean companies. Agile capabilities such as speed to market

and dependability were significantly correlated with all performance measures (sales turnover, market share, % of turnover, custom loyalty). It was revealed that agile companies outperformed lean companies in all performance measures.

Ren et al. (2000) explored how agility attributes influence competitive bases of enterprise. The competitive bases were defined as dimensions that a firm's production system must possess in order to meet demands of the target market. In this study, the following competitive bases were investigated: cost, quality, speed, flexibility, innovation, and proactivity. Ren et al. (2003) revealed that such competitive bases as speed, proactivity, and flexibility had the largest impact on overall enterprise competitiveness. The study showed that relationships between agility attributes and competitive dimensions had the largest values for following pairs: (1) strategic relationship with customers and speed, (2) quality over product life and costs, (3) product with value addition and quality, (4) first-time right decision and innovation, (5) enterprise integration and flexibility, and (6) rapid partnership formation and proactivity. Among obtained results, the strategic relationships with customers had the highest contributory weight (0.9902).

Zain et al. (2005) investigated if the technology adoption and acceptance have positive impact on organizational agility. The technology acceptance model proposed in this research hypothesized that attitude toward a new information technology (IT) system influences organizational agility through actual IT or system use. The attitude toward the new IT system is a function of the perceived usefulness and ease of use. The results supported the hypothesis that the perceived usefulness and ease of IT use influenced the organizational agility through the actual IT use and attitude toward technology. The study revealed that out of the six external variables (user involvement, job and system characteristics, user experience, top management support, and demographic characteristics) only two (job and system characteristics) had significant influence on agility.

6. Workforce agility

In the past, it was believed that agility and responsiveness of flexibility strategy can be achieved through sophisticated technologies such as computer-integrated manufacturing (CIM) (Youndt et al., 1996). However, recent research findings showed that manufacturing flexibility depends much more on people than on technologies. Upton (1995) stated that although computer integration can provide important competitive advantages, results of his study showed that the operational flexibility is determined primarily by plant operators and the extent to which managers communicate with them. It was concluded that achievement of manufacturing flexibility, requires developing and maintaining a "highly skilled, technologically competent and adaptable workforce that can deal with non-routine and exceptional circumstances ..." (Youndt et al., 1996).

The demands of AM also led to a conclusion that agility cannot be achieved without leveraging of employee's knowledge and skills (Dove, 1993; Forsythe, 1997; Nagel and Dove, 1991; Plonka, 1997). It is widely believed that workforce agility may provide wide range of benefits such as quality improvement, better customer service, learning-curve acceleration, economy of scope and depth (Herzenberg et al., 1998; Hopp and Van Oyen, 2004). Changes from traditional production approach to the agile one will place higher demands on the workforce in several domains of business. The domain of changes that require agile response has been documented by Dove (1993) and listed as installing improvements, adding additional process capabilities, responding to schedule changes, reconfiguration of processes to accommodate new products, and migration to new systems. Pinochet et al. (1996) showed that introduction of advanced manufacturing technologies and any computer-technology can have several specific effects on the workplace and workforce. Based on those findings, Gunasekaran (1999) suggested that AM will have different requirements of the workforce than traditional systems: (1) closer interdependence among activities, (2) different skill requirements, usually higher average skill levels, (3) more immediate and costly consequences of any malfunction, (4) output more sensitive to variations in human skill, knowledge and attitudes and to mental effort rather than physical effort, (5) continual change and development, (6) higher capital investment per employee, and (7) favor employees responsible for a particular product, part, or process (Pinochet et al., 1996).

In a changing business environment, the agile workforce faces uncertainty and is expected to provide fast response to unexpected events (Plonka, 1997). An agile workforce is also expected to effectively take part in any collaborative environment (Forsythe, 1997), whether it cross-functional project team, collaborative ventures with other companies, or a virtual organization (Van Oyen et al., 2001). The employed workforce in an AM environment utilizes flexible technologies and infrastructure that supports change and requires higher cognitive demands. In order to provide suggestions concerning improvements in controls and equipments, the operator has to be familiar with the equipment technology. This in turn will require acquisition of new knowledge, accelerated learning, and JIT delivery of training (Plonka, 1997). The information, communication, and mobile technologies from one hand will support and enhance the workforce ability for speedy action and operational flexibility (Goldman and Nagel, 1993; Yusuf et al., 1999), but from other it also increases the cognitive demands and the time pressure.

Based on the review of the demands of agile and lean manufacturing, Plonka (1997) determined some important attributes of agile workforce: (1) attitude toward learning and self-development; (2) problem-solving ability; (3) being comfortable with change, new ideas, and new technologies; (4) the ability to generate innovative ideas, and (5) accepting new responsibilities. Gunasekaran (1999) defined the agile workforce characteristics as follows: IT-skilled workers, knowledge in team working, negotiation, advanced manufacturing strategies, technologies, empowered employees, multifunctional workforce, multi-lingual workforce, and self-directed teams. Based on the review of the organizational agility literature, Breu et al. (2002) determined initial indicators of the workforce agility, such as responsiveness to external change, benchmark for skill assessment, speed of skill development, speed of adaptation to new work environments, speed of information access, speed of IT change, use of mobile technologies, workplace independence, mobile information access, collaborative technologies, virtual team, knowledge sharing, and employee empowerment.

Dyer and Shafer (2003) stated that achievement of organizational agility requires three main types of behavior in workforce: proactive, adaptive and generative. Proactive behavior consists of two aspects: initiate and improvise. Proactive initiative means active search for opportunities to contribute to organizational success and take the lead in pursuing those opportunities that appear promising. Proactive improvisation requires devising and

implementing new and creative approaches to pursuing opportunities and dealing with threats. Adaptive behaviors require assumption of multiple roles to perform in different capacities across levels, and projects often simultaneously move from one role to another very quickly. The employees have to simultaneously learn in multiple competencies areas and educate by actively sharing of information and knowledge. Table 6 presents workforce agility attributes described above.

The agility research mainly considered the agile workforce from an operations perspective. The investigations were focused on the attributes related to the factory shop floor and scheduling methods of multi-skilled, cross-trained workers (Van Oyen et al., 2001). Hopp and Van Oyen (2004) stated that the workers' cross-training is a powerful strategy that can ensure workforce agility. They argue that the workforce agility can be achieved via cross-training because cross-trained workers represent flexible capacity since workers can be shifted to where they are needed when they are needed. According to them, cross-training can increase the production flexibility of an organization. The workforce with the larger set of skills would perform efficiently wider range of tasks and would provide the task redundancy. Cross-training and greater task variety may also facilitate performance due to less fatigue, boredom, or repetitive stress. However, it should be noted that there is no empirical research that examined effect of cross-training on production agility and/or business performance.

7. Empirical research on workforce agility

Breu et al. (2002) empirically investigates the attributes of the agile workforce. Based on the review of the organizational agility literature, Breu et al. (2002) determined initial attributes of the workforce agility that were used to develop a questionnaire. The established workforce agility attributes Breu et al. (2002) assessed were in terms of two agility dimensions, speed, and flexibility. The factor analysis of determined agile workforce attributes revealed a single component that was recognized as a global indicator of the workforce agility. The analysis showed that the most important factors for workforce agility are speed of developing new skills; responsiveness to changes in customer needs and market conditions; and speed of acquiring the skills needed for business process change. Also it was found that none of the analyzed information and communication technology (ICT) factors were an important element of workforce agility. The adoption of new working models had stronger association with workforce agility than ICT adoption and an accurate information system (IS). Among new working models, the strongest association with workforce agility was found for virtual teams within and across organizations, and communities of practices. The identified workforce attributes were grouped into five higher level categories: intelligence, competencies, collaboration, culture, and IS. The grouping of the attributes into the categories is shown in Table 7.

Table 6
The workforce agility attributes

Author	Workforce agility attributes
Plonka (1997)	- Attitude toward learning and self-development - Problem-solving ability - Being comfortable with change, new ideas, and new technologies - The ability to generate innovative ideas - Acceptance of new responsibilities
Gunasekaran (1999)	- IT-skilled workers - Knowledge in team working and negotiation - Knowledge in advanced manufacturing strategies and technologies - Empowered employees; self-directed teams - Multifunctional workforce; multi-lingual workforce
Breu et al. (2002)	- Responsiveness to external change - Benchmark for skill assessment; speed of skill development - Speed of adaptation to new work environments - Speed of information access; speed of IS change - Use of mobile technologies - Workplace independence; virtual teams - Mobile information access; collaborative technologies - Knowledge sharing; employee empowerment
Dyer and Shafer (2003)	- Proactive behavior: initiate, improvise - Adaptive behavior: multiple roles assumption, rapid redeployment - Spontaneous collaboration - Generative behavior: learning, education

Table 7
Capabilities for workforce agility (after Breu et al., 2002)

Intelligence
Responsiveness to changing customer needs
Responsiveness to changing market conditions

Competencies
Speed of developing new skills and competencies
Speed of acquiring the skills necessary for business process change
Speed of innovating management skills
Speed of acquiring new IT and software skills

Collaboration
Effectiveness of cooperating across functional boundaries
Ease of moving between the projects

Culture
Employee empowerment for independent decision making

IS
Support of the IT infrastructure for the rapid introduction of new IS

Sumukadas and Sawhney (2004) conducted empirical testing of the theoretical model of the impact of several workforce management practices on workforce agility. The effect of employee involvement (IE) practices such as: (1) information sharing; (2) training; (3) reward; and (4) power sharing was investigated. Based on the previous research that studied the effects of IE practices on satisfaction and performance, Sumukadas and Sawhney (2004) assumed that the power sharing practice may have major effect on the workforce agility, and other IE practices have secondary effect both direct and indirect via power sharing on workforce agility. These hypotheses were tested with a structural equation modeling method. To measure the IE practices the scales of Lawler et al. (1992) was applied. The workforce agility was measured as proportion of the workforce able to perform multiple tasks, since there was no workforce agility scale available. The results showed that the power sharing techniques (job enrichment and enlargement, self-management teams, quality circles, suggestions systems) had strong and significant effect on the workforce agility. The information sharing practices failed to demonstrate a significant relationship with the workforce agility. Non-monetary incentives had both direct and indirect effect on workforce agility. Only the direct effect of team based production incentives on workforce agility was significant. All other IE practices had significant effect on power sharing, and thus an indirect effect on the workforce agility.

Kathuria and Partovi (1999) investigated the relationship between workforce management practices and managerial performance when the emphasis on manufacturing flexibility is high. In this study, the influence of the work force practices applied by the manager on perception of his performance by employees was analyzed. The workforce management practices were divided in three groups: (1) relationship-oriented; (2) participative leadership and delegation; (3) work-oriented practices (see Table 8). Kathuria and Partovi (1999) found moderating effect of flexibility on the relationship between workforce practices and performance. It was found that relationship-oriented, participative leadership, and delegation play important role in flexible manufacturing settings.

8. Workforce adaptability

The Minnesota theory of work adjustment (TWA) (Dawis and Lofquist, 1984) was developed to explain the workers behavior during the entering the new work environment. This theory is based on the concept of the correspondence (fit) between individual and environment, which describes the mutually responsive relationship. Each side of this relationship has its own requirements that have to be fulfilled in order to achieve the fit. The main assumption of TWA is that each individual seeks the correspondence with the environment. The work environment requires certain tasks to be performed, and the individual brings certain abilities and skill that enable she/

Table 8
Workforce management practices that promotes workforce agility (by Kathuria and Partovi, 1999)

Relationship-oriented practices
Inspiring
Recognizing
Supporting
Team building
Networking
Mentoring
Rewarding

Participative leadership and delegation
Consulting
Delegating

Work-oriented practices
Informing
Planning
Clarifying
Monitoring
Problem solving

he to fulfill the work requirements. The individual also has needs such as relevant work conditions and compensations that have to be met by the work environment. TWA describes the process of a person's adjustment to the environment. The correspondence between the person and environment is achieved through three types of behavior called adjustment style dimensions: activeness, reactiveness, and flexibility. "Activeness" occurs when an individual is acting on work environment and changing the environment to achieve a better fit. When an individual changes him/herself, the ability or behavior to improve the fit is defined as "reactiveness". The "flexibility" dimension is determined by the level of tolerance of mismatch between the person and environment. The three dimensions of the adjustment style are presented in Table 9. Satisfactory performance is considered as an external indicator of correspondence and an effect of good match between the work environment's requirements and the employee's skills. Good fit between employees need/values and the corresponding work environment conditions result in person satisfaction, which is an internal indicator of correspondence. Dawis and Lofquist (1984) hypothesized that experience with wide range of activities, with different people, or with having developed new ways of doing things, would increase the likelihood of people engaging in their styles of adjustment.

According to Allworth and Hesketh (1999), adaptive performance refers to those behaviors that demonstrate the ability to cope with change and to transfer learning from one task to another as job demands vary. The adaptive performance has two aspects: (1) cognitive component that related to application of learning and problems solving skills, and (2) non-cognitive (emotional) component, that represents the emotional adjustment to changing job or task requirements. Table 10 presents components of

Table 9
Adjustments styles dimensions in Minnesota theory of work adjustment (Dawis and Lofquist, 1984)

Dimension	Description
1. Activeness	Individual changing the environment to achieve a better fit
2. Reactiveness	Individual changes him/herself, ability or behavior to improve the fit
3. Flexibility	Level of tolerance of mismatch

Table 10
Components of adaptive performance (Allworth and Hesketh, 1999)

Component	Behavior
Cognitive component	• New learning • Use of problem-focused coping strategies such as planning for change • Accessing information about change • Anticipating and solving problems associated with change
Emotional component	• Confidence in one's ability to cope with the change • Willingness to allow change to occur and do not resist it • Positive emotional reactions to change and the opportunities that change brings

Table 11
Dimension of adaptive performance at work (Pulakos et al., 2000)

(1) Creative problem solving (problem solving of novel, ill defined, and complex tasks)
(2) Dealing with uncertain and unpredictable work situations (coping with the uncertainty)
(3) Learning work tasks, technologies, and procedures (learning new ways to perform a job, tasks; learning new skills set or tasks to retool a job or a new career)
(4) Interpersonal adaptability
(5) Coping with work stress
(6) Cultural adaptability
(7) dealing with emergencies or crisis

adaptive performance distinguished by Allworth and Hesketh (1999) and related specific behaviors.

Based on the literature review, Pulakos et al. (2000) identified eight dimensions of adaptive performance (see Table 11). The evaluation of validity of the eight dimensional model of adaptive performance showed that there are some evidence for the eight dimensions in self-reported measures of past experience, self-efficacy, and interests that were matched to the performance dimensions (Pulakos et al., 2002). They found significant correlation between adaptive performance and following factors: several interests, self-efficacy, experience measure, cognitive ability, emotional stability, and achievement motiva-

tion. The highest correlation was found between adaptive performance and emotional stability. The strongest support for predictive potential of adaptive performance was found for experience and self-efficacy scales.

Griffin and Hesketh (2003) combined the Minnesota TWA and Pulakos et al. (2000) taxonomy of adaptable behavior into one framework. Although the TWA was created during the times when the working environment was stable, it was assumed that since the TWA refers to the adjustability during the person's entry into the new environment, this theory may be also adapted to permanently changing work environment (Griffin and Hesketh, 2003). A changing working environment may antiquate personal skills, abilities, or work methods that are no longer appropriate to new work requirements, creating a mismatch between employees and work environment. According to the TWA, each person seeks a fit with the environment; thus, the mismatch resulting from the work change will motivate the employees to achieve the fit. Griffin and Hesketh's (2003) framework describes adaptability at work with three broad types of behavior: proactive, reactive, and tolerant which correspond to the three adjustment styles dimensions from the TWA (see Table 12). Proactive behavior occurs when a person initiates the activities that have a positive effect on the changed environment. This type of behavior includes the dimensions of creative problems solving and dealing with crises originally proposed by Pulakos et al. (2000).

Reactive behavior is based on changing or modifying oneself to better fit to a new environment and includes: new learning, interpersonal, cultural, and physical adaptability. Tolerant behavior is to continue functioning despite the changing environment or when proactive or reactive strategies may not be appropriate. Tolerant behavior includes coping with stress and coping with uncertainty when proactive or reactive strategies may not appropriate.

Griffin and Hesketh (2003) tested the proposed framework of work adaptability with principal component analysis. The analysis has not brought strong support from either Griffin and Hesketh (2003) or Pulakos et al. (2000) models. Only proactive and reactive dimensions were identified in the three types of the data: supervisors' ratings of adaptable behavior, self-reported job requirements for adaptable behavior, and self-efficacy for adaptable behavior. The items related to the tolerant dimension were loaded on a proactive factor. These results are in accordance with the literature on stress that defining problem-focused coping as a relatively proactive style of behavior. Griffin and Hesketh (2003) were not able to obtain the seven dimensions of adaptability proposed by Pulakos from the analyzed data. The investigation of situational variables showed that a complex work environment and a high level of support from managers were positively related to supervisor's ratings of adaptive performance. However, autonomy was not found related to adaptability.

Table 12
Adaptable behavior at work (synthesis of Minnesota theory and Pulakos) (Griffin and Hesketh, 2003)

Dimension	Description	Behavior
1. Proactive behavior	Person initiate the activities that have positive effect on changed environment	• Creative problems solving • Dealing with crises
2. Reactive behavior	Changing or modifying oneself to better fit to new environment	• New learning • Interpersonal, cultural and physical adaptability
3. Tolerant behavior	Continuing functioning despite changing environment or when proactive or reactive strategies are not appropriate	• Coping with stress • Coping with uncertainty

9. Summary of main approaches and concepts of enterprise agility (EA)

Two main approaches to understanding and defining agility have been distinguished among reviewed literature (Kidd, 1994; Sanchez and Nagi, 2001; Gunasecaram, 1999). The first approach is a very broad and imprecise concept that encompasses all definitions and description of various practices and technologies that have been implemented in industry during last two decades. For example, Yusuf et al. (1999) stated that agility is the "synthesized use of the developed and well-know technologies and methods of manufacturing". This view is supported by Goldman et al. (1995), who describes AM as the assimilation of all flexible production technologies, together with experience gained from total quality management (TQM), "JIT" production, and lean production. Thus, according to this approach, agility is mutually compatible with lean manufacturing, CIM, TQM, materials requirement planning II (MRPII), JIT, and employee empowerment.

The second approach to agility is much more narrow and focused. In this approach, the main emphasis is placed on the ability of rapid adaptation; however, it is not simply the speed of response (Sanchez and Nagi, 2001; Tsourveloudis and Valavanis, 2002). Agility is a rapid and proactive adaptation of enterprise elements to unexpected and unpredicted changes, and represents a new and radically different manufacturing business model (Kidd, 1994). Enterprise elements are the goals, objectives, technology, and organization. It has been argued that since most of currently applied and well-known practices are not adjusted well to uncertainty and unpredictability of the dynamically changing business environment, those methods cannot be included into the concept of agility.

Gunasekaran (2002) also noted that AM is not lean, or flexible manufacturing, or CIM. To clarify the differences between the AM and current practices, Sanchez and Nagi (2001) stated that the lean manufacturing is a collection of operational techniques focused on productive use of resources, whereas agility is an overall strategy. Those authors contrast agile and flexible manufacturing in reference to the type of adaptation: flexible manufacturing is reactive adaptation, while agile is proactive. According

to Tsourveloudis and Valavanis (2002), the flexibility is a capability of the whole factory to change from one task or production route to another, and agility is a strategic ability of the whole enterprise to adapt to unpredicted and sudden changes in the market. However, the term flexibility also is referred to the whole enterprise (Volberda, 1996; De Toni and Tonchia, 1998) and in this case it also defined as the ability to adapt and respond to unpredicted changes in the environment.

It can be noted that there is a significant difference in understanding of terms, flexibility and agility, if they are referred to the manufacturing strategy. Thus, AM can be considered as a manufacturing strategy that is different from the flexible, lean manufacturing, and other strategies and techniques. However, in a situation when terms flexibility and agility are applied to the whole enterprise, most authors define them in a very similar way. Therefore, the agile enterprise/organization may be considered as an approach with assimilated different practices, techniques, and ideas developed in the framework of adaptive and flexible enterprise/organizations, and that different manufacturing strategies depend on the requirements of actual situation in the business environment.

The development of an EA framework presents a serious challenge. First of all, the agility concepts are not yet clearly defined and conceptualized. Although the main and most important attributes of agility have been identified, those attributes are supposed to be applied to such complex structures as an enterprise. It has been proposed in the literature that, in reference to agility, the following components of the enterprise are most important: organization, people, and technology. Each of these elements is multidimensional and complex itself. Thus, numerous agility related concepts, practices and characteristics proposed in the literature can be summarized and classified in two main ways. First, it can be classified into groups according to the adherence or relevance to the main attributes of the agility. In the reviewed literature, a large diversity of agility attributes has been identified. Based on the review, the following main attributes for an agile enterprise can be distinguished: (1) flexibility and adaptability, (2) responsiveness, (3) speed, (4) integration and low complexity, (5) mobilization of core competences, (6)

high quality and customized products, and (7) culture of change. Table 13 provides the summary of concepts related to the main attributes and characteristic of agility.

It should be noted that among those attributes, the core and global characteristics of agility that can be applied to

Table 13
The summary of concepts related to main characteristics/attributes of agility

Flexibility	• Flexible product model • Flexible production systems • Workforce flexibility • Flexible organizational structures and practices • Workplace flexibility • Flexible business strategies
Responsiveness	• Responsiveness to change in customers' preferences, demands • Responsiveness to market and business environment changes and trends • Responsiveness to social and environmental issues • Adjustability of business objectives to the changes
Culture of change	• Environment supportive of experimentation, learning and innovation • Positive attitude to changes, new ideas, people, and technology • Continuous improvement, learning and employee training • Changes management • Organizational responsibilities change
Speed	• Learning, carrying out tasks and operations and making changes in shortest possible time • Time of operations, time of production changes, time of product/service delivery • Time of learning and time of adaptation to change
Integration and low complexity	• Intra-enterprise and inter-enterprise integration • Integration of people, technology and organization • Synthesis of diverse technologies, skills, competencies • Low complexity of structure, relationships between structure elements • Flow of material, communication and information between different organizational structures and systems components • Enhanced interaction between processes, products and suppliers • Easy and effortless process of making changes
High quality and customized products	• Products and services with high information and value-adding content • Quality over product life • First time right decision • Short development cycle time
Mobilization of core competencies	• Multi-venturing capabilities • Developed business practice difficult to copy • Skill and knowledge enhancing technologies • Rapid partnership formation • Close relationship with customers and suppliers • High rate of new product introduction

all aspects of enterprise include flexibility, responsiveness, speed, culture of change, integration, and low complexity. These core characteristics should be reflected in most important aspects of enterprise: production/service, organization, and workforce. Flexibility is considered as the ability to pursue different business strategies and tactics, to quickly change from one strategy/task/job to another. The strategies should be of course different in some reasonable extent, which will not endanger the integrity and main mission of the enterprise. Responsiveness is an ability to identify changes and opportunities and respond reactively or proactively to them. The term ''culture of change'' is a description of environment supportive of experimentation, learning, and innovation and is focused on the continuous monitoring environment to identify changes. Culture of change is an environment where people on all organizational levels have positive and fearless attitude to changes, different opinions, new ideas, and technology. In order to respond to changes the management and workers at all levels have to continuously scan the business and work environment to identify changes and opportunities related to customers, suppliers, and competitors that may be exploited by the enterprise. The market and business environment have to be monitored in order to determine new technologies, practices and methods of production, management, and organization that can be used by the enterprise to successfully respond and adapt to the changes. The speed is ability to complete requirements of all other agile characteristics in shortest possible time. The ability to learn, carry out tasks and operations and make changes in shortest possible time. The integration and low complexity dimension is defined as close and simple relations between the individual system components, easy and effortless flow of the materials, information and communication between the system components, organizational structures, people, and technology. The described general attributes have to be translated into specific indices for each of the main enterprise structure: organization, workforce, technology, and operations.

The other classification of EA concepts and characteristics is based on their adherence to the enterprise structures. The global agility attributes can be established as goals for the high-level management and are applicable to whole enterprise. Starting from these general goals of agility, the more specific sub-goals and the means to achieve them could be derived. The more specific goals and ways to achieve them would depend on the specificity of the each particular enterprise. However, at the highest and global level of the enterprise can be established few domains that should be the main focus for enterprise while trying to achieve agility. These main domains are focus on customer satisfaction, cooperation, learning and knowledge management, and development of culture of change (see Table 14).

Furthermore, in order to be agile the enterprise has to be adaptable and flexible and has to adopt the features of the

Table 14
Characteristics of agile enterprise: global strategies

Customer	• Enriching the customer • Customer-driven innovation • Customer satisfaction
Cooperation	• Cooperating to enhance competitiveness • Internal and external co-operation • Strategic relationship with customers • Close relationship with suppliers
Organizational learning and knowledge development	• Leveraging the impact of people, knowledge, information and creativity • Continuous training and development of people • Core competence management • Continuous extraction of tacit knowledge related to customer's preferences, service/production processes and work organization
Culture of change	• Continuous monitoring of internal and external environment to identify changes and opportunities • Continuous updating and revision of business strategies • Continuous improvement, experimentation and improvisation • Product-related change capabilities • Change competency within operations • Capability for re-configuration

Table 15
Characteristics of agile enterprise: organization and workforce

Organization		
Authority	• Decentralized knowledge and control • Fewer power differentials (fewer titles, levels, status dimensions, etc) • Less adherence to authority and control • Loyalty and commitment to project or group • Authority tied to tasks • Authority change when tasks change • Wide span of control	
Rules and procedures	• Few rules and procedures • Low level of formal regulation (in respect to job description, work schedules) • Fluid role definitions • Informally organized	
Coordination	• Informal and personal coordination • Delegation of tasks and decision making • Network communication • Goal-directed	
Structure	• Flat, horizontal, matrix, networked or virtual structure • Teamwork, cross-functional linkages • Loose boundaries among function and units	
HRM management practices	• Employee empowerment • Employee involvement • Job rotation • Job enrichment • Autonomy in decision making • Information and knowledge access • Teamwork • Multifunctional teams • Multiple skills trainings • Workforce development and training • Differentiation and diversity development	
Agile workforce Proactivity	• Anticipation of problems related to change • Solution of change related problems • Personal initiative	
Adaptivity	• Interpersonal and cultural adaptability • Spontaneous collaboration • Learning new tasks and responsibilities • Professional flexibility	
Resiliency	• Positive attitude to changes, to new ideas, technology • Tolerance to uncertain and unexpected situation • Coping with stress	

organic organization such as few levels of hierarchy, informal and changing lines of authority, open and informal communication, loose boundaries among function and units, distributed decision making, and fluid role definitions (Lawrence and Lorsch, 1967; Ashby, 1956; Hatch, 1997; Vecchio, 2006).

Organizations in order to be adaptable have to: (1) cultivate inquiry, learning, experimentation, and divergent thinking; (2) enhance external and internal interconnections; and (3) develop diversity, specialization, differentiation, and integration (Dooley, 1997). The characteristics of the flexible, adaptable, and agile organization are summarized in the Table 15.

The review of the literature allowed us to identify and summarize the most important attributes of the agile workforce. Based on the models of Griffin and Hesketh (2003) and Dyer and Shafer (2003), the attributes of the agile workforce were grouped in three dimensions: proactivity, adaptivity, and resilience (see Table 15). The proactivity refers to the situation when a person initiates the activities that have positive effect on a changed environment (Griffin and Hesketh, 2003). To this category belong such behaviors as: (1) anticipation of problems related to change; (2) initiations of activities that lead to solution of the change related problems and improvements in work; and (3) solution of change related problems. In order to anticipate the change related problems the agile workforce has to monitor and analyze the external and internal environment (market, workplace, consumers, and competition) to identify the changes, opportunities, and threats. In order to find solutions of change-related problems, the workforce has to be able to analyze and assess the information about change and to plan a response for change. The solution of change-related problems require: (1) new ways to perform the job and tasks; (2) improvisation and experimentation; (3) problem solving of novel, ill defined and complex tasks. The adaptive

dimension is based on the changing or modifying oneself or their behavior to better fit new environment. This dimension includes interpersonal and cultural adaptability when dealing with people with different background and experience. The adaptive dimension also includes constant learning of new skills, tasks, technologies, and procedures. Furthermore, adaptive behavior requires professional flexibility: ability to assume multiple roles, change easily from one role to another, and ability and competences to work simultaneously on different tasks in different teams. Resilience describes ability to function efficiently under the stress and despite changing environment or when applied strategies have not succeeded. To this dimension belongs: (1) positive attitude to the changes, new ideas, and technology; (2) tolerance of uncertain and unexpected situations, differences in opinions and approaches; and (3) tolerance to stressful situations and coping with stress.

10. Conclusions

There is no commonly accepted definition of EA, and there are a large number of opinions concerning the meaning of this term. Furthermore, there is a problem to differentiate the agility concept from adaptability and flexibility. Currently, all three terms: "adaptability", "flexibility", and "agility" are used in the research on how organization can cope with unpredicted and dynamically changing environment. In case of each concept, there is substantial confusion and ambiguity concerning the concept, it's definition, elements, or attributes. It seems that all three concepts are defined very similarly or the same way if applied to the whole enterprise level. However, these concepts have very different meaning if applied to the manufacturing environment. In this paper, it is suggested that these three terms represent the evolution of the idea of the organization or enterprise able to adjust to changes. Currently, the latest stage of evolution of this idea is represented by the agile enterprise that comprise all concepts and propositions developed in the frame of research on the adaptive and flexible organization and manufacturing. There is large number of publications on agility that are concerned with the specific strategies, techniques, and manufacturing and/or management practices. There is also a vast number and variety of strategies, techniques, and manufacturing and/or management practices described as a part of the agile enterprise. Only a few studies address the conceptualization and development of an integrated view of the agile enterprise concept. Although, some AM frameworks make an attempt to present a more integrated and holistic model, it still presents a view mostly focused on production and the technological aspects of enterprise. Moreover, most agility related publications are focused on the theoretical descriptions of agility and agility frameworks. Only few of those metrics and frameworks were investigated in empirical research.

The advantages of agile workforce have been described in the agility related literature for a long time. A range of attributes that are believed to be associated with workforce agility has been identified. However, there are a lack of studies that empirically investigate and determine the attributes of the workforce. The agility research mainly considered the agile workforce from the operations and work shop floor perspective. In general, it should be noted that the literature on workforce agility is rather limited. This state is partially due to the lack of a clearly defined framework of AM or EA. There is no theory identifying the implication of AM or EA on workforce characteristics and determining the concepts and indicators of agile workforce.

References

Allworth, E., Hesketh, B., 1999. Construct-oriented biodata: capturing change-related and contextually relevant future performance. International Journal of Selection and Assessment 7 (2), 97–111.

Arteta, B.M., Giachetti, R.E., 2004. A measure of agility as the complexity of the enterprise system. Robotics and Computer-Integrated Manufacturing 20 (6), 495–503.

Ashby, R., 1956. Design for a Brain. Wiley, New York.

Breu, K., Hemingway, S.J., Strathern, M., Bridger, D., 2002. Workforce agility: the new employee strategy for the knowledge economy. Journal of Information Technology 17 (1), 21–31.

Brown, S., Eisenhard, K., 1998. Competing on the Edge. Harvard Bussiness School Press, Boston, MA.

Burns, T., Stalker, G.M., 1961. The Management of Innovation. Tavistock Publications, London, UK.

Dastmalchian, A., 1993. The concept of organizational flexibility: exploring new direction. In: Dastmalchian, A., Blyton, P. (Eds.), Organizational Flexibility, Proceedings of a Colloquium. University of Victoria, British Columbia, pp. 15–25.

Dastmalchian, A., Blyton, P., 1998. Organizational flexibility in cross-national perspective: an introduction. International Journal of Human Resource Management 9 (3).

Dawis, R.V., Lofquist, L.H., 1984. A Psychological Theory of Work Adjustment. University of Minnesota Press, Minneapolis.

Donaldson, L., 2001. The Contingency Theory of Organization. Sage Publications, London, UK.

Dooley, K., 1997. A complex adaptive systems model of organizational change. Non-linear Dynamics, Psychology and the Life Sciences 1, 69–97.

Dove, R., 1993. Lean and agile: synergy, contrast, and emerging structure. In: Proceedings of the Defense Manufacturing Conference '93, San Francisco, CA.

Dove, R., 2001. Response Ability: the Language, Structure, and Culture of the Agile Enterprise. Wiley, New York.

Dyer, L., Shafer, R., 2003. Dynamic organizations: achieving market-pelace and organizational agility with people. In: Peterson, R.S., Mannix, E.A. (Eds.), Leading and Managing People in the Dynamic Organization. Laurence Erlbaum Associates, Mahwah, NJ.

Forsythe, C., 1997. Human factors in agile manufacturing: a brief overview with emphasis on communications and information infra-structure. Human Factors and Ergonomics in Manufacturing 7 (1), 3–10.

Goldman, S.L., Nagel, R.N., 1993. Management, technology and agility: the emergence of a new era in manufacturing. International Journal of Technology Management 8 (1/2), 18–38.

Goldman, S.L., Nagel, R.N., Preiss, K., 1995. Agile Competitors and Virtual Organizations: Strategies for Enriching the Customer. Van Nostrand Reinhold, New York.

Griffin, B., Hesketh, B., 2003. Adaptable behaviours for successful work and career adjustment. Australian Journal of Psychology 55 (2), 65–73.

Gunasekaran, A., 1999. Agile manufacturing: a framework for research and development. International Journal of Production Economics 62, 87–105.

Hage, J., Aiken, M., 1969. Routine technology, social structure and organizational goals. Administrative Science Quarterly 14, 366–376.

Hage, J., Dewar, R., 1973. Elite values versus organizational structure in predictinng innovation. Administrative Science Quarterly 18, 279–290.

Hatch, M.J., 1997. Organization Theory: Modern, Symbolic and Postmodern Perspectives. University Press, Oxford, UK.

Herzenberg, S.A., Alic, J.A., Wial, H., 1998. New Rules for New Economy: Employment and Opportunity In Postindustrial America. Cornell University Press, Ithaca, NY.

Hopp, W.J., Van Oyen, M.P., 2004. Agile workforce evaluation: a framework for cross-training and coordination. IIE Transactions 36 (10), 919–940.

Jackson, M., Johansson, C., 2003. Agility analysis from a production system perspective. Intergarted Manufacturing Systems 14 (6), 482–488.

Kalleberg, A.L., 2001. Organizing flexibility: the flexible firm in a new century. British Journal of Industrial Relations 39 (4), 479–504.

Kathuria, R., Partovi, F.Y., 1999. Work force management practices for manufacturing flexibility. Journal of Operations Management 18 (1), 21–39.

Kidd, P.T., 1994. Agile Manufacturing: Forging New Frontiers. Addison-Wesley, Reading, MA.

Lawler III, E.E., Mohrman, S.A., Ledford Jr., G.E., 1992. Employee involvement in total quality management: practices and results in fortune 100 companies. Jossey-Bass, San Francisco, CA.

Lawrence, P.R., Lorsch, J.W., 1967. Organization and Environment: Managing Differentiation and Integration. Harvard University Press, Cambridge, MA.

Lin, C.-T., Chiu, H., Chu, P.-Y., 2006a. Agility index in the supply chain. International Journal of Production Economics 100 (2), 285–299.

Lin, C.-T., Chiu, H., Tseung, Y.-H., 2006b. Agility evaluation using fuzzy logic. International Journal of Production Economics 101 (2), 353–368.

Lorsh, J.W., Allen, S.A., 1973. Managing Diversity and Inter-Dependence: An Organizational Study of Multidivisional Firms. Harvard University, Boston.

Mccarty, F.H., 1993. Agility in Manufacturing. Manufacturing Engineering 111 (6), 8.

Nagel, R.N., Dove, R., 1991. 21st Century Manufacturing Enterprise Strategy: An Industry Led View. Iacocca Institute, Lehigh University, Bethlehem, PA.

Nonaka, I., Umemoto, K., Senoo, D., 1996. From information processing to knowledge creation: a paradigm shift in business management. Technology in Society 18 (2), 203–218.

Pinochet, A., Matsubara, Y., Nagamachi, M., 1996. Construction of a knowledge-based system for diagnosing the sociotechnical integration in advanced manufacturing technologies. The International Journal of Human Factors in Manufacturing 6 (4), 323–349.

Plonka, F.S., 1997. Developing a lean and agile work force. Human Factors and Ergonomics in Manufacturing 7 (1), 11–20.

Pulakos, E.D., Arad, S., Donovan, M.A., Plamondon, K.E., 2000. Adaptability in the workplace: development of a taxonomy of adaptive performance. Journal of Applied Psychology 85 (4), 612–624.

Pulakos, E.D., et al., 2002. Predicting adaptive performance: further tests of a model of adaptability. Human Performance 15 (4), 299–323.

Reed, K., Blunsdon, B., 1998. Organizational flexibility in Australia. International Journal of Human Resource Management 9 (3), 457–477.

Ren, J., Yusuf, Y.Y., Burns, N.D., 2000. A prototype of measurement system for agile enterprise. In: International Conference on Quality, Reliability, and Maintenance. Oxford, UK, pp. 247–252.

Ren, J., Yususf, Y.Y., Burns, N.D., 2003. The effect of agile attributes on compettitive priorities: a neural network approach. Integrated Manufacturing 14 (6), 489–497.

Sanchez, L.M., Nagi, R., 2001. A review of agile manufacturing systems. International Journal of Production Research 39 (16), 3561–3600.

Sharifi, H., Zhang, Z., 1999. A methodology for achieving agility in manufacturing organisations: an introduction. International Journal of Production Economics 62 (1–2), 7–22.

Sharifi, H., Zhang, Z., 2001. Agile manufacturing in practice—application of a methodology. International Journal of Operations and Production Management 21 (5–6), 772–794.

Sharifi, H., Colquhoun, G., Barclay, I., Dann, Z., 2001. Agile manufacturing: a management and operational framework. Proceedings of the Institution of Mechanical Engineers Part B—Journal of Engineering Manufacture 215 (6), 857–869.

Stewart, A.M., Mullarkey, G.W., Craig, J.L., 2003. Innovation or multiple copies of the same lottery ticket: the effect of widely shared knowledge on the organization adaptability. Journal of Marketing Theory and Practice 11 (3), 25–44.

Sumukadas, N., Sawhney, R., 2004. Workforce agility through employee involvement. IIE Transactions 36 (10), 1011–1021.

Toni, D.A., Tonchia, S., 1998. Manufacturing—flexibility: a literature review. International Journal of Production Research 36 (6), 1587–1617.

Tsourveloudis, N.C., Valavanis, K.P., 2002. On the measurement of enterprise agility. Journal of Intelligent and Robotic Systems 33 (3), 329–342.

Upton, D.M., 1995. What really makes factories flexible? Harvard Business Review 73 (4), 74–84.

van Hoek, R.I., Harrison, A., Christopher, M., 2001. Measuring agile capabilities in the supply chain. International Journal of Operations and Production Management 21 (1–2), 126–147.

Van Oyen, M.P., Gel, E.G.S., Hopp, W.J., 2001. Performance opportunity for workforce agility in collaborative and noncollaborative work system. IIE Transactions 33, 761–777.

Vecchio, R.P., 2006. Organizational Behavior: Core Concepts. Thomson/Southwest Learning, Cincinnati, OH.

Volberda, H.W., 1996. Toward the flexible form: how to remain vital in hypercompetitive environments. Organization Science 7 (4), 359–374.

Weick, 1982. Managment of organiztional change among loosely coupled units. In: Goodman, P.S. (Ed.), Change in Organizations. Jossey-Boss, San Francisco, pp. 375–408.

Weick, K., Quinn, R.E., 1999. Organizational change and development. Annual Review of Psychology 50, 361–386.

Yang, S.L., Li, T.F., 2002. Agility evaluation of mass customization product manufacturing. Journal of Materials Processing Technology 129 (1–3), 640–644.

Youndt, M.A., Snell, S.A., Dean, J.W., Lepak, D.P., 1996. Human resource management, manufacturing strategy, and firm performance. Academy of Management Review 39 (4), 835–866.

Yusuf, Y., Sarhadi, M., Gunasekaran, A., 1999. Agile manufacturing: the drivers, concepts and attributes. International Journal of Production Economics 62 (1–2), 33–43.

Yusuf, Y.Y., Adeleye, E.O., 2002. A comparative study of lean and agile manufacturing with related survey of current practices in the UK. International Journal of Production Research 40 (17), 4545–4562.

Zain, M., Rose, R.C., Abdullah, I., Masrom, M., 2005. The relationship between information technology acceptance and organizational agility in Malaysia. Information and Management 42 (6), 829–839.