LEAN PRODUCTION AND AGILE MANUFACTURING – NEW SYSTEMS OF DOING BUSINESS IN THE 21ST CENTURY

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Abstract: The paper discusses main issues related to lean production and agile manufacturing. It provides a comparison between the attributes of lean and mass production as well as between agile manufacturing and mass production. Conclusions related to the comparison of lean production versus agile manufacturing are formulated.

Key words: lean production, agile manufacturing, waste minimization, responsiveness, virtual enterprise

1. Introduction
In the 21st businesses are restructuring and reengineering themselves to overcome the challenge of customers, seeking high quality, low-cost products and be responsive to their specific unique and rapidly changing needs. Two new systems of doing business in manufacturing have evolved in the recent decades – lean production and agile manufacturing. Lean production evolved in 1960s in Japan when Toyota Motors started innovative changes in mass production to deal with its domestic automotive market. Womack and Jones define lean production as “doing with less and less human effort, less equipment, less time and less space while coming closer and closer to providing customers with exactly what they wanted”[1]. In its turn, agility addresses new ways of running companies to meet these challenges and is based not only on responsiveness and flexibility but also on cost and quality of goods and services that the customers are prepared to accept. According to Gupta and Mittal (1996) Agile Manufacturing (AM) is “a business concept that integrates organization, people and technology into a meaningful unit by deploying advanced information technologies and flexible and nimble organizational structures to support highly skilled, knowledgeable and motivated people” [2].

2. Lean production – principles, attributes, lean versus mass production.
Lean production is based on four principles: (1) minimize waste; (2) perfect first-time quality; (3) flexible production lines; (4) continuous improvement [1].

Minimize waste. All principles derive from the first – minimize waste. Tatschichi Ohno’s list of waste forms include: (1) production of defective parts; (2) production of more than the needed number of items; (3) unnecessary inventories; (3) unnecessary processing steps; (4) unnecessary movement of people; (5) unnecessary transportation of materials; (6) waiting workers.
Perfect first-time quality. Quality control in mass production is defined in terms of an acceptable quality level (AQL), meaning that a certain level of fraction defects is sufficient even satisfactory. In lean production (LP), perfect quality is required. The JIT delivery discipline used in LP necessitates a zero defects level in parts quality while a single defect draws attention to the quality problem, forcing corrective action and a permanent solution. Table 1 contains the comparison of attributes between mass production (MP) and lean production.

Table 1 Comparison of MP and LP attributes

<table>
<thead>
<tr>
<th>Mass Production</th>
<th>Lean Production</th>
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<tbody>
<tr>
<td>Inventory buffers</td>
<td>Minimum waste</td>
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<tr>
<td></td>
<td>Minimum inventory</td>
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<td></td>
<td>Just-in-time delivery</td>
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<td>Acceptable quality</td>
<td>Perfect first-time delivery</td>
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<td>Taylorism</td>
<td>Workers teams</td>
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<td>Maximum efficiency</td>
<td>Worker involvement</td>
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<td></td>
<td>Flexible production systems</td>
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<td>“If it ain’t broke, don’t fix it”</td>
<td>Continuous improvement</td>
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Source: M. Groover

Flexible manufacturing systems (FMS). MP is based largely on the principles of Frederick W. Taylor, one of the leaders of the scientific management movement in the early 1900s, according to which workers had to be told every detail of their work methods and were incapable of planning their own tasks. LP makes use of worker teams to organize the tasks to be accomplished and worker involvement to solve technical problems. In MP, the goal is to maximize efficiency using long production runs of identical parts and long setup changeovers. Flexible manufacturing systems allow for smaller batch sizes and shorter setup changeovers required by LP in a dynamically changing market environment.

Continuous improvement. In MP, there is a tendency to set up the operation, and if it is working leave it as it is. LP supports the policy of continuous improvement – i.e. constantly searching for and implementing ways to lower cost, improve quality, and increase productivity. The scope of continuous improvement goes beyond factory operations and involves design improvements as well. It is accomplished doing one project at a time. The project could be related to cost reduction, MLT and WIP reduction, product design improvement, performance increase, etc.


Agile manufacturing (AM) has emerged after lean production. It can be defined as: (1) enterprise level manufacturing strategy of introducing new products into rapidly changing markets; (2) organization ability to thrive in a competitive environment characterized by continuous and sometimes unforeseen change. Studies have identified four principles of agility:

Organize to master change. An agile company is organized in a way that allows it to thrive in conditions of change and uncertainty while the human and physical
resources can be rapidly reconfigured to adapt to changing environment and market opportunities.

Leverage impact of people and information. In an agile company, knowledge is valued, innovation is rewarded, authority is distributed to the appropriate level of the organization. The management provides the resources that personnel need, the organization has entrepreneurial spirit, and there is a climate of mutual responsibility for joint success.

Cooperate to enhance competitiveness. Cooperation internally and with other companies is the top priority strategy of the agile companies. The objective is to bring products to market as rapidly as possible and the required resources and competencies are found and used, wherever they exist. This may involve partnering with other companies, even with competitors, to form “virtual enterprises”.

Enrich the customer. The products of an agile company are perceived as solutions to customers’ problems. Pricing the product can be based on the value of the solution to the customer, rather than on manufacturing costs. AM involves more than just manufacturing. It involves the firm’s organizational structure, the way the firm treats the people, partnerships with other organizations, and relationships with customers. The key enablers of AM include: (1) virtual enterprise formation tools/metrics; (2) physically distributed manufacturing architecture and teams; (3) rapid partnership formation tools/metrics; (4) concurrent engineering; (5) integrated product/production/business information systems; (6) rapid prototyping; (7) electronic commerce [3]. Manufacturing system reconfigurability and product variety are critical aspects of AM. According to Tu (1997) the manufacturing industry, particularly the one-of-a-kind production (OKP), tends to be lean, agile and global [4]. This leads to a new concept of a virtual company that consists of several sub-production units geographically dispersed in the world as branches, joint ventures and subcontractors. For some companies there is a need to be transformed into a virtual enterprise in order to become agile. Fig. 1 represents the model of explaining the AM paradigm. It takes into account the characteristics of the market, infrastructure, technologies and strategies. Achieving agility from manufacturing strategies and technologies’ view point, may require focusing on: (1) strategic planning; (2) product design; (3) virtual enterprise; (4) automation and IT (see fig. 2).

Strategic planning. Several substrategies are needed to achieve agility in manufacturing, including virtual enterprise, rapid–partnership formation, rapid prototyping, and temporary alliances based on core competencies. AM can be achieved through customer-integrated multidisciplinary teams, supply chain partners, flexible manufacturing, computer-integrated information systems, and modular production facilities. Current approaches to the design and construction of enterprise systems lead to fixed interdependencies between valuable resources. This constrains the resource reuse and the agility of systems, often preventing close alignment between system behaviour and business process requirements. Responsibility-based manufacturing (RBM) is a new architecture of production systems that falls under the AM paradigm.
Fig. 1 Agile manufacturing paradigm

Fig. 2 Agile manufacturing strategies and technologies
In a mass-customization environment, RBM allows most adjustments for process and product variety to take place dynamically and rapidly during production without the need for preliminary system reconfiguration. Active resources (mobile robots, intelligent pallets, etc.) take the responsibility for the production of individual parts/products, implementing the relation of individual customer to individual producer [5]. An integrated supply chain can act as a global network used to deliver products and services from raw materials to end-customers through an engineered flow of information and physical distribution. The supply chain management system focuses on resolving business process problems that are important to customers, facilitating the flexibility and responsiveness of an organization. Traditional methods of production planning and control (PPC) do not satisfy their needs for operations management of virtual companies. In an AM environment, the following PPC aspects should be considered: (1) modeling of evolutionary and concurrent product development and production under continuous customer’s influence; (2) real-time monitoring and control of the production progress in a virtual company; (3) flexible or dynamic company control structure to cope with uncertainties in the market; (4) adaptive production scheduling structure and algorithms to cope with uncertainties of the production state in a virtual company; (5) modeling of production states and control systems in a virtual company; (6) reference architecture for a virtual company. Achieving agility in manufacturing requires radical changes in line with a productive reengineering business process. This level of change in any organization demands the total support of top management in terms of providing necessary technical and financial support combined with employee empowerment.

Product design. Agility in manufacturing requires a change around the formation of product development teams including representatives with different expertise such as design, manufacturing, quality assurance, purchasing, marketing, field service, and support. AM requires a rapid product design system with objective of switching over to new products as quickly as possible. This needs a system to group various resources and products to reduce the non-value adding activities and hence the time to reach market with the right products at the right time. Virtual Design Environment (VDE) is information architecture to support design-manufacturing-supplier-planning decisions in a distributed heterogenous environment for systematic selection of planning alternatives that reduce cost and increase throughput.

Virtual enterprise. A virtual organization is the integration of complementary core competencies distributed among a number of carefully chosen, but real organizations all with similar supply chains focusing on speed to the market, cost reduction and quality. Virtual Enterprise (VE) environment places a number of special requirements on the process design activity. Since virtual enterprises are temporary, such organizations must be carefully assembled and disassembled. Individual partner organizations do not cease to exist during their membership of the VE. This highlights the important issue, related to security. Security matters require the establishment of appropriate industrial legislation and legal protection. Supply chain management in VE needs a different set of frameworks, strategies, techniques
and performance measurement criteria. The relationships with suppliers in lean organizations is based on long-term focusing on cost reduction. In AM, the relationship is temporary, focusing on responsiveness. Therefore, appropriate supply chain management strategies, methods and performance measurements should be established to improve the effectiveness of supply chain management in AM enterprises.

Automation and IT. AM needs intelligent sensing and decision-making systems capable of automatically performing many tasks traditionally executed by human beings. Visual inspection is one such task and hence there is a need for effective automated visual inspection systems in AM environments. AM requires agile-enabling technologies such as virtual machine tools, flexible fixturing, and agile design alternatives. Physically distributed manufacturing environments /VEs demand high-level communication systems such as Internet, EDI (Electronic Data Interchange) and Electronic Commerce to exchange information at various levels of manufacturing organizations. The systems for AM should include mostly software/decision support systems for various planning and control operations including material requirements planning, design, manufacturing resource planning, scheduling, production planning and control.

4. Agility versus mass production.

In mass production, companies produce large quantities of standardized products and ideally huge volumes of identical products are produced. Over the years, the technology of MP has been refined to allow for minor variations in the product (mixed-model production). In AM the products are customized. The comparison of MP and AM attributes is presented in Table 2.

<table>
<thead>
<tr>
<th>Mass Production</th>
<th>Agile Manufacturing</th>
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<tr>
<td>Standardized products</td>
<td>Customized products</td>
</tr>
<tr>
<td>Long market life expected</td>
<td>Short market life expected</td>
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<tr>
<td>Produce to forecast</td>
<td>Produce to order</td>
</tr>
<tr>
<td>Low information content</td>
<td>High information content</td>
</tr>
<tr>
<td>Single time sales</td>
<td>Continuing relationship</td>
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<tr>
<td>Pricing by production cost</td>
<td>Pricing by customer value</td>
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Along with the trend toward more customized products, today’s products have shorter expected market lives. MP was justified by the existence of very large markets for its mass-produced goods. Mass markets have become fragmented, resulting in a greater level of customization for each market [6]. In mass production, products are produced based on sales forecast. If the forecast is wrong, this can sometimes result in large inventories of finished goods that are slow in selling. Agile companies produce to order: customized products for individual customers. Inventories of finished products are minimized. Manufacturers of today keep adding
more and more features to the products to gain competitive advantage. They want to rely not on single sales but to have continuing relationships with their customers.

5. Conclusions

The emphasis in lean seems to be more on technical and operational issues, whereas agility emphasizes organization and people issues.

Lean applies mainly to the factory. Agility is broader in scope, applicable to the enterprise level and even beyond to the formation of virtual enterprises. The two systems do not compete.

Lean tries to minimize change, at least external change. It attempts to reduce the impact of changeovers on factory operations so that smaller batch sizes and lower inventories are feasible. It uses flexible production technology to minimize disruptions caused by design changes. The philosophy of agility is to embrace change. The emphasis is on thriving in an environment marked by continuous and unpredictable change. It acknowledges and attempts to be responsive to change, even to be the change agent if it leads to competitive advantage.

The capacity of an agile company to adapt to change or to be a change agent depends on its capabilities to have a flexible production system, to minimize the time and the cost of changeover, to reduce on-hand inventories of finished products, and to avoid other forms of waste. These capabilities belong to a lean production system. For a company to be agile, it must also be lean.

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