GENERATION OF THE WORLD CLASS MANUFACTURING SYSTEMS

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Abstract

World-Class manufacturing was the term introduced for referring to the goal of achieving and/or sustaining World-Class competitiveness through manufacturing excellence, attained through best practices. The mission of World-Class manufacturing is to bring manufacturing closer to the market by eliminating waste. This mission is translated into reality through the objectives of cost reduction, quantity control, quality assurance and respect for humanity. During the last 20 years the concept of WCM has evolved by changing its basic pillars. The article deals with the changes in the perception and construction of the concept. The author proposed the 3rd generation concept of WCM system based on agility.

Keywords: WCM, world class manufacturing generations

1. DEFINITION OF WCM

Attaining the highest level of manufacturing system organization requires low-cost structural flexibility [1] and the associated response speed and adaptability to the changing market and technological environment. Such postulates can only be met by the best presently defined form of organization called World Class Manufacturing (WCM). A literature review carried out within the WCM concept has shown that there is no universal, recognizable and worldwide accepted WCM definition [2,3]. However, it could be accepted that world class manufacturing is a manufacturing system organization method that enables the highest possible level of manufacturing organization to be achieved by implementing modern management methods. According to the WCM guidelines, organization means presently the highest achievable manufacturing organization level [4]. WCM is currently the standard of organizing contemporary manufacturing activity and may constitute a model for organizing the activity of the entire industrial enterprise. However, due to the diversity of the environment and the speed of changes in the conditions of functioning of enterprises, it is increasingly difficult to maintain its consistent standard in each enterprise, so:

- either *x Production System*s (xPS) are designed, which are based on so called production agility adjusted individually to the needs of each production enterprise,
- or existing systems are transformed towards increased production agility.

In economic practice, therefore, sets of uniform organizational guidelines (concepts, methods, tool, etc.) are created, which come within the scope of the implementation capabilities of any enterprise. This is necessary, as there is a wide latitude in establishing individual path to reaching the world class.

2. ORIGIN AND DEVELOPMENT OF WCM

Striving after manufacturing excellence and pursuing continuous improvement programmes in all aspects of functioning of enterprises contributed to the attainment of a leading position by the Japanese economy. Aspiring to attaining the highest level of utilization of production capacity, in a broad sense, contributed, therefore, to the formation of a unique form of manufacturing organization, which enabled the status of world class manufacturers to be achieved. Studies conducted on this subject at that time allowed one to draw the conclusions that of the greatest importance to achieving the competitive advantage in a long-term horizon is to develop organizational factors and human resources in the manufacturing structure [5].

The notion of WCM was first used in 1985 (Hayes and Wheelwright) for describing the organizations that had achieved global competitive advantage as a result of utilizing their possessed manufacturing capabilities and incorporating them into a strategy [6]. The term World Class appeared in many studies to describe the practices developed by Japanese and German companies, which enabled them to effectively compete in global markets. Those enterprises showed many mutual similarities, which the authors named Six World Class Manufacturing Practices, arguing that they are the key to the building of competitive advantage. These practices included [6]: the development of the skills and abilities of employees, the development of the technical competences of managerial staff, competition through quality, the stimulation of the involvement of direct production workers, rebuilding the manufacturing engineering through investments into technological innovations, and incremental improvement methods. At the initial stages of development, the WCM concept was used for determining the leaders in efficiency in individual industries, to distinguish them from traditional manufacturers. A world class manufacture is the one who is able to compete with the best ones in any place in the world [7].

The WCM concept appeared also in studies by Hall, who gave the term World Class Manufacturing to the approach to managing an organization's functioning that fundamentally differed from the known approach [8], and by Gunn, who defined WCM as a set of innovative technologies that help to achieve competitive advantage [9].

The development of the WCM concept, as proposed by Hayes and Wheelwright, was continued by, fascinated by the advantage of Japanese enterprises, Schonberger who expanded the set of practices up to 16 world class manufacturing principles, including cultural, operational and strategic issues (the practice originally proposed by Schonberger were referred to a the Programme of Actions Towards the Manufacturing Excellence [10]. On the grounds of the good practices proposed by Hayes, Wheelwright and Schonberger, Giffi, Roth and Seal defined the set of attributes that should be possessed by a world class production enterprise, by grouping them into categories related to the manufacturing strategy, production capabilities, management methods, organizational factors, human resources, technology and the measurement of productivity [11]. Subsequent studies extended the WCM concept by focusing their attention on two aspects: the implementation of innovative technologies as a success factor and the importance of the customer in carrying out manufacturing processes [12].

A breakthrough in the concept of WCM compatible organization was the inclusion of lean manufacturing practices in it. Womack argued that the principles of lean manufacturing could be used identically in any industry worldwide [13], and initial research showed that an integral part of world class manufacturing were: the knowledge and skills of employees (hence the need for their improvement), ability and capability to compete through quality, employee involvement in carrying out processes, and continuous improvement. It was also recognized that a prerequisite for the implementation of good WCM practices was the emphasis on developing organizational culture and the construction of the appropriate organizational structure assuring the proper fulfilment of those practices [14]. In turn, by making a synthesis of his studies, Voss isolated 46 detailed practices and means that made up world class manufacturing, including the practices recognized previously as the foundation of WCM, associated with employee skills and capabilities, competing through quality and employee involvement in conducted processes. They were grouped in six key areas [15]: organization and organizational culture, logistics, manufacturing organization, lean manufacturing, concurrent engineering and focus on quality. On the grounds of their studies on good practices within WCM, Motwani, Kumar, Kathawala made an attempt to systematically identify the critical factors making up organizational requirements for world class production. As those factors, they categorized the following [16]: elimination of losses, delivery quality management (timeliness of high quality deliveries), manufacturing control, employee involvement and orientation to quality. Clark, in turn, supplemented the practices used within WCM by including quality management and the JIT concept, naming them New Manufacturing Practices [17]. In turn, Farsijani and Carruthers (1996) made the classification of 28 most commonly used techniques and tools within the WCM concept [18]. In 1997, the team of B.B Flynn, R.G. Schroeder, E.J. Flynn, S. Sakakibara and K. A. Bates

ultimately defined the set of practices proposed by Hayes and Whellwright and developed by Schonberger and others [19]. A comprehensive synthesis of practices used within WCM were studies by Sharma and Kodala, who made the analysis of identified 23 structures and 252 WCM elements [20]. The grouped good practices (concepts, methods and tools) provided foundations for building the concept of the WCM organization based on so called technical and management pillars.

3. CONTEMPORARY WCM INTERPRETATION

WCM is currently perceived in the world as a set of operation management methods which contribute to an improvement in the productivity of enterprises [21] and make it possible to build a strong competitive position in the market. WCM is a way to solve the problem of how to manufacture at the lowest possible costs, while ensuring acceptable order delivery times and generating the highest possible added value for the customer. There are many operation management methods that try to solve this problem, including [21]: Lean Organization, Six Sigma, Theory of Constraints, Total Productive Maintenance, **Reliability Centered Maintenance,** Quick Response Manufacturing, Benchmarking, Supplier Relationship Management, Total Quality Management or Total Industrial Engineering. Taking them into consideration enabled common WCM principles to be worked out, which include [21]: dedication to quality, employee involvement, measurement, continuous improvement, achieving growth in top line.

At present, enterprises wishing to take account of the environmental variability, as well as increasing customer requirements, have to be very flexible and, at the same time, thrifty (that is agile). So, the current WCM concept fundamentally differs from the concept of good practices proposed by Hayes and Wheelwright and Schonberger, which is due to its natural evolution. It is recognized as a management model, which is used by the management of organizations having the world's best manufacturing systems, and which relies on the following basic principles [21]: employee involvement, new way of work, accident prevention, customer's voice, respect for established sets and standards, consistent and rigorous use of all methods and tools, no tolerance to losses, visualization of error, removing causes rather than effects.

The contemporary understanding of world class systems is based on the agile manufacturing paradigm. The he agile manufacturing paradigm is presently a new competition model, which came into being as a result of combining the principles of mass and lean manufacturing with the modern form of network industrial cooperation in the supply chain. Industrial cooperation allows the system operation efficiency to be increased through the synthesis of innovation in manufacturing, information and communications technologies with thorough restructuring of the organization and new market strategies [22]. Agile manufacturing has developed because of the occurring organizational limitations and shortcomings of lean manufacturing, resulting from constant and unpredictable changes in the turbulent environment. By assuming the effectiveness of the use of resources by minimizing losses and adding values, lean manufacturing was unable to quickly and effectively respond to environmental changes (to use opportunities), while maintaining its resource flexibility and reducing the so-called band of resource-available opportunities. The effect of the progressing global competition was the need for meeting the requirements of customers (different in local markets), who expected products with innovative features and new functional values, at a low cost and a high quality level [23]. In a general meaning, agile manufacturing is understood as the manufacturing that provides enterprises a fast response to dynamic changes in customer requirements and as a way of responding to critical production problems [24]. Quick response is most often associated with the operational capabilities of the system (its flexibility), while the identification of customer demands, with strategic-marketing tools. Presently, agile manufacturing, in a general meaning, encompasses fast product delivery, highly flexible manufacturing and the integration of dispersed enterprises [25]. As stressed by the literature, the main advantages resulting from the implementation of agile manufacturing are [26]: short time-to-market, fast new product development, short / fast order processing, low volumes, low quantities, high product mix, configurable components, fast supplier deliveries, short lead times,

short cycle times, highly flexible and responsive processes, highly flexible machines and equipment, quick changeover, empowered employees.

The natural evolution of the WCM concept, taking place under the influence of both environmental changes and the conditions of conducting manufacturing activity, has developed many models which can still be successfully used.

4. SELECTED WCM MODELS

All models have come into being by the modification of the base WCM model comprising the set of best practices. Nachiappan et. all [27] added that lack of clear consensus and systematic reason or background in the process of selection of tools to form WCM models, has resulted in an inconsistency between different tools and techniques, and increased the chance of unavailing implementation in various conditions. For this reason, the majority of models were formed by grouping good practices into sets of methods and concepts and attributing to them common effects of influence on enterprises. **Figure 1** summarizes selected WCM models and their basic components.

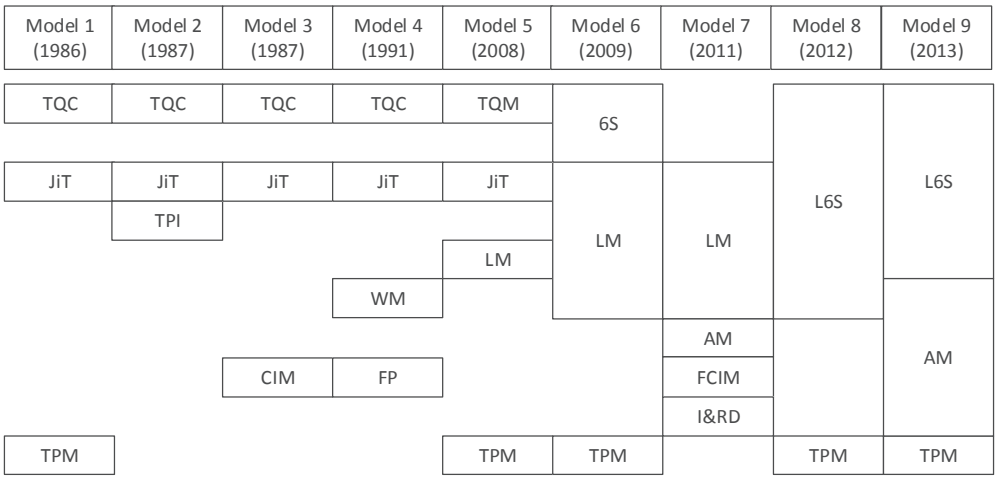

Figure 1 Selected WCM models and their basic components

The most widely known WCM models include:

1) Schonberger's model (1986). It is based on the set of good practices written in the form of rules. The WCM status can be achieved by any of the two parallel paths: the quality path, and the JIT production path. Hence the presence of concepts, such as: TQC (Total Quality Control), JiT (Just in Time), TPM (Total Productive Maintenance).
2) Hall's model (1987), which is based on three pillars: TQC, JiT Manufacturing, TPI (Total People Involvement), and in practice is often referred to as the value-added manufacturing model.
3) Gunn's model (1987). It is based on the set of good practices grouped in three pillars: CIM (Computer Integrated Manufacturing), TQC, JiT Production.
4) Maskell's model (1991). It is based on the set of good practices grouped in four pillars: TQC, JiT, WM (Workforce Management), FP (Flexible Production).
5) Sharma and Kodali's model (2008). It is based on the set of good practices grouped in four pillars: TQM (Total Quality Management), LM (Lean Manufacturing), TPM, JiT, called also the ME/WCM model (ME - Manufacturing Excellence).
6) Nachiappan et. all model (2009). It is based on the set of good practices grouped in three pillars: TPM, 6S (Six Sigma), LM.

7) Gandhi et. all model (2011). It is based on the set of good practices grouped in four pillars: LM, FCIM (Flexible Computer Integrated Manufacturing), AM (Agile Manufacturing), I&RD (Innovation and R&D).
8) Okhovat et. all model (2012). It is based on the set of good practices grouped in two pillars: L6S (Lean Six Sigma), TPM.
9) Dudek (2013). It is based on the set of good practices grouped in three vertical pillars: TPM, L6S, AM, and two horizontal pillars: TFM (Total Flow Management) and TSM (Total Service Management) [1].

All of the presented contemporary models (since 2008) are based on the classic system of two pillars: technical and managerial. Technical pillars are sets of organizational guidelines in the most important production areas, responsible for so-called production adaptivity. Managerial pillars are a complement to the technical-area pillars. The creation of individual world class manufacturing systems involves the definition and selection of, most often, ten basic technical and managerial pillars from the set of the available areas of potential improvements.

5. WCM SYSTEM GENERATIONS - EXAMINATION RESULTS

Based on the analysis of the components and the concepts, methods and tools most often used in the business practice of Polish production enterprises organized on the WCM basis, the key (crucial) changes in the perception, understanding and evolution of WCM components. Most changes were observed in the areas of perceiving quality, productivity, efficiency and flexibility. Those changes influenced the concepts, methods and tools used in ongoing activity. The analysis of these changes, as well as the moments of their occurrence, helped to create the time-frame and distinguish three generations of WCM systems:

- first-generation systems are based on main concepts, such as: TQC, TPM, JiT,
- second-generation systems are based on main component concepts, such as: TQM, TPM, LM,
- third-generation systems are based on component concepts, such as: L6S, TPM, AM.

The studies carried out have been consistent with the analysis of literature on this subject indicating the occurrence of also two breakthroughs in the understanding of WCM concepts (the introduction of production leanness and the introduction of production agility). These breakthroughs constitute, therefore, the conventional boundaries of division of selected WCM models into 3 generations. Their conventional division is shown in **Figure 2.**

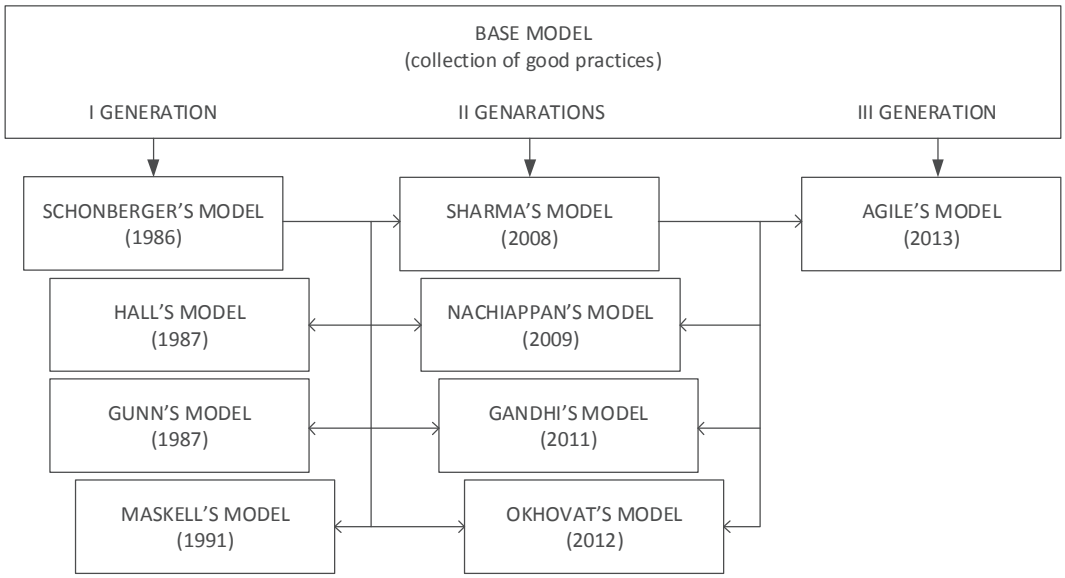

Figure 2 Selected WCM models and generations

In the case of both the empirical studies and the literature review, the division boundaries result from the natural evolution and from the changes in understanding and interpreting individual component concepts. Thus,

- the first boundary (I/II) results primarily from the exchange of the TQC concept for TQM/6S; change, in particular, in the area of so-called common involvement and the comprehensive perception of quality (both for the quality of products and for their comprehensive effectiveness in processes), and change from the implementation of lean thinking to organizational processes (which resulted, inter alia, in the inclusion of JiT in the set of the basic principles of lean production);
- the second boundary (II/III) results chiefly from the partial inclusion of the LM concept in the 6S area (the simultaneous elimination of the variability and wastage through the effective management of customers, processes and employees) and in the AM area (balancing of the flexibility and leanness of processes through, inter alia, low-cost flexibility [1].

6. CONCLUSIONS

Evolution, or the process of passing from simple forms into increasingly complex and perfect forms, applies also to world class manufacturing processes. The change process discussed in the paper resulted both from the changes in the enterprises' environment (e.g. tough competition, globalization, escalation of customer requirements) and from the internal need for adaptation to those unpredictable changes (especially to changes in technology, computerization and automation, and increased intellectual involvement backed by the systems of analyses and assessments).

The analysis of the change processes made based on selected Polish enterprises organized on the basis of the original WCM postulates has found, inter alia, that:

- world class systems are built based on different models, most often, however, those categorized into the second generation,
- implemented organizational solutions are, more often, based on an enterprise's own individual compositions of particular base concepts (xPS),
- there is a shortage of tools increasing the response speed at the strategic level,
- a predominant model, upon which world class manufacturing systems are now to be built, should be the agility model,
- in practical solutions, attaining the manufacturing agility should normally be accompanied by a transient state, which is lean manufacturing (concepts, methods and tools that are used in practice are generally those that have been developed by the lean manufacturing paradigm, assuming that agile manufacturing is a natural extension of lean manufacturing),
- a dedicated organizational criterion integrating activities in the manufacturing agility area should be the criterion based on the network of relationships, used for acquiring and integrating dispersed resources from the network (such integration results in an increase in the flexibility of actions, while maintaining the lowest possible system operation cost).

REFERENCES

[1] DUDEK M. Zwinność produkcji czyli niskokosztowa elastyczność systemu. Przegląd Organizacji, Nr 9, 2013, pp. 22-29.

[2] OKHOVAT M. A. ARIFFIN M. K., NEHZATI T., HOSSEINI S. A., Development of World Class Manufacturing Framework by Using Six-Sigma, Total Productive Maintenance and Lean. Scientific Research and Essays, Vol. 50, No. 50, 2012, pp. 4230-4241.

[3] KODALI R., SANGWAN K.S., SUNNAPWAR V. K. Performance Value Analysis for the Justification of World Class Manufacturing Systems. Journal of Advanced Manufacturing Systems, Vol. 3, No. 1, 2004, pp. 85-102.

[4] HENDRY C. L. Applying World Class Manufacturing to Make-To-Order Companies: Problems and Solutions. International Journal of Operations & Production Management. Vol. 18, No 11, 1998, pp. 1086-1100.

[5] YAMASHINA H. Challenge to World-Class Manufacturing. International Journal of Quality & Reliability Management, Vol. 17, No. 2, 2000, pp. 132-143.

[6] HAYES, R. H., WHEELWRIGHT S. C. Restoring Our Competitive Edge: Competing Through Manufacturing. John Wiley & Sons: New York, 1985.

[7] BURCHER P., STEVENS K. Measuring Up to World Class Manufacturing. IOM Control Magazine, Vol. 22, No 1, 1996, pp. 17-21.

[8] HALL R.W. Zero Inventories, Dow Jones-Irwin: Homewood, IL, 1983.

[9] GUNN T.G. Manufacturing for Competitive Advantage: Becoming a World Class Manufacturer. Ballinger Publishing Co: Cambridge, MA, 1987.

[10] SCHONBERGER R.J. World Class Manufacturing: the Lessons of Simplicity Applied. Free Press: New York, 1986.

[11] GIFFI C., ROTH A., SEAL G. Competing in World Class Manufacturing: America's 21st Century Challenge. Business One Irwin: Homewood, IL, 1990.

[12] FLYNN B. B., SCHROEDER R. G, FLYNN E. J., SAKAKIBARA S., BATES, K.A. World Class Manufacturing Project: Overview an Selected Results. International Journal of Operations & Production Management, Vol. 17, No. 7, 1997, pp. 671-685.

[13] WOMACK J., JONES D., ROOS D. The Machine That Changed the World. Rawson Associates: New York, 1990.

[14] ROSS D. F. Aligning the Organization for World Class Manufacturing. Production and Inventory Management, Vol. 32, No. 2, 1991, pp. 22-26.

[15] VOSS C. A., BLACKMOON K. The Impact of National and Parent Company Origin on World Class Manufacturing. Findings from Britain and Germany. International Journal of Operations & Production Management, Vol. 16, No. 11, 1996, pp. 98-115.

[16] MOTWANI J., KUMAR A., KATHAWALA Y. WCM Practices of North American Manufacturing Organizations. Industrial Management & Data Systems, Vol. 94, No. 7, 1994, pp. 18-23.

[17] CLARK K. B. Competing Through Manufacturing and the New Manufacturing Paradigm: Is Manufacturing Strategy Passé? Production and Operations Management, Vol. 5, No. 1, 1996, pp. 42-58.

[18] FARSIJANI H., CANUTHERS A. World Class Manufacturing: Techniques for Implementation for Small and Medium Sized Enterprises. In IEMC 96 Proceedings. International Conference on Engineering and Technology Management, 1996.

[19] FLYNN B. B., SCHROEDER R. G, FLYNN E. J., SAKAKIBARA S., BATES, K. A., World Class Manufacturing Project: Overview an Selected Results. International Journal of Operations & Production Management, Vol. 17, No. 7, 1997, pp. 671-685.

[20] SHARMA M., KODALI R. Development of A Framework for Manufacturing Excellence. Measuring Business Excellence, Vol. 12, Iss. 4, 2008, pp. 50-66.

[21] DE FELICE F., PETRILLO A. Optimization of Manufacturing System Through World Class Manufacturing. In Proceedings of IFAC, Vol. 48, No. 3, 2015, pp. 741-746.

[22] GUNASEKARAN A. Agile Manufacturing: Enablers and Implementation Framework. International Journal of Production Research, Vol. 36, No. 5, 1998, pp. 1223-1247.

[23] LEBER M., BASTIC M., BUCHMEISTER B. The Trends in Usage and Barriers of Innovation Management Techniques in New Product Development. Journal of Mechanical Engineering, Vol. 60, No. 6, 2014, pp. 382-388.

[24] JIN-HAI L., ANDERSON A. R., HARRISON R. T. The Evolution of Agile Manufacturing. Business Process Management Journal, Vol. 9, No. 2, 2003, pp. 170-189.

[25] GUNASEKARAN A. Agile Manufacturing: A Framework for Research and Development. International Journal of Production Economics, Vol. 62, 1999, pp. 87-105.

[26] MANIVELMURALIDARAN V., Agile Manufacturing - An Overview. International Journal of Science and Engineering Applications, Vol. 4, No. 3, 2015, pp. 156-159.

[27] NACHIAPPAN R. M, ANATHARAMAN N, MUTHUKUMAR N. Integrated Approach to Total Productive Lean Six Sigma (TPLSS). Journal of Operations Management, Vol. 8, No. 2, 2009, pp. 14-35.