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REVIEW OF 35 YEARS OF LEAN PRODUCTION – OUTLOOK DEVELOPMENT TO LEAN, AGILE, AND IOT

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Abstract: Lean production (or lean management) gained popularity in several waves. The last three decades have been filled with numerous attempts to apply these concepts in companies. However, this has only been partially successful. The roots of lean production can be traced back to Toyota's just-in-time production. This concept, which according to Womack's, Jones' and Roos' research at MIT was employed by Japanese car manufacturers, became popular under its international names "lean production", "lean-manufacturing" and was termed "Schlanke Produktion" in Germany. This contribution provides a review of lean production in Germany over the last thirty-five years: development, trial & error and implementation as well. An outlook will be presented of the further development of processes and products with lean and agile success tools and the advancement towards IoT.
Keywords: application, JIT, lean production, review, trial and error, agile, IoT

1. INTRODUCTION

JUST-IN-TIME (JIT) was developed by Taiichi Ohno and Shigeo Shingo in the 1950s and was only later labelled "Toyota Production System" (TPS) [1], [2]. However, it was not until the first oil crisis in 1973 and Toyota's success during this period that JIT began to attract attention. As the oil price began to stabilize, JIT came to the fore. In 1979/1980 the second oil crisis followed, leading to one of the most severe recessions in German history in 1981/82 with subsequent changes in the political landscape. At this very moment in time, a publication comparing average sizes in stock in Europe and Japan made headlines. In short: while the production itself was comparable, the Japanese logistic, which utilized simple, manual KANBAN–cards (material requirement card, developed by Toyota's Ohno in 1947), was considerably more efficient and straightforward at very low costs. Over the next decade, all attempts to implement KANBAN-systems were unsuccessful. JIT was not seen as JIT production, but as JIT delivery. The prerequisites, such as Zero-Defect-Production, production methods with a smoothed assembly via short setup times, small production batch sizes, multifunctional workers, standards as well as reliable facilities (Total Productive Maintenance TPM) were largely ignored, while little notice was taken of English literature published after 1980 [3]. Hence JIT was sometimes discredited as Just-in-congestion". Opinions such as "stock on wheels" were popular. However, nothing could be further from the truth – distances are covered on streets, not space and time. Demand and supply are coordinated via pull-production. German manufacturers attempted to become more competitive through automation and "Computer Integrated Manufacturing" (CIM).

2. DEVELOPMENT OF LEAN PRODUCTION

— After the Great Flood: A Dry Spell

In 1990, the report of MIT's "International Motor Vehicle Program" (IMVP) was published as a book under the title "The second revolution in the automobile industry" [4]. It illustrated the principles of a production system, which was superior in terms of productivity and quality and gave it the name "lean production". Such a "Big Bang" had rarely been seen in this industry. Seminars and conferences on this topic as well as pilgrimages to Japan by legions of managers and consultants demonstrated the frantic activity resulting from attempts to close the gap. Books depicting new methods of management were published every few months – looking back, this could be called a "wave of new methods". For example, one would have been able to discover a book on "Six Sigma", but this was to be largely ignored for another ten years [5]. With the elimination of the seven types of waste (Muda) according to Toyota's definition, the "Sea of inventory" became relevant once again. Continuous Improvement (CIP), and workplace organisation (i.e. 5S or 5A) were among the principles to achieve prominence [6]-[9].

CIP's usefulness was certified as a complete success by Lopez' office at VW in 1994, as it had led to a 21 percent increase in productivity and had saved several billions. The target figures in 1994 were between 5000 and 6000 CIP-workshops and the training of 800 CIP moderators for VW and their suppliers [10]. The Japanese real estate and stock market bubble in Japan burst and lean production was largely forgotten about in most companies for the next ten years. The great flood was followed by a ten-year dry spell.

— Chinese Whispers

The engagement with lean production was comparable to the game "Chinese whispers". Toyota/TPS gained prominence as "lean management" (the term was coined in the US). The concept was adapted in Germany. However, direct exchanges

between TPS/Toyota and its German users remain relatively rare [11]. And why would there be? After the bubble had burst, ideas from Japan were no longer held in high regard. Although a lot was tested, only a few companies would continue to work towards the implementation of lean production with a shift of their production culture in mind.
At the time, sustainability was still a widely unknown concept and the majority of companies were too preoccupied with other matters (Development of a global player, deep slumber, destroying capital etc.).

— Awaking from the Slumber

The Toyota Prius, the first mass-produced hybrid car in the world, was introduced in Japan in 1997 and in Europe three years later. As the Prius was named "Car of the Year" by the European media in 2005 and Toyota replaced Ford as the second largest car manufacturer in the world, the car industry was torn from its sleep: Toyota displayed development competence and was poised to become the market leader, a position they were then to hold for a long time.
This news was – once again – followed by frantic reactions and associations such as VDA and VDI organized seminars and workshops [12], [13]. Once again the elimination of waste was made a top priority – the removal Muda in accordance with Toyota's 1950s concept: Over-production, Unnecessary transportation, Inventory, Motion, Defects, Over-processing, Waiting. While it already had been alluded to thirty years ago, it was only recently that the importance of the eighth form of waste, the unexploited potential of the labour force, has been fully recognized. If implemented mechanically without real values and conviction, the 5S or 5A workplace organizations can reach grotesque dimensions. These particular problems had already been identified during the introduction of lean management in 1992 [14]. Yet again a great fuss was created and had little impact.
Over the course of the last few years, various companies implemented derivatives of the TPS. Case studies show the success lean production has had in the removal of waste as well as its potential to streamline processes. Possible shortcomings are the employees' qualifications and the prevention of waste, which are presented in seminars on the topic "Reckoning for the last 15 years" [15]. The focus lies predominantly on waste (i.e. Muda). Unevenness (Mura) as well as overburden (Muri) are marginal topics.

2.4 It is Crucial to Understand the Basics

How to proceed was outlined in 1991 [16]: "The key is not to adopt the methods and the systems, but to understand their foundations. The next step is to assess which parts can be adopted or adjusted to the circumstances at hand and, most importantly, what could be improved. Extensive English literature on the Toyota production system as well as Japanese production methods has been in circulation for the last ten years. If it required research at MIT to understand the signs of the time, then many companies have misinterpreted the development of an entire decade. This period in time cannot be made up for by imitation, but rather through development leaps or innovative products and production methods. This is a challenge German car manufacturers will now have to face. It is important to make use of the time while the industry remains healthy, which is illustrated by the current situation in the East. If the necessary structural changes are left too late, crisis management will become the order of the day".
This is precisely what is taking place at the moment – costs and crisis management following decades of neglect. Advancements are made through real understanding and not through the language exercises of the different translations of 5S and 5A as in [17] - [19]: From 5 S's to 5A's and back to 5S's again - what progress!

Seiri	Sortiere aus	Aussortieren	Sort
Seiton	Stelle ordentlich hin	Aufräumen	Stabilise
Seiso	Säubere	Arbeitsplatz-Sauberkeit	Shine
Seiketsu	Standardisieren	Anordnung zur Regel Machen	Standardise
Shitsuke	Sichern / ständig verbessern	Alles einhalten / verbessern	Sustain

In fact, this hardly comes as a surprise considering that waste is yet to be interpreted in a correct manner. This was illustrated as in [20]:

1) "Empowering the employees" vs. "Avoid waste": It is important to minimize waste. However, this will only be sustainable if minimizing waste ceases being the sole target after a certain point.
2) Minimizing waste should be the result not the goal. It is more important to empower all employees to contribute to the accumulation of knowledge at their own work station, in order to optimize procedures – otherwise the danger arises that the accumulation of knowledge will be neglected in favour of focusing all efforts on the avoidance of waste. In this case, one would never progress beyond the initial success. When "Avoid all forms of waste!" is declared the sole target, many will hesitate to invest in areas that have a history of underfunding. Typically this affects the local accumulation of knowledge. This situation even affects some of the big corporations, which have a history of lean production, because they failed to realize that.
3) The quintessence is not "avoid waste", but "empower the employees to not produce unnecessary costs", with the emphasis lying on "empowerment".

"Muda" does not have the same meaning as "waste" – it is something that you do that is useless, something that is done for no particular purpose. It is less concerned with material, but rather with actions. Muda distinguishes between fruitless

and useful actions. Tangible Muda are always the result of actions that had not been thought through. This is a point that cannot be stressed enough, otherwise "the baby will be thrown out with the bath water" [20].

3. THE RECALL DEBACLE AND RECOVERING

How should one judge the current vehicle recalls by Toyota? For the company, they are a disaster. Yet the fact that Ford had to recall nearly 14 million vehicles at the same time was met with little to no public reaction. The question is: Why? The FAZ came up with its own answer [21]. According to their research, the US wanted to hit Toyota and cover up negligence of their own administrational bodies: *"Toyota undoubtedly has problems. However, these vehicle recalls only became a worldwide scandal, because they suited the needs of the American car industry. The company was caught up in the trappings of politics. (…) Others would interpret this as political opportunism."* [22], [23].

In Germany in 2008, there were 148 motor vehicle recall actions with KBA involvement, which were distributed amongst all manufacturers. Thus, the German car industry hardly qualifies as the paradigm of reliability either [24]. More importantly: how will the former model student, who gained an impeccable reputation for quality and reliability, be able to recover from this recent fall from grace? Anyone who has seen Toyota's apology as well as the statements made before congress by the leading figures of the US car industry, will recognize who has shown a greater sense of orientation, responsibility, personal honour and trust. Here are the appropriate links for anyone who wants to see for themselves: Toyota President Aiko Toyoda on Toyota Recalls [25] and The 'Big Three' testify on Capitol Hill [26].

Toyota returned to their roots and returned to full strength. According to a statement from Toyota's procurement manager on June 18th 2010 the company aimed to lower its total costs by 30 % by 2013 through the development of 165 model-independent modules [27]. Another measure is a radical redesign of the components as in [28], [29]. As early as 1996, Toyota already released a motor with 30 % less parts and potential savings of similar proportions [30], but even today this achievement has gathered little attention. Only four different types of screws are required for a motor whereas 24 are used in the German premium automotive market.

Once these vehicles, which have been assembled with significantly fewer parts, are on the streets, the rest of the automobile industry will once more trail ten years behind and will be confronted with the failures of the last 25 years. Where should the competitive advantage come from, if everyone uses lean concepts or engages in outsourcing, but nobody takes preventive action or advances their own developments? After all statements such as "Who only follow the trails of their predecessors, will never be able to overtake them" or "The best Japanese are the Japanese", "Don't imitate – innovate" and the like have been known for twenty years as in [31].

4. THERE IS STILL A LONG WAY TO GO

It takes a lot of time and effort to understand and implement the Toyota production system and develop the employees as benchmark for lean production. It is also necessary to adopt sustainable process improvements with a new production philosophy and not to rely on efficiency programs, which ultimately turn out to be absurd austerity programs. Lean production is a successful way to enhance quality and productivity. Numerous case studies illustrate its successful implementations, which often had to overcome trials and confusion or even an all-out re-start along the way. A few companies have interpreted it as one continuous path that they have been following for twenty-five years and have since integrated into their production philosophy, but although this may be very, very good, it is not good enough, it is not excellent.

The road with and towards lean production remains long and trying. But now is the time to make preparations for further development. In 2007, Peter Wickens, the Director of Personnel and Information Systems of the Nissan Motor Manufacturing (UK) Ltd. called for "a system of 'lean production' managed by people who care about people" [32]. The employees are to be regarded as the source of innovation and need to be further empowered. Lean production must be advanced beyond production itself to include the basis of a "Lean and Green" agenda.

5. LATEST DEVELOPMENT - LEAN, AGILE, AND IOT

After the financial crises and the new development towards electrical vehicles with China situated as the leaders in this, the automotive industry showed panic and hectic reactions. Lean, agile, Industry 4.0 and IoT are the new directions.

Some of the approaches currently under wider discussion as part of 'Industry 4.0' (IoT) have previously been introduced at companies or are in their rollout stage. For the companies, Industry 4.0 (IoT) does not mean production without people and also does not necessarily mean increasing automation. In this context, the main issue for the companies is the reasonable application of new technologies to provide ideal support to the workers in production, logistics and production planning. Day-to-day work and the new skill levels required for people working in digital factories are different from today's traditional workers as shown in Figure 1 [33, 34].

Besides intelligent data management, the approach also includes sophisticated human-robot systems that can significantly improve ergonomically unfavourable work procedures. As the digital and the physical worlds grow closer together, new opportunities arise that allow people to cooperate more efficiently in the company's global production network. Mobile assistance systems will offer improved support to production and logistics workers in the future. In all

these efforts, the focus is not on the technical feasibility, but on the specific benefit in production technologies that actually reach the end customer.

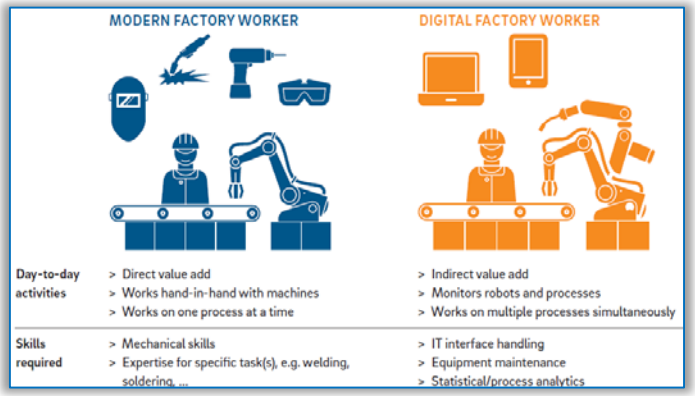

Figure 1 – The worker of tomorrow [33, 34]

Big data is the next buzz word and like a fashion trend. A large amount of data is not necessary big data. The term *big data* was first used to refer to increasing data volumes in the mid-1990s. In 2001, the notion of big data also included increases in the variety of data being generated by organizations and the velocity at which that data was being created and updated. Those three factors - volume, velocity and variety - became known as the 3Vs of big data. Big data analytics is the process of examining large and varied data sets - i.e., big data - to uncover hidden patterns, unknown correlations, market trends, customer preferences and other useful information that can help organizations make more-informed business decisions.

Network control and the management of manufacturing equipment, asset and situation management or manufacturing process control bring the IoT within the realm of industrial applications and smart manufacturing [35]. The IoT intelligent systems enable rapid manufacturing of new products, a dynamic response to product demands and real-time optimization of production and supply chain networks in manufacturing, by networking machinery, sensors and control systems together [36].

Digital control systems to automate process controls, operator tools and service information systems to optimize plant safety and security are within the purview of the IoT [37]. But it also extends itself to asset management via predictive maintenance, statistical evaluation and measurements to maximize reliability [38]. Measurements, automated controls, plant optimization, health and safety management and other functions are provided by a large number of networked sensors [36].

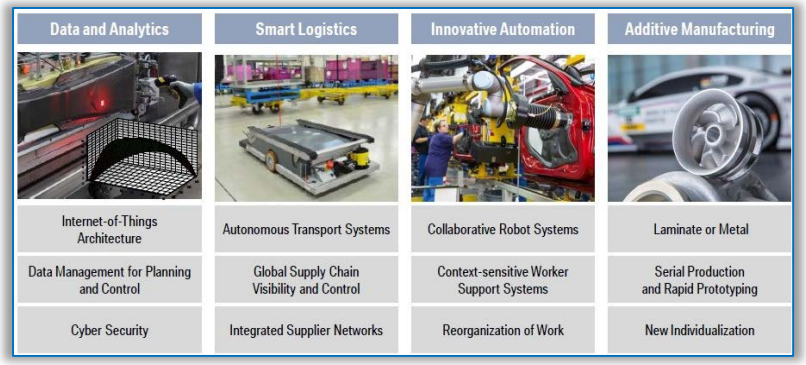

Figure 2 – Intelligent and innovative production – Digitisation creates new potential

The term industrial Internet of things (IoT) is often encountered in the manufacturing industries, referring to the industrial subset of the IoT. IoT in manufacturing could generate so much business value that it will eventually lead to the fourth industrial revolution, the so-called Industry 4.0. It is estimated that, in future, successful companies will be able to increase their revenue through Internet of things by creating new business models and improving productivity, exploiting analytics for innovation, and transforming the workforce [39]. The potential for growth through the implementation of IoT will generate $12 trillion of global GDP by 2030 [39].

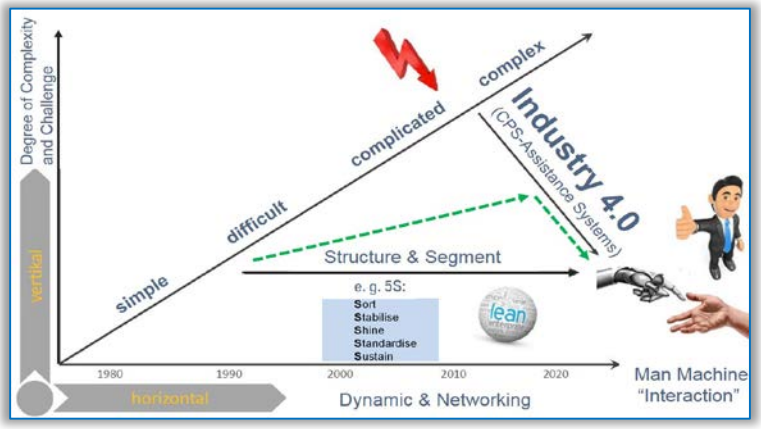

Figure 3 –Lean Production and Industry 4.0: Reducing complexity

Figure 2 shows examples of intelligent and innovative production with the application of data and analytics, smart logistics, innovative automation and additive manufacturing [40].

The products and production systems are growing ever more complex with increasing numbers of variants and faster times to market. The core of Lean and IoT is to respond in a timely, flexible and resource-efficient manner through better planning and control principles. With lean, the complexity is reduced by applying simple means to achieve simple solutions. Complex problems and systems are structured and segmented into simple, operationally more controllable units. For reducing costs and the complexity of M2M and IoT solutions via lean principles e. g. 5S and CIP [42], see Fig. 3.

However, this has limits. Industry 4.0 starts here. The reduction of the complexity of the systems and processes can be achieved through simple interfaces from the perspective of the user. This can be achieved by an increasingly decentralized control systems and the use of assistants [42], see Figure 3.

The further development of products and processes with lean and agile methods, success tools towards IoT [42] is shown in Figure 4: Conceptual design/design planning with the use of design thinking, development serial production with DFX tools [43], project management with the application of scrum & working out loud [44].

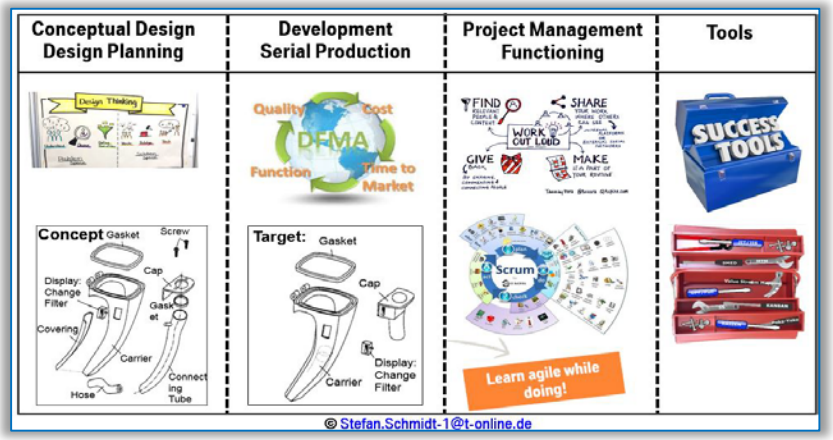

Figure 4 –Lean and agile product and process development [41]

6. CONCLUSION

Before business processes are digitised, simplification and standardisation are necessary. Japanese lean management and agile methods can help. Above all, it needs a passion for developing a company and the people working there. It depends on how quickly something can change for the better. The behaviour of each employee is decisive with regard to how innovative and productive a company and how big the product variety and the quality could be. The aim is to be the "perfect process" or, in analogy to Formula 1, to become the best team.

The basis is the continuous improvement process CIP. CIP is not just a project or a method, but a compre-hensive mind-set. In daily working life, this must be implemented continuously by the entire company workforce from management to the individual employee, in order to ensure constant improvement on a small scale. With CIP and 5S, the gradual improvement is aimed towards attaining perfection. The focus is on employees and teamwork. Small groups are formed, in which the processes are regularly analysed, discussed and optimized.

A lean and agile production according to Industry 4.0 also requires a completely different form of organi-sation. In a hierarchical control system, which divides standardized workflows into sub-processes and time intervals, this is difficult. Small, agile, autonomous teams are much more efficient, as they allow problems to be quickly exposed and decisions to be made quickly.

The digitisation introduced in factories in the context of Industry 4.0 is merely an instrument. With digiti-sation alone, you cannot achieve added value. As a basis, the processes must be standardized, the necessary separated from the unnecessary (Seiri/Sort) and the required resources optimally provided in the workplace (Seiton/ Stabilise). This leads to a conscious and correct execution (Shitsuke/ Sustain) of these activities. Clean (Sort) up first, streamline processes and then digitise. Clean (Sort) up and standardise is the foundation, otherwise only chaos will be automated: Standardisation of processes comes before digitisation. A lean / agile transformation of a company is a task of several years and must cover the entire company, not just production.

Note

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