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Lean Compendium

Introduction to Modern Manufacturing Theory

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To my son Marco and to the memory of my parents.
Hic liber vade mecum est ubi sapientia gaudet adiuvare usu.

Foreword

Lean Compendium: Introduction to Modern Manufacturing Theory

Fabricare necesse est—but how?

The industrial production has witnessed within the last decade a drastic change in the reputation in public and mostly political view. Ten years before, the general opinion on production in highly developed countries was that industrial value adding is old-fashioned and needs to decay, while future-oriented industrial nations develop in the direction of a service society and aim at a share of industrial value creation of 10% of BIP and less. Today especially those countries are in an unfortunate situation and look desirously onto those economies formerly termed as old-fashioned that have kept their industrial value creation up at over 20%. It was clearly recognized that only non-value-adding businesses do not sustain a national economy. Where the limits of stability are is not really known, but all the reshoring initiatives today in highly developed and thus high-wage countries demonstrate impressively the societal value of industrial production, despite the fact that in the foreground the motivation is to keep or bring back the most recent and fashionable technological developments, the hypes of manufacturing like additive manufacturing, industrie 4.0 and formerly nanotechnologies. Following up the growth of the tertiary economic sector, it must be kept in mind that a good share of this is due to outsourcing of services from producing industries, and those services would also vanish by reducing the industrial value creation. The local industry is the best customer for service organizations.

It shall not be denied that quite some of the industrial value creation eroded away and became outsourced to low-wage countries, which are fierce competitors to industrial value creation in highly developed countries. Production was regarded as an easy task, so easy that it could be managed in underdeveloped areas of the world. Production was in comparison to old times, where the fuming factory chimneys were the symbols of status and wealth, no longer looked at as being worthwhile to

sustain, which ended in disregard, divestment and thus old-fashioned equipment and organizations. This is then the point, where outsourcing becomes inevitable. But the most important error was to not realize that efficient production is not a simple task, just an annex to the ingenious product creation and sales.

It is the complexity of production, lack of strict scientific approaches, number of influencing variables, restrictions, interrelations, knowledge and experience including aspects of finances, resources, people and technologies which makes seeking for optimal solutions in production so difficult and leads to industrial managers hoisting the white flag of surrender, which is called outsourcing. It seemed so easy, just to get rid of the management-attention-swallowing burden of manufacturing and deport it to places, where due to low wages almost every however stupid organization could survive.

Since the task today is facing the huge competition of globalization and challenges of ecologic sustainability to achieve more with less resources, the resource-based manufacturing needs to be changed to knowledge-based manufacturing. And against plagiarism such knowledge-based manufacturing is the best way to protect intellectual properties. While the innovation in product development needs to be presented in the market and thus to the Argus eyes of plagiarism, the innovation in processes, which means striving for technological as well as organizational excellence, can be kept non-disclosed and guarantees a threefold time span competitive advantage over the product innovation. The transition towards knowledge-based manufacturing requires highest skills and excellent leadership from the production management and is at the same time the chance to answer the question how to keep industrial production in the high-wage countries with their well-trained and skilled workforce. All the former fundamental industrial changes also termed as industrial revolutions aimed at exploiting technological innovations for efficiency in production, not really taking into account that also the organization needs to follow. And also the most recent technology change, introduction of Internet technologies, called Industry 4.0, finds industry orientationless especially on how to apply this technology for business excellence, despite some quite striking examples of benefit already demonstrated in economy and to a lesser extent even in production.

But towards operational excellence, the great change, if not revolution, took place with Toyota Production System (TPS) or synchronized production system (SPS) after the Second World War. Here a solution for operational excellence was presented completely independent of technologies and thus ever valid. For the Western world, this came out of the nothing, outperforming traditional production organizations. It is based on simple principles such as removing the nine kinds of muda, pulled material flow and permanent improvements. However, outside of automotive industry, this or similar systems have not fully been received, which might be due to disregard of production as such or still not realizing the great chance offered by a disruptive change of production philosophy.

Now, this lean compendium written by a real expert, combining scientific insight with practical experience, offers the great chance to enter into the fascinating modern art of production of the best performing production systems in the world. It combines logical and enlightening arguments and explanations with clear

proposals on how to set up such systems in production of whatever size and product. It succeeds in presenting a comprehensive basis for a theory of production, on which a systematic optimization can be built upon, thus getting rid of beliefs and fashions in favour of a data and reality-based assessment and improvement of production. It serves as a guideline on how to salvage production industry in high-wage countries serving as railing as well as life buoy in one.

This book, although for sure not complete and comprehensive, is a good base to understand what the TPS, the today's best performing production system, consists of, which helps productioneers to improve present manufacturing systems radically. This book is for sure an enrichment of present production literature for students as well as experienced engineers and managers and all those who want to know how a modern and competitive production system is really functioning.

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12 April 2017

Prof. Dr.-Ing. Konrad Wegener

Prologue

Lean Manufacturing (LM) is often seen as a hands-on practitioner-driven approach to implement the Toyota Production System (TPS). This is not wrong—introducing Lean needs a lot of perseverance to succeed. Taiichi Ohno once said: "The challenge is to develop a learning organization that will find ways to reduce the number of Kanbans". Indeed, the importance and criticality of the practical human dimension of improving a Lean system has not to be underestimated. Continuous improvement is the winning management philosophy how to run successfully a company from the operational point of view to face and to adapt to new challenges. Even so, the implicit theoretical dimension of Lean is often neglected and seldom seen comprehensively formalized as if it was a given fact. To the contrary: besides Kaizen and Muda elimination, at the base of the TPS is a solid theoretic framework which rarely is talked about because of not being formalized or, if ever, limited to a trivial didactic simulation comparing a single piece flow (SPF) versus a batch and queue (B&Q) manufacturing modus explaining Little's Law.

Therefore, in this compendium—being in fact a "vademecum" which should accompany every Lean expert—we are entering into the dimension beyond Muda and Kaizen; we will consolidate the underlying manufacturing theory of Lean with regard to performance. We will structure and formalize the existing fragmented Lean theory framework of manufacturing concepts into generalized practitioner-conforming production laws, putting together a systematic and integrated set of generally valid theorems and corollaries which govern manufacturing, helping to form ex post the base of LM systems theory. In a nutshell, we will give a solid structure to Lean beyond the fuzzy TPS philosophy. On the other hand, we will not repeat statistics or queuing theory, well described in many academic textbooks, nor will we talk about the Lean management tools as well as shopfloor concepts and Kaizen practices of a learning organization that are needed to run and improve the TPS; other books already exist on these topics. We want to enter the dimension between practical description and academic theory. We will use the strict minimal necessary math combined with a comprehensible language for engineers and practitioners as well as students of mechanical engineering curriculums to

understand the underlying theory of Lean, i.e. the omnipotent governing technical principles, which characterizes TPS. Thus, the intention is not to write another book about Lean but to complement the existing literature. Nevertheless, this compendium represents the copestone to bridge the gap between basic description of Lean systems and its related analytical manufacturing theory.

Dr.-Ing. Bruno G. Rüttimann

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Chapter 1
Introduction

The TPS has become the reference of modern high performance manufacturing systems. It has been spread and adopted in Europe under the American label of Lean Manufacturing (LM) also among other industries than the automotive because of its superior performance. Apart of the Kaizen-based continuous improvement management philosophy, the underlying TPS theory bases on a Just-in-time (JIT) type manufacturing approach. This manufacturing approach bases on "flow on pull" with Heijunka-pitch scheduling, i.e. self-controlled mixed-product cells, which performance is by far higher than those of traditional computer-controlled and optimized MRP 2-type (manufacturing resource planning) or ERP-type (enterprise resource planning) systems relying mainly on push "batch & queue" (B&Q) manufacturing. Indeed, Lean stands in contradiction to the Western "high performance" thought of B&Q manufacturing of large batches to minimize setup downtimes and reducing cost per piece, exploiting equipment output, keeping blue collar workers busy and hurrying, i.e. showing an apparent high productivity. But the high level of busyness may contain a lot of non-necessarily needed activities, such as searching, bringing, handling, piling, waiting, so-called non-value add activities or inefficiencies which the Japanese call Muda (waste). Fujio Cho has defined waste as "anything other than the minimum amount of equipment, materials, parts, space, and worker's time, which are absolutely essential to add value to the product". Instead of a hurrying activism, the Japanese prefer not a calm but a waste-less sequence of activities at a constant pace resulting at the end of the day in a higher efficiency and efficacy.

Another difference is the concept of built-in quality of the TPS, every employee contributing to guarantee error-free products not necessitating final inspection. Exactly the final check has been typical of Western production systems to guarantee quality, scrapping defective products at the end of the line bearing the highest value content. The Japanese even foster the culture to allow blue collar workers to stop the assembly transfer line in case they discover a non-conformity. Until not many years ago, such a contentious behavior in a Western automotive plant would have lead to the immediate consequence of being fired. At the base to implement such an

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error-free culture stands the SPF, allowing to discover defects and to act immediately solving the problem. SPF and Jidoka therefore go hand in hand to guarantee a JIT zero mistake culture which allows on-time-delivery (OTD). The cultural change needed is drastic but the resulting performance improvement showed the benefit [1].

During the last two decades also the industry logic changed profoundly. Globalization revolutionized the way of thinking. Globalization brings not only more opportunities through a larger world market, it entails also more competition and therefore a threat. Different globalization forms are observable bearing different underlying business types with different rationales [2]. Understanding the changing rationale by understanding the development of value-add chains is decisive to survive the competitive challenge. These changes have transformed vertically integrated value-chain business models into horizontal networks exploiting rather economies of scope than scale [3]. The industry logic and consequent operational rational has changed. Indeed, in the meanwhile the automotive industry logic has mutated from a value-add per car to a value-add per hour logic [4]. Indeed, to increase brand recognition with multiple beneficial effects forces management to increase throughput to have more cars circulating on streets. Western mature economies will face increased competition and will forcedly need to change behavior regarding marketing mix and production. Innovation is seen as a "deus ex machina" paradigm; this is not wrong but the companies need also to produce these new products with acceptable cost. Otherwise the epitaph on the tombstone of Western high cost industries will read: "He was a good inventor but a bad producer" [5].

To have success in today's intensive competitive environment not only the product has to be the best; to provide a unique selling proposition, also the price has to be aligned as well as the ancillary boundary conditions, such as immediate availability and service have to be observed. The SPQR model summarizes these requirements [6]. Here, SPQR does not stand for "Senatus PopolusQue Romanus" but for the today's necessary minimal competitive cardinal variables to be satisfied: speed (i.e. process lead time PLT), punctuality (i.e. on-time delivery OTD), quality (i.e. Z-level), as well as a minimum of attractive return (profit) for the investor. Return has to be part of the equation because only a profitable company allows the system to be viable. These system variables are interacting with the stakeholder variables customer (voice of customer VOC and satisfaction), employee (voice of employee VOE, appreciation, empowerment, and satisfaction), shareholder (return on investment ROI and satisfaction) and give origin to a positive (amplifying positively or negatively according to the input) feedback governed system dynamics. Moreover, the model shows clearly, that the Western investor-centric philosophy around shareholder satisfaction is short-term oriented and does not represent a long-term viable model. This also reflects the sometimes encountered mess between vision and mission statement of governing company statements. Indeed, it is the customer stakeholder-centric model which is the only long-term viable winning solution, exactly what the Toyota philosophy of acting represents. All stakeholders have to contribute to value-generation but also to receive back their

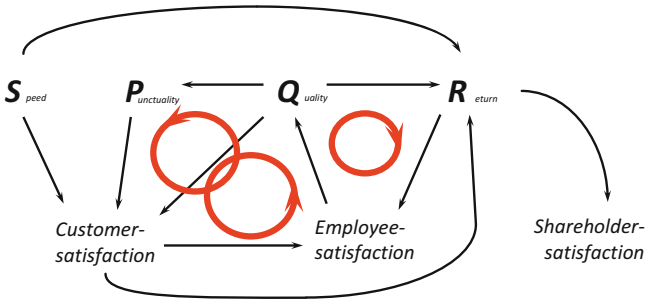

Fig. 1.1 SPQR model showing systemic effects between the cardinal objectives [from 6]

compensation according to their personal value system in order to be satisfied to give their max. Further, this SPQR model shows the central place of JIT Lean, but also Six Sigma, within the whole operations performance. It shows the crucial importance of the employee on quality and the other variables. The true assets of a company are the employees and customers—not the machines, which become obsolete and have to be amortized, and for sure not the inventory—allowing the solution of the "money-for-value" equation. The basic SPQR requirements can be considered to be time-invariant and constitute a sort of a minimal axiomatic multi-objective system which has to be observed in any case to be successful in business (Fig. 1.1).

Under the Lean label, the TPS has been described and divulged in several books, e.g. [7–10]. Nevertheless, they are stressing far more the philosophy of the TPS and the Kaizen-based shopfloor continuous improvement culture of a learning organization as well as describing the believed omnipotent tools rather than the implicit theoretic governing laws of the TPS. The theory framework is widely ignored or neglected [11, 12]. However, different than in Anglo-Saxon countries, in Europe, and especially in Switzerland, LM is only making a reluctant appearance at university level [13] showing the missing of a driving high performance-demanding automotive industry. We will not investigate the further root causes regarding the scarce presence of Lean courses. However, we will put the attention to bridge the lack of divulgation of the underlying theoretic and implicit manufacturing framework of Lean. In order to educate state of the art production managers and engineers, the production theory of TPS has to be taught, opening the "academic dimension" of Lean not only for students but also for already field-proven practitioners being in responsible positions, often consisting of engineers with now obsolete knowledge. It is not the responsibility of industry to educate production managers with Lean Sensei or Lean Six Sigma Black Belt courses aligning them with "state-of-the-art" knowledge.

This compendium intends to bridge application and theory by following a Cartesian-type logic of reasoning to model Lean, although it does not pretend to be comprehensive in all topics. It begins by presenting a new cognitive-oriented, systemic-based Lean model, i.e. describing the systems-based functioning of Lean.