# Roland Berger Focus

October 2018

## The race for efficiency

Industry 4.0 and its impact on electronics assembly

Roland Berger

# Management summary

With a current value of around EUR 1.5 trillion, electronics assembly is one of the world's biggest industries. It has grown rapidly in recent years, forming the basis for the innovations that are transforming the way we live our lives – from self-driving vehicles and artificial intelligence to portable electronic devices and wearable technology. Growth of the industry is expected to continue at a rate of around four percent a year.

But the electronics assembly industry is also under constant pressure, from two factors: declining average sales prices and ongoing innovation. These twin pressures, combined with increasing numbers of customers and products, shorter innovation cycles and faster time-to-market expectations are forcing players to improve their efficiency wherever they can.

We believe that the key to making the radical improvements to efficiency required can be found in Industry 4.0 – the "fourth industrial revolution", a combination of trends and technologies including the Industrial Internet of Things (IIoT), new manufacturing techniques such as 3D printing, and cyber-physical systems such as augmented reality. Industry 4.0 will have a tremendous impact on the electronics assembly industry in both technological and economic terms. It will directly affect original equipment manufacturers, manufacturing service providers and original design manufacturers, and will also have a major effect on the equipment suppliers and software providers that support them. We are convinced that all electronics industry players can leverage Industry 4.0 to boost their operations. The race for efficiency is on – and Industry 4.0 offers the potential to turn also-rans into winners.

In this paper we take a closer look at that potential. We investigate the current maturity level of manufacturers with respect to Industry 4.0: To what extent have they adopted and implemented the technology blocks associated with the new industrial revolution? We look at the direct impact of Industry 4.0 on manufacturers: What technology blocks they should be prioritizing and what is the potential impact of those blocks on their EBIT and ROCE? We also look at equipment suppliers and software providers, analyzing the indirect impact of Industry 4.0 on these players: How can these companies best deal with the challenges they face and leverage the opportunities ahead of them?

Throughout the discussion, we underline the fact that the electronics assembly industry is home to a wide variety of companies, from large multinational original equipment manufacturers (OEMs) to specialized tech startups. Players need transparency over their own operating models and those of the companies they buy from and supply to. Only then can they correctly prioritize the key technology blocks from Industry 4.0 for their business operations. As we discuss below, a key success factor for companies is selecting the right partners to work with on developing and implementing specific technology blocks.

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Only then can they offer the technology blocks that those companies prioritize

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## Chapter 1:

# Industry 4.0 will take the efficiency of electronics assembly to the next level

But companies still have a long way to go on the road to full implementation

The electronics assembly, today worth around EUR 1.5 trillion, is one of the world's most important industries. It has produced the wide diversity of innovations that are transforming our everyday lives: self-driving vehicles, portable mobile devices, wearable technology and the like. Such innovations have driven growth of the industry over decades and will continue to do so – at approximately four percent a year, according to forecasts.

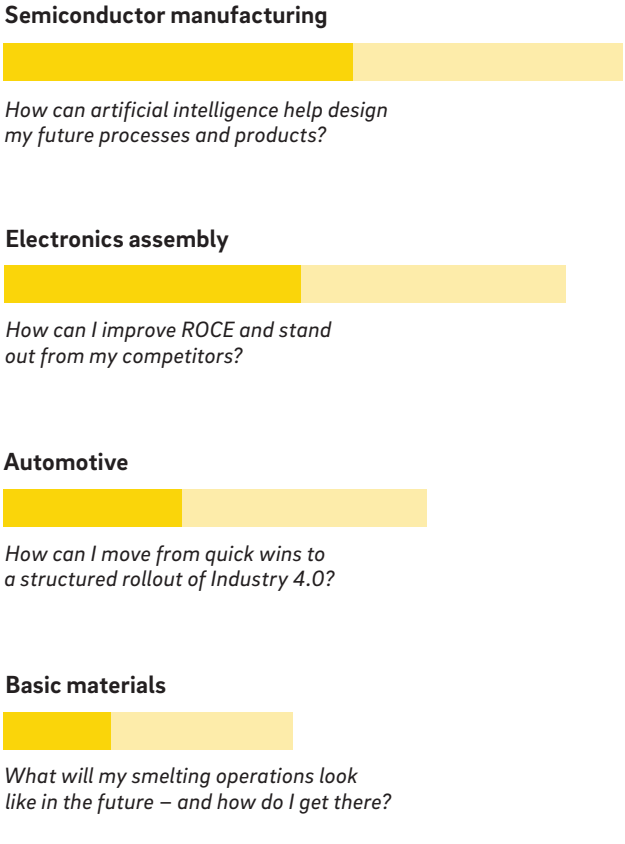
But declining average sales prices and a continuous stream of new innovations in the pipeline put industry players under constant pressure to find ways to improve the efficiency of their operations. The numbers of customers and products are expanding, innovation cycles are shortening and time-to-market is speeding up. The need for streamlined, efficient operations has never been stronger.

Fortunately, a new industrial revolution is under way that has the potential to take the efficiency of the electronics assembly industry to the next level. "Industry 4.0" is the name commonly given to the combination of trends and technologies including the Industrial Internet of Things (IIoT), new manufacturing techniques such as 3D printing, and cyber-physical systems such as augmented reality. In this paper we use the term more broadly to refer to the full integration and digitalization of industrial value creation, part of the larger process of digital transformation. For us, Industry 4.0 is thus not restricted to production systems but also encompasses further parts of the value chain and other business functions.

Looking at different industries today, we find various levels of maturity with respect to implementing Industry 4.0. The semiconductor industry is currently at the forefront, for example, while electronics assembly follows closely behind. Both are far ahead of the automotive and metals industry in terms of maturity. → A

How can we best understand Industry 4.0 and the impact it will have on electronics assembly? Our ap-

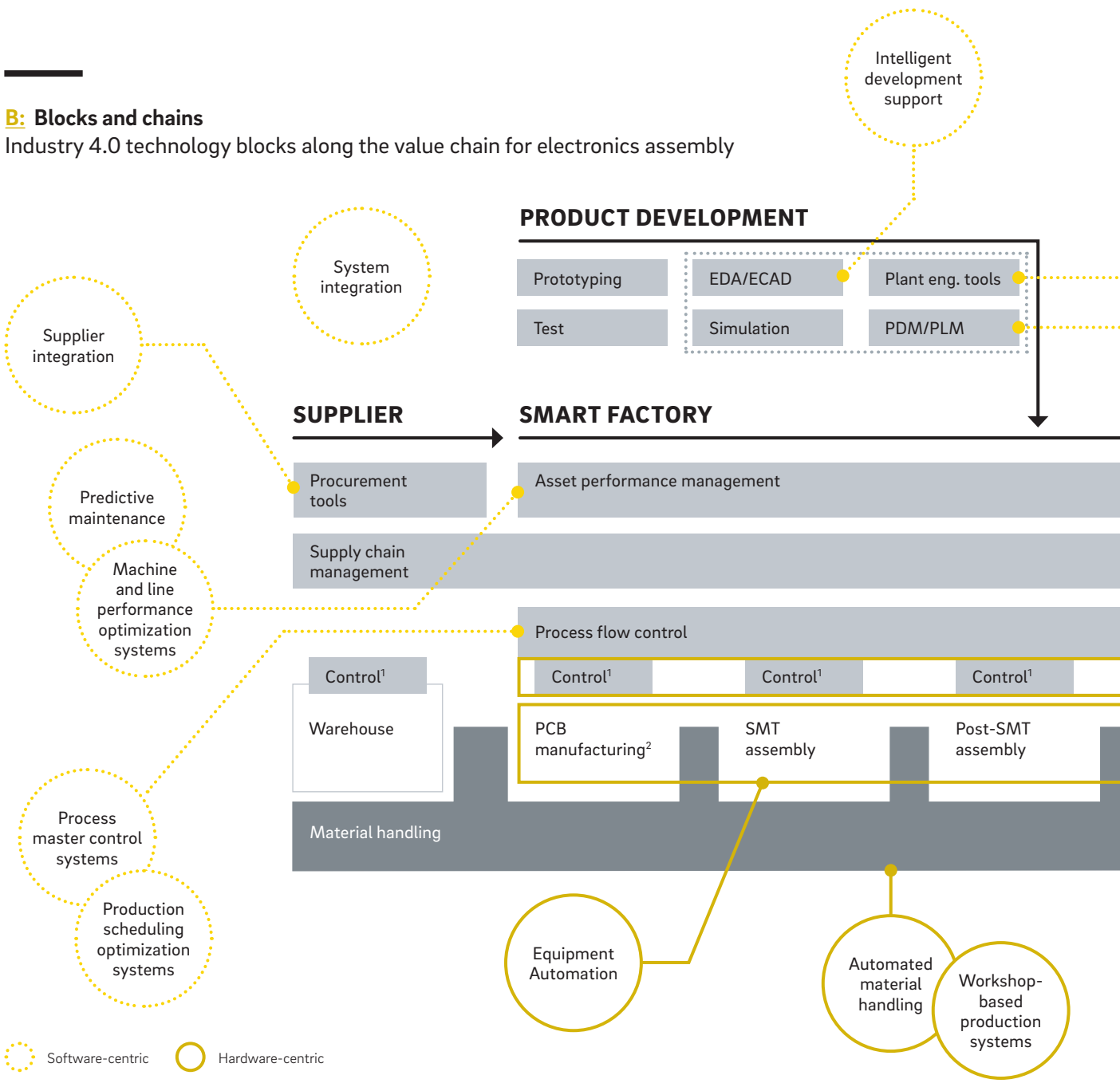
**A: A mixed picture**
Maturity of different industries with respect to Industry 4.0




Source: Roland Berger

**B: Blocks and chains**

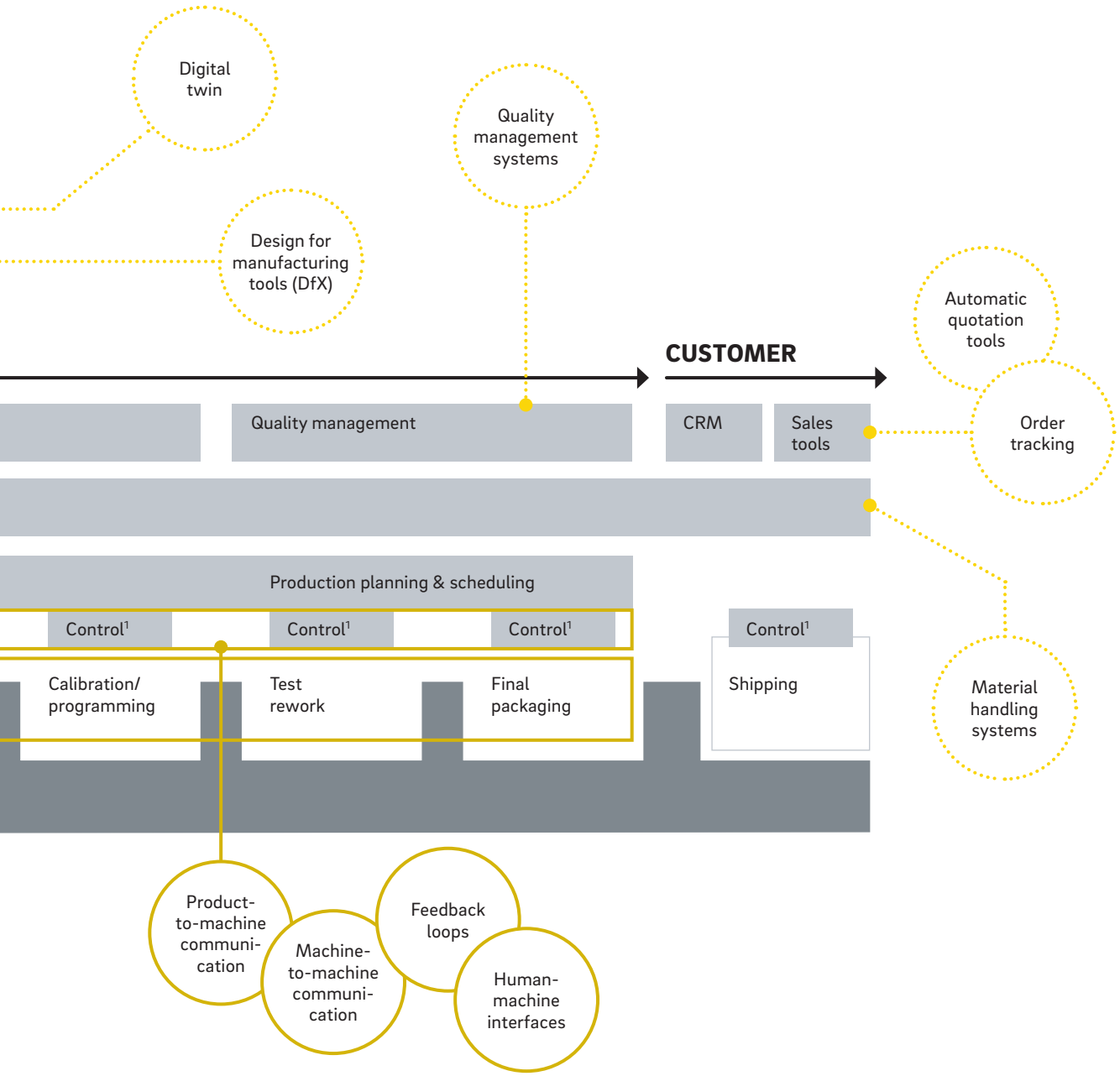
Industry 4.0 technology blocks along the value chain for electronics assembly




1 Machine control and/or line control including software interfaces

2 Not usually part of the electronics manufacturing process

Source: Roland Berger


Digital twin
Quality management systems
Design for manufacturing tools (DfX)
Automatic quotation tools
CUSTOMER
Quality management
CRM
Sales tools
Order tracking
Production planning & scheduling
Control[1]
Control[1]
Control[1]
Control[1]
Calibration/ programming
Test rework
Final packaging
Shipping
Material handling systems
Product-to-machine communi-cation
Machine-to-machine communi-cation
Feedback loops
Human-machine interfaces

proach is to identify the most important "technology blocks" within Industry 4.0. We construct a framework featuring 20 separate technology blocks relevant for electronics assembly, split into hardware-centric blocks and software-centric blocks. Each technology block occupies a fixed position along the value chain of suppliers, smart factories, product development and customer relationships. For example, the software-centric technology block "supplier integration" clearly relates to suppliers, while the software-centric block "predictive maintenance" relates to smart factories. The hardware-centric block "automated material handling" also relates to smart factories, while the software-centric block "quality management systems" relates to product development, and so on. → B

The 20 Industry 4.0 technology blocks shown in our framework have a direct impact on the key performance indicators (KPIs) of electronics manufacturers. Under this umbrella term we include: original equipment manufacturers (OEMs), electronics manufacturing service (EMS) providers and original design manufacturers (ODMs). The 20 Industry 4.0 technology blocks also have an indirect impact on the business of equipment suppliers and software providers – a group that we discuss in detail in the third section of this paper.

In our analysis, we calculate the effect of the technology blocks on five concrete KPIs for electronics manufacturers: overall equipment effectiveness (OEE), number of full-time equivalents per assembly line, daily output, work in progress and delivery performance (delivery ability multiplied by delivery reliability). Then, we map the effect of these KPIs on top line and bottom line using a standardized model of an electronics assembly business system, to calculate their effect on profitability.

Our calculations reveal an overall improvement potential for electronics manufacturers of up to nine percentage points on EBIT (earnings before interest and taxes) and as much as 20 percentage points on ROCE (return on capital employed). Cost remains one of the most important criteria in purchasing decisions within the electronics assembly industry, so those players that do best in implementing Industry 4.0 are also expected to gain significant amounts of business from their competitors. In addition, the winners of the efficiency race can generate substantial amounts of extra revenue by achieving a faster time-to-market and greater flexibility.

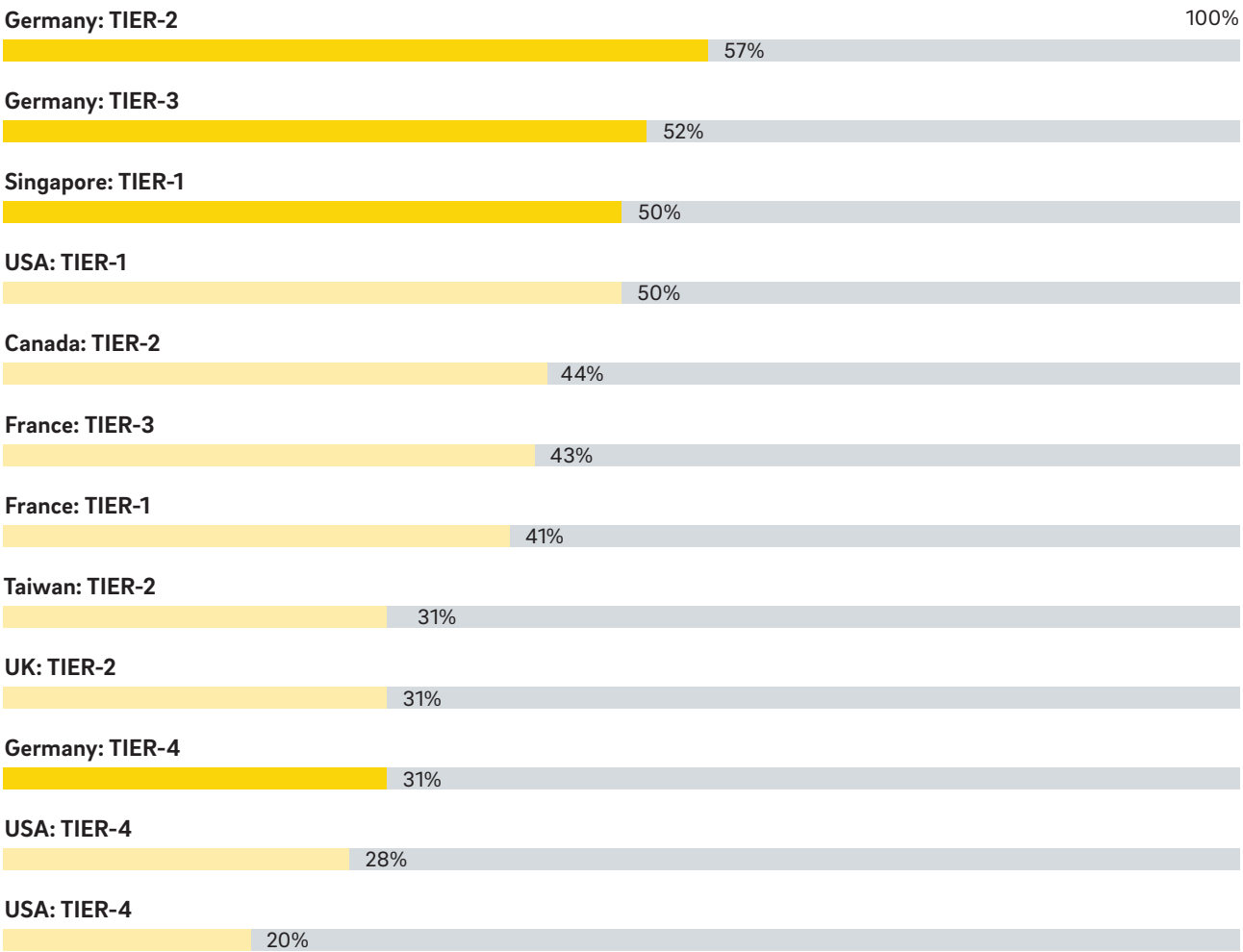
How are electronics manufacturers currently doing when it comes to implementing Industry 4.0? We saw above that different industries have different levels of maturity in terms of Industry 4.0. The same is true of electronics manufacturers of different sizes and in different countries. We questioned a range of companies about their degree of implementation of Industry 4.0. Based on their answers, we then rated their maturity. Our conclusion? Even the leading players are only about halfway along the road to full implementation. Many others are trailing behind them, and some still have a very long way to go. → C

The figures above refer specifically to electronics manufacturers. But, of course, as soon as the maturity of these players increases, the way that they make decisions about equipment and software will also change. This will then have a secondary effect on the companies that supply them. Electronics assembly equipment and software providers therefore need to prepare themselves to react to the upcoming Industry 4.0 requirements of their customers.

We turn now to the question of what electronics manufacturers and their suppliers should be doing to ensure that they win the race for efficiency. In the two following sections we take a "deep dive" into the tentative agenda of different players, first manufacturers and then suppliers.

## C: The long, long road ahead

Maturity of electronics manufacturers with respect to Industry 4.0




Note: Assessment based on RB I4.0 in EA technology building block segmentation and rating.
Tier-1 players: revenues > USD 5 bn; Tier-2 players: revenues USD 500 m to 5 bn ; Tier-3 players: revenues USD 50 m to 500 m ; Tier-4 players: revenues < USD 50 m

Source: Roland Berger

## Chapter 2:

# Electronics manufacturers must choose the right technology blocks and partners

The correct approach depends on their own product volume and mix

Electronics manufacturers – OEMs, EMS providers and ODMs – vary widely in character. The fact that some produce millions of cell phones while others produce just a few pieces of highly specialized medical equipment creates a complex picture.

To throw some light on the situation, we group companies based on their operating models, looking specifically at their production volume and mix. Three different clusters can be clearly distinguished: players with a low-volume, high-mix (LVHM) operating model, players with a high-volume, low-mix model (HVLM) and players with a medium-volume, medium-mix model (MVMM). We then look at the specific challenges facing each cluster. Naturally, given the complexity of the picture, there can be no one-size-fits-all solution. Each operating model requires a specific solution for the Industry 4.0 migration path. The companies in each cluster must focus on those technology blocks that are most relevant for their own product volume and mix.

Some companies follow more than one operating model simultaneously. While this may make sense given the firms' specific area of business, the challenge will be to prioritize different technology blocks in different parts of the organization, simultaneously. Special management attention is needed to mitigate the increased risk inherent to such a parallel approach. Some companies, especially EMS providers and ODMs, may not be aware of their operating model. Their first task will be to create transparency over which parts of their company follow which operating model. On this basis they can begin to implement the relevant Industry 4.0 technology blocks. We investigate such challenges in our recent Roland Berger Focus "Non-standard profits from non-standard electronics".

## LOW -VOLUME, HIGH-MIX

An LVHM operating model is typically found for electronics assembly manufacturers working in the aerospace and defense industry and the medical industry, for example. These manufacturers' operations involve a relatively high degree of manual work and low capital expenditure (CAPEX) utilization, especially in the back end. They have highly complex support processes due to the large number of changeovers.

We calculate that by implementing the right Industry 4.0 technology blocks, electronics manufacturers with an LVHM operating model can add six percentage points to their EBIT and up to 20 percentage points to ROCE. Even more importantly, they can significantly increase their flexibility and reduce their time-to-market, giving them the edge over their competitors.

The three key technology blocks for LVHM players to prioritize are flexible workshop-based production systems, production scheduling optimization systems and process master control systems. In flexible workshop-based production systems, assembly lines (especially in the back end) are replaced with process-oriented workshops. Products are routed through the workshops depending on the specific production processes they require. Using the same workshops for various products dramatically increases flexibility and equipment utilization.

Production scheduling optimization systems help achieve an optimum balance between the workloads of each line in the front end and each workshop in the back end. They also ensure the shortest possible changeover times. Unlike traditional production scheduling, carried out by experienced employees, these systems, mostly based on artificial intelligence, take a comprehensive approach to optimizing production schedules, identifying the best possible tradeoffs between equipment performance, changeover times, and so on, taking into account equipment capacity and availability of workers.

To handle the increased complexity of workshop-based production and ensure that the new, more

complex production schedules are met, companies should also introduce a sophisticated process master control system. This will ensure that each product is routed through the right production steps and that workers perform the right tasks at the right time. Besides assuring smooth production, process master control systems can also increase worker utilization by assigning available workers to planned and unplanned tasks in an optimal manner.

These three technology blocks have a direct impact on the five KPIs for electronics assembly manufacturers listed above. Overall equipment effectiveness (OEE), daily output and the number of FTEs per assembly line improve thanks to the reduction in changeover times. Work in progress decreases due to optimized production schedules. The number of FTEs improves due to the increase in worker utilization. And the increased flexibility provided by workshop-based production significantly improves delivery performance.

How should companies go about implementing these three prioritized technology blocks? The implementation of flexible workshop-based production systems needs to be driven mainly by the company itself, in-house. Companies can engage automation providers for support but there is currently no standard offering to choose from. Additionally, in many cases, the back-end production setup is considered core know-how, as it will represent a key differentiator in the future.

In most cases, we recommend choosing a partner to help implement the production scheduling optimization and process master control systems. Solutions available on the market offer a high level of customization and are mostly provided by machine suppliers or manufacturing execution system (MES) providers. While machine suppliers currently offer better integration with their own equipment, their support for third-party machines is limited and interfaces are often closed. Companies should therefore think about their existing equipment base as well as their future equipment strategy when choosing a suitable partner.

In a brownfield situation, LVHM players should also think about their legacy software systems and how they will be integrated into the new production scheduling optimization and process master control systems, as integration costs account for a significant portion of the overall investment. Given the complexity of finding the right partner and the significant integration effort, players are recommended to build up their own software development know-how so that they are not completely reliant on suppliers when it comes to integration.

## HIGH-VOLUME, LOW-MIX

An HVLM operating model is typically found for electronics assembly manufacturers producing consumer electronics, computers and communication devices, such as cell phones, for example. These players usually have a relatively high degree of automation in their factories.

Due to the small amount of variety in their product portfolios and the high batch sizes, HVLM players do not gain much from the increased flexibility created by many of the Industry 4.0 technology blocks. However, by prioritizing the right technology blocks, we calculate that electronics manufacturers with an HVLM operating model can still add up to two percentage points to their EBIT and as much as six percentage points to ROCE by implementing Industry 4.0.

The three priority technology blocks for HVLM players are further equipment automation, predictive maintenance, and machine and line performance optimization systems. Further equipment automation is enabled by the latest developments in factory automation. It includes upgrades to equipment (adding new functions and increasing the level of automation) and the use of new technology such as co-bots, allowing previously non-automatable process steps to be automated, especially in the back end.

Predictive maintenance, applied instead of the common preventive maintenance, increases the availability of equipment by predicting breakdowns using sensor data. This helps avoid unscheduled downtime and reduce scheduled maintenance. Machine and line performance optimization systems also use data from sensors to optimize machine and production-line parameters, thereby improving both performance and quality, such as first pass yield.

In terms of KPIs, increasing automation reduces the number of FTEs per line and raises OEE and daily output by means of improvements to quality and performance. Similarly, predictive maintenance and machine and line performance optimization mostly affect OEE by improving equipment availability, quality and performance and the number of FTEs per line required for maintenance tasks.

To implement further equipment automation, companies should keep a close eye on the market for standard equipment and automation solutions. This will enable them to identify new functions and technologies early on. They then need to drive the implementation of these technologies by cooperating closely with relevant partners.

When it comes to predictive maintenance and machine and line performance optimization systems, machine suppliers have a strategic advantage thanks to their knowledge of their own hardware. However, their offering for the electronics assembly industry is currently rather limited. HVLM players therefore need to rely on in-house development or specific software players providing model-free solutions that can predict changes in a machine's dynamic behavior without any previous knowledge about its dynamic. While most market solutions are still immature, the latest developments in machine learning significantly improve the performance of these model-free solutions and lessen the disadvantage of these players over machine suppliers.

Similarly, a limited number of standard solutions are available for optimizing parameters across lines. HVLM players need to rely on in-house development combined with existing platforms and toolboxes. Solutions can be built on the cloud platforms of specific software players or solutions from MES providers, who even offer the necessary interfaces with assembly equipment.

### MEDIUM-VOLUME, MEDIUM-MIX

An MVMM operating model is typically found for automotive electronics production, for example. Located between LVHM and HVLM, it involves a relatively high degree of automation combined with significant potential for increasing CAPEX utilization. Due to regular changeovers, players tend to have rather complex support processes.

By prioritizing the right technology blocks, electronics manufacturers with an MVMM operating model can add up to three percentage points to their EBIT and as much as nine percentage points to ROCE.

The three key Industry 4.0 technology blocks for MVMM players are further equipment automation, workshop-based production systems, and machine and line performance optimization systems – in other words, a combination of the priority technology blocks for LVHM and HVLM players, as one might expect. In terms of the KPIs for companies, these technology blocks reduce the number of FTEs per assembly line, increase OEE and daily output and improve delivery performance.

In terms of implementation, our comments on the relevant technology blocks for LVHM and HVLM players above also apply here. Thus, to implement further equipment automation, MVMM players should constantly monitor the market for new functions and automation solutions, and engage partners, while to implement workshop-based production systems and machine and line performance optimization, they should draw on in-house development, combined with assistance from external partners who offer solutions which are to at least some degree equipment-vendor independent.

## Chapter 3:

# Equipment and software providers need a better understanding of the companies they serve

Only then can they offer the technology blocks that those companies prioritize

We turn now to the equipment and software providers that serve the electronics manufacturing companies described in the previous section. The impact of Industry 4.0 on equipment and software providers is similar to that for manufacturers, but now we are dealing with an indirect impact rather than a direct one. Accordingly, these companies and software providers need to identify the operating model of their customers and adjust their strategy to best fit their customers' needs.

The electronics assembly equipment and software provider landscape is fragmented, with many different types of players. We believe that Industry 4.0 will have the biggest impact on four specific types of players, which we focus on below. These four are machine suppliers, automation providers, manufacturing execution systems (MES) providers, and specific software providers. Most of these players are currently offering solutions for the Industry 4.0 technology blocks discussed above. However, many of those solutions are proprietary and largely incompatible with each other. Moreover, the market offering is highly dynamic and in a state of constant change.

## MACHINE SUPPLIERS

Currently, the focus of machine suppliers is on technology blocks related to hardware and machine-related software. They are the main suppliers of solutions for technology blocks such as further equipment automation, product-to-machine communication and machine-to-machine communication, and feedback loops. Most companies in this group view software as a supplementary product to their hardware rather than a separate profit stream.

Going forward, these players need to adjust their business offering and focus on the specific technology blocks prioritized by their customers. Those blocks include process master control systems, production scheduling optimization systems, predictive maintenance, and machine and line performance optimization systems. Several players already offer software suites partly covering some of these software-based technology blocks, but their solutions are often focused on their own equipment and allow limited interfaces with third-party equipment.

To remain successful, machine suppliers need to start viewing software as an important profit pool. At present, many such companies lack the necessary software skills and have insufficient employees with an IT background. They will need to either acquire software companies or form partnerships with startups – the latter option being particularly relevant for medium-sized firms.

## AUTOMATION PROVIDERS

Automation providers are companies that develop customized automation solutions. They are usually able to cover many different types of automation problems within the factory.

Automation providers are ideal partners for developing customized solutions for hardware-related technology blocks, such as workshop-based production systems and automated material handling. Some companies have already selectively partnered with machine suppliers to pilot solutions in these areas, but the concrete offering and the companies' experience here is often limited.

Partnerships with players with electronics assembly experience, such as machine suppliers or electronics manufacturers, would give them the chance to showcase solutions for these technology blocks and establish themselves as leading providers. They could potentially go even further and partner with software companies to offer a combined product for selected hardware and software technology blocks, such as workshop-based production with process master control systems.

To establish themselves as leading suppliers for Industry 4.0 technology blocks, it is not enough for automation providers to wait until the orders start rolling in from their customers. Rather, they should proactively develop and market solutions for the technology blocks prioritized by their manufacturer customers.

## MES PROVIDERS

MES providers cover many of the software-related Industry 4.0 technology blocks, such as process master control systems, production scheduling optimization systems, automated material handling and quality management systems – mostly with a single piece of software. Players with dedicated solutions for the electronics assembly industry already offer standard solutions for numerous technology blocks.

Unlike hardware manufacturers, MES providers focus on hardware-independent solutions and are increasingly offering solutions that can even integrate legacy equipment. As machine suppliers struggle to build up software competencies, MES providers have a chance to fill the gap and expand their offering to technology blocks such as predictive maintenance and machine and line performance optimization systems. However, to provide seamless integration with assembly equipment, they will need to form partnerships with machine suppliers in areas such as production scheduling optimization system and, to an even greater extent, predictive maintenance.

MES providers need access to specialized hardware knowledge to simulate specific machine behavior. This can then form the basis for optimizing production schedules or predicting machine failures by identifying irregularities in machine dynamics. Gaining access to this knowledge is therefore vital for MES providers who wish to leverage their software competencies. It will enable them to offer solutions for the many of the technology blocks on their customers' priority list.

MES providers should also carefully consider the software platforms on which they build their solutions, at the equipment interface as well as at the human-machine interface (HMI). Platform strategies strongly influence the adaptability, transferability and longevity of their solutions.

## SPECIFIC SOFTWARE PLAYERS

Many specific software players focus on Industry 4.0 technology blocks that are not part of traditional MES systems or which are located at the enterprise level. Players include both large companies and small startups focused on highly specialized areas.

To defend their position against MES providers, and potentially against machine suppliers and automation providers who may be encroaching on their territory, specific software players need to find their market niche and build a competitive edge around it. Alternatively, they may choose to form partnerships with those very machine suppliers and automation providers who wish to enter their traditional territory. This could create a win-win situation, with both parties standing to profit significantly from Industry 4.0.

In conclusion, let us return to our main insights. Companies that hope to become Industry 4.0 leaders and take their efficiency to the next level will search in vain for a one-size-fits-all solution; no such solution exists. Instead, electronics manufacturers, as well as equipment and software providers, must develop a strategy based on their own business model, and the business models of the companies they serve. On that basis, they must identify which Industry 4.0 technology blocks will bring them and their customers the most value.

The next step is to decide how they can best develop or implement these prioritized technology blocks. Is there a solution for the technology block already available on the market, or do they need to develop such a solution themselves? Is their current know-how sufficient for this task, or would they be better off teaming up with a partner? Which partners would be suitable for such an undertaking? By diligently answering these questions electronics manufacturers, as well as equipment and software providers, can realize the full potential of Industry 4.0 – and win the race for efficiency.

# Credits and copyright

## WE WELCOME YOUR QUESTIONS, COMMENTS AND SUGGESTIONS

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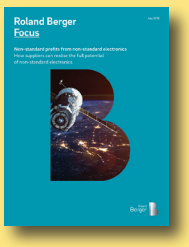
# About us

Roland Berger, founded in 1967, is the only leading global consultancy of German heritage and European origin. With 2,400 employees working from 34 countries, we have successful operations in all major international markets. Our 50 offices are located in the key global business hubs. The consultancy is an independent partnership owned exclusively by 220 Partners.

## Navigating Complexity

Roland Berger has been helping its clients to manage change for half a century. Looking forward to the next 50 years, we are committed to supporting our clients as they face the next frontier. To us, this means navigating the complexities that define our times. We help our clients devise and implement responsive strategies essential to lasting success.

**Roland Berger Focus**
**Non-standard profits from non-standard electronics.** How suppliers can realize the full potential of non-standard electronics




Non-standard electronics represent a vital segment of the wider electronics industry. Our analysis suggests that companies offering non-standard electronic solutions generate a wider range of profits than those offering standard electronic solutions, with non-standard electronics suppliers generating up to 10% higher EBIT margins if these business models are well understood and operated.

**Roland Berger Focus**
**Predictive maintenance –**
From data collection to value creation


From 2016 to 2022, the worldwide market for predictive maintenance will grow by 20 to 40 percent per year, reaching about USD 11 billion by 2022. However, we believe that more than 50 percent of companies are not yet pushing their own predictive maintenance business model. Companies must start seeing predictive maintenance not just as a means of collecting data, but as a tool for creating additional value for their customers.

## Publisher

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