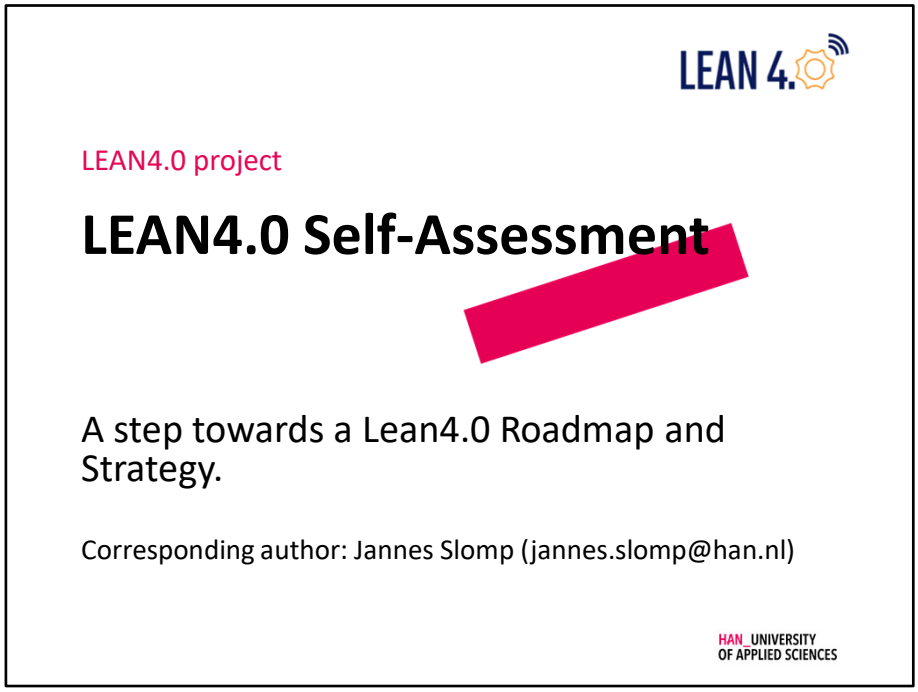
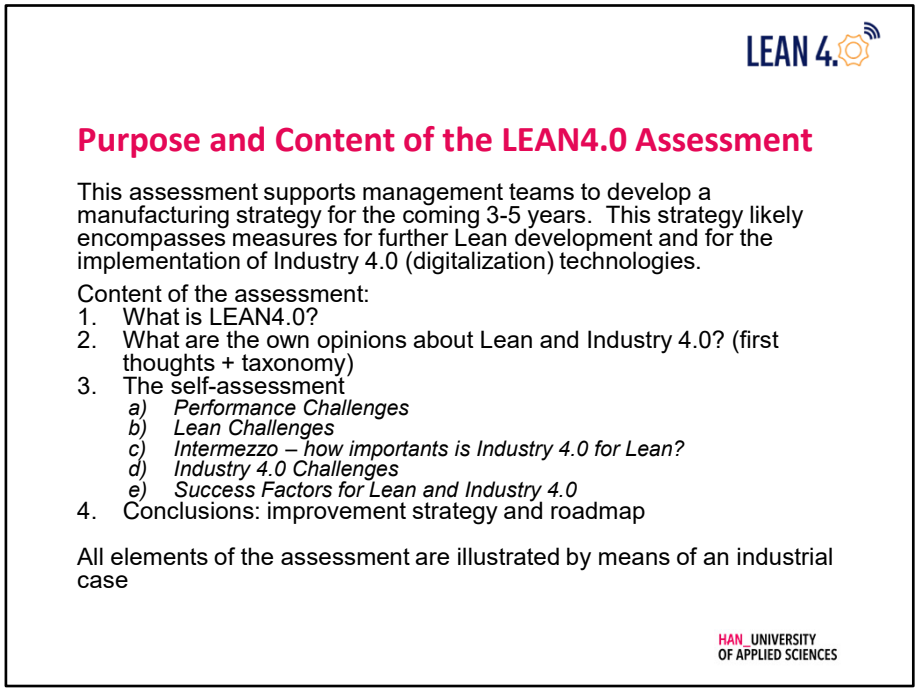


The purpose of the self-assessment and the taxonomy is to give managers input for creating a Lean4.0 roadmap and strategy for their company. Managers are responsible for making decisions about the development of lean principles and methods in their company. They also need to think about the use of Industry 4.0 technologies for improving the performance of their company. During the self-assessment, managers learn about the key elements of Lean and Industry 4.0. Simultaneously, they will reflect on their own situation and they will specify the importance of the various elements. Furthermore, they will think about the critical success factors which are important for the success of improvements in the area of Lean and Industry4.0. Finally, they are challenged to define a roadmap for the development of a socio-digitally controlled company.

The self-assessment is developed in such a way that managers may apply the methodology in their own organization without external support. However, in our experience, an external facilitator can be of great support to stimulate and organize the discussion.



The self-assessment is ideally performed with a team of managers who work in the same company and play a role in the development and execution of a manufacturing strategy. The whole assessment takes about 2.5 – 3 hours. Results of the assessment are input for the development of an improvement strategy and roadmap. It may be useful to organize an new session for this purpose..

The session is started with an introduction about LEAN4.0 and an introduction of all participants. After this, the self-assessment starts.

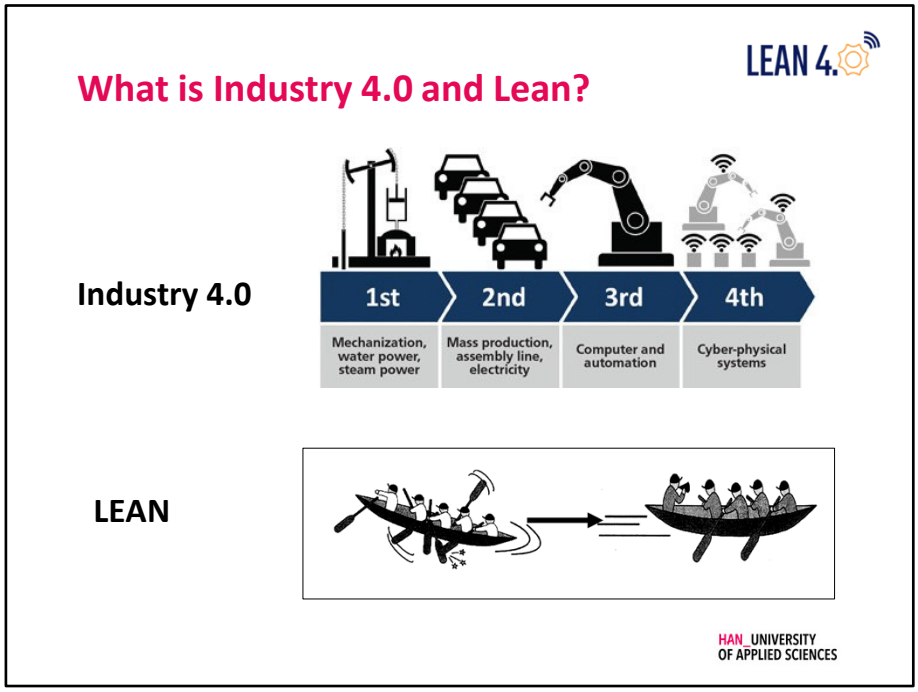
An industrial case serves as illustration during the self-assessment. The case concerns a company which produces and delivers metal sheets and bars to metal working companies. The company consists of more than 1000 workers, including truck drivers. Major activities in the company are the manufacturing of metal sheets (from rolls of metal), sawing of bars, the ordering process, order picking and bringing the material by trucks to the various companies. Delivery times are less than 24 hours. Their markets are in The Netherlands, Germany and Belgium. To serve confidentially, we do not mention the name of the company and we slightly changed some of the outcomes of the case.

An Illustration of the impact of new (Industry 4.0) technology

To illustrate the impact of technology, here is an example of the modern garage. The first picture, top left, shows how the car mechanic of the future will be supported: robots/cobots that help with heavy work and standard operations, a tablet with all required information, and a mobile by which the car mechanic will communicate with the customer and/or others. The second image shows that the car mechanic extracts relevant information from his tablet during the work. The third image, bottom left, indicates what the image can be on an Augmented Reality Device. The technician is given step by step information and instructions on where to do something. The fourth image shows how everything is digitally linked. Information from supplier, car, car user, workshop and sales are linked: anyone can access anything... This allows the service to be improved and to simplify the (flow of) activities….. It will also have a great impact on the organization of all processes in the garage.

We could also have taken the example of the modern farm, where cows swallowed sensors which allow continuous monitoring of each cow (see https://smaxtec.com/de/), where cameras that track cows, where computers are connected to feed wagons that can take care of each cow individually, etc. It's good to look at the use of smart technology, also outside the own company.

This self-scan is intended to support managers in developing a LEAN4.0 roadmap and strategy. Starting point in the self-scan is the conviction that successful implementation of new (Industry 4.0) technology requires a (Lean) process focus.



Industry 4.0 is so called because it is the fourth industrial revolution. In the first revolution, mankind learned to obtain mechanical energy from water and steam power. In the second revolution, mankind learned to produce standardized products (in mass production) and developed the use of electricity. Important inventions were lamps, radio, vacuum cleaner, etc. The third revolution concerns the rise of digitization: the computer, automation. In the fourth revolution, systems are linked, wireless. Everything is connected. Important technologies are Big Data, Augmented/Virtual Reality, Internet of Things and Artificial Intelligence. With these technologies, companies can realize better and faster processes. Industry 4.0 technologies can support and relieve people.

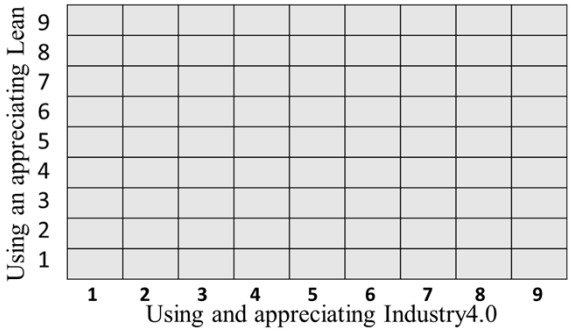
The second picture illustrates what LEAN is. Lean, which originated at Toyota in the middle of last century, assumes that customer value is realized in processes. And in those processes a lot of waste often occurs, activities that customers do not want to pay, such as waiting, searching, overproduction, transport, etc. There are all kinds of lean techniques that help to eliminate these wastes. Industry 4.0 techniques can also help.

This page/slide is an introduction slide. It is good that participants introduce themselves. This gives useful information for the facilitator of the session who, probably, does not know the company well. It is also good to know which important managers are absent. This has an impact on the value of the assessment.

Attendees of the assessment do have their own opinions about Lean and Industry 4.0. It is good to share (within the team of the company) some idea's and opinions before going further with the assessment. This is a possible starting point of the assessment. Asking attendees about their experiences with Lean and Industry 4.0 provides valuable information for the facilitator of the session.

It is also fine to skip the 'experience' questions in order to save time.

First opinions about Industry 4.0 and Lean



Put, based on data from the previous slide, an Industry 4.0 arrow in the X-axis indicating the difference between the current role of Industry 4.0 technologies and their importance. lean.

Put, based on data from the previous slide, a Lean arrow in the Y-axis indicating the difference between the current role of lean and the importance of lean.

The two arrow's together give a first impression which mix of Lean and Industry4.0 technologies will be important for the company. Draw the resulting axis.

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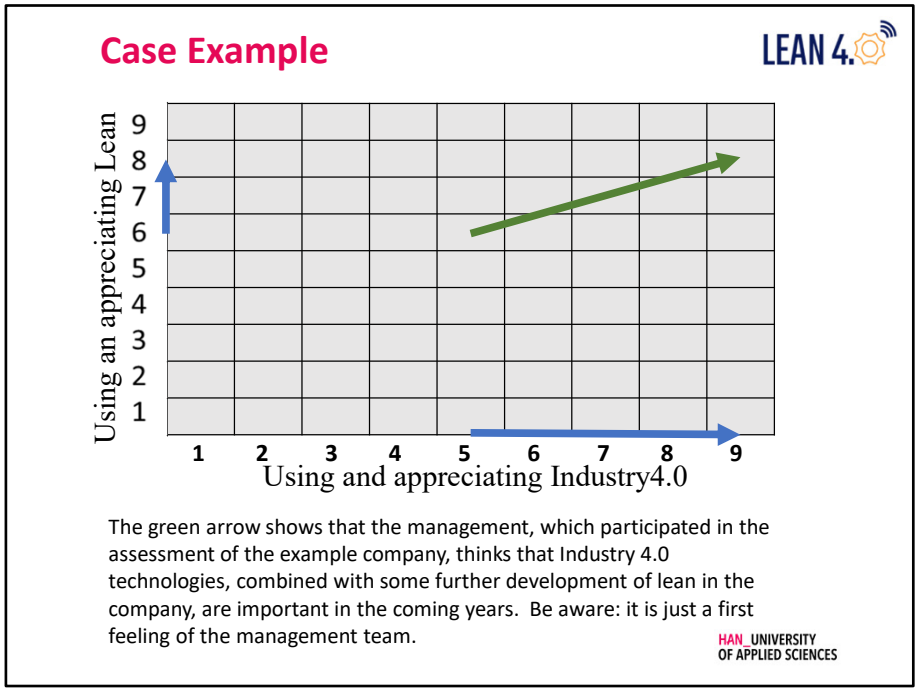
This page gives a first impression what the focus is of the management team, the participants in the self-assessment. Later in the assessment we will specify what Lean and Industry 4.0 more precisely means for the company. This may have impact on the resulting arrow (i.e. where to focus most on)…..

You find an example on the next page.



This figure presents outcomes of the real-life example used as illustration in this assessment. The figure shows that the managers of the company see Lean and Industry 4.0, both, as enablers of their strategy. In the discussion, they mention that especially lean 4.0 technologies can make the difference for them.

A further specification of what Lean & Industry 4.0 means for this company will be dealt with later in this assessment.

3. The self-assessment – stepwise towards a Lean 4.0 strategy and roadmap

LEAN 4.

The developed assessment methodology supports the management of companies in developing an improvement strategy for the next 3-5 years. This strategy includes measures to improve workflow using lean methods and/or digital technologies. Elements in the methodology are:

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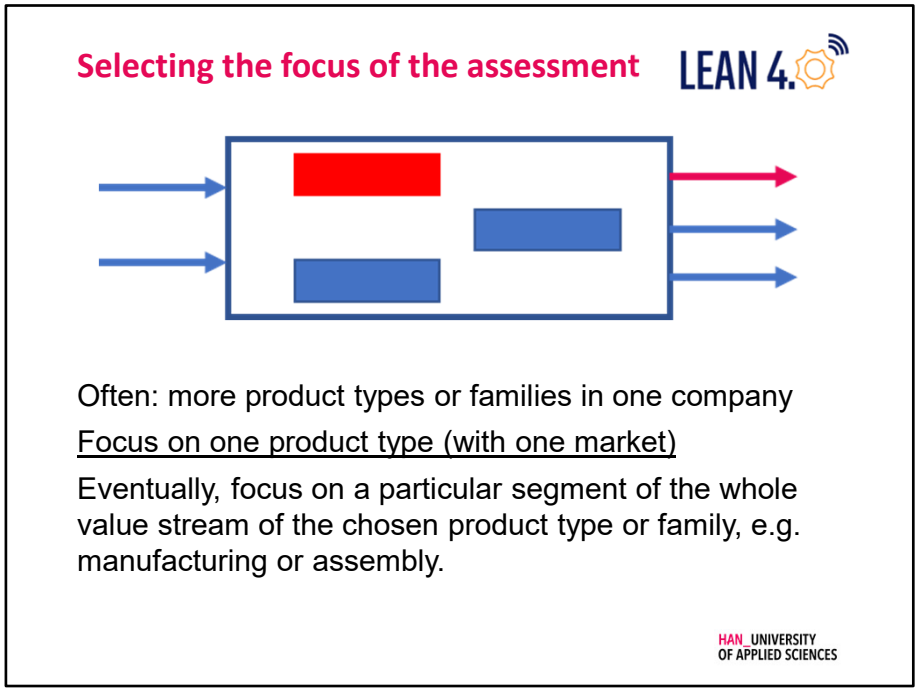
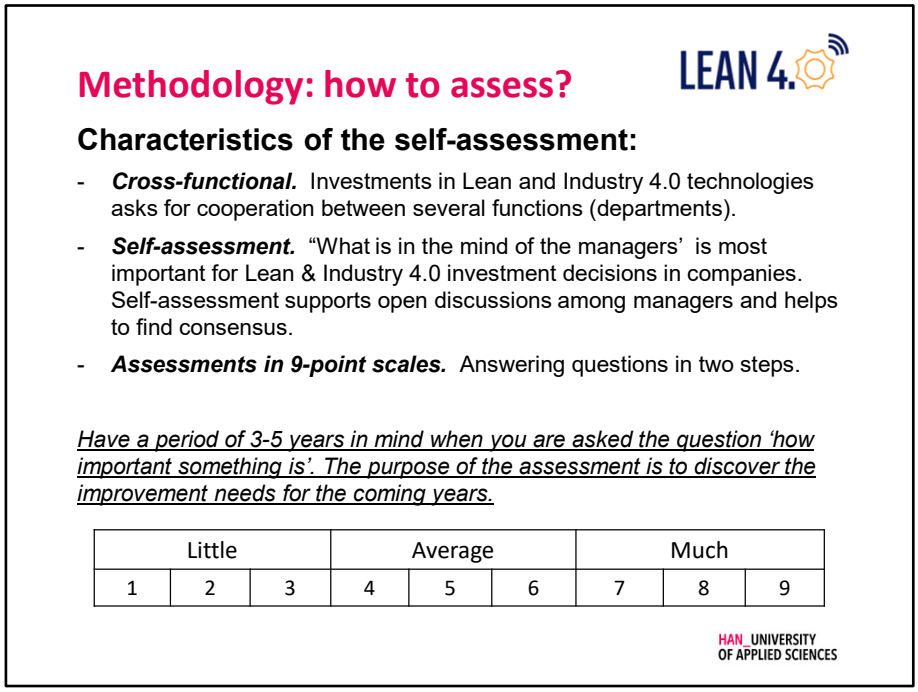
Elements in the assessment are: (i) identifying performance challenges for the next 3-5 years), (ii) identifying challenges related to achieving flow (lean challenges), (iii) identifying digital (Industry 4.0) opportunities that help with those challenges, (iv) the status of success factors in the company that determine whether you can achieve the desired development and (v) formulating a strategy and roadmap. The latter is important and provides input for periodic evaluation: are you still on track, does the roadmap need to be adjusted?



Many companies produce more than one product. Complexity and routings of these products may be different. Also customers may differ. It is important to agree with the assessment team which product type will be in focus at the assessment. Companies should select an important product type, of family, on which they want to improve there competitive performance by means of Lean and/or Industry4.0 technologies. The focus in this assessment is especially on the operations function.

Of course, during the assessment it may be useful to make links to the value stream of other product types and families. In most cases, companies make use of shared resources.

The selection of the focus of the assessment equals with the selection of a Focused Target Market Segment (FTMS) within Quick Response Manufacturing (QRM), the 'lean approach' for companies which produce a high-variety of products. More information about QRM can be found in Rajan Suri's book 'It's about time' (2010).

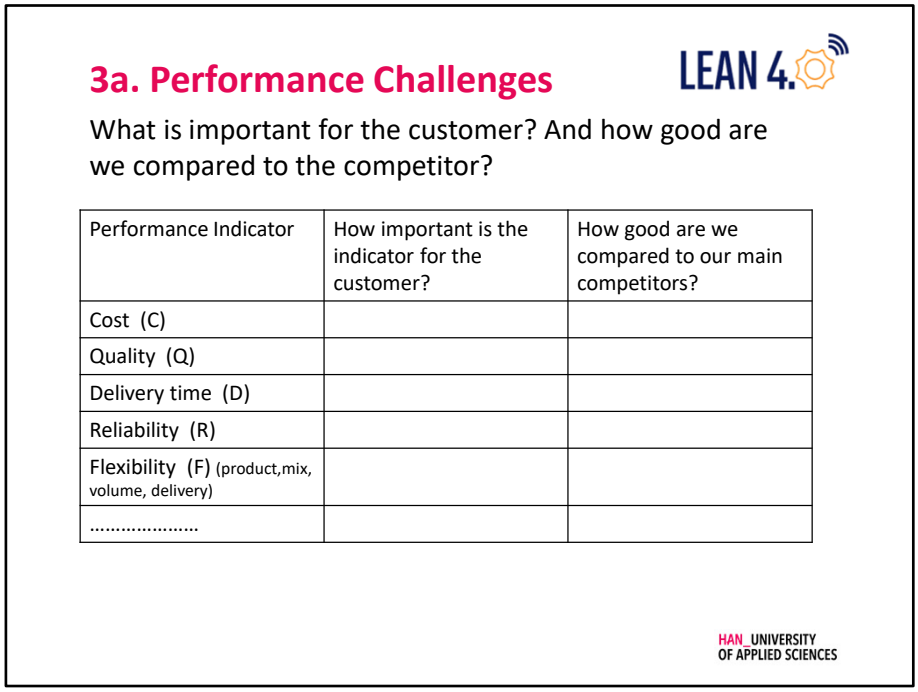


The Lean 4.0 self-assessment is a cross-functional assessment. It is important that key managers involved in the development of the operations function of the company are present at the session. They are the decision makers. It is essential that these managers embrace the same strategy. Lean and Industry 4.0, furthermore, consists of various aspects and ask for input from various disciplines in the organization: planning, operations, marketing, IT, etc. It is good to have a cross-functional team in the assessment.

The assessment is a self-assessment. We will ask to assess the own situation relative to the 'ideal LEAN4.0' situation and to judge to what extent this ideal situation is desirable for the company in the near future (3-5 years). Agreement about this, is a first step towards the development of a LEAN4.0 strategy. Sometimes, managers may disagree: this is a nice opportunity for discussion.

The assessments are made by using a 9-points scale. This scale offers the possibility to answer questions in two steps. First by making a rough assessment (little, average, much), and next by nuancing this answer.

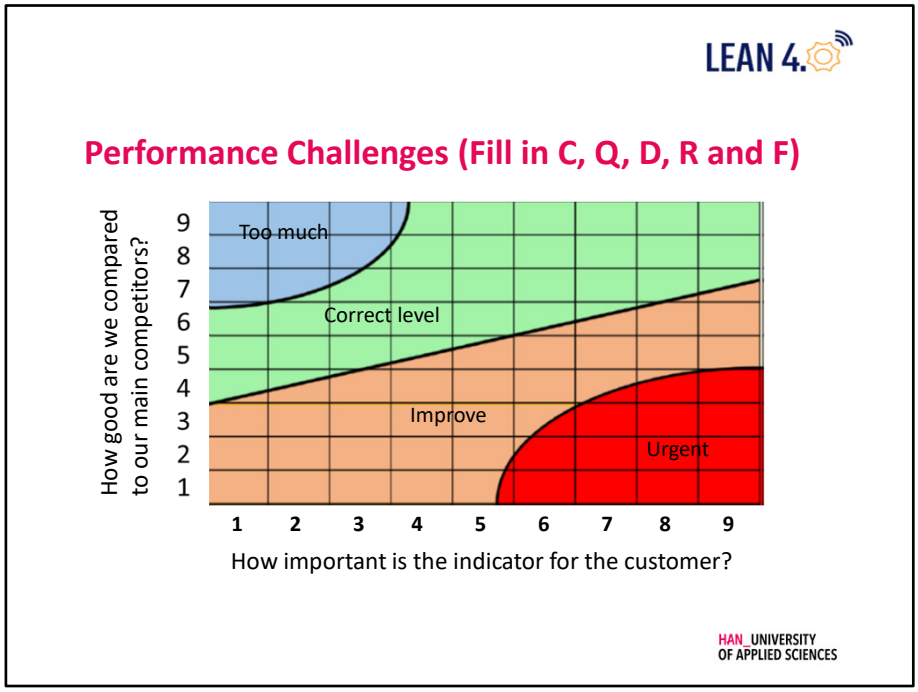
The goal of the assessment is to find LEAN4.0 elements for strategic choices for the coming 3-5 years. It is important that the attendees of the assessment have that in mind.



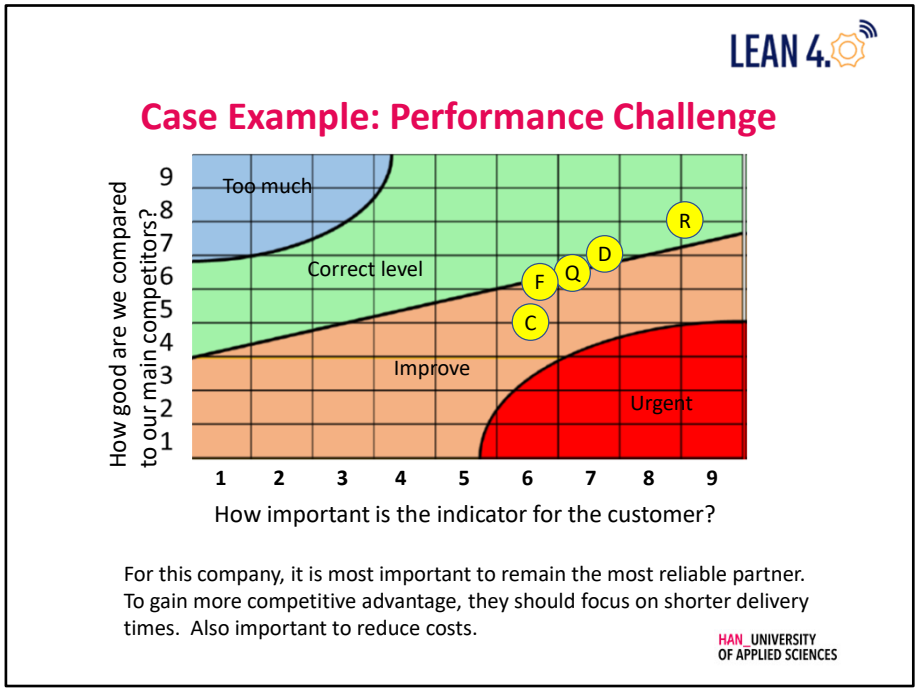
We use here the five performance indicators mentioned by Slack e.a. (Operations Management, 9e editie, Pearson). These are important indicators for the operations manager. It is good to discuss these indicators in the management team, in the assessment. Managers should have a same idea about these indicators and how it can be measured. Measurement is not important in this assessment, but understanding 'how it can be measured' helps to give a qualitative (1..9) assessment score.

The five performance indicators are general indicators. It is fine if managers replace these indicators by more specific indicators which better serve their situation. A good question is: "What are the reasons that customers come to your company instead of the company of the main competitor?" and "What are the reasons why (desired) customers sometimes decide not to purchase at your company?".

It is good that attendees fill in the matrix individually and then discuss about the chosen values. Discussion is important for gaining consensus. In our experience, this part of the assessment may give a lot of discussion among the managers. It is good to give managers time to discuss. Setting these figures provides targets for improvement by means of Lean and/or Industry 4.0 technologies.

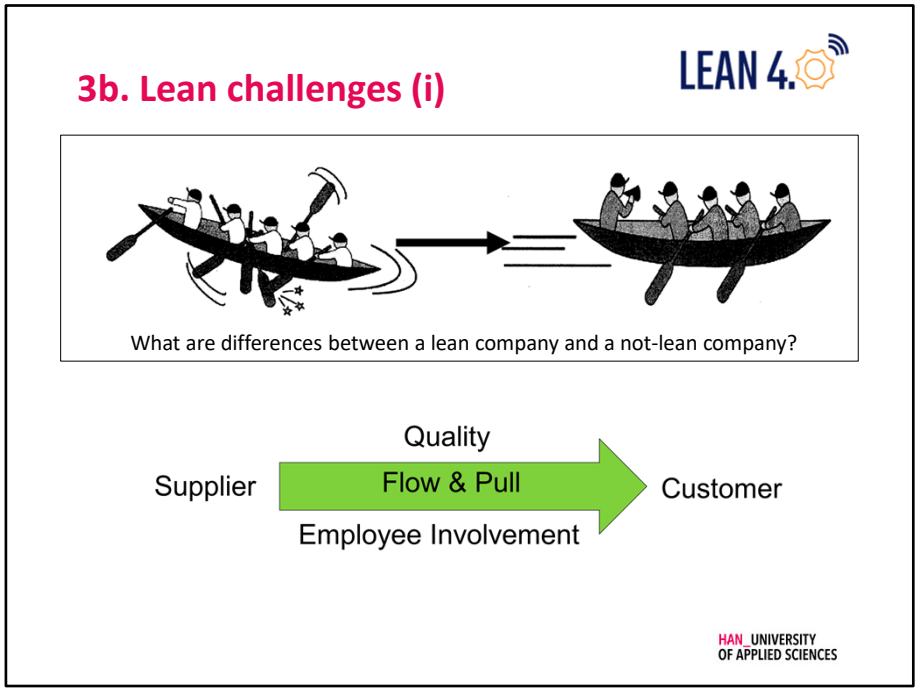


This figure is a good means to illustrate the performance position of the company. The figure, a performance-importance diagram, shows which indicators are most important for the customer and on which indicators the company performs best. Based on this figure, the management team may decide which indicators should improve most when investing in lean and/or Industry4.0.



This example is from the example company. In our experience, this part of the assessment was very important and required time. Attendees did have, to a certain extent, different options. Based on the results, the management team of the company decided for a particular focus: to reduce delivery times under the condition that the reliability will not suffer. Also the costs should not go up. If possible: go down.

With this focus in mind, the attendees are asked, in the next parts of the assessment, to think about the value of Lean methods and/or Industry 4.0 technologies.



This sheet/page is meant to explain the main focus area's of lean (realizing flow, continuous improvement). As mentioned earlier in the assessment, the figure of the boat is appealing for managers: they recognize the waste in their company. Communication and alignment are mostly poor elements in company.

To get flow, we need to improve in various areas. We need a good and regular *supply* of goods from suppliers. If purchased components are not good, then we will have problems in parts manufacturing of assembly (or, worse, the customer may have problems). We also want a good balance between availability of capacity and the *customer* demand. This is, in many cases, a big challenge. Good customer contact is important to align customer demand and availability of resources. Next, *quality* of processes and of the intermediate products are essential for being able to realize flow. Quality problems with respect to products and resources will disturb the flow. Furthermore, *flow and pull* in the goodsflow can only be realized if changeover times (setup times) are low, if the flow is visible at the workfloor (teams, cells, lines) and if the control is triggered by pull signals from the (internal) customer. Finally, the ideal of flow production can only be realized in case of *involved workers* who are cross-trained and work in teams to reduce all the wastes in their work. The area's mentioned here (i.c. supplier, customer, quality, flow & pull, employee involvement) are used in the next sheet/page.

Lean Challenges (i)

LEAN 4.

Focus area	#	Element	Description	How good are we?	How important is it?
SCM	1	Feedback to suppliers	Give regular feedback to suppliers about their performance.		
	2	JIT delivery by suppliers	Ensure that suppliers deliver the right quantity at the right time and the right place.		
	3	Supplier commitment	Ensure supplier development so they become more involved in the production process of the organization.		
	4	Customer involvement	Have customers involved in the improvement of products and production. Stimulate a regular flow of customer orders. Stay focused on their needs.		
JIT	5	Pull	Encourage JIT production, including pull signals (i.e. Kanban cards) that serve as a signal to start or stop production.		
	6	Continuous flow	Structure products and equipment in such a way to facilitate continuous flow.		
	7	Reduction setup time	Reduce process downtime between product changeovers.		
TQM	8	Total productive/preventive maintenance	Use the principles of maintenance management (visualization, organized preventive maintenance, etc.) to obtain a higher level of equipment availability.		
	9	Statistical process control	Systematically improve the quality of each part of the process for the supply of failure-free units to successive parts of the process.		
HRM	10	Employee commitment	Give employees a role in solving problems, strengthen their cross-functional perspective, work in teams.		

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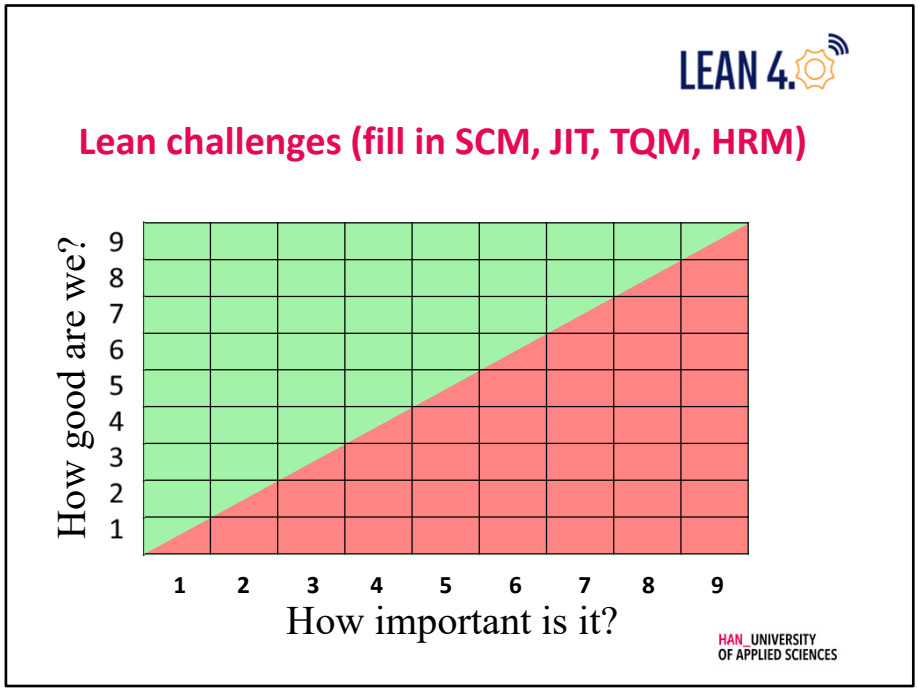
This page shortly describes a number of lean challenges for realizing flow. The division in four focus areas comes from Shah & Ward, 2013 (Lean Manufacturing: context, practice bundles, and performance, Journal of Operations Management, 21 (2001) 129-149). The descriptions are summarized from Shah & Ward, 2007 (Defining and developing measures of lean production, Journal of Operations Management, 25(4) (2007) 785-805).

Few terms may not be completely clear. Within JIT, there is the concept of 'Reduced Setup Time'. Setup Time is the time needed to prepare a machine, or system, for the manufacturing of other jobs. Changeover time is probably a better term: it indicates that the time needed between the manufacturing of two different product may be sequence dependent. Reducing setup time, or changeover time, is important for reducing lot sizes and for producing a higher variety of products.

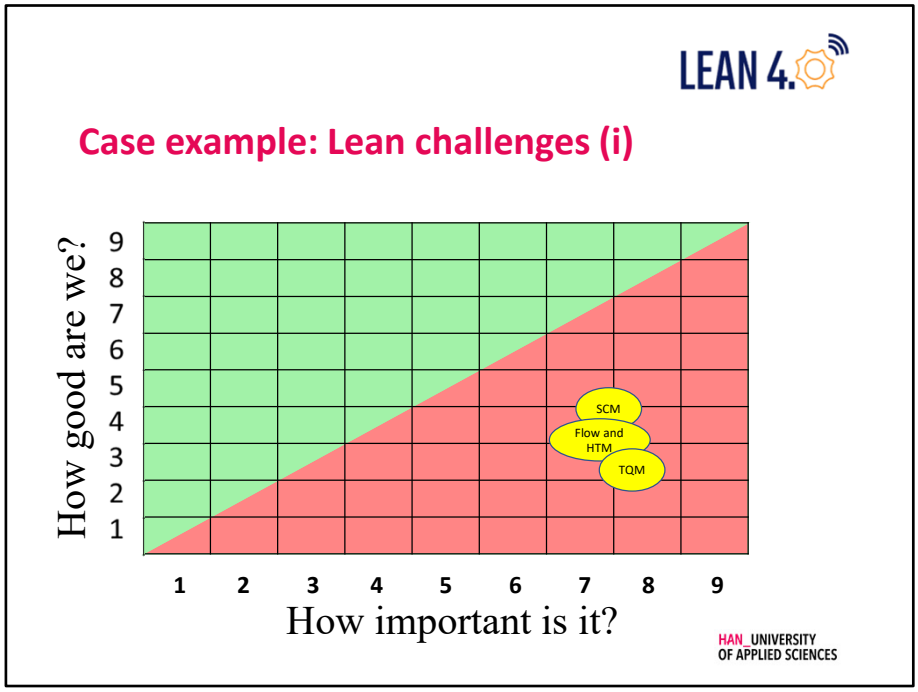
Statistical process control stresses the importance to measure and to make decisions based on valid data. Without measuring quality, it is not possible to improve.

Attendees have to assess the current situations and the importance of each topic. Good to do this independently and use that as input for a discussion. This will, hopefully, lead to consensus. This consensus is the input for the the figure on the next page/sheet.



This figure is helpful to check the deviation between the current and the desired state, in relative sense. The more below the diagonal line, and the higher the importance, the more important it is to improve on this focus area. In the next page, you can find results from the case example.

It is good that managers discuss about the improvement importance of the focus area's of lean. Within this discussion, it is good to link this to the performance challenges, earlier discussed.



This case example shows that the company recognizes the need to improve their lean level. Most important in the attendees' option is to improve the quality. It is important to avoid mistakes… It is interesting to note that all lean components deserve improvement. In the resulting discussion, the conclusion was: TQM activities (incl. standardization) are a key condition for getting more flow (or shorter delivery times) in the process and to reduce costs. After this, flow and pull can be organized. This conclusion specifies the lean goals of the company, linked to their strategic challenges.

Lean challenges (ii): the relation between product and process development

LEAN 4.

Focus area	#	Description	How good are we?	How important is it?
Variety and commonality of products	1	Achieve variety in products with modular components that have standardized interfaces.		
	2	Standardize components where possible.		
	3	Common product platforms (i.e. product parts) exist for different products.		
Alignment of product and production.	4	Design for X (manufacturing, assembly, service, sustainability) methods are explicitly used in product development.		
	5	The design of new products takes into account the possibilities of new production technologies (possible core competence technologies).		
	6	Strategic consideration is given to the choice between outsourcing and self-doing.		
Organizational coordination of product development and production.	7	The design, testing and renewal of production processes takes place in parallel with the development of new products.		
	8	Representatives of production, quality and purchasing are explicitly involved in the product development.		

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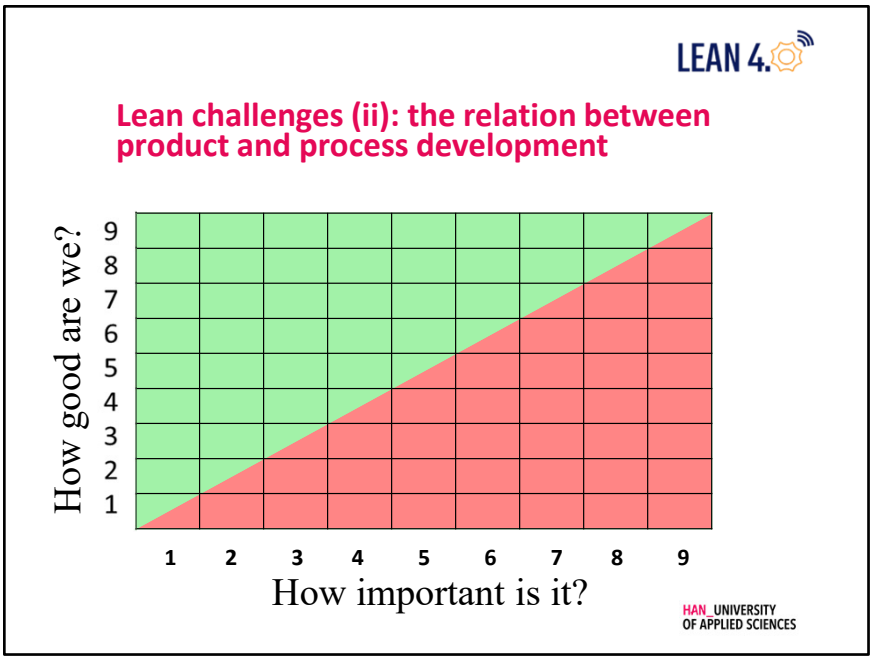
This page briefly describes a number of lean challenges for the alignment between product development and the production function. From a production perspective, it is important to investigate whether these elements play a role in the development of the company's products. These elements are derived from Lean Product Development literature (see Knoblinger, C., PDSAT – A New Product Development Self-Assessment Tool. (Technical University of Munich and Lean Advancement Initiative (http://lean.mit.edu), Munich and Cambridge, MA, 2011)



Here, too, the deviation between the current and desired state can be visualized. Both the importance of an item and the size of the gap, i.e. the straight distance between the slant and the position of the item, can play a role in the choice of an issue to be worked on.

In the case example, the link between product and process development did not play a role: the firm does not develop own products. It is our experience that the relation between product and process development deserves attention in many companies with own products.

3c. Intermezzo – how importants is Industry 4.0 for Lean?

LEAN 4.

Just think a few minutes about how Industry 4.0 technologies (digitalization) may support Lean.

Some Industry 4.0 technologies	**Some Lean terms (link to focus area)**
Data Acquisition and Data Processing • Sensors and Actuators • Cloud computing • Big data • Analytics Machine to Machine communication • Vertical Integration • Horizontal Integration Human-Machine Interaction • Virtual Reality • Augmented Reality	Milkruns (SCM) Heijunka (balancing the load, JIT) Takt time (JIT) Pull flow (JIT) Jidoka (TQM) Standaardization (TQM) Man-machine separation (TQM) Waste reduction (TQM) 5 S (TQM) Kaizen (HRM) People and teamwork (HRM)

Source: Wagner, T., C. Herrmann, and S. Thiede. 2017. "Industry 4.0 Impacts on Lean Production Systems." Procedia CIRP 63: 125–131.

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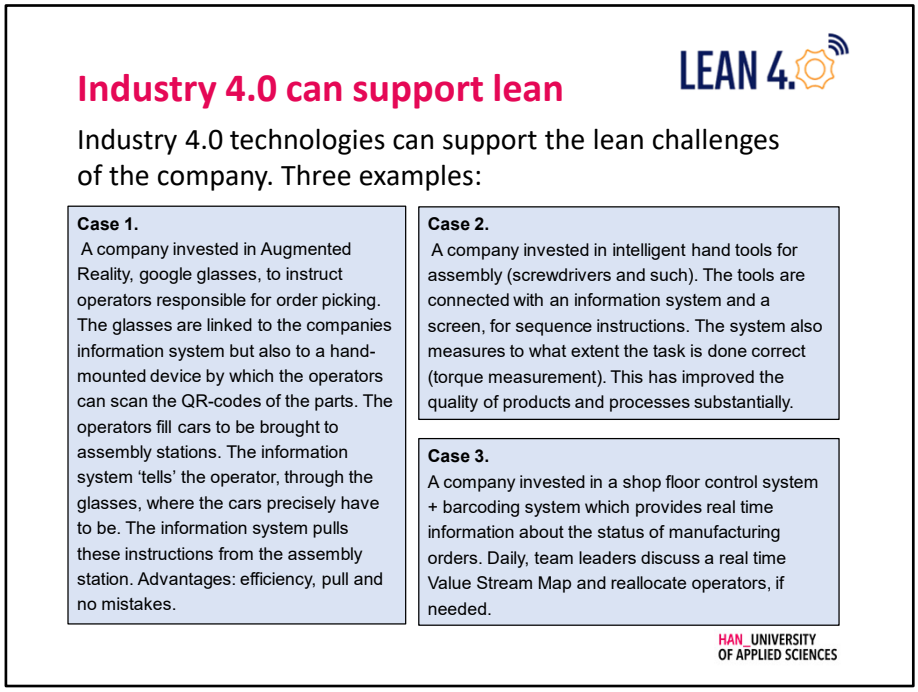
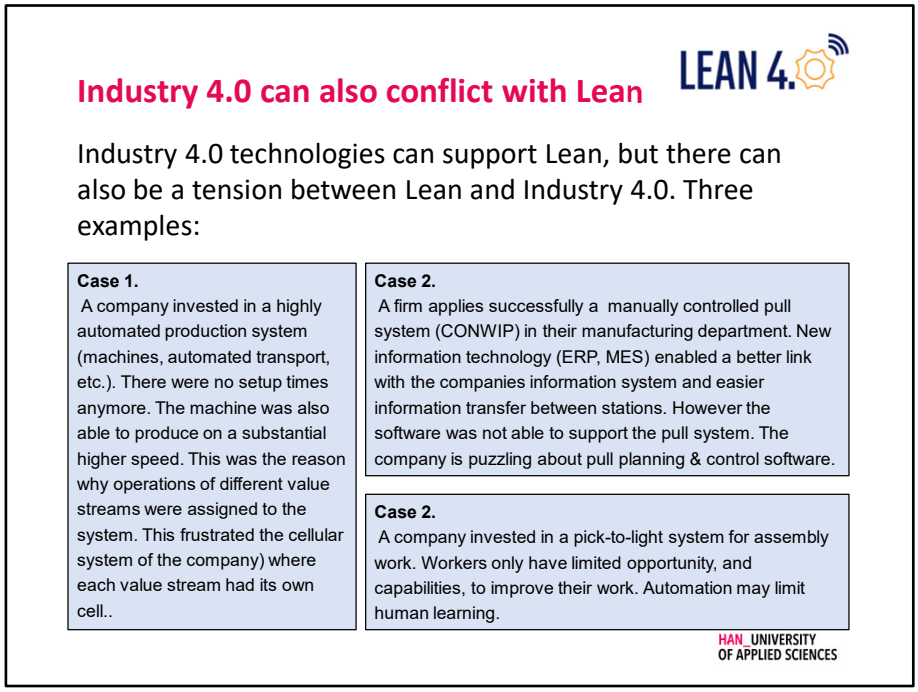
By studying this page, the attendees get more feeling about what Industry 4.0 precisely is and what important techniques are in Lean. It has to be stressed that both lists are not complete. The Lean terms come from a paper of Wagner et al. (2017) who try to link Industry 4.0 technologies with Lean methods. Case studies and other research methods are needed to gain more insight in the relation between Industry 4.0 and Lean.

It is fine to discuss shorty the link between Lean and Industry 4.0. How can they strengthen each other? It is especially good to notice that Industry 4.0 technologies ask for standardization, which is also a key element in the lean strategy. In the next pages, you can find some examples showing the link between Lean and Industry 4.0. How they can strengthen each other, but also how they may frustrate each other.



These are some examples of the application of Industry 4.0 technologies which support Lean thinking. It is fine if attendees do have more examples.

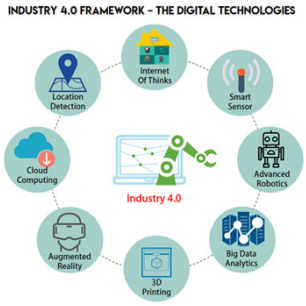


Probably also the attendees know examples of mis-investments in new technologies. There are many examples, where robots are not able to do their job well and are inflexible, where intelligent shop floor control systems are not able to grasp the real situation and constraints at the workfloor, etc.

By showing these examples, the attendees understand that investments in Industry4.0 technologies deserve careful study.

3d. Industry 4.0 Challenges

Industry 4.0, or the Fourth Industrial Revolution, is set to revolutionize the manufacturing and production industry by integrating the Internet of Things (IoT), cloud computing, data integration and other technological advances into the heart of production and manufacturing systems.



(Source: https://medium.com/@winix/industry-4-0-the-digital-technology-transformation-b23ba02a7dd2)

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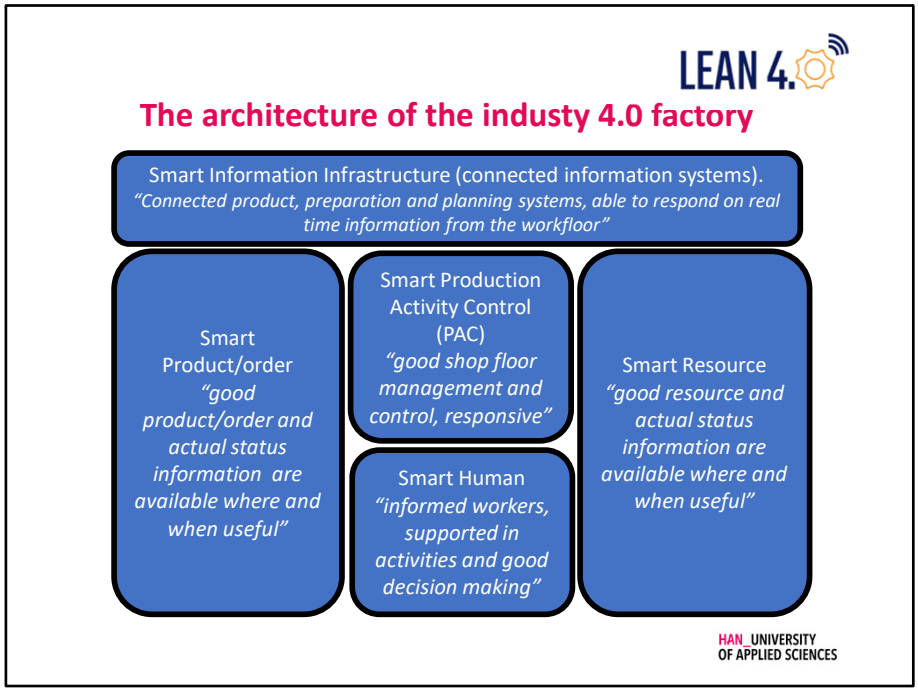
Important for Industry 4.0 is the idea that there is no limit on the information flow: all fixed and real time information about customers, suppliers, products, resources and human are everywhere available and can be, or is, used to optimize and control the goods flow.



We use the words 'smart', according Mora, E., et al., 2017 (Exploiting Lean Benefits Through Smart Manufacturing: A Comprehensive Perspective, Cham, Springer International Publishing). An alternative is the use of the word 'ubiquitous', which indicates the omnipresence of all data needed from resources, products and humans. See: J. S., Shin, S. J., & Suh, S. H. (2012). A conceptual framework for the ubiquitous factory. International Journal of Production Research, 50(8), 2174-2189. Here, we will use the word 'smart', because it is more known in industry. However, the presence of data does not make products, resources and humans smart….

The architecture briefly described in this slide distinguishes five elements of the digital factory. First, a good information infrastructure is needed where information systems used in the design (CAD), preparation (CAPP), and planning (ERP) are connected. The involved functions may be able to respond on 'disturbances' from the work floor. Second, useful product/order data + the status data of each product is needed in order to select actions with respect the products/orders. Resources for performing the transformations of products/orders are essential. So, information about the characteristics and the status of these resources are needed to make assignment decisions and to perform timely maintenance actions. Humans are essential assets in companies. Technology may help them to avoid mistakes and to give them actual data on which they can make decisions in case of abnormalities. The control of the goods flow is, in many cases, complex.

Production Activity Control systems can be used to make decisions based on real time data and a precise model about the behavior of the system. A PAC system can be an automated Shop Floor Control system, but it may also be Digital Twin or Digital Shadow which supports human decision making. Some authors mention this a Manufacturing Execution System (MES). In our terminology PAC equals MES.

There are various Industry 4.0 techniques behind the blocks in the architecture. Below a list of techniques. The list is not complete: it is just meant to give examples. The list is derived from literature and practice.

Smart Info CRM (Customer Relationship Management), CADCAM (2d/3d -Computer-Aided Design/Computer-Aided Manufacturing), WMS (Warehouse Management Software), ERP (Enterprise Resource Planning), MRPI&II (Material Requirement Planning/Manufacturing Resource Planning); **Smart-product** RFIDs (Radio Frequency Identification), SIMs (Subscriber Identity Module), Big data; **Smart Resource** Additive manufacturing/3D printing, Robots and cobots, AGV's (Autonomous Guided Vehicles), ASRS (Automatic Storage Retrieval Systems), Flexible manufacturing cells and systems; **Smart PAC** MES (Manufacturing Execution Systems, sometime linked to Artificial Intelligence, SCADA/DCS (Supervisory Control and Data Acquisition/Distributed Control Systems), PCS (Process Control Systems), Shop Floor Control Systems, Digital Twin, Internet of Things, Cloud computing; **Smart-HRM** Mobile (Personal Digital Assistant, Smart phone, Tablet), Augmented reality (AR glasses, such as the Google glasses or the Microsoft HoloLens), Virtual reality (VR), Pick-to-light, Digital decision support tools (intelligent devices)

Industry 4.0 Challenges

LEAN 4.

Focus area	#	Element	Description	How good are we?	How important is it
Smart Info	1	Information systems	Information systems (CAD, CAPP, PLM, ERP) are up to date and connected.		
	2	Information infrastructure	Information systems are able to respond on real time information from the shop floor.		
Smart product	3	Product information	Product/order information is up to date (e.g. required processes, processing time, complexity..)		
	4	Status information	The status of each product (order) is available where and when useful"		
Smart resource	5	Resource information	Resource information is up to date (available capacity, complexities).		
	6	Status information	The status of each resource (availability, maintenance need) is available where and when useful"		
Smart PAC	7	Shop Floor Management Systems	Shop Floor Planning and Control systems are 'intelligent' and adaptive and able to exchange data with products and resources.		
	8	Integration of management systems	Product/Order, Resource, Quality, Safety, Labor, and Environmental management make use of real time data.		
Smart human	9	Digital Support	Digital systems (e.g. AR/VR, sceens) support humans in doing a good job.		
	10	Information access, decision making	Operators can access manufacturing information anywhere, anytime, for good decision making		

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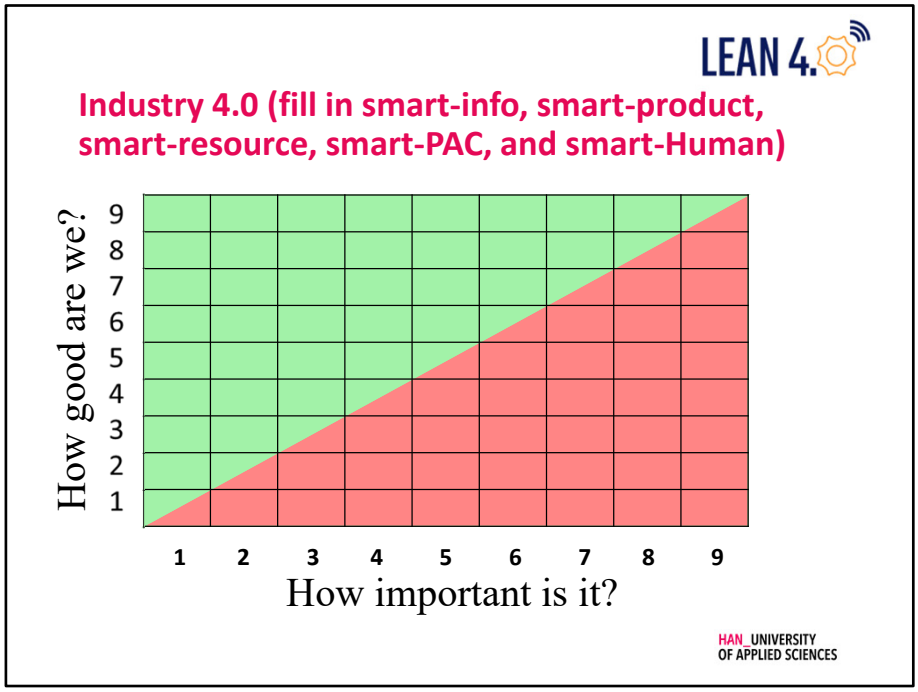
This is not an easy matrix to fill in. The attendees (management teams) have to think about the quality of their digitalization and the importance to improve this. The area's are to a certain extent dependable. Without a good information infrastructure, the idea of smart products, smart resources and smart human is not realistic. Smart PAC, furthermore, ask for smart products and resources. These dependably should be taken into account in the discussion about Digital Technologies, later in this assessment.

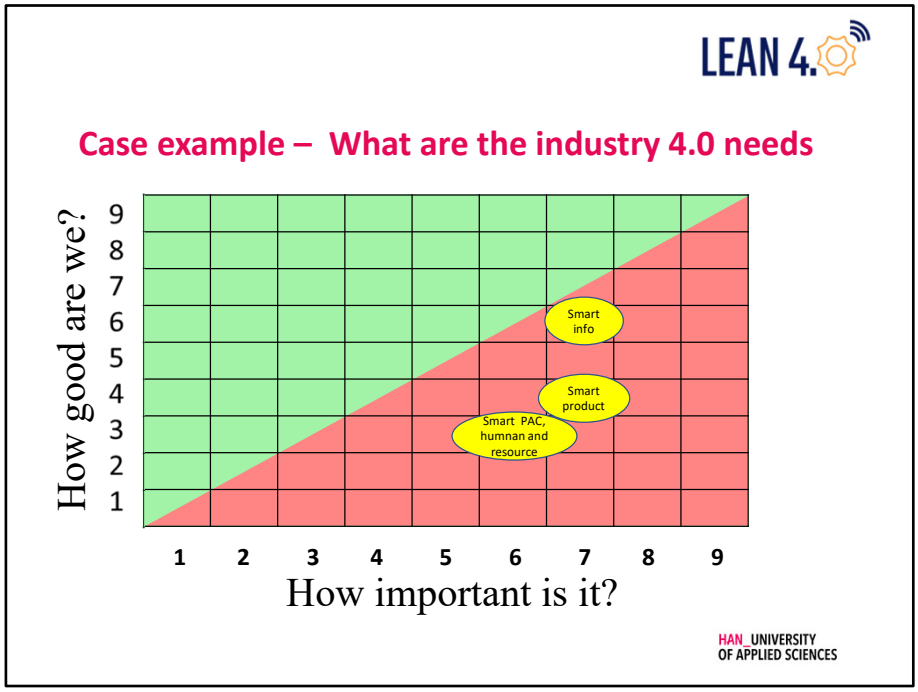


This page illustrates the importance to digitalize the company. As mentioned in the previous slide, the Industry 4.0 area's are related to each other (see also: Bokhorst, J., Knol, W.H., Slomp, J., On the synergy between smart industry technologies and lean principles, paper submitted to the International Journal of Production Economics).

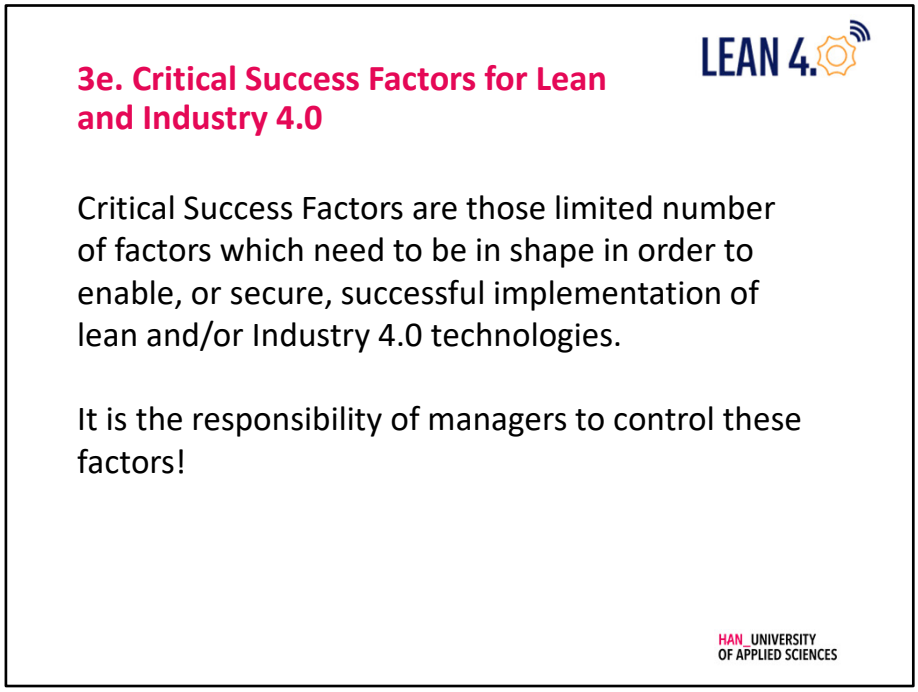
It is valuable that managers discuss this by answering the following questions:

a. Is it important to make better decisions at the work floor (smart-PAC)? What are major resources to control (or bottlenecks) with respect to realizing flow? Wat are critical resources (bottlenecks) with respect to quality?
b. Is sufficient information available about products (smart products), resources and workers (smart resources) to make good and timely decisions for these bottlenecks? Who needs this information?
c. How can the information be gathered (smart-info)?
d. How to support operators/workers and managers to perform their operations better and to make better decisions?

Based on the answers on these questions, management teams may get an idea about the steps to be taken in the digitalization of their company. It is also important to link their ideas to the performance challenges mentioned earlier in this assessment session.



This figure shows that the case company recognizes the need and opportunity to improve by means of further digitalization. There is little need to improve their main information systems. More important is to gain information about the status of products/orders (i.e. smart product). This information, in combination with more accurate data about the availability of resources, gives the opportunity to create more flow in manufacturing and to support operators (less mistakes, better sequencing decisions). So, first priority is on gaining actual product/order information (position, where located, quality).



The term 'critical success factors' comes from Rochart (Rockart, J. (1982). The Changing Role of the Information Systems Executive: A Critical Success Factors Perspective. CISR Sloan Working Paper WP#85, Massachusetts Institute of Technology, Center for Information Systems Research, Sloan School of Management, Massachusetts). He argues that management is not able to control everything, they have to focus. This focus should be on socalled 'critical success factors'. These factors can be found by means of causal analysis (why-why-why does something happen), with input of various stakeholders. There are many studies about critical successfactors for all types of improvements (e.g. lean, continuous improvement, kaizen, ERP, BPR, etc.).

Critical Success Factors for LEAN 4.0

Focus area		Description	How good are we?
Vision	V	Company-wide shared long-term direction, objectives, and goals for improvement, aligned with the company vision and strategy	
Top Management Support	T	Top management take responsibility for and positively participate.	
Communication	C	Three way communication (top down, bottom up and horizontal), honest and clear	
Improvement culture	IC	Supportive middle management, instead of 'stearing bosses'	
		Focus on people, not on methods	
		Mistakes are opportunities for improvement	
Improvement structure	IS	Sufficient time and money is made available	
		Training (everybody)	
		Performance management	
Integral focus	IF	Supplier cooperation	
		Customer cooperation	
		Activities of all departments are in line with the improvement vision	

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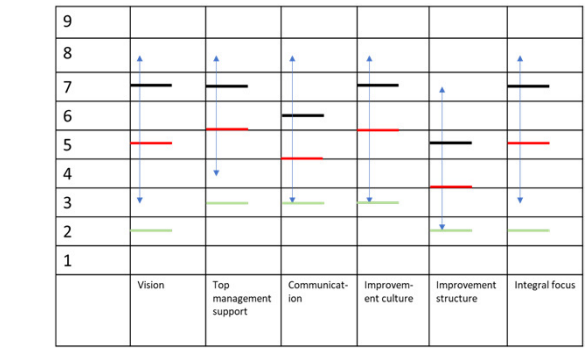
These factors are derived from a broad literature study on Critical Success Factors for Lean (more than 70 references), summarized in Knol et. al. , 2018 (Knol, W.H., Slomp, J., Schouteten, R.L.J. and Lauche, K. (2018), Implementing lean practices in manufacturing SMEs: testing 'critical success factors' using necessary condition analysis, International Journal of Production Research, Vol. 56 No. 11, pp. 3955-3973). This study also shows that the importance of each factors differs for various levels of lean implementation. This will be used in the figure on the next page.

Critical Success Factors for Lean 4.0
+ benchmark (fill in the levels of the success factors)



Source: Knol, W.H., Slomp, J., Schouteten, R.L.J. and Lauche, K. (2018), Implementing lean practices in manufacturing SMEs: testing 'critical success factors' using necessary condition analysis, International Journal of Production Research, Vol. 56 No. 11, pp. 3955-3973

Bottleneck score in case of Lean level 5 (is needed to get that level)

Bottleneck score in case of Lean level 6 (is needed to get that level)

Bottleneck score in case of Lean level 7 (is needed to get that level)

Range we found in assessments

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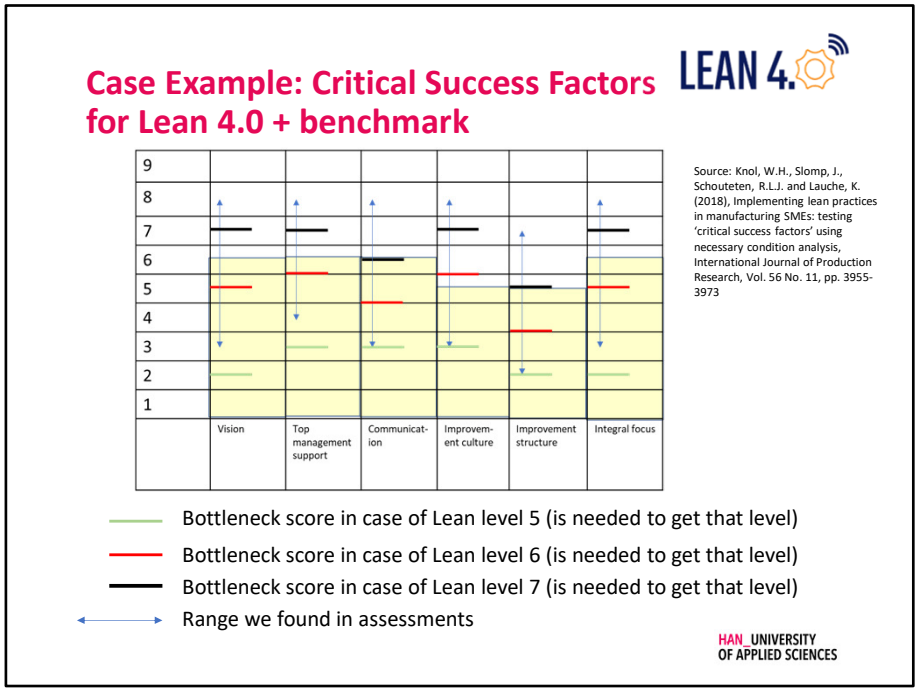
This graph asks for some explanation. The small horizontal lines (green, red and black) give information about the minimal level of critical success factors needed for being able to realize a certain level of lean. Source: Knol et. al (2018). The current and desired level of lean can be estimated from an earlier slide, where the scores on SCM, JIT, TQM and HRM are determined. Take, for instance, the average of the current and desired scores on SCM, JIT, TQM, and HRM. The arrows in the figure indicate the range of values coming from more than 30 companies. It provides a kind of benchmark for companies. The next slide gives an example.



The yellow bars in the figure indicate the current 'level' of the case company on the critical success factors. The positions of these levels within the various arrows, show that the company is dong relatively well on all success factors.

According the opinion of the attendees of the assessment session, the company has currently a 'lean level' of about 3.5. The desired lean level is substantially higher: 7. The figure on this page/sheet shows that the company can reach lean level 5 without investing in critical success factors. To realize level 6, the company first has to invest in realizing an improvement culture. For getting the high level of 7, several other success factors deserve attention (vision, top management support, improvement culture and integration (support congruence)).

Although it is difficult to indicate precisely what each lean level means, the figure helps to find the most critical success factors in the lean journey of the company.

Critical Success Factors for the digital/smart factory

LEAN 4.

Focus area		Description	How good are we?
Human Factors	H	Project team, communication, education and training, user involvement	
Technological Factors	T	Technology selection process, technological infrastructure, data management	
Organizational Factors	O	Top management support, project management, change management, business process re-engineering, implementation strategy and acceptance control	

Source: Daniela Invernizzi, Paolo Gaiardelli, Emrah Arica, and Daryl Powell, MES Implementation: Critical Success Factors and Organizational Readiness Model, Published by Springer F. Ameri et al. (Eds.): APMS 2019, IFIP AICT 567, pp. 493–501, 2019.

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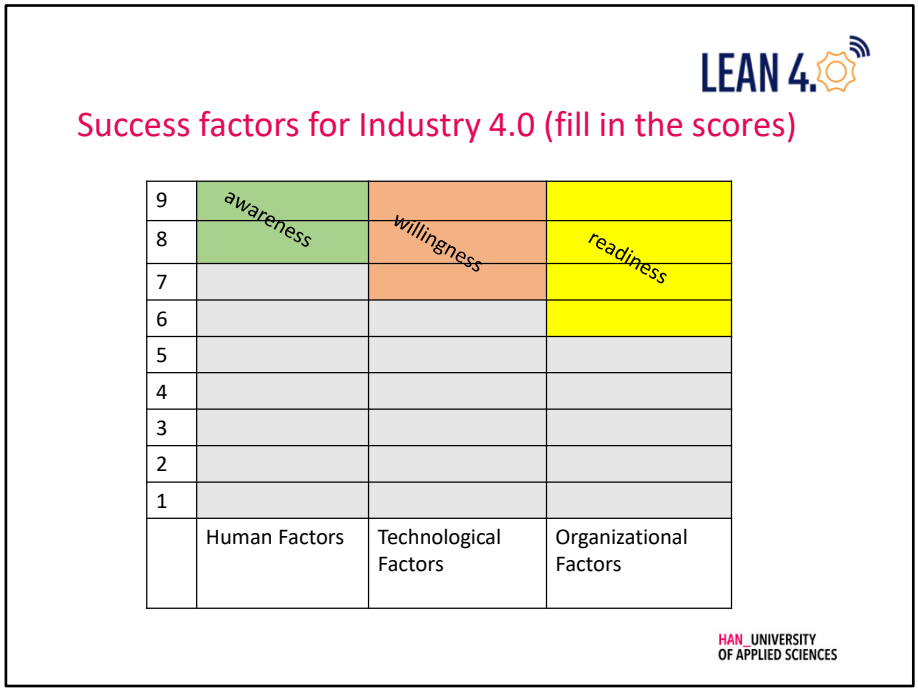
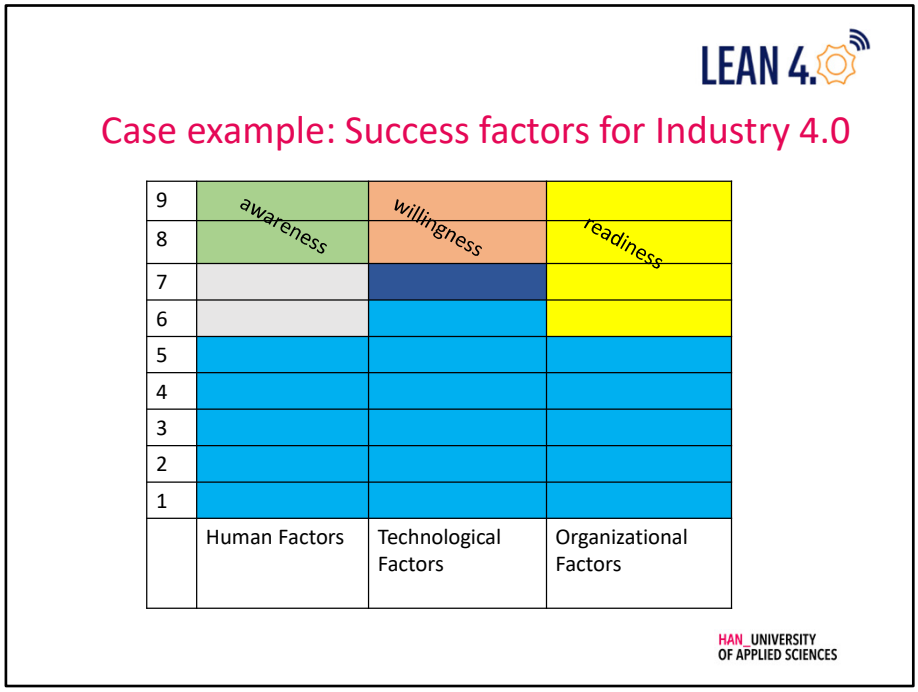
These critical success indicate which factors should be correct in order to be able to implement a MES (or PAC) system, or a 'Smart Production Activity Control System' successfully. Such a system is the heart of the digital factory.



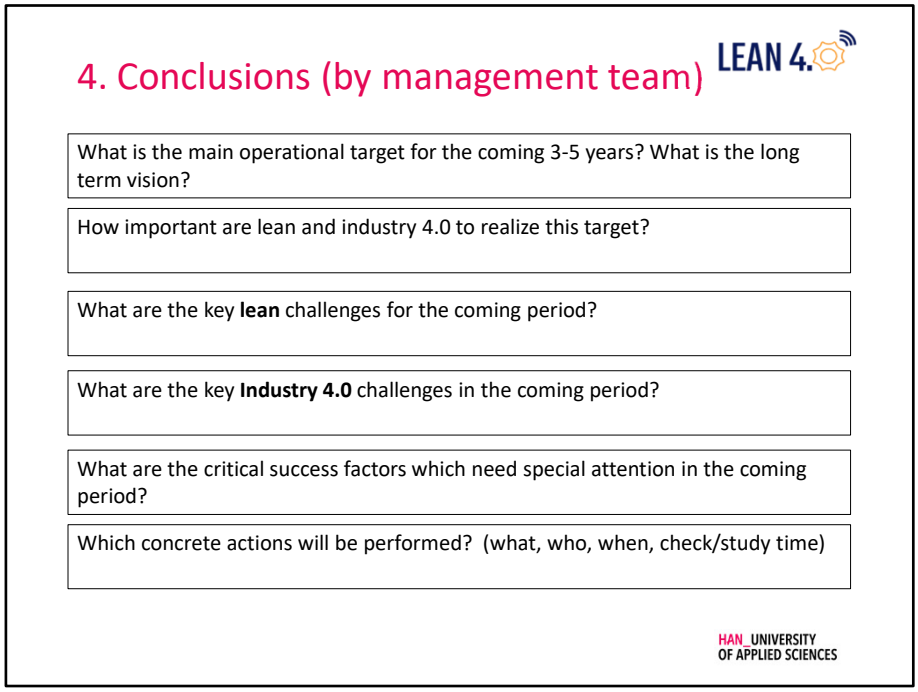
Different phases in the development of the digital factory can be distinguished. First, company wide **awareness** is needed to define LEAN4.0 possibilities for the company and to gain acceptability. Human factors are most important here. A level of 8 or 9 is probably needed for human factors to get successful implementation of integrated technology. Next, there should be broad **willingness and abilty** in the company. This means that, next to the human factors, also the technological factors need to be in shape. Finally, **readiness** for the digital factory asks for good organizational factors. A clear implementations method and strategy is needed.

This is a rough, not very precise, description of the importance of the various factors in the phases towards the digital factory. Understanding the 'sequence' of awareness, willingness and readiness may support management teams to take appropriate actions.



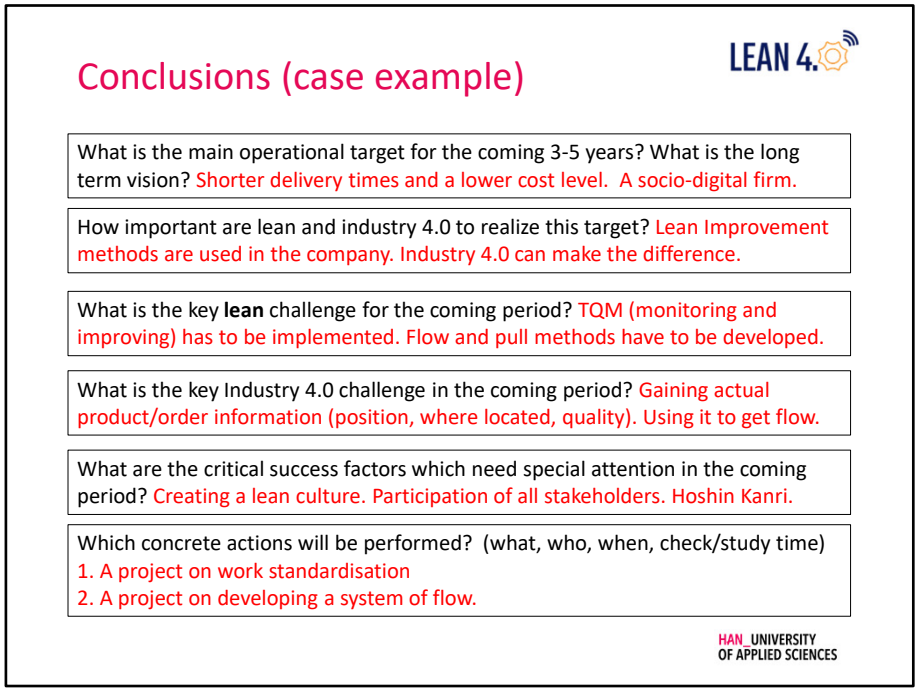
In order to realize the Industry 4.0 ambition, technological factors are not most difficult for the case company. There is sufficient knowledge available in the company. More important is the current culture in the company where each team, each worker, has its own way of working. People at the shop floor have to understand the reason for implementing Industry 4.0. Otherwise, there is a big risk a lack of acceptance. This can be a bottleneck in the transition to a more controlled flow. Next to this, also management has to take its role in this transition. They have to manage all the changes in the organization and have to align all initiatives to the company's goal.

It is interesting that this result is in line with the assessment on the critical success factors of Lean. It is important to let workers participate in improvement projects, so that they understand the importance of digital technologies and to improve in a lean way.

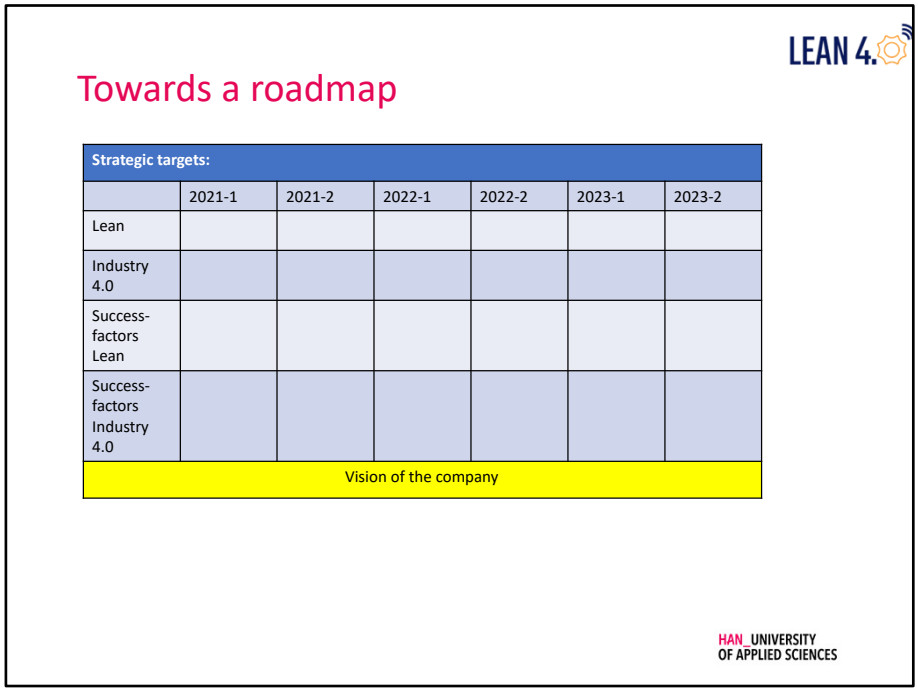


Here the 'outcomes' of the assessment can be summarized. It is the challenge for management teams to create a logical and acceptable story for the development of their company and to specify the improvements to be performed. Filling in this page, may serve the communication in the management team and the whole company.

It is our experience that a concise and precise set of conclusions, including motivation, can be best made after the assessment and be done by the facilitator of the session. These conclusions can be discussed in a short follow-up meeting. It is the task of the management to specify a more precise roadmap for LEAN 4.0 development, although also here a facilitator can be supportive.

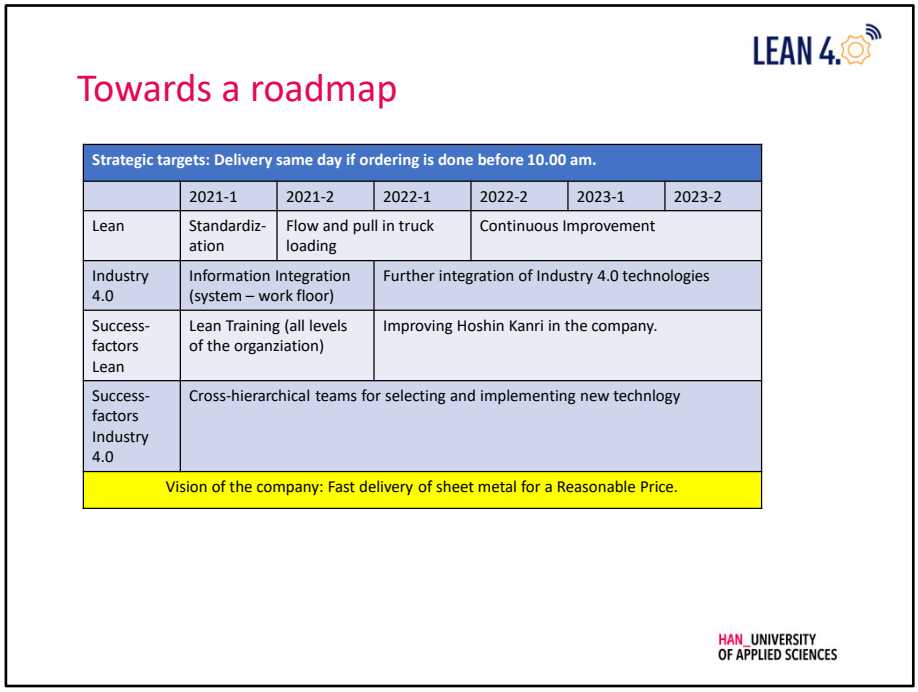


Here just some 'outcomes' are summarized. It is the challenge for management teams to create a logical and acceptable story for the development of their company and to specify what has to be done.



This is a simple template for a roadmap for a three years period. It shows which activities (projects) in the field of Lean and Industry 4.0 require attention in the course of time. It may then be wise to translate the elements in the roadmap into a more specific roadmap in which it becomes clear for each functional area (human resources, finance, production, product development, etc.) which activities must be carried out in which period. By means of arrows, relationships between activities of the various functions can be indicated.

Creating a clear roadmap is difficult. It is not sure what will happen in the future. If it is expected that new technologies (e.g. 3D printing, AR, ...) will be available on the market in about three years, then it is good to anticipate this. Management of the company also has to anticipating expected changes in the market (e.g. increasing importance of sustainability)..



For the case example, we made a kind of roadmap showing the need for a focus in each period of time. This roadmap deserves further specificiation towards the setup of project and the participation of the various departments in these project. Ideally, this fits in a Hoshin structure.

LEAN 4.0 self-assessment

- This LEAN4.0 self-assessment is developed in a number of PDCA cycles in which more that 10 companies were involved;
- The assessment is highly appreciated by managers:
  - *"it makes issues clear"*
  - *"it creates awareness, creates good discussions"*
  - *"it forces us to think about the current situation and about what is needed"*
  - *"it helps to create consensus, it aligns us"*
- The assessment can easily be done online, for example using MS Teams.
- The assessment is developed in Work Package 1 of the LEAN 4.0 project. The Work Package leader was prof. Jannes Slomp, HAN University of Applied Sciences, The Netherlands. Companies interested in the assessment are invited to contact him: jannes.slomp@han.nl

"We need operations managers able to link opportunities of Industry 4.0 with Lean techniques, methods and philosophy to improve business processes", Erlend Alfnes, project leader of the LEAN 4.0 project.

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