Erasmus Project Lean 4.zero

LEAN 4.0 Taxonomy

Understanding the LEAN4.0 grows of a company

Jannes Slomp
(contact: jannes.slomp@han.nl)

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Another word for taxonomy is 'classification'. In the Lean 4.0 taxonomy, presented in this presentation, companies are classified according their maturity of using Continuous Improvement routines ánd using information integration technologies. This taxonomy is meant to help companies, and operations managers, to understand what their main challenges are with respect to the development of Lean and Industry 4.0 technologies. Major assumption is that the presence of Continuous Improvement routines is a main condition for Lean improvement, and information integration (connectivity) is a condition for making good use of Industry 4.0 technologies, such as Big Data, Augmented Reality and the Digital Twin concept.

Content of the presentation

1. The link between Lean and Industry 4.0 tools
2. Does Lean need Industry 4.0, and vice versa?
3. Lean and Industry 4.0 development maturity matrix – a taxonomy
4. Findings from case studies
   - *Impact on operating routines*
   - *Impact on improvement routines*
5. How to use the maturity taxonomy?

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The purpose of the presentation is to challenge the operations manager to think about the link between Industry 4.0 and Lean in their company. We will do that through several lenses. First, in section 1, we will present the lens of the tools of Industry 4.0 and Lean. This illustrates that Industry 4.0 and Lean tools can strengthen each other. Examples from practice however, discovered by the researchers in the LEAN4.0 project, shows that there can also be a tension between Industry 4.0 and Lean. There are cases showing that Industry 4.0 tools may frustrate lean principles. The second lens, used in sections 2 concerns the link between Lean principles and the key focus of the Industry 4.0 tools. Based on empirical data, we will show that Lean can be developed without substantial use of Industrial 4.0 tools. On the other hand, advanced use of Industry 4.0 requires the adoption of Lean principles in a company. These two lenses brought us to the 'Lean and Industry 4.0 development maturity matrix' and the taxonomy related to it. The matrix is based on the lens of improvement. There are two improvement axes in the matrix: (1) the extent to which Lean improvement is embedded in the organization, and (2) the extent to which Industry 4.0 technologies serve the road towards perfection. The positioning of a company on these two axes gives the manager insight in the main challenges of his/her company. This matrix brought us to a LEAN4.0 taxonomy of companies. We distinguish three basic categories of companies in the taxonomy. This is explained in

section 3. In section 4, we explain, based upon cases, how companies which are growing in LEAN4.0 have to adapt their operating and improvement routines. This is a main challenge for the operations managers of the future. Finally, section 5 explains how the maturity taxonomy can be used, also in combination with the LEAN4.0 self-scan developed in our LEAN 4.0 project.

1. The link between Lean and Industry 4.0 tools (1)

	Data Acquisition and Data Processing				Machine to Machine Communication (M2M)		Human-Machine Interaction (HMI)	
	Sensors and Actuators	Cloud Computing	Big Data	Analytics	Vertical integration	Horizontal integration	Virtual Reality	Augmented Reality
5S	+	+	+	+	+	+	++	+++
Kaizen	+	++	+++	+++	+++	+++	+++	+++
Just-in-Time	++	++	+++	+++	+++	++	+	++
Jidoka	+	+++	+++	+++	++	++	+	+
Heijunka	++	++	+++	+++	+++	++	++	+
Standardisation	++	+++	+++	+++	++	++	+++	+++
Takt time	+	+	+++	+++	+++	+++	+	+
Pull flow	++	+	+	+	+++	+++	+	+
Man-machine separation	+	+	+	+	+	+	+++	+++
People and teamwork	+	+	+	+	+	+	+++	+++
Waste reduction	+	+	++	+++	+++	+++	+	+

Industry 4.0 technologies may strengthen the various Lean concepts, according experts

See: Wagner et al. (2017)

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Based upon expert knowledge, Wagner et al. (2017) create a matrix to indicate which Industry 4.0 technologies are helpful for which Lean concepts. They claim that this matrix helps managers to select Industry 4.0 technologies if they want to improve certain Lean concepts. See: Wagner, T., C. Herrmann, and S. Thiede. 2017. "Industry 4.0 Impacts on Lean Production Systems." Procedia CIRP 63: 125–131.10.1016/j.procir.2017.02.041

Stories behind the links are missing, but probably obvious. It, however, shows that Industry 4.0 technologies deserves attention in the Lean community.

The link between Lean and Industry 4.0 tools (2)

Industry 4.0 technologies may strongly support Just-in-Time (flow) and Jidoka (quality control).

Industry 4.0 technologies do not clearly support waste reduction and People and Team work.

(Rosin et al. 2020)

Discussion: Does this mean that a focus on 'waste reduction' and 'people and team work' is not needed anymore in an Industry 4.0 organization?

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Based on published papers, Rosin et al. (2020) show that Industry 4.0 technologies strongly support Just-in-time and Jidoka. Industry 4.0 technologies however do not, or almost not, support waste reduction and People and Team work. There is, therefore, a clear need to pursue the deployment of Lean management while improving certain Lean principles using Industry 4.0 technologies. See: F. Rosin, P. Forget, S. Lamouri, and R. Pellerin, "Impacts of Industry 4.0 technologies on Lean principles," International Journal of Production Research, vol. 58, no. 6, pp. 1644–1661, 2020.

It is good to discuss the following question: Does this mean that a focus on 'waste reduction' and 'people and team work' is not needed anymore in an Industry 4.0 organization?

Our answer is: People and teamwork are very important in Industry 4.0 companies: less people are more responsible for higher capital investments. Attention for the well-being of these workers is a key topic. Furthermore, new technologies are more complex and ask for various expertises. Teamwork is essential. Waste reduction remains an important topic in Industry 4.0, although the removal of waste may ask more expertise because it need to be aligned with the digitalization in the company.

This will ask for well-organized improvement routines.

Examples: how Industry 4.0 may support Lean

Industry 4.0 technologies can support the lean challenges of the company. Three examples:

Case 1.
A company invested in Augmented Reality, google glasses, to instruct operators responsible for order picking. The glasses are linked to the companies information system but also to a hand-mounted device by which the operators can scan the QR-codes of the parts. The operators fill cars to be brought to assembly stations. The information system 'tells' the operator, through the glasses, where the cars precisely have to be. The information system pulls these instructions from the assembly station. Advantages: efficiency, pull and no mistakes.

Case 2.
A company invested in intelligent hand tools for assembly (screwdrivers and such). The tools are connected with an information system and a screen, for sequence instructions. The system also measures to what extent the task is done correct (torque measurement). This has improved the quality of products and processes substantially.

Case 3.
A company invested in a shop floor control system + barcoding system which provides real time information about the status of manufacturing orders. Daily, team leaders discuss a real time Value Stream Map and reallocate operators, if needed.

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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. They can find them on the LEAN 4.0 website.

Examples: how Industry 4.0 may frustrate Lean

Industry 4.0 technologies can support Lean, but there can also be a tension between Lean and Industry 4.0. Three examples:

Case 1.
A company invested in a highly automated production system (machines, automated transport, etc.). There were no setup times anymore. The machine was also able to produce on a substantial higher speed. This was the reason why operations of different value streams were assigned to the system. This frustrated the cellular system of the company) where each value stream had its own cell..

Case 2.
A firm applies successfully a manually controlled pull system (CONWIP) in their manufacturing department. New information technology (ERP, MES) enabled a better link with the companies information system and easier information transfer between stations. However the software was not able to support the pull system. The company is puzzling about pull planning & control software.

Case 2.
A company invested in a pick-to-light system for assembly work. Workers only have limited opportunity, and capabilities, to improve their work. Automation may limit human learning.

Lean needs industry 4.0. But a careful introduction of these technologies are needed!!

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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.

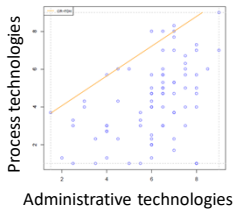
By showing these examples, the attendees understand that investments in Industry 4.0 technologies deserve careful study.

2. Does Lean need Industry 4.0, and vice versa?

Survey among about 100 companies showed:

- That Key principles (standardization, flow, continuous improvement and supplier links) cannot served independently. Lean develops as a 'whole'.
- Industry 4.0 technologies develop through two lines: (i) administrative technologies (information technologies, work-on-screen) and (ii) process technologies (digital automation of processes, MES systems)

Process technologies require a certain level of administrative technologies. Administrative technologies can be found in industry without the presence of process technologies. See:



The survey also shows the positive performance effect of both Lean and Industry 4.0. Combining provides the best performance.

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Within the LEAN4.0 project, Bokhorst, Knol and Slomp (2020) investigated the link between Lean and Industry 4.0 by means of a survey. About 100 companies participated in the survey. Based upon the results, Bokhorst et al. (2020) found that:

Lean key principles (standardization, flow, continuous improvement and supplier links) cannot served independently. Lean develops as a 'whole'.
Industry 4.0 technologies develop through two lines:

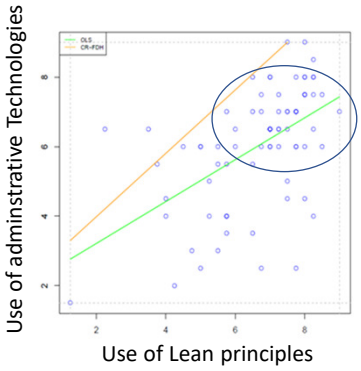
- Administrative Technologies (information technologies, work on screen)
- Process Technologies (digital automation of processes, MES systems)

The survey indicates that development of process technologies in companies require a certain level of 'administrative technologies'. Administrative technologies, on the other hand, are in many cases well developed without substantial development of process technologies.

The survey also shows that Lean as well as Industry 4.0 serves the overall performance (costs, time, quality) of the company. Combining Lean and Industry 4.0 provides the best performance. Bokhorst et al. further investigated to what extent Industry 4.0 needs Lean, and vice versa.

The survey project was part of Work Package 1 of LEAN4.0. In this survey project, we were searching for robust industrial information about the performance impact of Lean and Industry 4.0 technologies, separately and in combination. We were also interested in the link between the use of Lean principles and Industry 4.0 technologies in companies. How this link is, will be made clear in the next slides.

How does Adminstrative Technologies interact with Lean?



Conclusion: Many companies that make extensive use of Lean principles, also make use of advanced administrative technologies. But not all companies….

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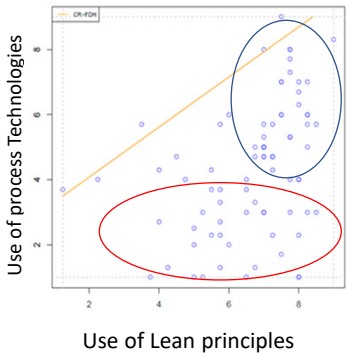
The results presented here, come from applying the Necessary Condition Analysis. The figure shows that a substantial use of Lean Principles goes hand in hand with the use of administrative technologies. But there are exceptions.

How does Process Technologies interact with Lean?



Conclusion: Implementing smart process technologies (digital automation, MES) increasingly ask for more intensive (or serious) use of Lean Principles. See bleu circle. Lean Principles are not dependent on the use of process technologies. See red circle.

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The results presented here, come from applying the Necessary Condition Analysis. The figure shows that there is no company using substantial process technologies without making use of Lean Principles (the empty triangle and bleu circle). The figure also shows that many 'lean' companies did not adopt advanced process technologies.

Conclusions from the survey:

- Lean and Industry 4.0 may both contribute to the performance of a company. Independently or together;
- Administrative technologies are, in many cases, supportive to the lean journey of companies;
- Advanced process technologies ask for an advanced (serious) use of Lean principles;
- Applying lean principles is not strong dependent on the use of smart technologies.

These conclusions are used in the taxonomy developed in the LEAN 4.0 project.

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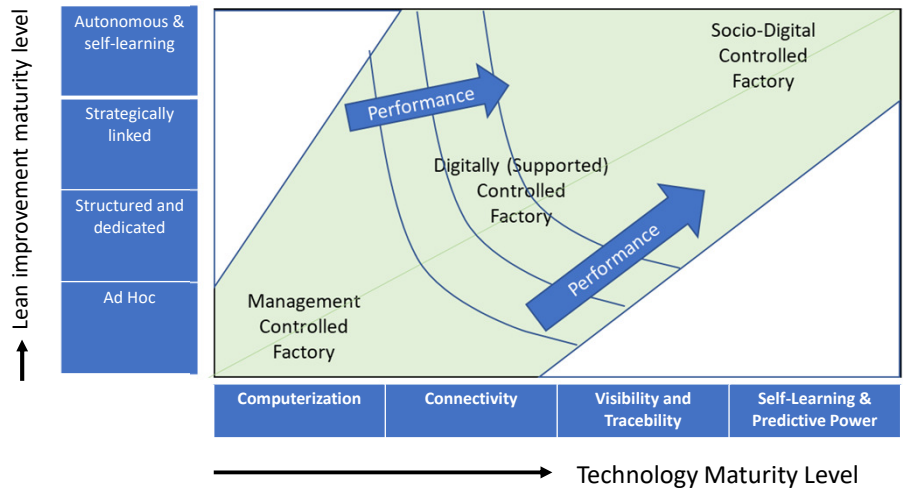
3. Lean and Industry 4.0 development maturity matrix – a taxonomy



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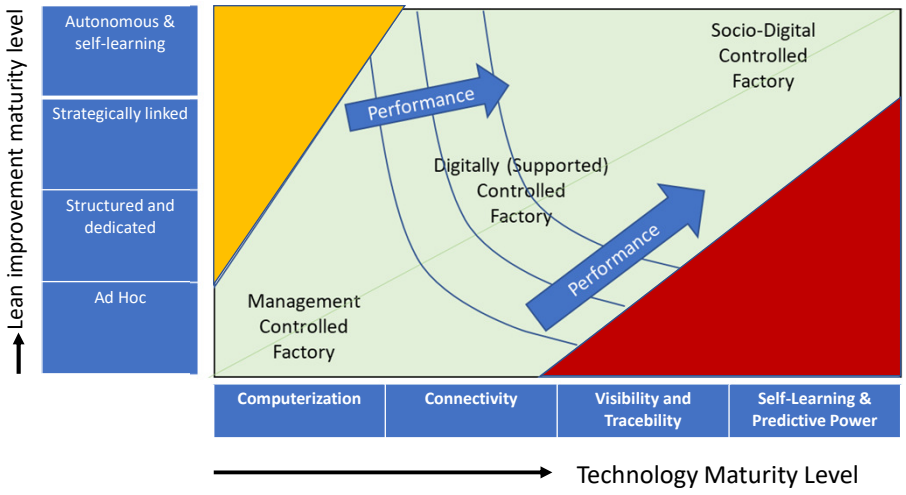
This figure links 'Lean Improvement Maturity' with 'Technology (or Industry 4.0) maturity. The lean improvement maturity level indicates to what extent companies have integrated improvement in the dna of their workers. The lowest level ís 'ad hoc': based on what happens, new improvement projects start. In the next level, there is a certain structure and dedication in the setup of improvement projects. Probably, there are improvement boards, a suggestion box, and such. The start of these improvements, however, is not based on the strategy of the company, but more on the problems in practice. In the third level, there is policy deployment. Improvements are linked to the strategy of the company. No, suboptimization. The fourth level indicates a company where improvement is a 'dance'. Improvement initiatives are not dependent on top management, but comes from the communication between the several organizational levels and department. The company applies Hoshin Kanri in a structured manner, including catchball principles. It is a self-learning system. This classification comes from: "Bessant, John, Sarah Caffyn, and Maeve Gallagher. 2001. An Evolutionary Model of Continuous Improvement Behaviour. Technovation 21 (2): 67–77. doi:10.1016/S0166-4972(00)00023-7".

The technology maturity level illustrates how companies grow from (i) just using

computers for main functions (e.g. CAD, CAPP, ERP), to (ii) more connectivity between the various applications, to (iii) a well-performing link of information systems with the actual status of products and resources, to (iv) a system which uses all data to continuously improve the whole system, in an automated, self-learning way. This maturity level is, to a certain extent, linked to the move from industry 2.0 to industry 4.0. The technology maturity levels are to a certain extent in line with the four stages presented in Tao and Zhang (2017), where they discuss the evolution of the interaction between physical and virtual space. See Tao, F., & Zhang, M. (2017). Digital twin shop-floor: a new shop-floor paradigm towards smart manufacturing. Ieee Access, 5, 20418-20427.

The bended lines in the figure presents 'performance lines'. It shows that performance improvement asks for a balance between lean (learning) and industry 4.0 investment. Let's dive deeper in elements of the taxonomy to understand its' logic.

There are no companies in certain area's of the matrix



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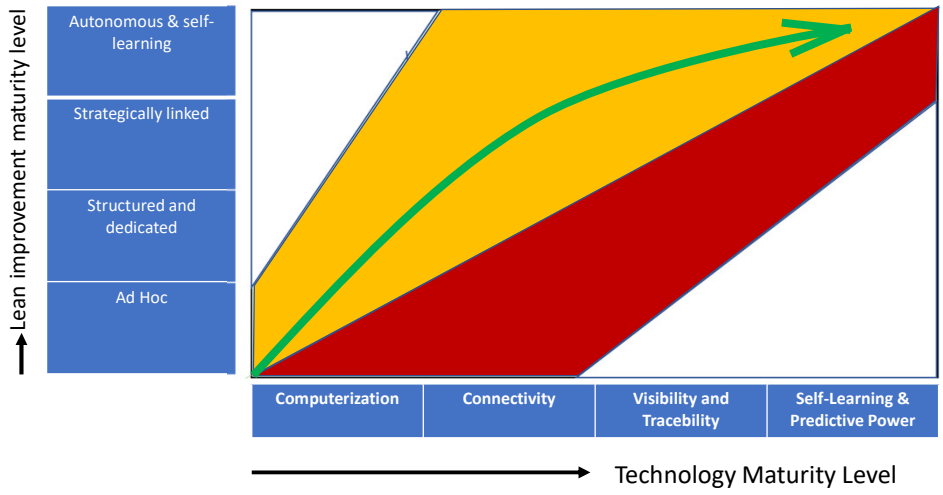
There are no companies in the yellow and red part of the matrix. The sizes of the triangles are based on the survey presented earlier. The yellow area, which is relatively small, shows that using Lean principles needs the support of administrative technologies (i.e. the level of computerization). Further levels in the use of lean improvement can be realized without the use of 'higher' levels of technology. Lean can be done without extensive use of digital technologies. On the other hand, using more advanced levels of technology ask for more advances levels of the use of Lean principles. The red part of the matrix, therefore, is emply. There are no companies that use advanced techology without attention for Lean principles.

First more Continuous Improvement capability, then Industry 4.0



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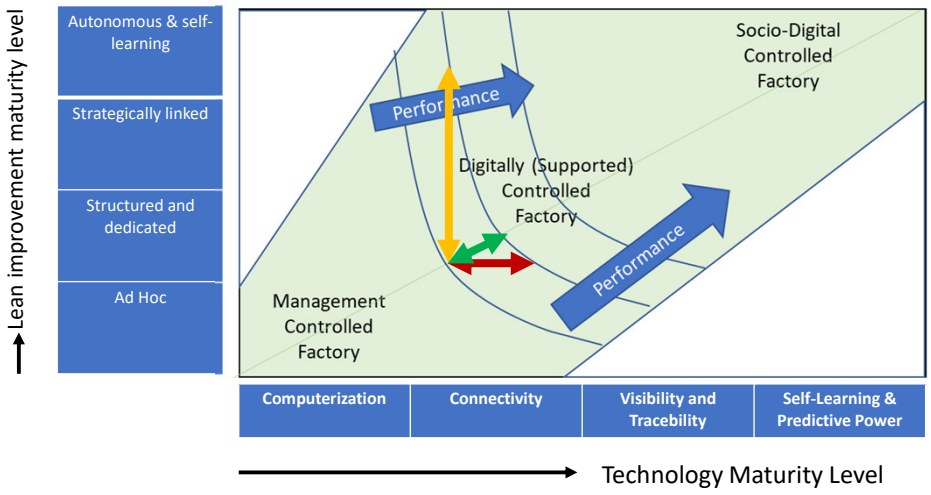
As a consequence of the previous slides (the link between lean techniques and Industry 4.0 technologies and the LEAN 4.0 survey), we think that the most appropriate way to develop is given by the green arrow. It is wise for companies to develop their Lean improvement capabilities before implementing (too) much Industry 4.0 technologies.

Balance Lean and Industry 4.0 to gain performance improvements in the most efficient way.



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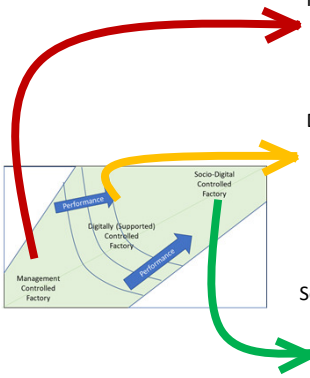
The bended lines in the figure presents 'performance lines'. Each line represents a performance of the company. In order to jump from one curve to the other, investments in Lean Improvement capability and/or Industry 4.0 technologies have to be made. This figure shows that a balance is needed: a good application of Industry 4.0 technologies also needs Lean Continuous Improvement efforts. This balance created creates the shortest, most efficient way, of growing to a higher operational performance level.

Taxonomy – the three basis types



Managerial Controlled Factory:

Information systems have limited functionality. They are not connected. Industry 2.0. Management spends substantial time on fire-fighting. The company is functionally organized. Improvements comes from the management.

Digitally (Supported) Controlled Factory:

Information systems have a good functionality. They are to a certain extent connected. The information exchange with the shop floor is limited: no real time data. Improvements are local. Industry 3.0. Management experiences a gap between information coming from the systems and reality. Moving towards (semi) autonomous teams.

Socio Digital Controlled Factory:

Information systems are fully connected. Information is everywhere available. There is no gap between information and reality. Improvements are local as well as cross-departmental and focused on improving value streams. Semi-autonomous teams are fully responsible for parts of the value streams. Intelligent software is used for the coordination between the teams and for their links to suppliers and (external) customers. Industry 4.0. Management focuses on realizing an agile factory.

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There are many types of companies that can be distinguished in this framework. In fact, we made a 4x4 matrix. A number of cells are empty. The remaining cells can be seen as a classification of companies who are more or less busy with Lean and Industry 4.0. Here three types of companies are presented.

We explicitly mention the development of semi-autonomous teams in LEAN4.0 companies. Less people become responsible for expensive capital goods. Working in teams provide a pleasant environment for them and a shared responsiblity.

It is our experience that companies recognize themselves in one of the three types. It is interesting to see what happens with organizations when they further develop in the direction of the socio-digital (controlled) factory. We performed a number of case studies to gain some insight in organizational challeges in the transition towards the socio digital company.

4. Findings from case studies

We performed four case studies and came to the following observations:

Increased use of Industry 4.0 technologies requires more formalization of operating routines. Also, more centralization of these routines (citate: "Planning now determines the sequence of jobs. The manufacturing teams have to obey this sequence. They don't get information about due dates anymore."

Increased use of Industry 4.0 technologies leads to sharper boundaries with respect to improvement routines (citate: "*Previously, managers were heavily involved in setting-up and executing improvement projects. Now, the teams have to organize the improvement activities themselves. They are also fully responsible to gain the desired output. Management is more focused on improving coordinating routines.*"

We noted that Industry 4.0 technologies may have impact on the roles and responsibilities of working teams and managers. Managers become coordinators and need to facilitate the working teams. They need to be focused on improving the response time of the company. The working teams become specialists and fully responsible for improving their processes. Good Hoshin Kanri (policy deployment) is essential, where computer specialists (MES systems) will have an important role.

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5. How to use the Taxonony

The taxonomy provides support for operations managers to think about the future of their companies. They are responsible for developing the operations function and organizing the operating and improvement routines of the LEAN 4.0 factory.

Each slide in this powerpoint may open a discussion between managers and/or academia.

Important questions are:

- What is your experience with the link between Lean and Industry 4.0 technologies? Do these technologies support Lean?
- To what extent do you apply administrative technologies (IT and work-on-screen)? Are these technologies linked to process technologies in the company (MES, automated machines)? Could new technologies create more flow in your company?
- Where do you position yourself in the taxonomy scheme? To what extent is your company a socio-digital factory?
- Do you see the establishment of semi-autonomous teams as a challenge in your company?
- How will this change operating and improvement routines in the company? How to realize this change?

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Final suggestion for operations managers

It is important to create a long term vision of the operations function of a company, a vision by which managers and employees feel inspired and which stimulates LEAN 4.0 initiatives and experiments.

The LEAN 4.0 Operations Manager has a main responsibility to develop such a vision and to organize the roadmap of the company.

The European LEAN 4.0 project provides support for the LEAN 4.0 operations manager and students who are interested in an operations management career.

The taxonomy is currently rather basic. More research is needed to identify appropriate roadmaps for companies towards the socio-digital factory. This will likely be context dependent.

Create a vision for you operations function

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