Lean European Action-learning Network utilising Industry 4.0

WP 6 – Pilot Projects for Smart Lean Operations (Pilot Projects Results Report)

D 6.1 Smart Lean Operations Pilot Descriptions
D 6.2 Pilot Project Learning Process Descriptions

Version: Approved

Date: 29-12-2021

Project Reference: 601227-EPP-1-2018-1-NO-EPPKA2-KA

Co-funded by the Erasmus+ Programme of the European Union

LEAN 4.0 Version Control Table

Deliverable Title	Pilot Projects Results Report
Prepared by	SINTEF Manufacturing AS, Norway
Evaluating Partner	UGent
Version date	29.12.2021
Contact	Daryl Powell (daryl.powell@sintef.no) Serkan Eren (serkan.eren@sintef.no) Eivind Reke (eivind.reke@sintef.no)

Revision History:

Date	**Version**	Summary of Changes	Initials
15.11.2021	First draft		DJP+SE
09.12.2021	Second draft	First draft modified after meeting's suggestion	SE
17.12.2021	Draft ready for internal review	Second draft modified after meeting's suggestion	SE+ER
23.12.2021	Draft ready for external review	Updated after feedback from internal evaluation	SE
29.12.2021	Approved		SE

Contents

Table of Figures

Table of Tables

-

1 Introduction

1.1 LEAN 4.0

LEAN 4.0 is a collaborative initiative between four leading HEI and four industry partners with the objective to integrate Industry 4.0 smart technologies with the proven Lean Manufacturing paradigm. LEAN 4.0 builds on the knowledge gained on the EuroLEAN+ strategic alliance. LEAN 4.0 will educate the operations managers of the future in the best practices in the field of Lean & Industry 4.0. A main output is an open knowledge sharing platform to organize Blended Network Action Learning in practice and digital teaching content for the new and growing "Lean 4.0" community.
LEAN 4.0 will bring HEI closer to the labour market and facilitate the development of future curricula and the skillsets of the future operations managers which will improve the transparency and coherence of qualifications of students. The project's outputs will become the foundation for innovation and knowledge creation in future collaborative improvement and research projects.

1.2 Pilot Projects for Smart Lean Operations

1.2.1 Description of WP

WP6 brings the theoretical, conceptual, and infrastructural elements (WP1-WP5) into practice. Pilot projects will be carried out within the industrial partners in this phase, in order to further develop, test, and refine the Blended Network Action Methodology (WP3) and LEAN 4.0 Platform, as well as the Smart Lean Operations theory and practices. The industrial partners will implement Smart technologies and Lean practices in small-scale pilot projects, in an attempt to improve their own operations and their ability to learn, teach and share knowledge.
WP6 consists of two primary tasks:
6.1 Pilot Project Execution
6.2 Knowledge capture and lessons learned

As such, this report presents results framed under this structure:
D6.1 Smart Lean Operations Pilot Descriptions (Chapter 3)
D 6.2 Pilot Project Learning Process Descriptions (Chapter 4)

2 Background - Blended Network Action Learning

Guba and Lincoln (1994) suggest that researchers are typically encouraged to ground their research in a research philosophy consisting of an ontology (reflecting the researcher's understanding of self, own experience, the nature of the relational world and the nature of knowledge and theory), an epistemology (expressing how the researcher seeks to know), a methodology (articulating the set of ideas justifying the approach which the researcher adopts for the process of inquiry), and finally a method (for planning enacting, evaluating and understanding research).
In terms of a philosophy for BNAL, ontology is reflected in Revans (1982 p.83) statement that *"there can be no learning without action, and no action (sober and deliberate) without learning."* The classic formulation (equating learning and knowing) L=P+Q provides an epistemological basis. Most significant for this deliverable is that of methodology, which we base on Revans' (1971) theory of action and science of praxeology of cyclical systems - alpha, beta and gamma:

- *System Alpha*: In BNAL, system alpha frames the complex organizational problem to be solved. It focuses on identifying and analysing a real organizational problem including analysing the external environment, current organizational performance, and management values (what the managers want to achieve).
- *System Beta*: Revans' scientific method presents us with a method for investigating, understanding and solving problems, in action. In BNAL, system beta concerns the deployment of the scientific method and involves exploring the problem-solving process, through multiple cycles of action and reflection. Action learners uses appropriate theoretical perspectives to frame the results of the action and reflection cycles, with a view to identifying emergent actionable knowledge.
- *System Gamma:* The (individual and collective) learning is the focus of system gamma. In BNAL, the active participation of action learners in developing and executing systems alpha and beta has implications for the scope of system gamma. The action learners' involvement in system gamma exposes the process of how their engagement with the problem has challenged their own thought processes, to further inquiry. The interpretation and evaluation of each action learner's own involvement underpins the emergent actionable knowledge, ensuring the quality of the BNAL process.

Lean thinking executives abandon all preconceptions of traditional management reasoning. For example, *defining* "problems" in the board room, *deciding* what must be done to resolve them, *driving* execution through action plans, and then *dealing* with unexpected consequences (4D) is not an effective means to grow a business. Lean leaders must *find* problems by going to the "Gemba" in order to see the problems faced by workers and customers with their own eyes. This lets them develop a clear understanding of what factors are preventing them from hitting current targets. Armed with first-hand, specific knowledge, lean leaders then *face* the main challenges (the "elephants" in the room / the obvious problem(s) no one wants to discuss) by creating key operational indicators such as improving quality, speeding up delivery, or reducing incidents. Next, they *frame* the challenges and goals in such a way that everyone in the company can understand them and know how they can contribute - lean leaders will propose lean solution types to problem types, such as pulling (instead of pushing) the workflow in order to create value faster for clients or by applying value analysis/value engineering (VA/VE) to conceive and deliver products that clients love, over and over again. Finally, lean leaders support and develop people in order to enable them to *form* their own solutions, so that the sum of all local solutions and ideas forms an effective, collective response to the main challenges.

This forms the basis for the BNAL process – where the organization's leaders must adopt Gemba-leadership to encourage and guide people in their improvement activities, and must begin by accepting the workplace-based, ground-up strategic thinking of finding and facing problems at the Gemba, framing those problems with pre-defined conditions (e.g. just in time, zero defects etc.), and facing them together with the teams themselves (4F). The BNAL process is guided further by Revans' (1971) theory of action and science of praxeology of cyclical systems - alpha, beta and gamma:

2.1.1 System Alpha – Finding, facing and framing (or re-framing) the problem

System alpha concerns the process description for constructing action in the BNAL methodology. This subtask aims to provide a set of guidelines for constructing a BNAL project to address a problem, including recruitment and initial contact of network participants, selecting the type of participation / mobility (physical or virtual), and arriving at a (broad) definition of learning and improvement needs.

Gemba visit
The BNAL approach begins with a problem or a technological challenge. Which triggers a process of reflection and questioning insight at the gemba ("the real place") in order to locate the problem or challenge in practice. The gemba visit should be carried out at least by the company representatives (project owner / -sponsor / -manager) and the BNAL facilitator (learning coach), as well as other representatives from HEI and industry, where applicable.

Find and face the problem
Participants in the gemba visit have the potential to discover many problems. Some can be solved with existing solutions and programmed knowledge (these problems are referred to as puzzles and, though amenable to experts, such problems are not amenable to action learning), while others require a great deal of reflection and insightful questions (solving such complex, organizational problems is the primary goal of BNAL). Finding and facing problems effectively often requires the local management team to be challenged by the facilitator (learning coach) to think differently about the observed situation. Facing the main issues of the business by starting with the management team's own misconceptions and taking a helicopter view to find the challenges which limit organizational growth is a critical part of this phase.

Frame the problem
Framing the problem can often mean aligning the entire organization (or indeed network) around compelling learning goals. In the case of LEAN4.0, the facilitator would apply the readiness assessment tool at this stage to help frame the problem and identify the necessary learning and improvement needs (the next step).

Define learning and improvement needs
Though the participants in the BNAL process may not have prior experience of either blended- or network action learning, they may be familiar with the Deming cycle (Deming, 1986): plan-do-check-act (PDCA). This well-established cycle of action and reflection is often referred to as the *learning* cycle.
For companies engaging in BNAL, all improvement actions must be rooted in shared concerns – and a shared understanding of the problem(s) where:

1. Improvement and learning go together, with the share objective of overcoming a problem for which there is no single solution.
2. Simply treating the problem as a puzzle and attempting to solve it with (existing) commercial solutions is not a solution in itself. Rather, if seen as a means and rational for engaging with the problem, the puzzle provides a vehicle for engagement with the real problem.
3. Knowledge gaps present the set with learning needs, where the group must engage in action learning. Simply assigning a reading task or a lecture would be to introduce P only. The plan is to take action, thus questioning insight (Q) from the action must be combined with P in order to solve the problem. This process emphasizes the important role of the learning facilitator – who will help the problem-owner to identify whether the organization has the necessary skills and knowledge to solve the problem alone, or indeed whether external parties should be engaged in the action learning process. This then leads to the identification and construction of the network (see the following section).

Identify and construct network
A first consideration is to decide whether the problem can be satisfactorily addressed using an organizations in-house network. The degree of complexity of the problem and the available resources in the organization determine whether the problem can be solved within the own organization or if other actors should be involved. In the latter case, the learning facilitator should assist the organization in sourcing the relevant expertise externally – acting as a knowledge broker to create ties with external stakeholders. Such ties can be formulated both through physical and virtual (blended) communication. Assuming the problem is significantly complex that it cannot be solved by the organization in isolation, the first step for the learning facilitator is to assess the knowledge, competency and capacity of the existing network of the organization. This is because existing ties require little effort to build the mutual trust which is beneficial for knowledge transfer and learning interventions in BNAL. Also, as BNAL is focused on problems with a high degree of complexity that often cannot be solved in the organization due to lack of available resources, the organization should reach out to actors beyond the network to start an alliance. By bundling the knowledge and resources of the actors in the network the complex problem can be more easily solved.
Thereafter, the BNAL set is tasked both with action on the initiative as well as with extracting learning from the experience of action towards a solution for the wider problem. As such, the network needs to include an appropriate mix of levels, affiliations, disciplines, functions, responsibilities and experiences. The network also needs to interact on a regular basis throughout the BNAL initiative, where some of this interaction is through participation in scheduled meetings, each with practical, commercial and learning outcomes. A plan for such interaction is the topic of the next section – forming and implementing the solution(s) to the problem.

2.1.2 System Beta – Forming and implementing the solution(s) to the problem

System beta concerns the process description for planning action. This subtask aims to develop a set of guidelines for selecting programmed knowledge from existing theory to help form solutions to the problem defined in the previous step, and also considers how blended learning approaches can be used to provide network participants with fundamental knowledge required in order to address the problem at hand. Important issues to raise here are definition of network roles and responsibilities, assessment of current state, identification and discussion of existing theory, and planning for milestones and performance deadlines.
System beta also concerns the process description for taking action. This subtask will develop a set of guidelines for how the individuals in a network can effectively take action to solve the problem, also with a view to creating new knowledge and learning. Important considerations include identification of emerging issues as well as review of training and facilitation needs.

Define Network Roles and Responsibilities

A core part of BNAL is the network (also known as the "set"). The individuals that make up the network are those who are responsible for solving the problems – through constructing action, planning action, taking action and reflecting over the action. After the problem is identified, the foundation for the network should be laid using the following six steps, for which we rely on the work Sydow *et al.* (2015) to further conceptualize the intra- and inter-organizational networks, namely allocation, regulation and evaluation, as well as the important role of the network administrator.

Allocation: Once the partners for the network are selected, the resources, tasks and responsibilities should be allocated and aligned across the network partners. The partners are

tied together in the network and strong cooperation is needed to solve the problem. It is important that this is all formalized.

Regulation: In this step, rules for the collaboration are formalized and implemented. All network partners should live by the rules of the game (though these rules can be both formal and informal). When a new partner enters the network, she should comply with the existing rules in the network. However, the rules of engagement may change over time as the network evolves.

Evaluation: The last step in creating an effective network to solve problems with BNAL is evaluation. The network should be evaluated regularly to see whether it is going in the right direction. The contributions of the individual partners, the performance of the whole network and the relations between the network partners are evaluated. It should be evaluated if actions should be taken to stay on track. On top of that, it is important that every partners' opinion is considered in the evaluation. Organizations weigh up the disadvantages and advantages of being part of the network and this in turn influences the effort they will make. Effort to maintain quality relationships with other partners and effort to take action and share knowledge. Thus, the effectiveness of the network depends on how the partners rate the quality of the network.

Network administrator: A network administrator should also be appointed to facilitate the network – this is a distinctly different role to that of the learning facilitator. The network administrators job is to administer knowledge sharing among partners, while the learning facilitator strives to enhance the network's ability to learn and take meaningful action. With regard to the evaluation, the network administrator evaluates the network from his perspective. Is the way the network facilitator sees the network equal to how the individual partners experience it? If not, it is the job of the network facilitator to find the imbalance and take action. For an effective network in which partners are willing to share their knowledge, resources and learnings, high levels of trust and reciprocity are important. In the evaluation it should be considered if the levels of trust and reciprocity are desirable or that actions should be taken.

Planning and taking action

Having established the roles and responsibilities within the network, the set can begin to plan and take action in order to address the problem at hand. This involves using the scientific method as follows:

1. *Assess Current State*
2. *Agree on Target State*
3. *Plan for Action (Incl. Selection of Programmed Knowledge)*
4. *Take Action (using loops of PDCA)*

Having also found and framed the problem in the previous step, A3 management is a well-known and well-documented scientific problem-solving process that presents leaders with a step-by-step approach to plan and take action, closely modelled on PDCA (Richardson and Richardson, 2017). The term A3 in fact refers to an international standard paper size (297 x 420 mm). Toyota adopted the name A3 drawing on insight that every issue an organization faces can and should be captured on a single sheet of A3 paper. While the basic thinking for an A3 follows a common logic, the precise format and wording are flexible, and most

organizations tweak the design to fit their unique requirements (Shook, 2008). As such, a BNAL-specific A3 template has been designed in LEAN4.0, as shown in Figure 1.

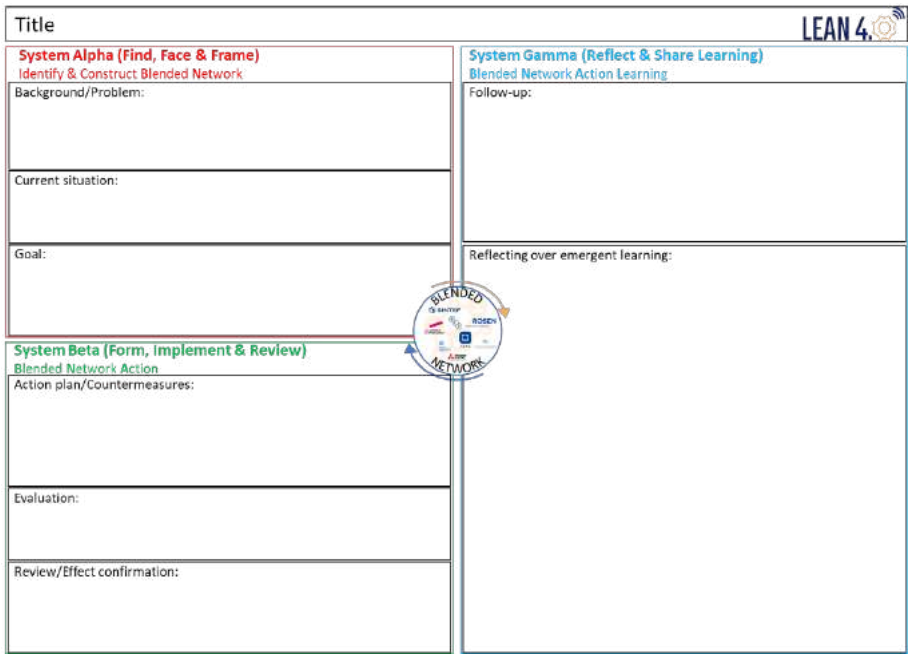


Figure 1. BNAL A3 template

A3 management also serves as an important means of communication – such that countermeasures developed during the problem-solving process can be standardized and shared with others (Liker and Hoseus, 2008). Richardson and Richardson (2017) present this form of "standardized storytelling" as a powerful tool to engage and empower leaders as well as front line personnel. They conclude that it is the thinking behind paper, not the A3 paper itself, that is most important.

2.1.3 System Gamma – Reflecting over learning and emergent actionable knowledge

With regard to the A3 process, the effect confirmation and follow-up phases are critical for system gamma. Here, the participants in the network (set) must study the effects of the action (preferably at the Gemba) and use insightful questioning to identify important lessons learned. Here questions must be prioritized over statements.
Any emergent learning should be documented (on the A3 or otherwise) and communicated within and across the participating organizations, so as to share and re-apply any emergent actionable knowledge.

3 Pilot Project Descriptions

In this section of the report, we provide case examples in which we combine smart technologies and Lean Manufacturing to solve contemporary problems for Industry partners. The examples are structured using the BNAL A3 template as shown in Fig. 1.

Digital Campus and Digital Gemba Walk Prototype at HSOS and ROSEN

LEAN 4.

System Alpha (Find, Face & Frame)

Identify & Construct Blended Network

Background/Problem:

Manufacturers are faced with increasingly individualized products. More complex production steps and test trials that can often take many months before anything is put into practice. Engineers and designers cooperate awkwardly, sending drawings, protocols and e-mails back and forth multiple times. Technical support should enable the testing process of different concept variants along production lines and improve collaboration between employees. The Corona pandemic has proven that remote support could gain more value in the future.

Current situation:

Currently, tools and product pieces must be physically and manually drawn and assembled until the first actual problems become apparent.

Goal:

To test digital shadow and digital gemba walk by using drone and smart glasses.

System Beta (Form, Implement & Review)

Blended Network Action

Action plan/Countermeasures:

Use of drones, Hololens 2 and Oculus Rift:

A student will first try out the method on campus by taking photos with a drone and then programming a prototype for the Hololens (MR) and the Oculus (VR). The method will then be presented to ROSEN for use in digital production lines.

Evaluation:

The resulting prototype is very successful. A very detailed campus built based on a role-playing character allows interested students to virtually walk through the campus. Since the environment could be recreated in such detail, individual buildings, offices, entrances, exits and common rooms can be visited.

Review/Effect confirmation:

Since the student only had 3 months, only one main hallway of the campus was replicated. It is a matter of time before there is a complete campus to walk through digitally. The added value in the public presentation of the university increases enormously.

BLENDED NETWORK

System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

The very successful project is further developed and presented to the company ROSEN. The hope that the methodology used can also be implemented in practice also reveals potential for further digital twin use cases. ROSEN's outdoor areas are to be replicated first so that customers can get an impression of what goes on in the company. In the future, production lines can be replicated to demonstrate showcases to customers.

Reflecting over emergent learning:

- It is a complex and time-consuming solution.
- A lot of resources are needed to build such prototypes (computer, smart glasses, software, license, time, employees)
- Results are positive and a lot of new use cases for company partners are revealed
- Solution must be further developed
- Easy operation of the prototype by clicking on a link
- Video game character

Figure 2. Pilot 1: Digital Campus and Digital Gemba Walk Prototype

Virtual Production with the use of Mixed Reality and Smart Glasses at ROSEN

LEAN 4.

System Alpha (Find, Face & Frame)

Identify & Construct Blended Network

Background/Problem:

Manufacturers are faced with increasingly individualized products. More complex production steps and test trials that can often take many months before anything is put into practice. Engineers and designers cooperate awkwardly, sending drawings, protocols and e-mails back and forth multiple times. Technical support should enable the testing process of different concept variants along production lines and improve collaboration between employees. The Corona pandemic has proven that remote support could gain more value in the future.

Current situation:

Currently, tools and product pieces must be physically and manually drawn and assembled until the first actual problems become apparent.

Goal:

To test mixed reality technologies in order to integrate new components into production.

System Beta (Form, Implement & Review)

Blended Network Action

Action plan/Countermeasures:

Use of Mixed Reality with a MS Hololens 2:

Using the ARES software from HoloLight GmbH, a partner of the university, virtualization using Hololens 2 is being tried out, analyzed and validated for different areas of application at ROSEN.

Evaluation:

This process can be optimized by visualizing components via augmented reality based on CAD files. With the help of the HoloLens II and the ARES software, employees can exchange information using online transmissions and more quickly understand whether components can later be integrated into the series process. The first attempts were successful, but the added value compared to CAD drawings on normal computers was not clear enough. Collaboration with multiple glasses on virtual objects is the second case that still needs to be tested.

Review/Effect confirmation:

The feedback on the application was not good enough. In the second case they expect connection-problems since the remote support needs to be applied in unexpected areas like forests.

System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

The shop floor workers all agreed that they want to continue working in this new way. It is still unclear what benefits this method brings and whether it addresses the problems.

Reflecting over emergent learning:

- It is a complex but expandable solution.
- The cooperation with the university and HoloLight is very useful.
- Results are positive, but not clear how to further develop.
- Solution has to be reviewed for more functions and use cases.

Figure 3. Pilot 2: Virtual production with the use of Mixed Reality and Smart Glasses

Digital Gemba-Walk and Remote Support at the shopfloor of QMH Masks in Hamburg

System Alpha (Find, Face & Frame)

Identify & Construct Blended Network

Background/Problem:

In order to fast growth of SMEs it is necessary to scan the business- and production processes periodically. Increasing volume of products and need for information leads to unclear overview. Problems at machines appear and inefficient processes will be ignored which leads to high waste of resources. The technology solution should not only identify problems but give a clear overview of optimization possibilities.

Current situation:

Due to the ever-changing guidelines regarding the production of protective masks in Corona time, machines must always be reprogrammed. Utilization of production fluctuates very strongly and certain problems on machines cannot be solved or even detected due to ignorance of the technology. This leads to severe inefficiency of production.

Goal:

To test assisted reality and virtual-sensei concept.

System Beta (Form, Implement & Review)

Blended Network Action

Action plan/Countermeasures:

Use of Smart Devices or Laptops

The well-known Gemba Walks are to be digitized. A digital Gemba Walk should allow an expert to look through the eyes of the store floor employee and identify optimization and problem-solving opportunities. This will also be a form of remote support for complex machine maintenance.

Evaluation:

The first digital Gemba Walk took place with laptops and the connection of a MS Teams conference only. The store floor employee had used the camera of his laptop to demonstrate the production line to a team of experts and address current problems. Solutions were suggested and even further optimization proposals for logistics and machine documentation were discussed. Thus, the first run was very successful. All solutions were summarized in a follow-up.

Review/Effect confirmation:

The feedback on the application was mostly positive. In a second case they expect the use of smart phones or smart glasses to optimize the quality of a remote support case.

System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

The shop floor workers all agreed that they want to continue working in this new way and worries that it was a one-time activity. They also are interested in the use of smart devices and how they will improve the quality of remote support or digital gemba walks.

Reflecting over emergent learning:

- It is a simple and expandable solution.
- MS Teams is a well known and professional solution.
- Results are mostly positive.
- Solution has difficulties with WLAN Connections in critical production areas.
- First tries with a smart glass failed also because of the WLAN Connection.
- As an improvement, recorded videos from the 1st-person view can be used as tutorials for new employees as well.
- Implementation of more smart glasses so people can connect with two smart glasses in one videoconference which could add value to the remote support cases.

Figure 4. Pilot 3: Digital Gemba walk and remote support in the shopfloor

Goods-Identification with autonomous robotics: DRONES at ROSEN

LEAN 4.

System Alpha (Find, Face & Frame)

Identify & Construct Blended Network

Background/Problem:

In order to meet the increasing volume of products, logistics and need for information, to not lose control over goods and search times, technical support is needed. Not only good goods-overview of the company promises long-term advantages, but also be ably of further develop a digital twin of the organization. One big issue is the integration and documentation of scans into the organizations ERP-System (Identified in a Gemba walk).

Current situation:

The goods-overview requires periodic and actual scans of the current situation in outdoor storages. The real time scan is important for the employees to go for the right storage places since the outdoor storage is very large. Every wrong chosen direction leads to high time lost. Since the goods are highly individual and produced by magnetic materials they cannot just be tagged with RFID tags, so another way of identification needs to be applied.

Goal:

To test drones to scan outdoor storage and identify goods with QR/bar codes.

System Beta (Form, Implement & Review)

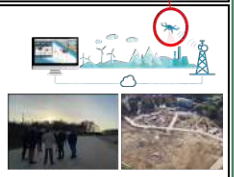
Blended Network Action

Action plan/Countermeasures:

Use of automated guided vehicles to scan the storage field in real time with drones. Automatically took pictures and footage of the storage space, scan of QR/BAR codes from the air could help to identify all goods and send information to the ERP-System with a cloud-solution.

Evaluation:

First problems appear in the evaluation with lack of scan- possibilities. Photos and videos are not giving enough information and the scan of RFID tags can be problematic because of magnetic materials. One solution could be to scan codes or color-codes from the air and send the information to a ERP-system. Here is the second problem: The connection to an ERP-system requires an expensive cloud-solution needs to be further researched. They expecting service-solutions by companies for this use case.



Review/Effect confirmation:

The feedback on the application was mostly positive but with many unsolved issues. Currently the solution works to find lost goods but doesn´t give the exact position of every product on the field.

System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

The research will be expanded to possible use cases of drones and other AGV with the hope to find more added values of the technology. The main problem could not be solved. Services of companies with the focus on such topics will be reviewed as well.

Reflecting over emergent learning:

- It is a simple and expandable solution.
- Results are mixed: Helpful but not a full solution for problems.
- Solution has to be reviewed for more use cases.
- Solution has to be reviewed for more AGVs.

Figure 5. Pilot 4: Goods identification with autonomous robotics

Remote maintenance support with smart glasses at the shop floor of ROSEN

LEAN 4.

System Alpha (Find, Face & Frame)

Identify & Construct Blended Network

Background/Problem:

In order to meet the increasing volume of products and need for information, access to the required information and solution for problems must be further developed for the shop floor at production lines. The solution should not only replace phone calls and speed up remote support processes, but also enables a variety of functions and applications by using handsfree devices and new technologies (identified via Gemba walk).

Current situation:

The remote support process requires the transmission of the current situation as a livestream, video or photos. For a smooth and efficient remote support it is also important that fast feedback and visual marks can be given by the helper because the products are highly individual.

Goal:

To test MS Hololens 2 smart glasses for remote maintenance support.

System Beta (Form, Implement & Review)

Blended Network Action

Action plan/Countermeasures:

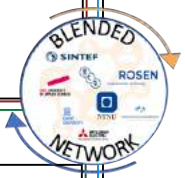
Use of Mixed Reality with a MS Hololens 2
Implement Remote Support software like "Remote Assist" from Microsoft and validate all possible use cases at the shop floor by analysing requirements and compare to alternatives.

Evaluation:

In the first department the use of the Hololens has proven to be very useful since it is easy to use and addresses all requirements: Employees can talk to professionals, hands-free and fast via livestream and can also record assembly processes to upload them to external experts as well. One issue needs still to be analysed: Possibilities to feedback from external helpers.

Review/Effect confirmation:

The feedback on the application was mostly positive. In the second case they expect connection-problems since the remote support needs to be applied in unexpected areas like forests.



System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

The shop floor workers all agreed that they want to continue working in this new way and worries that it was a one-time activity. They also have bad experiences with smart glasses like the Real Wear and need to be convinced.

Reflecting over emergent learning:

- It is a simple and expandable solution.
- MS Teams is a well known and professional solution.
- Results are mostly positive.
- Solution has to be reviewed for outside use cases.
- Solution has difficulties with WLAN Connections with hard safety barriers.
- As an improvement, recorded videos from the 1st-person view can be used as tutorials for new employees as well.
- Implementation of more smart glasses so people can connect with two smart glasses in one videoconference which could add value to the remote support cases.

Figure 6. Pilot 5: Remote maintenance support with smart glasses at the shoopfloor

Pick-by-Vision at ROSEN

LEAN 4.

System Alpha (Find, Face & Frame)

Identify & Construct Blended Network

Background/Problem:

In order to meet the increasing volume of logistics and need for information, access to the required information must be simplified. The solution should not only reduce the high running and working times, but also minimize the high paper consumption (identified via Gemba walk).

Current situation:

The picking process requires the use of both hands. For a smooth and efficient workflow it is also important that the order picker has access to the required information at all times to check the order data.

Goal:

To test out Pick-by-vision as a means of improving picking flow more efficiently.

System Beta (Form, Implement & Review)

Blended Network Action

Action plan/Countermeasures:

A Vuzix Blade (Smart Glasses).

Evaluation:

Pros:
- Simple expandable solution

Cons:
- Problematic for people with impaired vision
- Visualization of the pallet rack (suitable colour code)

Review/Effect confirmation:

The feedback on the application was mostly positive

System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

- A solution has to be found for people with visual impairment.
- Implementation of a finger scanner is planned.

Reflecting over emergent learning:

- It is a simple and expandable solution.
- Results are mostly positive.
- Solution has to be reviewed for people with visual impairment.
- Solution has difficulties with visualization of the pallet rack.
- As an improvement, images from real life may be inserted.
- Implementation of a finger scanner may improve the process.

Figure 7. Pilot 6: Pick-by-Vision

QC documentation by using Check-by-Vision at ROSEN

LEAN 4.

System Alpha (Find, Face & Frame)

Identify & Construct Blended Network

Background/Problem:

In quality management, the volume of criteria to be observed is also increasing. Documentation processes are becoming more complex, and many companies are working with inefficient use of paper. Above all, products are becoming more and more individualized, and the documentation effort is increasing, so that this process must be digitized and communicated quickly.(identified via Gemba walk).

Current situation:

In the pick-by-vision area, the Vuzix Blade comes with an offline-based programmed software that is in the same departmental area where quality management issues occur.

Goal:

To test Check-by-Vision process by using Pick-by-Vision technology.

System Beta (Form, Implement & Review)

Blended Network Action

Action plan/Countermeasures:

A Vuzix Blade (smart glasses)
With student help, new prototypes are
programmed and tested in quality management
to compensate for inefficiency and enable rapid communication.

Evaluation:

- Simple expandable solution/prototype.
- Checklist's character.
- Very easy to use and integrates with ERP system for seamless communication.
- Not an innovative solution with features, but merely a paper and enamel substitute.

Review/Effect confirmation:

The feedback on the application was mostly positive

System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

- A solution must be found for people with visual impairment.
- Implementation of a finger scanner is planned.
- A dynamic solution that can be integrated into the ERP system must be developed
- Further value-added services / use cases can be uncovered with this method

Reflecting over emergent learning:

- It is a simple and expandable solution.
- Results are mostly positive.
- Solution must be reviewed for people with visual impairment.
- If accompanying documents are in use, it makes sense to provide them with QR/BAR codes to enable scanning and thus simplify the bridge to the ERP system.

Figure 8. Pilot 7: QC documentation

Indoor positioning system (IPS) at Overhalla Betonbygg

LEAN 4.

System Alpha (Find, Face & Frame)

Identify & Construct Blended Network

Background/Problem:

Overhalla Betonbygg produces big concrete elements. In their WIP warehouse, they adopt zoning to locate the products and they store the information on paper sheets. Elements are however moved and changed of place, and most of the times the information are not updated, resulting in time losses for locating the elements.

Current situation:

Due to the fact that the update of the position of the elements is done manually by the operators and that sometimes they forget to update such information, elements needs to be searched throughout the WIP warehouse, and this takes on average 30 hrs/week.

Goal:

To test indoor position system (IPS) to eliminate time waste for searching components in the WIP warehouse.

System Beta (Form, Implement & Review)

Blended Network Action

Action plan/Countermeasures:

The company wants to simplify and render more accurate the location of the element. To do so, the company wants to automatize the locating operations in order to avoid the fact that operators might forget to scan the barcode. The company contacted NTNU who created a network (blended) with HAN and MCB, since MCB had some experience on tracking & tracing. Based on the indications of the company and on the discussions with MCB, the company decided to test the indoor positioning system (IPS) available in the Logistics 4.0 Lab at NTNU.

Evaluation:

The IPS was tested for one week at the WIP of Overhalla. Elements were tracked and traced thanks to the IPS tags placed on the elements. The results were ambiguous: some IPS tags provided accurate locations and some not.

Review/Effect confirmation:

The supplier of the IPS solution was contacted and it suggested some improvements in the setup. After such improvements, the IPS provided better tracking and tracing of elements. However, the environment under consideration (characterized by concrete elements) is not optimal for the use of IPS (as confirmed by the supplier), and further improvement actions need to be taken.

BLENDED NETWORK

System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

The company recognized the improvements provided by the IPS, which facilitated the location of the elements. The company is still using it and will keep using it borrowing it from NTNU, and they are in continuous contact with NTNU and the supplier to solve the existing problems. The system is, in fact, not always stable, with the location of the elements that is sometimes indicated wrongly by the system. If the collaboration with NTNU and the supplier will result in a stabilization of the system, the company will proceed with the purchase.

Reflecting over emergent learning:

The following are the main lessons learned:

- When implementing a new and advanced solution, the contact with the supplier is critical since it can solve issues, optimize the setup and assist with doubts
- A close collaboration between the company and NTNU was ensured by the fact of having a master student involved; in this way, the company and NTNU were brought closer and the student focused on carrying out the main activities.
- The blended part was useful both at the beginning, while determining possible solutions (blended network between the company, NTNU, MAB), and at the end when implementing the solution and carrying out actions (blended network with the supplier).
- However, when scoping and understanding the problem, the company needed to be supported physically by NTNU.

Figure 9. Pilot 8: Indoor positioning system for storage location

Kaizen Proforma's : Loading in Flow

LEAN 4.

System Alpha (Find, Face & Frame)

Identify & Construct Blended Network

Background/Problem:

The planning and loading of approx. 100 trucks is batch and push oriented where on daily basis the order intake ends 12:00 AM and picking is already started at 06:00 AM. This causes delays because the products are for 80% already picked, packed and transported to the loading docks while the trucks where the goods needed to be loaded on are not assigned yet. Result is that loading is slow due to time needed to search and locate the picked goods

Current situation:

Due to slow loading process the loading is not in time ready , so the trucks are not on time leaving the warehouse, which causes waiting costs and increasing the risk that goods are not in time delivered at the customer.

Goal:

To test pull instead of push at loading dock by planning and assigning prior to picking and packing.

System Beta (Form, Implement & Review)

Blended Network Action

Action plan/Countermeasures:

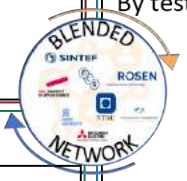
1) Different types of loading sequences were identified where it is possible to first plan the truck and then start picking/packing and loading.
A number of trucks and goods are assigned on daily basis after testing the new procedure.
2) Full Truck Loads or near Full Truck Loads are a second group of trucks which can be planned first before the picking starts. A change will be made in SAP where these shipments will be recognized before the picking starts so that the goods can be planned and assigned to a separate loading dock. Picking and packing will start after planning in order to eliminate unnecessary movements and search time in the loading docks.

Evaluation:

The number of trucks suitable for the new procedures is still limited to a few, where the idea is that more trucks or routes are possible to be planned at a pull manner. The change in SAP for FTL and near FTL recognition is not yet ready and will be implemented in January 2022.

Review/Effect confirmation:

Currently the procedure on daily basis is implemented and the crews are getting used to load several trucks during the day. The procedure will be extended to the FTL and near FTL trucks.



System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

It took some time to get used to the idea that a truck is first planned and then the picking and packing starts, but now it is a daily recurring operation for a few trucks and it will be extended to more trucks in the near future.
The change in SAP will be ready early December but already the warehouse departments are open to the idea of waiting with the picking of the Full Trailer of near Full Trailer Loads in order to avoid unnecessary movement of finished products.

Reflecting over emergent learning:

By testing the procedure and starting with 1 truck during a longer time of a number of weeks, the people get used with the advantages of planning first and the start picking etc.
Up to the point where the operators asked themselves for more trucks to use with the new procedure.

Figure 10. Pilot 9: Kaizen Proforma's: Loading in flow

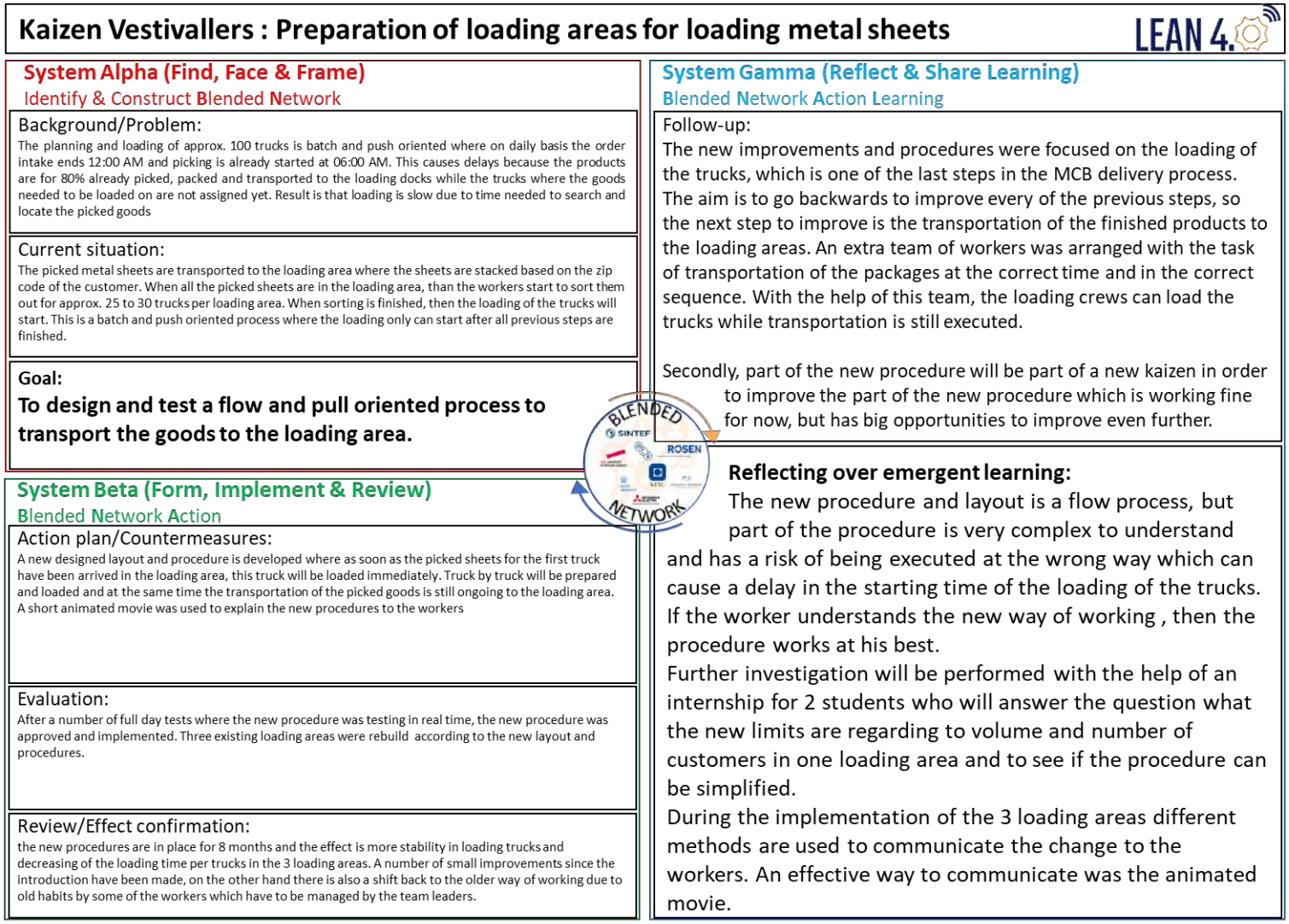


Figure 11. Pilot 10: Kaizen Vestivallers: Preparation of loading areas

Kaizen Pull Movers: Trucks in flow

LEAN 4.

System Alpha (Find, Face & Frame)

Identify & Construct Blended Network

Background/Problem:

The loading process of MCB takes place at 2 different warehouses and approx. 80% of the trucks must be loaded at both warehouses. This means that every evening/night approx. 70 trucks have to be transported from warehouse JFK to Warehouse De Vest and back to warehouse JFK. The main way of working is that first they focus on the transportation of all the trucks to De Vest and later in the process they focus on the transportation back to JFK. Result is that too much trucks are parked at the same time at the start of the loading process at warehouse De Vest which causes delays in loading because it takes too long to find the trucks or to walk to the right truck to drive the truck to the beginning of the process.

Current situation:

Up to 25 – 30 trucks are standing on daily basis at the entrance of the first building, waiting for the start of the loading. It is not known which truck will be used first or where the truck is standing at which location. It is a push and batch driven process.

Goal:

To design a flow and pull oriented process to transport the trucks between the both warehouses and between the loading areas where the right truck is at the right time at the right place.

System Beta (Form, Implement & Review)

Blended Network Action

Action plan/Countermeasures:

- A model was designed to overview the movements of the trucks between the warehouses to get a better insight in the status of the loading process.
- Part of the model is in use with the new procedures for the loading areas of sheets at warehouse De Vest. This is manually done
- In order to use the full model it is necessary that the movements of the trucks are automatically registered in SAP so that real time the location is known to everybody. This automated registration will be executed with the use of a GPS tracker on every trailer. With this real time information it is not necessary to transport all the trucks , but the trucks will be transport at the right time.
- An investigation was performed by 2 students in order to set up a model which influences the sequence of the loading of the trucks. The outcome proves that with different ways of sequencing of the trucks the throughput time of the total loading process can be decreased significantly.

Evaluation:

The real time tracking with GPS is still in development, so testing in real time was not yet executed. The manual part of the flow is daily in use, but is limited to 1 spot. Further investigation is necessary how to use the sequence on daily basis.

Review/Effect confirmation:

Looks promising, but too early to make conclusions

System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

-The use of the GPS tracking is necessary in order to change to a pull process of the trucks. In December 2021 the GPS interface will be ready and testing can start with the real time tracking during loading.

- To determine the best sequence, a simulation model is needed in which the daily shipments and loading bays are uploaded from SAP. The simulation model calculates the shortest throughput time which can be used to sent the trucks in the right order to the loading bays. This procedure has to be set up and tested in Q1 2022.

Reflecting over emergent learning:

- During the testing of the manually operated model it was clear that pull works better, but that a shift in thinking by the operators is needed to change from push to pull.
- And during the same testing it was obviously that manually booking of the status of the trucks results in low accuracy because manually a booking is easily forgotten to execute. If not all the bookings are made properly, than the information is useless to steer the daily loading process.

Figure 12. Pilot 11: Kaizen pull movers

Kaizen Kartrekkers: Shuttle process improvement

System Alpha (Find, Face & Frame)

Identify & Construct Blended Network

Background/Problem:

At location De Vest where the metal sheets products are produced and order picked, there are 4 buildings for the production and picking of metal sheets. In these buildings are over 31 halls and between these halls the products are transported from the one hall to the other hall and between the buildings to get the products to the right production or loading hall.
This shuttle process of products is on daily basis a complex process due to the huge number of different transportation combinations where also the goods needs to be transported to the right hall and the shuttle driver needs to know where to pick up the goods and where to deliver the goods.

Current situation:

Two tow trucks are transporting the goods which are loaded on a trailers with a max load of 20 tons. The goal was to be ready with transportation before 16:00 hrs, but after the kaizens regarding the loading process, the goal was changed to transport the right products at the right time to the loading areas.

Goal:

To design a flow and pull shuttle process to deliver the right products to the loading halls.

System Beta (Form, Implement & Review)

Blended Network Action

Action plan/Countermeasures:

- Because of the shift of the goal towards right time and right products in stead of all products before a certain deadline, the goods are divided in 2 priorities. Prio 1 (High priority) and the other products. The prio 1 products have to be picked, packed and loaded on the trailers in order to transport them as early as possible to the loading halls. When the right products arrive early , then the loading process can start with the first truck, while still the other products are moved to the loading hall.
- In the previous situation, the trucks and the workers in the shuttle process were delivered by the crewmembers of the loading teams with as result that every week other people were working in this process with a lot of communication errors and mistakes during the execution of the process. A change was made in de team organisation where a dedicated team leader and his team was assigned to the shuttle process in order to get a steady and consistent execution of the shuttle process.

Evaluation:

The new shuttle team has a daily , steady focus on the process and the first results are promising. Better communication because always the same workers are working in the shuttle process and they communicate to the same workers in the picking halls, this improves the execution because always the same people interact with each other.

Review/Effect confirmation:

The volumes in this part of the year are lower than usual, so they can easily can be ready on time. If the volumes will go up, than the process has to be checked if it also works with higher volumes.

System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

- Better procedures are being developed where the working times are being changed and where there is focus on transporting the right products.
- For 2022, an IT project is defined in order to develop digital tools to help with the steering and control of the different transportation flows.

Reflecting over emergent learning:

- This was an example where due to the every week changing of workers , the previous situation was a chaos.
- By founding a Shuttle Team there is now a steady execution of the process where the same people perform the same tasks and get experienced with the new process.
- Also an example where the solution was not to change the procedures at first but to change the organisational set up and put the right leadership on the new team. Later the procedures can be adapted or changed.

Figure 13. Pilot 12: Kaizen Kartrekkers: Shuttle process improvement

The company in 3D – CI platform

System Alpha (Find, Face & Frame)

Identify & Construct **B**lended **N**etwork

Background/Problem:

Throughout the organisation and culture of the company, continuous improvement (CI) is not yet widely accepted. To be able to rise in number of products (to be used in buildings) sold, built and maintained, we need to improve processes throughout the whole organisation. Problem is: the importance and know-how on CI is still insufficiently present.

Current situation:

Most employees don't see the urge to improve their daily processes, or don't have the know-how, time and appropriate tools to improve. Although we are preparing our company technically and physically for growth in number of products, our processes and CI-culture must develop with it, to create a sustainable company future.

Goal:

To create a platform that supports and nourishes the possibility for employees to start improving their processes and daily work.

System Beta (Form, Implement & Review)

Blended Network Action

Action plan/Countermeasures:

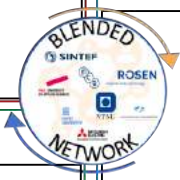
Creating a platform (3D platform - Dream Dare Do in multiple dimensions) build on management support, company long term goals and Lean-QRM world class performance knowledge, which allows our process development team to execute A3- improvement projects while coaching and teaching multidisciplinary teams of employees in the importance and approach of successfully doing A3-improvement projects. By doing so, we hope to be simultaneously improving our processes and creating an almost contagious 'learning by doing' environment.

Evaluation:

Although the platform and first few A3-project were widely embraced by employees (mainly because of them being directly responsible for their own process and learning how to improve it), the further development of the platform and start-up of new A3-projects was stopped due to management decisions. Management felt forced to try an other approach of improving on specific departments, because of some bad developments in the strategic-growth-plan.

Review/Effect confirmation:

Initially enthusiastic and positive, with great improvements in prospect. After the provisional "3D –CI platform" cancellation disappointment and confusion.



System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

- After multiple conversations between management and process development, the 3D-CI platform is still in provisional cancellation.
- Management keeps the option open to start the platform back up again in the future, but process development wonders and doubt if the support amongst employees has not disappeared.
- Further discussion is on hold.

Reflecting over emergent learning:

- The first few A3-improvement projects were a great start towards creating a breeding ground for continuous improvement throughout the organisation. One of the first projects even created a momentum at one of the departments, where the employees are now working together more than ever, towards a better and standardized process.
- Over all, the momentum for structured continuous improvement stopped. To start again with creating support amongst employees will take a lot of energy. Conclusion: once the ball starts rolling, don't stop the ball.
- However a good initiative does not always have to start with management support, it certainly needs the support of management to not stop.

Figure 14. Pilot 13: CI platform for a company in 3D

Implementation of new ERP system

LEAN 4.

System Alpha (Find, Face & Frame)

Identify & Construct Blended Network

Background/Problem:

Our goal was to set up a new production organization that would produce and deliver the newly developed lift within Europe. Because we wanted to produce the new elevator using the latest techniques, we needed a new IT system to support the new processes.

Current situation:

Our current IT system Acto does not have the ability to create and control production orders with our new machines and CAD software. This system is intended for the installation industry and not for a production organization.

Goal:

To set up a system that is able to communicate with the new machines and software and can administratively complete production orders.

System Beta (Form, Implement & Review)

Blended Network Action

Action plan/Countermeasures:

1. Make or buy decision
2. Proof of concept
3. Phase 1, basic process implementation
4. Follow-up phases to set up integrations
5. Optimizations based on test cases

Evaluation:

After going live with the system in July 2021 many reorganisation changes were made. Because of this the system had to be adapted as well. In addition, a maintenance plan / test plan for IT developments proved necessary. With a lot of connected systems there is also a risk of falling down after an update.

Review/Effect confirmation:

The system itself provides more overview / insight into current orders. This alone ensures better decision-making for new improvements.

BLENDED NETWORK

System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

- At the moment, we are still working on optimising the system, but we are not getting enough programmers to implement this quickly enough. The pace of improvement is therefore far from ideal. We are looking for a solution.
- Because we are still dealing with new processes, many changes are still being made. The effect on the design of the systems is sometimes still not clear. For this reason, discussions are being set up with the departments in order to better divide/arrange the tasks.

Reflecting over emergent learning:

- Provide a clear process overview of what needs to be implemented. This reduces changes afterwards.
- Provide enough test cases and give room to adjust the system based on the practical tests.
- The system to be selected must be easy to adapt afterwards so that optimisations will not have to wait too long. This must be part of the plan of approach.
- Make sure the integrations don't become too many. Many integrations create a lot of complexity.
- In the case of a buy decision, the supplier must be able to provide sufficient capacity for improvements afterwards. Agreements must be made about this during the purchasing process.

Figure 15. Pilot 14: Implementation of a new ERP system

Optimising warehouse space and resources

LEAN 4.

System Alpha (Find, Face & Frame)

Identify & Construct Blended Network

Background/Problem:

As a company we want to increase the production of lifts by at least 400%. This extra production has to be fed by parts from the warehouse. At the moment there is not enough room for this. Also, order picking in a large warehouse is becoming increasingly time consuming.

Current situation:

We have a small shelving warehouse of about 800m2 for the production of 150 lifts. This contains small material.

Goal:

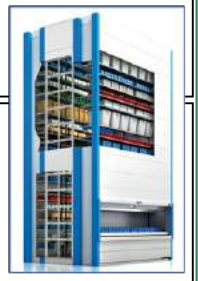
To optimize warehouse space and resources to provide production with the necessary parts.

System Beta (Form, Implement & Review)

Blended Network Action

Action plan/Countermeasures:

Looking for innovative ways to store small goods. Paternoster systems from Kardex seemed a good choice to reduce order picking time and space by 80%.



Evaluation:

The Kardex cabinet works great. It saves a lot of space and eliminates order picking time.

Review/Effect confirmation:

Pros: space reductive of 80%+ / low order picking time / less missing parts because one can not just take stuff.
Cons: People, like mechanics, can't take a quick look at the goods to verify they have the right part

BLENDED NETWORK

System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

- It is now even more important to get the data right in the systems. We are still missing photos, dimensions and other data.
- The kardex cabinet is already 90% full, have we chosen the right amount of cabinets or has our stock policy changed?

Reflecting over emergent learning:

- Good preparation is absolutely necessary
  - What numbers do you want
  - What items do you want
  - How many boxes do you need of each size
  - Does your system contain all necessary data such as
    - Photos
    - Dimensions
    - Type numbers
- Extra options like pick/put to light are really valuable options and well worth the money when you look at the whole investment.
- Don't work in a hurry. The kardex cabinet had to be ordered even before it was clear what the stock was going to be and how much was needed.

Figure 16. Pilot 15: Optimising warehouse space and resources

PROVE configurator

System Alpha (Find, Face & Frame)

Identify & Construct Blended Network

Background/Problem:

In order to achieve a better market position in Europe, we want to be able to make higher numbers with a more standardised product. At the same time, we want to do this as much as possible within the current available capacity. At the moment our processes and systems are not suited to run through the process from customer demand to produced lift quickly and efficiently.

Current situation:

At the moment all projects are being executed as an Engineering-To-Order (ETO) process.

Goal:

To setup a Configure-to-Order process for a new product line (PROVE), where all customer input is recorded in a Sales Configurator that is connected to a Product Configurator) and an ERP system

System Beta (Form, Implement & Review)

Blended Network Action

Action plan/Countermeasures:

The development of a Sales Configurator which records all customer requirements in the form of parameters. These parameters are input for the Product Configurator and the ERP system to make (automatic) drawings and to do the purchasing and production of the project.

Evaluation:

In the process of developing the Sales Configurator, the biggest challenge turned out to be aligning all interests: there are the interests of Sales to meet the customer's wish, the interests of engineering and production to keep the product technically feasible, the technical interests of getting the parameter data from A to B to C, and so on. Clear communication between all parties involved is essential to be able to meet the customer's wishes on the one hand and to keep it realistic and feasible on the other.

Review/Effect confirmation:

The initial process was difficult, because pouring customer wishes into a configurator automatically means that as a sales person you have less freedom to deviate from the standard options (that is after all the purpose of a standardized CTO product). But now we have found the right balance in customer wishes/manufacturability and we have a successful product.

System Gamma (Reflect & Share Learning)

Blended Network Action Learning

Follow-up:

- Improvements are still being made to the PROVE Sales Configurator and the CTO process. This mainly involves expanding the standard design scope to meet even more customer needs. In doing so, we must be careful not to make the technical model at the back end (product configurator) too complex to maintain.
- Also in terms of usability, there have been quite a few actions afterwards that are still ongoing, to make the configurator easier or more intuitive. A lift is quite a complex thing to configure so it would be going too far to put that on the customer, but the goal is that the salesperson together with the customer can fill in the configurator. To achieve this, the configurator still has to make some steps forward in terms of user friendliness.

Reflecting over emergent learning:

- During the development of the CTO process and the Sales Configurator we were meanwhile busy with the implementation of an ERP system, the design of the new product, and the change of the organization. There were many large projects running simultaneously, with many dependencies between the projects. This caused a lot of confusion, missing information and extra work.
- A master planning in which a logical sequence is indicated in each phase of the sub-projects would greatly help to make the development projects more efficient.

Figure 17. Pilot 16: PROVE configurator

4 Pilot Project Learning Process Descriptions

This section of the report provides a narrative of the pilot projects in which we describe the main elements, processes, modes of communication, and documentation methods for before, during and after the BNAL pilot project execution. We focus particularly on aspects of learning during the Smart Lean interventions – reflecting over system Gamma of the BNAL methodology.

On each A3 case given in chapter 3, smart technologies that were planned to be used are explained as *system Beta*, to solve the problems that are described in *system Alpha*. The following technologies and methods were tested in the case examples given in A3s:

- Smart glasses (assistive reality)
- Drone
- Virtual reality
- Digital twin / digital model
- Pick by vision
- Indoor positioning system
- Pull production
- Just in time (JIT)
- ERP system
- Paternoster vertical cabinet storage

The suggested technologies were then implemented, and their effects evaluated and confirmed. The review of this action learning process concludes *system Beta* of the BNAL methodology. Even though learning and reflection may (and should) occur during system Alpha and system Beta, the majority of learning process, sharing the learning, and reflecting occurs in *system Gamma* of the BNAL methodology. The following learnings and reflections were collected during all of the case examples that are summarized in the previous A3 reports:

- Complexity of the technologies.
- Difficulties on applications
- New discoveries and opportunities for future
- Anecdotical mostly positive outcomes
- Network collaboration (virtual meetings)
- Need for technical expertise to implement and/or support the smart technologies
- Smart technologies as smart glasses and VR that are not applicable for visual impaired people.

As explained in WP3, the facilitators of BNAL projects aimed to create safe learning environments to foster observation and reflection, and ultimately intra- and inter-organizational learning. Due to the unusual circumstances related to the pandemic, such learning environments were not able to be set as intended on majority of the cases. During the project, it is assumed that having blended network under Covid-19 situation would not be affected by having meetings virtually instead of physically, using smart technologies that would substitute physical activities, etc. However, some of the cases has shown that this assumption failed, due to the fact not all activities (particularly those involving action) can be converted to virtual. These outcomes are discussed further in the Chapter 5 more in details. On almost all the case examples, learning, reflecting, and sharing occurred in the intra-organizational network.

However, inter-organizational learning processes were mostly observed to be limited to physically-close partners, such as institutions, research centres within the same country.

5 LEAN4.0 Lessons Learned and Concluding Remarks

This section of the report provides key insights regarding critical issues, potential pitfalls, prerequisites, as well as limitations of BNAL in practice. We also offer avenues for further work beyond the LEAN4.0 project.

We have observed in the pilot case examples that the smart technologies that were suggested as solutions in system Beta turned into learnings, reflections, further discussions, new discovered opportunities, and new discovered problems in system Gamma of the BNAL methodology. Since commitment to learning is one of the six main components that make up the BNAL framework, having learning outcomes is desired for BNAL methodology. However, in some cases we have observed that by implementing smart technologies, instead of solving the problem, we have discovered (even created) more problems. This outcome underlines the fact that the smart tools themselves should be seen as countermeasures to the real problems which the firms are struggling with, rather than simply implementing them on a nice-to-have basis (Powell, Morgan & Howe, 2021).

In general, Covid-19 lock down measures disrupted the network's ability for international collaboration and physical mobility. Though virtual mobility became the default form of mobility during Covid pandemic, physical gemba visits and action-taking were severely hindered. Though many participants assumed that BNAL would work under covid lockdown measures, just as Revans (1971) suggests that there can be no learning without action and no action without learning; we can also conclude that there can be no *blended network* learning without *blended network* action! Gemba is the greatest teacher, and this requires that at least some actors in the network can gain physical access to gemba in order to carry out action and generate actionable knowledge.

On a more positive note, the LEAN 4.0 consortium agree that the BNAL method holds significant promise for advancing organizations on their digitalization journeys, with a particular emphasis on education current and future operations managers. We also recognize a need to advance beyond operations and involve representatives from other functions within the host organizations. As such, MCB and the HAN in the Netherlands and SINTEF and NTNU in Norway have already agreed to continue developing the BNAL methodology beyond the LEAN4.0 project and will already meet to continue this important work in January 2022.

6 References

ARGYRIS, C. 1993. *Knowledge for action: A guide to overcoming barriers to organizational change,* San Francisco, Jossey-Bass.

BALLÉ, M., JONES, D., CHAIZE, J. & FIUME, O. 2017. *The Lean Strategy: using lean to create competitive advantage, unleash innovation, and deliver sustainable growth,* New York, McGraw Hill Professional.

COGHLAN, D. & COUGHLAN, P. 2010. Notes toward a philosophy of action learning research. *Action Learning: Research and Practice,* 7**,** 193-203.

COUGHLAN, P. & COGHLAN, D. 2011. *Collaborative strategic improvement through network action learning: The path to sustainability,* Cheltenham, Edward Elgar Publishing.

DEMING, W. E. 1986. *Out of the Crisis,* Cambridge, Massachusetts Institute of Technology.

FREUND, Y. P. 1988. Critical success factors. *Planning Review,* 16.

GUBA, E. & LINCOLN, Y. 1994. Competing paradigms in qualitative research. *In:* DENZIN, N. K. & LINCOLN, Y. (eds.) *Handbook of qualitative research.* Thousand Oaks, CA: Sage.

INGRAM, H., BIERMANN, K., CANNON, J., NEIL, J. & WADDLE, C. 2000. Internalizing action learning: a company perspective. Establishing critical success factors for action learning courses. *International Journal of Contemporary Hospitality Management,* 12**,** 107-113.

LIKER, J. K. & HOSEUS, M. 2008. *Toyota Culture: The Heart and Soul of the Toyota Way,* New York, McGraw-Hill.

MARQUARDT, M. J. 2004. *Optimizing the power of action learning: solving problems and building leaders in real time,* Palo Alto, CA, Davies-Black Publishing.

POWELL, D. J. & COUGHLAN, P. 2020. Rethinking lean supplier development as a learning system. *International Journal of Operations & Production Management*.

POWELL, D. J., MORGAN R., & HOWE, G. (2021) *Lean first…then digitalize: a standard approach for Industry 4.0 implementation in SMEs.* In: Dolgui A., Bernard A., Lemoine D., von Cieminski G., Romero D. (eds) Advances in Production Management Systems. Artificial Intelligence for Sustainable and Resilient Production Systems. APMS 2021. IFIP Advances in Information and Communication Technology, vol 631. Springer, Cham. https://doi.org/10.1007/978-3-030-85902-2_4

REVANS, R. W. 1971. *Developing effective managers: A new approach to business education,* New York, Praeger.

REVANS, R. W. 1982. What is Action Learning? *Journal of Management Development,* 1**,** 64-75.

RICHARDSON, T. & RICHARDSON, E. 2017. *The Toyota engagement equation: How to understand and implement continuous improvement thinking in any organization,* New York, NY, McGraw Hill.

SHANI, A. R. & DOCHERTY, P. 2003. *Learning by design: Building sustainable organizations,* Oxford, Blackwell.

SHOOK, J. 2008. *Managing to learn: using the A3 management process to solve problems, gain agreement, mentor and lead*, Lean Enterprise Institute.

SYDOW, J., SCHÜßLER, E. & MÜLLER-SEITZ, G. 2015. *Managing inter-organizational relations: Debates and cases*, Macmillan International Higher Education.