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DIAGNOSING OPERATIONAL EXCELLENCE PERFORMANCE

Tarkastaja: Professori Janne Huiskonen

TIIVISTELMÄ

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Diagnosing Operational Excellence Performance

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Eurofins toimii testausalalla ja sillä on yli 900 laboratoriota maailmanlaajuisesti. Yritys kasvaa huomattavaa vauhtia orgaanisesti sekä yritysostojen kautta ja pyrkii kehittämään toimintaansa yhtenäisesti Lean-periaatteiden mukaisesti. Tämän takia Eurofinsin konsernilla on oma Operational Excellence tiimi, joka koostuu kokeneista Lean-ammattilaisista, jotka matkustavat arvioimaan ja kehittämään laboratorioita globaalisti.

Tämän diplomityön tutkimushaasteena oli se että, corporaation Lean tiimin jäsenet tekevät tällä hetkellä viikon kestävän laboratorion arvion eri tavoin. Tämä johti siihen että, riippuen tiimin jäsenestä laboratorioille tuli erilainen kehityspolku. Yritys halusi yhtenäisen mallin, jonka avulla laboratoriot arvioidaan globaalisti, ja jonka avulla jokainen laboratorio pystytään arvioimaan viikossa yhtenäisesti.

Nykytila-analyysi suoritettiin haastattelemalla Lean-tiimin jäseniä, jonka pohjalta pääkehityskohdat tunnistettiin. Tämän pohjalta myös laboratorio-alan erikoisuudet pystyttiin tunnistamaan ja huomioimaan myöhemmin työssä.

Kirjallisuuden pohjalta pystyttiin määrittämään Leanin neljä pääelementtiä, jotka tulisi arvioida. Pääelementit ovat: Työkalut, Mittarit, Järjestelmät ja kulttuuri. Jokainen elementti lisäksi koostui useista eri alaotsikoista, joita tunnistettiin yhteensä 23. Kirjallisuuden mukaan myös yleisin tapa diagnosoida operatiivista kyvykkyyttä on maturiteetti-mallit.

Kirjallisuuden, haastatteluiden sekä Eurofinsin toiveiden pohjalta luotiin maturiteettimalli, koulutusaineisto, aikataulu sekä esityspohja. Näiden avulla jokainen tiimin jäsen ja myös ulkopuolinenkin pystyy analysoimaan operatiivisen suorituskyvyn yhtenäisesti.

ABSTRACT

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Eurofins is a testing company and it has over 900 laboratories globally. Company is growing with significant speed organically and in-organically. The company is developing the operational performance using Lean-principles. Therefore, Eurofins corporation has Operational Excellence team which consists of highly experienced Lean experts who travel globally to different labs to diagnose and improve the operational performance of the labs.

The research challenge of this thesis is that Eurofins Lean team members perform the one-week operational excellence performance diagnostic differently. That leads to creation of different kind of improvement roadmaps for the labs depending on the member of the team. The company wants one unified model which would allow them to diagnose the labs globally through one agreed way.

Current state analysis was done by interviewing the Lean-team members, and based on the interviews the existing challenges were identified. During the interviews the Lean-team members also explained the differences and challenges of the laboratory testing when comparing it to the regular industrial work.

Based on the existing literature four key Lean elements were identified which are: Tools, KPIs, Systems and Culture. Each element consists number of topics and total of 23 topics were identified. The literature also pointed out that the most common way to diagnose operational performance is the maturity models.

Based on literature, interviews and Eurofins wishes a maturity model, training material, schedule and result presentation template was created. By using these tools each member of the team are able to perform the diagnostic the same way.

FOREWORD

Completing the master studies has been a dream for years. When writing these foreword of the thesis, and the actual thesis is finalized, and only couple papers are still to be returned until the masters' diploma will be achieved. Feeling is unreal, as there were moments when finalizing the studies and especially the thesis seemed to be so far away. Now when the university studies are finalized, it is time to focus on work, family and friends.

I want to thank especially my family, friends and co-workers who has supported me during the studies and when writing the thesis.

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Harri Palomäki

SISÄLLYSLUETTELO

1 INTRODUCTION

1.1 Background

Operational Excellence and Lean has become a widely known topic around the globe in many different industries. It started from automotive industries and was quickly adopted by many different manufacturing companies. Still many people think it as a tool only used by heavy industry manufacturing companies.

The case company of this thesis is Eurofins. Eurofins is a large European testing company which has over 900 laboratories and 47 000 employees all around the globe. Testing covers almost everything on the planet, but the biggest divisions are Food & Environment, Clinical Testing and Microbiology. Eurofins does not manufacture anything, but instead test customer samples and the product of the Eurofins is the result report.

Most of the laboratory companies globally do not focus on Lean, because laboratory companies do not have raw materials, work is scientific and laboratory cannot fully control when the production can be started as the sample is provided by the customer. In Eurofins Lean is highly valued and the target of the company is to shorten Turn-Around-Time (TAT), Improve Quality and improve the customer experience through implementation of Lean

1.2 Thesis aim, problem and scope

In Eurofins the Lean has been successfully implemented widely and the testing volumes are increasing rapidly. Eurofins buys many smaller labs every year, and the aim is to merge those as well as possible. Therefore, Eurofins Group has Operational Excellence team which consists of Lean experts. The Lean Expert travels to the site and has one week to do a full operational excellence performance diagnostic which reveals all bottle necks, improvement needs and process potential. Following the diagnostic, the Lean Expert creates a development roadmap for the lab and helps the lab to go through the transformation during the following months.

At the beginning of this thesis, the diagnostic was done differently between different experts which ends up to variety of different results. Due the different results the roadmap for labs differentiate depending on the expert.

The aim of this thesis is to define standardized way to do the performance diagnostic at the lab which would work globally for all kind of labs and could be performed in a week.

The scope of the diagnostic also includes creation of the supporting material needed for the diagnostic which may include check lists, maturity models, slides or other kind of supporting material which is suggested by this thesis. The material does not need be created from the scratch as Eurofins Group already has large amount of material created. The scope does not include transformation and project management that will take place after the diagnostic week.

1.3 Research questions and deliverables

Prior the research the thesis worker and Eurofins defined five major research questions and five deliverables.

The **research questions** to be answered are:

1. What are the things to be evaluated when evaluating the lab performance?
2. How the labs should be evaluated and graded?
3. What are the criteria and scales for each thing to be evaluated?
4. What are the criteria how the development projects are chosen and validated?
5. How will the results be presented?

Each of the questions above focus on how the performance can be evaluated in such a short time with high quality. The number things to be evaluated needs to be limited to the most critical ones.

The research **deliverables** are:

1. Lab evaluation template
2. Updated 5-day schedule which tells in which order the lab should be evaluated
3. Create/combine from the existing material one presentation that covers the entire evaluation week
4. Template to present the results
5. Extensive report on the background of the chosen things to be evaluated

Aim is to hand out to the Eurofins the supporting material needed to perform the diagnostic in one week.

1.4 Research methodology

The research methodology of this thesis is qualitative. As the thesis does not focus on a single process, lab or even country, the decisions needs to be made based on the qualitative principles. Also existing Lean material from laboratory environment is very limited, which means many of the theory researched for this thesis is not made for laboratory environment and needs to be validated and evaluated if it will work in the labs before use.

Therefore, the research is also inductive and requires making conclusions and combining the existing information and based on those making new theory for operational excellence in a lab.

1.5 Structure of the thesis

The thesis will start with the short introduction to the topic, which gives the reader an overview of the thesis and the problem to be solved.

After the introduction the current situation analysis will be done, as the current situation is not clear and the clarification of the current situation includes number of interviews. Based on the interviews the things to keep and things to be improved should be clarified. The current situation analysis should also have effect on the theory to be studied as the improvement points are clear.

The existing theory research will follow the current situation analysis. Theory will aim to well-known Operational Excellence and Lean evaluation literature. The aim is to find existing performance evaluation methods and best practices. Due the lack of the lab environment Lean theory, the applicability of the theory in a lab environment will be evaluated by the researcher and Lean experts.

After the theory research the new Eurofins best practice model will be created, defined and instructed.

At the end of the thesis the results will be evaluated and the thesis questions will be answered.

2 CURRENT SITUATION ANALYSIS

In this chapter the current situation will be first determined with number of interviews and existing material. After the current situation is clear it will be analyzed and potential bottlenecks analyzed.

2.1 Structure of the Lean organization in Eurofins

Eurofins is a de-centralized organization which does not have a matrix organization structure. Therefore, each one of the 900 laboratories in Eurofins has more freedom and responsibility to structure and develop their laboratory in a way local leaders decide. Of course the group gives guidelines, but the control of the group is not as strong as in most of the large centralized organizations.

Eurofins Group has Lean/Operational Excellence team that consists of the global manager and nine program leaders reporting to him. Each one of the program leaders are highly experienced in Lean and hold global degrees/belts which makes them matter experts. The group Lean team arranges number of different kind of Lean trainings through class rooms, skype, e-learning and online material. The most popular training is the 5-day Local Lean Manager training which is held once per quarter in Asia, Europe and US. The laboratories send employees who are responsible of the development of the operative performance at the lab to the training.

After the lab has at least one person who has attended the training and whose responsibility is to develop the operative performance, the lab can request for corporate Lean support.

Corporate Lean Support means a Lean Program Leader from the group will travel to the site and do with the local lean manager a five-day full diagnosis to the site. After the week the laboratory will have a full development roadmap to follow, with steps and improvements clarified. After the roadmap and plans are created the local Lean manager is responsible of driving the projects forward at the laboratory. The Group Program Leader will support the local Lean Manager with a visit every month or so for the following 4 – 12 months, but the main implementation responsibility is at the local manager.

This thesis focuses on improving the standard method of diagnosis week where the development projects, roadmap and steps are determined. Currently the members of the Group

Lean Team perform the diagnostics differently, which leads to different roadmap, projects and results depending on who performed the diagnostic.

2.2 Current Diagnostic

Current state analysis of the diagnostic was made through 7 interviews of the Group Lean Team members. Also the writer of this thesis is a member of the team and does diagnoses to many sites every year. At the time of the interviews the team consisted of nine members and the manager, where two of the members had just started and had no experience in Diagnostic and one of the members is the writer of this thesis. Therefore, only 7 valid interviews took place.

Four out of seven members interviewed said they do not have a standard structure for the diagnostic. Each one of these members are experienced in Lean and therefore during the diagnostic they are able to observe at the lab the needed improvements quickly without structured schedule or plan. Also each one of these four members said the labs differentiate significantly from each other in terms of business, Lean status and targets which makes it harder to have standardized way of diagnosing the labs.

Three members of the team had structured way for diagnosis and the structures were very close to each other. Each one of these members described three different stages of the diagnosis, which were: Prior the diagnostic week, During the diagnostic week and after the week. Next chapters will define the current situation of each of these stages.

2.2.1 Actions prior the Diagnostic

All of the three members held several Skype calls with the labs being diagnosed before the diagnostic week. Each one of these members held the first call 4-10 weeks prior the diagnosis week. The first call worked as introduction call for both parties as in most cases the Program Leader had not met the laboratory personnel before. During the first call they wanted to clarify and agree on the following things with the laboratory:

- Short introduction on what the lab does
- Current Lean Status of the lab
- Local Lean Manager qualification & Availability (Has the person attended Group 5-day training)
- Targets set for the Lean support by the lab (TAT, Business, Quality improvements)

- Schedule the Diagnostic week
- Agree the next steps (Lean Survey, Data Collection, Reservations, Agenda Creation, Next Call)

Overall the purpose of the first call is to create a high level understanding of the current situation at the lab and what are the areas where the lab wants to focus on during the Lean support. Most of the sites have set targets for the support, as they had to determine those when requesting for the Group support.

The agreed next steps always included that the site had to complete the Lean Survey which is an evaluation form which consists of 15 different key Lean topics. For every topic there is defined five different levels which are described in detail at the form. After reading the descriptions the lab has to identify at which level they are at. Then based on the answers the lab management and Group Program Leader can define which areas should be improved and focused during the diagnostic week.

The labs are also requested to collect data from the areas of being improved. Usually labs want to improve certain processes at the lab. Because the diagnostic weeks are short, the labs are requested to measure and collect all the necessary data prior the diagnostic week.

These three members also made the lab to be responsible of the agenda creation. The group team has made an example agenda with all Lean topics as a guideline for the lab, but the group members request the lab to create the agenda because they know their local lab better, and are able to define the things they want group lean team to focus on. Also as the agenda requires many invitations, reservations and other set ups, it is easier for the local manager to do the arrangements. The team members had observed few challenges with this approach. Sometimes local managers do not always know the importance of some topics because they have not implemented them yet and are not familiar with them. Therefore, they do not put those into the agenda. Other pain point is that the lab schedules too many topics for one week, or leaves too little time for some large topics. Therefore, the Group Lean Program Leaders always schedule a call where they go through the agenda with the local Lean Manager and clarify each point and align thoughts about the agenda.

The first call with the site was very similar with all of the three members. But the schedule of the next calls differentiated quite much. One of the members held first call eight weeks prior the diagnostic, second four weeks prior the diagnostic and after that every week until the week of diagnostic. Other members held only total of two to three calls total. No matter the schedules were different, the common factor was to keep the first call over a month prior the diagnostic and last call the week before. The call schedules between the first and last call did differ. But each of those calls between the first and last calls were maximum 30 minutes and mostly just updates on the data collection, agenda and other questions and changes.

Each member held the last call on the week prior the diagnostic. During that call the agenda, data, Lean Survey and all other topics were clarified in detail and made sure that everything is in place.

The main purpose of all the calls and actions prior the diagnostic week was to prepare all required material upfront and make the diagnostic week as efficient as possible. The purpose of the calls was not to diagnose or develop the processes yet.

2.2.2 Diagnostic week

The diagnostic week is always from Monday to Friday. For the week the local lean manager had to be fully available for the entire week. Very often the team leader or lab manager also works as the Local Lean Manager, and therefore for the diagnostic week the calendar needs to be free. Also the local BU/Site manager has to be on the site during the diagnostic week as he may be needed for certain decisions.

Each one of these three members including the thesis writer usually followed the same “rough plan” for the week:

- Monday – Quick introductory to site, targets, who is who, quick lab tour
- Tuesday – Operational performance observations, Operational Improvements
- Wednesday – Data analysis, Finishing the operational improvements
- Thursday – Management Routines, other topics
- Friday – Wrap up, planning, Next steps

Some of the topics were analyzed on different date and lab specific areas were added for certain labs.

Monday was always an introductory to the site, where the Lean Program Leader wanted to understand all the needs, challenges and what the site is actually doing. The lab tour was always a high level tour where the purpose was to give the Lean Program Leader a high level overview of the lab.

On Tuesday usually the in detail operational analysis took place, where the KPIs, data and actual processes in lab were analyzed. Operational analyze in the lab consisted of observations and interviews. Based on the analyze the Program Leader usually identified many improvement points and listed those up.

On Wednesday the Tuesday results and remaining data was often analyzed and improvement projects were defined.

On Thursday usually the management routines were analyzed and lab specific other topics were gone through. On Thursday usually the roadmap and exact project plans were created.

Friday was usually left for wrap up, finishing up the plans and defining the next steps. Very rarely on Friday new topics were introduced.

At the end of the week the target is that the roadmap has been created for the lab including several projects that are scheduled. The lab should also feel confident when starting the implementation of each project. The next steps including next visit should also be identified. Each of the days during diagnostic also included Lean training in topics. The purpose of the trainings is to teach and coach more people at the lab which should create awareness into Lean and also help the implementation.

Some of the members also created a PowerPoint or some other file for the lab which summarized the entire week and diagnostic.

2.2.3 Actions after the diagnostic week

This thesis mainly focuses on the diagnostic week, therefore all the other actions related to the site supports are not described in detail.

After the diagnostic week each of the three members including the thesis writer scheduled a follow up calls with the local manager. The purpose of the calls was to identify the status of the projects, help the local manager and also identify if some of the projects needed to be improved/changed.

The next visit of the Group Program Leader usually took place in 4-8 weeks after the diagnostic.

2.3 Diagnostic Challenges

The team members had identified several challenges with the current diagnostic but also most of the members said one standard diagnostic method would not fit all the labs.

The members who did not follow the existing diagnostic method did not like the method as they always fully tailored the diagnosis to the lab. Some of the members also said they don't call it diagnostic as usually when they go to the lab they can immediately see what needs to be developed. This kind of observation method is also called Ohno-circle where the expert looks for a central place in the lab and stands in the central place and observes the processes in the lab. Experienced Lean expert can identify number of improvements just by observing.

The challenge if the support is done only through observations is that not all of the Lean topics are went through systematically. Also data may not be looked at all. Pure observation may therefore lead to limited results, which could be enhanced with standard agenda.

The other challenge admitted by members who did not have agenda prepared, was the availability of the lab employees. When the agendas are prepared weeks prior the diagnostic the availability can be ensured.

2.4 Summary of the current situation

Three out of seven members interviewed does follow somehow standard method in diagnosing the labs. The members who do not follow standard method at all, usually fully tailor diagnostic agenda or go without prepared agenda, and trust on their ability to observe the challenges.

The members who were following the diagnostic agenda were able to divide the diagnostic to three different phases which were: Prior the Diagnostic, During diagnostic and after the diagnostic. Each one of the phases included several steps which were described in chapter 2.2.

The Eurofins Group has plenty of Lean and Diagnostic material available already which can be used for this thesis.

Based on the observations during the interviews the thesis writer believes one standardized diagnostic method can be created to unify the diagnostic done by different members of the team. The agenda needs to a have little bit space for adjustments that can be made for some of the labs, but it should unify the topics that are being analyzed during the diagnostic, to ensure all of the potential improvements are considered.

3 BEST PRACTICE THEORY

In this chapter the existing best practices for diagnosing operational excellence in the literature are being described. As Lean is very large topic, and it has changed over the years, first the key elements of Lean will be determined based on the existing literature. Three well-known models created by the famous Lean writers has been chosen, as these writers has done over 20 books about Lean over the years. After the key elements based on these three different models are determined each one of the elements will be investigated and key components of each element will be described.

3.1 Key Elements of Lean

Originally after second world war Lean was mainly just a set of tools that were used in organization to improve processes quickly. Lean has developed significantly after that to much larger topic including many different elements. Therefore, this theory will start from determining which are the key elements Lean consists now days, and which should be evaluated when performing operational excellence diagnostic.

The Shingo Prize model which is one of the most well-known operational excellence model and prize, determines five key elements in Lean: Culture, Guiding Principles, Systems, Tools and Results. Based on Shingo those are the key elements which each one consists of number of components that are being evaluated during the Shingo Prize. (Huntsman, 2020)

Marc Helmold also in his book *Lean Management and Kaizen* determines Culture as one of the key elements of Lean. He also determines tools, guiding principles and KPIs as the key elements. All these four key elements described by Helmold are described quite the same way as Shingo has described them. Some differences are visible though. (Helmold. 2020)

The Lean Manufacturing which is written on 2000 by William M. Feld also defines five different key elements of Lean which are: Manufacturing Flow, Organization, Logistics, Metrics (KPIs) and Process Control. (Feld, 2000)

Feld describes the Organization very closely the same way as Shingo and Helmold describes Culture. Each one of these writers also evaluate the culture in their books. Therefore, one of the elements that needs to be taken into the future model is Culture.

Also each one of these writers describe KPIs as the key element of Lean. They determine KPIs as the enablers to be able to steer the company to the chosen direction and prove if the systems are working. Therefore, KPIs will be also taken to the future model.

Shingo also describes Systems as processes and workflows that has been put in place to make the organization work. They are put in place to enable the leaders shift from firefighters to process developers and enablers. Feld describes Process Control the same way and the importance of standard working procedures has been highlighted also in the book written by Helmold.

Tools are also the obvious one that all three books mostly consist of. Feld described Manufacturing Flow and Logistics as individual elements, but those are in other books seen as tools.

The last thing are the principles. Helmold and Shingo both described certain amount of principles that company should adopt. But Shingo also wrote that principles are part of the culture. Therefore, Principles will not be treated as separate element. They will be treated as culture enablers in this thesis.

Therefore, the four main elements of Lean based on the literature are:

1. Culture
2. KPIs
3. Systems
4. Tools

3.2 Lean Culture

The foundation of an organization is the culture. Culture change is usually driven through several systems and tools. Each one of the systems targets to create a long-term, principle-based culture which drives sustainable organizational excellence, instead of policy driven short-term organization. Every organization consists of individuals and when organization is able to create productive improvement focused culture, the individuals feel empowered and the organization can grow. (Huntsman, 2020)

William Feld described organization culture as *"Those activities that go on within a company when management is absent"*. Feld says the hardest and the most lucrative part of Lean is to implement the Lean way of thinking to everyday culture. (Feld, 2000)

Shingo and Helmold describe that the organizational culture should be implemented using ten principles. Table below shows the principles defined by both.

Table 1 Ten quiding principles defined by Shingo and Helmold

Ten Guiding Principles	
Shigeo Shingo	Marc Helmold
1. Respect Every Individual 2. Lead With Humility 3. Assure Quality at the Source 4. Improve Flow & Pull 5. Seek Perfection 6. Embrace Scientific Thinking 7. Focus on Process 8. Create Value For the Customer 9. Create Constancy of Purpose 10. Think Systemically	1. Challenge People to Think 2. Lead by Example 3. Take Lots of Leaps of Faith 4. Create an Environment Where It Is Okay To Fail 5. Eliminate Concrete Heads 6. Be a Great Teacher 7. Show Respect To Everyone 8. Motivate Your Followers 9. Develop a True Team Environment 10. Encourage People to Make Contributions

Helmold and Shingo both have defined several key guiding principles that point out the importance of the Lean leadership. In Lean leadership the leader should respect, trust, involve and teach the employees and lead by example. Leader should lead with questions and admit they do not know everything. Overall the leader should participate much more than in the classic non-Lean organization. (Helmold, 2020)

Once everyone feels their work and themselves are respected they feel empowered and are willing to improve. To be able to make everyone feel they are respected, everyone should always remember when challenges occur to attack the process instead of people. (Huntsman, 2020)

However, culture change always takes time and it requires a shift in behaviors and systems that drive behavior. Culture change is only possible if the leadership is committed to it. (Huntsman, 2020)

When evaluating the culture in organization the employees needs to be interviewed. In Lean culture the employees are aware of Lean principles and they feel they are able to improve processes and they are respected. They are being taught and valued.

3.3 KPIs

To be able to lead the change and steer the organization to the right direction Key Performance Indicators (KPIs) are required. However too often organization uses KPIs that were just easy to measure at the point of the KPI creation. That leads to KPIs that are not relevant to the team observing them and do not help to reach the targets set for the organization. The KPIs and targets should always be linked to the organization strategy. (Huntsman, 2020)

William Feld writes that "*We are what we measure. … Improvement comes only from that which is visible. … A hidden problem reveals nothing.*" He states that KPIs make problems and success visible and quantifiable. After the KPIs are in place, the most important thing is that every KPI has an owner, and the owner knows how the metrics work and how to make the factor rise or fall. (Feld, 2000)

Dimitar Karaivanov (Karaivanov, 2019) defined seven most important Lean KPIs which were:

1. Average Lead Time (Minutes/Hours)
2. Average Cycle Time (Minutes/Hours)
3. Distribution on Effort (%)
4. Number of Items in Progress (Count)
5. Number of Open Issues (Count)
6. Number of Customer-reported open Issues (Count)
7. Number of Recurring Issues

Dimitar also highlights that every Lean Metric should assist in identifying true value from the perspective of your customer. The metrics should measure value added and non-value added operations and help streamline the processes. (Karaivanov, 2019)

If KPIs are not reviewed frequently they do not bring value for the company. Therefore, in Lean the standard performance management meetings take place often every day or once a week. Performance management meetings are not only for the top management, but for each level of the company from the top management to the laboratory operators. In the laboratory level the performance meetings usually take place in front of the white boards at the laboratory and they last no longer than 5 – 10 minutes. The KPIs needs to be important for the team reviewing them and the team needs to have a possibility to affect the metrics on the board. (Ras, 2015)

3.4 Systems

In this topic the systems do not mean IT systems. Systems stand for all the structured systems that organization has created to make the organization work. The Shingo Model defines three different kind of systems: management systems, improvement systems and work systems.

With standard systems and processes in place, the primary role of managers should shift from firefighting to designing, aligning and improving these systems. The purpose of the management system is to develop the system leaders. The improvement system focuses to make the organization better and the work system focuses purely on the workflows. Each one of these systems should be visible on the organization. (Huntsman, 2020)

Standardizing the systems and processes work a certain way is the key in Lean. Classic work organizations rely on skilled individuals who are free to do the job the way they feel the best, as long as the job gets done. That causes variability in process quality, lead time and end process. Also when process is not standardized it is hard to develop. Feld underlines that whenever process is developed, after that it should be "Locked down" as new standard. After the process has been developed, the operators should continue continuously looking for improvements. (Feld, 2000)

In order to achieve the process control and standardized processes and to be able to improve them further on, Feld suggest implementation of six Lean tools:

1. Single-Minute Exchange of Dies (SMED)
2. Total Productive Maintenance (TPM)
3. Poka-Yoke (Fail Safe)
4. 5S (Housekeeping)
5. Visual Controls

6. Graphic Work Instructions.

Feld says these six tools help to achieve the process control in operation side. For continuous improvement he suggests Just Do It program, Standardized Gemba Walks or other standardized program that drives continuous improvement. (Feld, 2000)

Each one of the six tools listed above will be described in chapter 3.5 where other Lean tools are also described.

3.5 Tools

There is a number of Lean tools available. The tools are the key of creating the culture and change in the organization. Therefore, in this thesis the tools are discovered in depth as the diagnostic focuses on the implementation and results of different Lean Tools. As Eurofins is the leading company in Laboratory Lean, one of the sources is also the Lean Book which is created by the Eurofins.

3.5.1 Choosing the right tools for laboratory environment

The laboratory environment differs significantly from regular production. The greatest differences between regular production and laboratory are:

1. Lab cannot choose when to start the production, as the customer sends the sample and that works as a trigger
2. As the lab does not build anything, there is no raw materials. Only some consumables used for the lab equipment
3. Most of the lab machines work with batches. So one machine takes 96 – 384 samples in at once, and process them at once.
4. Work is more scientific

There are almost 100 different tools for Lean production. Based on the differences to regular production described above, the writer has chosen from the existing literature in cooperation with Eurofins the Lean tools that are relevant for laboratories, that will be described in the next chapters. The decision which tools to include was done with the team, as several members of the team holds global Lean Black Belt or Master Black Belt the decision makers were very well aware of the use and the applicability of each tool.

3.5.2 7 Wastes

The core of Lean are the seven wastes. All of the other tools focus on minimizing the seven Wastes. The seven wastes have an acronym TIMWOOD and the wastes are:

1. **T**ransportation
2. **I**nventory
3. **M**otion
4. **W**aiting
5. **O**ver-production
6. **O**ver-processing
7. **D**efect

The first waste Transportation stands for transporting samples, tools, information or anything else. Transportation is a non-value added activity which customer does not pay for. Transportation can be minimized with several tools described below. (Pinto et al. 2018)

Inventory should always be minimized and optimized. Inventory takes space which could be used for other activities. Also having big inventories costs for the company significantly, and there is always numerous risks with inventories including due dates. (Sayer, 2007)

Motion is the most common and often obvious waste in the process. Motion stands for people or samples moving during the operations. Motion can be significantly reduced by improving the layout and 5S which will be described in the following chapters. (Ras, 2015)

Waiting means time which operator is waiting for machine or any other action to perform. Customers do not pay for the waiting, as during the waiting time next steps or tests could be prepared, which would save time on the next run. (Tapping, 2007)

Over-production stands for producing too much. In Lean the aim is to produce as much as required at the time when required. Producing without demand causes growing inventories and the time could be used for producing products that have demand. (Sayer, 2007)

Over-Processing means producing something too much or creating quality that the customers does not even expect or pay for. In Lean the products should always meat the customer requirements but additional steps should be reduced. (Ras, 2015)

Defects are the worst one of the seven wastes as all the work, motion, inventories and other wastes are already used to produce the product, and at the end of the process the product does not meet the requirements so all the efforts were wasted. (Ras, 2015)

3.5.3 Single-Minute Exchange of Dies (SMED)

Single Minute Exchange of Dies (SMED) focuses to reduce the changing times between products. The changing time is defined as "*the time elapsed from the manufacture of the last valid part of a series to the production of the first correct part of the next series*". The changeover times becomes significant when production is aiming for just in time production, where large batches are being avoided, and more changeovers take place. (Pinto et al., 2018)

Main tools of SMED are to improve the layout (5S and organizing), synchronizing and simplifying tasks and preparing the tools and other needs prior the change. In SMED operator tasks are divided to two categories:

1. IED (Input Exchange of Die) – Tasks that can only be performed when the machine is not running
2. OED (Output Exchange of Die) – Tasks that can be performed while the machine is running.

After the steps tasks are categorized, the IED things needs to be evaluated and determined if they can be improved or removed. OED tasks should be synchronized so all of the OED tasks are completed before the machine stops running. Very often with this categorization and re-organization operator may achieve up to 30% improvement in changeover times. (Pinto et al., 2018)

After all the steps are identified and categorized a standard working procedure for executing them has to be put in place, to minimize the variation and to achieve the best performance level available. (Sayer, 2007)

3.5.4 Total Productive Maintenance (TPM)

Total Productive Maintenance (TPM) is a toolset used for minimizing the downtime of machines. TPM is also called predictive maintenance planning. The core of the TPM is to reduce the following six phenomena defined by McCarthy:

1. Breakdowns due to equipment failures
2. Set up and unnecessary adjustments
3. Idling and minor stops
4. Running at reduced speed
5. Start-up losses
6. Rework and scrap.

Each one of the six phenomena described above are non-value added time and therefore defined as waste in Lean. (McCarthy, 2004)

TPM consists of three key pillars to minimize the downtime of the process which are autonomous maintenance, planned maintenance and predictive maintenance. (Sayer, 2007)

Autonomous Maintenance means the operators of the work modules perform their own regular maintenance as part of their daily work. This keeps the machines well maintained and also the operators are much more prepared to solve all minor challenges by themselves**.** (Sayer, 2007)

Planned maintenance is a vital part of Lean. Planned maintenance stands for the maintenance that are predicted, scheduled and planned upfront to minimize the unexpected breakdowns. (Sayer, 2007)

Predictive maintenance stands for actions how organization can anticipate failures not only based on the yearly schedule. Also the organization is prepared with spare parts and actions for routine, planned and emergency maintenance, to minimize the downtime and confusion when some unexpected things happen. (Sayer, 2007)

The main KPI for TPM is Overall Equipment Efficiency (OEE%). The higher OEE% organization has the better. OEE% is calculated like this:

OEE% = Availability x Performance Rate x Quality

(Sayer, 2007)

3.5.5 Poka-Yoke

Poka-Yoke, also called as error-proofing, stands for actions how organization can ensure no mistakes can take place. Poka-yoke is especially quality tool but also it reduces the confusion when performing the operations which leads to better efficiency and less rework. (McCarthy, 2004)

We are surrounded by poka-yoke examples. One example is for example that when filling up the gasoline tank of your car, you cannot put diesel to gasoline car, as the pump spout is different shape for the cars. This is a typical example of Poka-yoke. Making it impossible to do a mistake. (Sayer, 2007)

3.5.6 5S

When talking about Lean, 5S is the first tool most people think, as it is the most visual and implemented.

5S was first introduced together with TPM in 1980s. 5S is a tool which improves workstations, organization and productivity by maximizing the value added work through organized work stations and equipment in right place. It also improves safety and health at the workplace. (Pinto et al. 2018)

5S stands for five Japanese words that has also been translated into English:

1st S = Seiri (Sort)

2nd S = Seiton (Set in Order)

3rd S = Seiso (Shine)

4th S = Seiketsu (Standardize)

5th S = Shitsuke (Sustain)

The tool can be summarized as first at every work place items, tools and materials should be sorted between items needed daily, weekly, monthly and unnecessary items. The more frequently items are needed the closer the daily work station they have to be. Items needed daily should be directly at the workstation with easy access. The amount of items at the daily station should be minimized to improve the flow. (Pinto et al. 2018)

After the items are sorted the standardized place for each item should be looked for. Then the area should be cleaned very well to make it “shine”. After all the items have a place and place is shined, the new standard has to be standardized by marking the place for each belonging with a tape and name. That ensures items stay at the new best place and ensures adequate work space. (Pinto et al. 2018)

Sustain stage stands for continuous improvement and also for standard audits where leaders make sure the change stays. (Sayer, 2007)

3.5.7 Visual Management

Visual management aim to work place where all the information is visually available instead of hidden in computers and brains. After implementing visual-management the leaders can lead by eye as they don’t need to look for things, people or defects. (Sayer, 2007)

5S which was described in chapter 3.5.5 is a one of the most significant visual management tools which immediately reveals when something is somewhere where it does not belong. (Pinto et al. 2018)

Implementing visual management includes colors, lights, boards, sounds visual cues and spaces. These are usually implemented through visual boards, Andon and Pictograms. Visual boards are typically either white boards on the wall or screens which shows KPIs, information and status. Andon is on the other hand a simple signal usually a light or sound informing about a problem. (Sayer, 2007)

3.5.8 Layout

In Lean the great focus is on flow, as most of the tools focus on reducing the waste which disrupts the flow. To achieve good flow and minimize walking, layout plays a significant role.

In terms of Lean the counterclockwise flowing U-shape work cells are recommended. Reasons for U-shape are numerous, but the main reason is that with U-shape the walking distances are much shorter than with any other layout and it also enables safer working environment as only the operator is in inside the U-shape, and all maintenance and material replenishment occurs from outside. (Sayer, 2007)

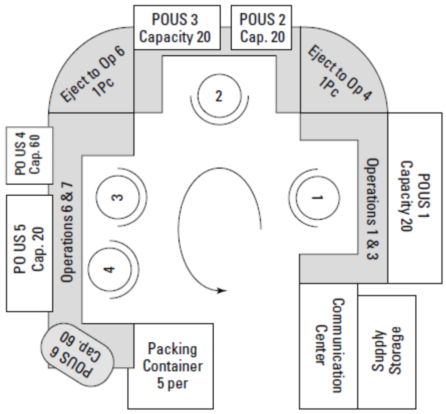

Figure 1 Example of U-Shape (Lean For Dummies. 2007)

In Lean layout all walking should be removed. In laboratories the samples are usually very small, and slides, conveyer belts and runners should be used whenever possible. The target is to reach a situation where not a single step or any other non-value added action is needed during the entire process. To achieve this state all of the items, tools and materials should be brought to the point on use. No matter all of the movement is usually extremely hard to totally remove, it should be the aim when designing layouts. (Ras, 2015)

3.5.9 Pull & Push

Push and Pull production methods are one of the first tools implemented by Toyota when creating Toyota Production System (TPS). However, in testing business the meaning of Pull & Push is little bit different, as in testing business you are not able to produce into stock, as the customer always has to send the sample before any operations can take place. Therefore, in terms of final products (= Reports) are always produced in Pull method as they are also produced based on demand. On the other hand, inside processes certain stations may perform push or pull, and therefore the topic is important.

In Pull system operations and actions only take place when there is a demand or signal from the next station of the process. Therefore, the work in progress stocks are controlled between different stations and better flow is often achieved as everything is produced based on demand. (Pinto et al. 2018)

In Push system the previous station produces based on its own pace, no matter if there is a need for the product at the next station. This may lead to uncontrolled stocks in between the stations which leads disruptions to the flow. However, in many cases this is used when flexible resources are available, which can be easily re-located. (Pinto et al. 2018)

Most common tools to implement pull are Kanban, Andon and different kind of signaling systems which tells the previous station when to start producing**.** (Sayer, 2007)

3.5.10 One-Piece Flow (Continuous flow)

In Eurofins the one-piece flow or as in Eurofins called “Single-Piece Flow” is one of the major Lean topics, and areas of focus, as in many labs the test volumes are between 1000 – 100 000 samples a day.

The one-piece flow stands for process model where each station of the process produces only one product at a time and passes it to the next one before starting to work with the next one. (Tapping, 2007)

In laboratory environment you can improve turn-around-time (TAT) significantly when you switch from batch testing to single-piece flow. When working with big batches the first sample which has been treated, will always wait on the table until the last one of the batch is treated. In single piece flow the sample will not wait for any other samples, the in-process inventories are minimized and the work is faster. (Ras, 2015)

Sometimes single piece flow is not possible because machines require more than one piece, increased consumable costs or long transportation distances. Then the testing/production should we performed with smallest batch size possible. (Ras, 2015)

3.5.11 Problem Solving

One of the key tools in Lean are the problem solving tools which are also called as root cause analysis (RCA) tools or root cause counter measures (RCCM). Cristopher Wright said in his book *Fundamentals of Assurance for Lean Projects* that human are tended to fix and act only based on the symptoms or immediate causes, not to fix the root cause. He explained his point as: “*If I dont deal with a weed in my garden it will spread. If I cut it off at ground level, it will grow back again –maybe not there but somewhere else.*” (Wright, 2017)

The point of RCA tools is to help people find the root cause of every problem to help people fix the root cause and make sure the problem never takes place again. NASA requires their employees to resolve the problems using RCA tools and to be able to answer to following questions:

1. What happened? (Analysis based on the data, not the gut feeling)
2. What led to the occurrence?
3. Where it happened? (All locations and timings)
4. How and why it happened? (Detailed description)
5. What are the likely solutions and how cost effective will each be?

(Wright, 2017)

One of the most popular and easiest root cause analysis tools is the 5 Whys. The point of the tool is to simply first ask why the problem has taken place, and then answer to the question. Then ask make a next why question based on the previous answer and answer to that. And so on until you have asked five or more times why. The tool is very powerful as it peels of the layers one by one which are covering the root causes. (Sayer, 2007)

3.6 Eurofins Specific evaluation areas

Eurofins has defined number of areas that are company specific and described in depth in internal materials. These areas drive waste reduction and are modified from existing literature, as the business area Eurofins is in, is unique. Eurofins wants to evaluate these areas in maturity model also.

3.6.1 Input Problems

Input problems are something that mostly only high volume testing company faces. Input problems refers to the problems, when customer send their sample to the laboratory and not all necessary information, parts and requirements come with it. Also the sample may be wrong kind of sample or it has not been treated correctly during the transportation to the lab. If any of the previous cases take place, the testing cannot start or it will be slowed down, until the problem has been fixed with the customer. This is a common problem in laboratory that production companies do not have.

To be able to minimize the input problems, they first have to be measured with specific KPIs that explain which are the most common issues. After identification all of the issues that can be eliminated through root cause analysis tools, should be eliminated or minimized. (Ras, 2015)

However almost all of the labs face input problems, but the frequency varies between the labs. As the input problems are common, there has to be created a standard working procedure to treat them. The standard procedure should not involve number of calls and hand written papers, but standardized working procedure either in the system or in the registration are with Kanban boxes or some other solution. (Ras, 2015)

3.6.2 Consumable Management

Consumable management in high volume laboratory business differs significantly from regular warehouse management, as the consumables are very temperature, time and treatment sensitive. Some of the very small amounts of consumables cost tens of thousands of euros and some are only few euros. Consumable also have direct correlation too the test results and therefore they need to be managed well.

The best practice defined in Eurofins is to have a warehouse management software in place which is able to track the due dates, locations and conditions. However, this is expensive and time consuming solution for smaller labs, and therefore there is number of workarounds.

All of the consumables also needs to be delivered to the point of use in right amounts and sequence. Kanban is a great Lean tool used for this. Kanban means there is a signal maker at the station when more is needed, for example two boxes where the consumables are, and when the first box is empty it works as a signal to the warehouse that more is needed.

3.6.3 Supporting Processes

Laboratory differs from regular factory significantly when comparing the level of education of employees. Level of education also affects significantly the cost of employee.

In traditional lab the staff usually held a laborant, master or PhD degree, and they do all the work by themselves from preparing to the cleaning. However, when moving to high volume testing which requires significant amount of employees this approach becomes very expensive very quick.

Therefore, in Eurofins the target is to make highly educated personnel only do the testing parts that required very high level of education and knowledge. All the preparations, cleaning and easier tests needs to be outsourced to supporting staff which do not require as high education.

When splitting the process to number of individual steps employees also specialize in certain roles which improves quality and also the efficiency and especially the flow.

Also in laboratory the creation of master mixes and other preparations should be their own separate step from the main process. By separating the creation of consumables the main process flow stays disrupted which allows higher number of tests performed in certain time and also makes the process predictable.

3.6.4 Management of Equipment capacity

Laboratories use number of different kind of analytical equipment. Analytical equipment is very expensive and highly regulated. Analytical equipment differs from normal production equipment, because they need to be very precise and for the lab to be able be in business the analytical equipment need to be maintained and inspected based on the maintenance plan. If the main equipment is not fully maintained based on the maintenance plan the regulations forbid the lab from doing any tests. Therefore, postponing the maintenance of the equipment is not an option. Maintenance for a single equipment cost from few hundreds to tens of thousands of euros yearly.

Based on the cost of equipment, maintenance and space the lab should manage their equipment capacity based on Eurofins best practices, to optimize the number of equipment. Each lab should measure the OEE which is described in chapter 3.5.4, for each main equipment they have.

The equipment capacity should also be always compared to the demand and predictive actions should be taken if the capacity is too low.

3.6.5 Labor Planning & Flexibility

Because of the nature of laboratory work and scientific image, very often in the lab staff is trained to do only certain tests which does not allow the staff to be moved based on the demand. Also when there is only one or two persons who can perform certain test it is a huge risk for business continuity.

Best practices in Eurofins defines that labs should have skill matrixes available and even visible on the wall. There should be a training plan defined for employees and work rotation should take place. By high level of training in the resource flexibility grows which enables much better resource planning based on demand.

Labor planning should also take place at the lab. Not all the staff has to start at the same time, if early in the morning there is no work for everyone. Therefore, active labor planning based on demand should take place at the labs. The lab should also actively move the staff during the day to the point of need.

3.7 Digitalization

Implementation of digitalization tools may lead to significant reduction of waste in the process. This chapter is written based on Eurofins group operational excellence best practices, as the Eurofins has defined certain areas in digitalization which every factory should focus on.

3.7.1 Pre-Registration

Eurofins has built website, mobile application and other solutions to be able to enable customer pre-register samples before sending them to the tests. This reduces the need of sample registration and possible misunderstandings at the lab. This digitalization tool was first created on 2013, and after that developed further on. However most of the labs still manually register samples when they arrive, which causes more mistakes, extended TAT and risen costs in staff.

3.7.2 Sample Tracking/Paper-free Lab

Another solution provided by the group and implemented by many labs is the possibility to scan every sample at all stations instead of writing manually to the system or to paper all the information of the sample. This tool reduces typos and TAT significantly, as in many labs samples passes several stations during the testing.

Eurofins is also aiming for paper-free labs, which has not been achieved at many places. Most of the labs still deliver order sheets, quality control sheets and other kind of paper sheets with the samples through the process, and write manually all the information to the papers, instead to the system. Using the laboratory management systems, reduces the risk of losing some of the papers and also makes operating faster.

3.7.3 Data Transfer & Automatic reporting

Automatic reporting and data-transfer tools are one of the most important tools in Eurofins, as Eurofins creates over 400 million reports a year. Most of the modern time laboratory equipment can be connected to the computer and make the equipment automatically transfer the data to the database once the tests are ready. However, in many labs still the data is manually read from the machine and being inserted to the paper or other system. Once the data is available the report will be created. Many labs still invest significant amount of money for employees who manually write all of the test reports. Eurofins has automatic reporting software implemented at many labs which allows the report to be created with push of one button, or in many labs without any buttons. The data should be automatically transferred from the equipment to the system, which automatically creates the report and sends it to the customer.

3.8 Maturity model

Maturity is described as a state in which an organization is fully capable of achieving its own goals and objectives (Andersen, Jessen 2003). By definition, maturity as a concept is too wide to consider as a whole. Therefore, maturity needs to be broken down into smaller sections i.e. maturity of things that the organization specifically wants to observe and develop. Maturity assessment usually focuses on either process maturity, object (e.g. software product) maturity, or people capability. Process maturity describes the extent to which certain process is defined, managed, measured, improved, and effective. Object maturity describes the extent to which certain software or machine reaches a defined level of sophistication. People capability describes the extent to which employees are able to improve competence and create knowledge. (Mettler, 2011)

Maturity is usually examined by measuring organization, function, or process from different aspects. Maturity is the ultimate objective for any organization, and it can be reached via a systematic and documented development path. This path consists of several intermediate states of maturity. (Klötzer, 2017)

Maturity model is an assessment tool for organizations to define how comprehensively it has adopted and implemented a specific and desirable way of working. Maturity model divides implementation into different stages and aspects. These stages are reviewed and graded one by one comparing the current state with the defined maturity levels (Jording, 2016). Grading scale is based on a number of pre-defined maturity levels. Each maturity level is defined by unique characteristics related to it. Maturity levels must be clearly differentiated from each other so that gaps between maturity levels are visible. This clarity helps the assessment. Each characterized level has a number that acts as a grade. Grading scale goes from lowest to highest level of maturity. Typical maturity models consist of four to six, often five maturity levels. (Proença, 2016)

Jording and Sucky (Jording, 2016) describe a maturity model as "*a construction-based model which consists of an anticipated, limited development path, separated into stages with defined characteristics and dimensions. It has one or more objectives related to the stage evaluation, gap identification and transformation.*" As a development tool, the maturity model helps an organization to detect the gaps between their current maturity level and desired maturity level e.g. in digitalization or operational excellence. Current state of maturity must be identified against defined maturity levels and after the gaps are found, the next steps for improvement can be planned. Maturity model is a proven technique for the systematical continuous improvement providing a systematic and documented path for development and transformation of an organization. (Klötzer, 2017)

Depending on the observed topic, the maturity assessment can be performed as self-assessment in organization, or third party can perform it. Official certification requires an objective external assessment, but when maturity models are used as tool in transforming organization, self-assessments are typical.

3.8.1 Capability maturity model

The first widely known maturity model was presented in 1979 by Philip Crosby in his book Quality is Free. Crosbys Quality Management Maturity Grid had five levels for maturity with six measurement categories i.e. assessment dimensions for quality. About a decade after this, the Capability Maturity Model (CMM) was developed by the Software Engineering Institute in years 1987-1993. The framework was developed in response to a request by U.S. Department of Defense who needed a method for assessing the capability of its software suppliers. On the other hand, it was also intended to be a tool for the contractors to unveil the improvement areas in their software processes. (Paulk, Curtis et al. 1993)

The CMM has five well defined maturity levels and each step towards higher maturity consist of a set of process goals that describe one important part of the software process. By achieving a new maturity level organization has increased its process capability. CMM follows the principles of continuous improvement methodology which idea is to repeatedly feed incremental improvements to the existing processes and thus achieve better performance in terms of quality and efficiency. (Paulk, Curtis et al. 1993)

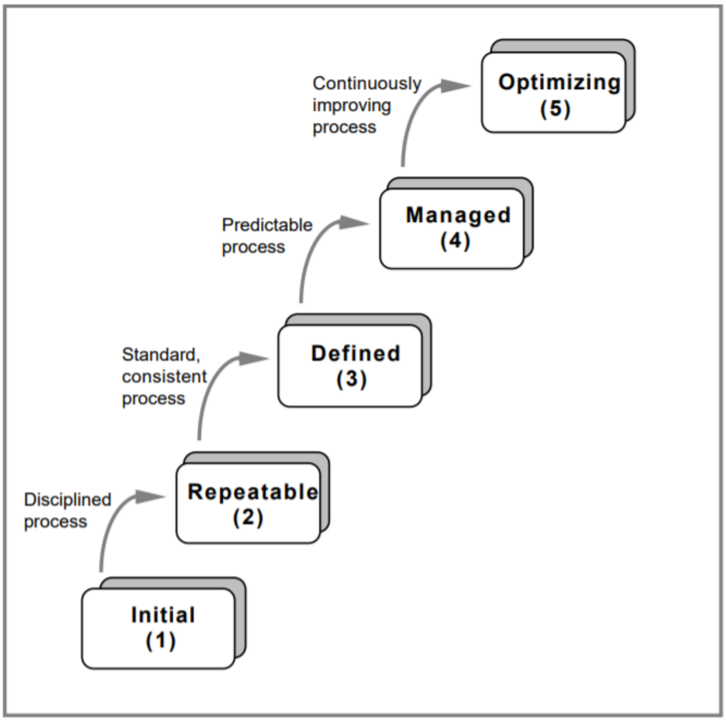

Figure 2 The five levels of software process maturity in the CMM (Paulk, Curtis et al. 1993)

Figure two illustrates the five maturity levels of CMM. First level called initial means that software processes are mostly undefined, ad hoc, and even chaotic. At this level success depends on individual effort. Second level, called repeatable, is a state where basic processes for project management are created to track schedule, budget, and functionality. Discipline exists to repeat earlier successes on similar projects. Third maturity level – defined – means that software process for management and engineering activities is standardized, documented, and integrated into organizations main process, and that all software projects are utilizing it. Software process is managed on the fourth level, when detailed quantitative measures concerning product quality and software process are collected, and these measures are used to control and gain better understanding on software processes and products. The ultimate level five in CMM is called optimizing. This means that quantitative feedback from the process is actively supporting continuous improvement. (Paulk, Curtis et al. 1993)

3.8.2 Maturity models in Lean assessment

Capability Maturity Model was developed for the software processes. Afterwards other industries have adopted this framework for different processes and purposes. Consequently, maturity models have spread to numerous industries to help reforming processes, organizations, and objects.

Maturity model can be utilized to assess the degree of lean implementation, which aims to improve quality and productivity. Maturity of lean implementation can be assessed by reviewing lean practices. Lean practices can be divided into eight dimensions based on the 14 principles in Toyota Production System. Suggested dimensions are strategic planning, quality at source, processes and tools, problem solving, people, supplier integration, continuous improvement, and customer focus. Each dimension contains different aspects to evaluate it from. (Santos Bento, Tontini 2018)

Table 2 Lean maturity levels (Santos Bento, Tontini 2018)

Level	Maturity Level Description	Understanding
1	Not implemented or implemented informally	The process has not yet been implemented or is being implemented informally, with unstable results.
2	Formally implemented	A formal deployment process has been initiated by the company. There is a deployment schedule in place.
3	Deployed and documented, with occasional failures	The process has been formally deployed (documented), but there are some implementation flaws.
4	Implemented and documented with indicators under control	The process has been completely implemented in an area or several areas and with established indicators. The planned results are being achieved.
5	Implemented, controlled, and continuously improving	The process has been fully deployed, has established indicators, has effective results, and has exhibited continuous improvement over the last 12 months.

Table 2 contains the five maturity levels in lean implementation, and their descriptions. In this example of lean maturity model there are equal amount of maturity levels with CMM, and there is a strong resemblance between their descriptions.

Research shows evidence that the higher maturity level organization has achieved in lean, the higher operational performance it has (Santos Bento, Tontini 2018). Operational performance indicators that had a positive correlation with higher lean maturity levels are indicated in table 3 below.

Table 3 Description of operational performance indicators (Santos Bento, Tontini 2018).

Variable	Description
Cost	Seeks the lowest price compared to competitors, the lowest total production cost, or the highest production capacity.
New products	Entry of products into a specific market aiming to attract new consumers and/or retain current ones. Related to products with new characteristics and functionalities.
Quality	Zero-defect manufacturing or manufacturing of durable products.
Flexibility	Quick changes in product design, quick introduction of new products, quick changes in production volume, broad variety of products, or quick changes in product mix.
Delivery	Quick delivery, or reliability in timely deliveries.
Overtime	The amount of time someone works beyond normal working hours.
Inventory turnover	The number of times a company's inventory is sold and replaced over a period of time.
Lead time	The period of time that it takes for goods to be delivered after a customer has ordered them.
Setup	Period during which production is interrupted while the manufacturing equipment is adjusted to another product.

Results of the maturity model can be visualized with a radar chart. After each dimension have been assessed via defined grading scale (maturity levels), the average maturities for each dimension can be calculated. These averages can be illustrated in radar chart concurrently with the desired maturities.

Figure 3 Example of a radar chart for maturity model results

Radar chart of the maturity model, example in figure three, gives a clear illustration for maturity in its different dimensions. It is a powerful way get understanding of the development areas at first sight.

3.9 Number of levels in Maturity Model

As described in chapter 3.8 most of the maturity models have five levels which are then defined in depth. There are also different scales being used in different maturity models. After reviewing the Eurofins Key Group Documents (KGDs) all of the existing maturity models in Eurofins use scale 1-5 and therefore the operational excellence maturity model should also use that one, as then the scores can be summed up and also they will be comparable.

The Eurofins also uses maturity models where the levels are explained in depth instead of just giving a grade based on the feeling how mature you are. Therefore, this maturity model should also have in depth explanations and requirements for each level.

The requirements have to be clear and concise and if the lab wants to achieve the next level, all the requirements for the previous one needs to be achieved first.

3.10 Prioritization of improvements

The prioritization model is used to prioritize the improvement ideas found during the diagnostic week. The important thing about the model is the ease of use as it needs to be taught to number of people in few minutes.

3.10.1 ICE – Prioritization tool

ICE is a very well-known prioritization tool invented by Sean Ellis. ICE stands for Impact, Confidence and Ease. *Pavel Kukhnavets* describes those as follows:

1. ***Impact*** *demonstrates how much your idea will positively affect the key metric you're trying to improve.*
2. ***Confidence*** *shows how sure you are about Impact. It is also about ease of implementation in some way.*
3. ***Ease*** *is about the easiness of implementation. It is an estimation of how much effort and resources are required to implement this idea.*

   (Kukhnavets, 2018)

The idea of the tool is to list all of the improvement ideas and then score them. Each idea should be given a score for each topic individually: Impace, Confidence and Ease. The scoring scale is 1-10 and the scale is explained in table 4 below. (Ice Scoring Mode, 2019)

Table 4 Ice scoring (Ice Scoring Mode, 2019)

Score	**1**	**10**
Impact	Very low Impact	Significant impact
Confidence	Very Low confidence	Significant Confidence
Ease	Very long time frame & Complex	Short Time Frame & Easy

After each one of the improvement ideas are scored the Ice score needs to be calculated, simply by multiplying each factor. The formula is:

Impact x **Confidence** x **Ease** = **ICE** score

(Kukhnavets, 2018)

Below on table 5 is an example of completed ICE prioritization. On the left are the ideas, next to it are the scores given for Impact, Confidence and Ease. Then all of the scores are multiplied together using the formula above. After that the prioritization model is completed, and the one with the highest ICE score should be the one with the highest prioritization. That way the projects are now prioritized. (Kukhnavets, 2018)

Table 5 Example of completed (Kukhnavets, 2018)

Project Idea	Impact	Confidence	Ease	ICE Score
Billing system	7	1	5	35
Community tab	7	2	8	112
Update receipt design	5	5	3	75

3.10.2 Value vs Complexity

Value vs Complexity map is commonly used tool to highlight the effort versus value. Tool is extremely simple and therefore also widely used. As seen in figure four, the figure has two axels:

1. Value – Shows how much value the improvement can bring
2. Effort – How much effort does the implementation require

(Steigerwald, 2019)

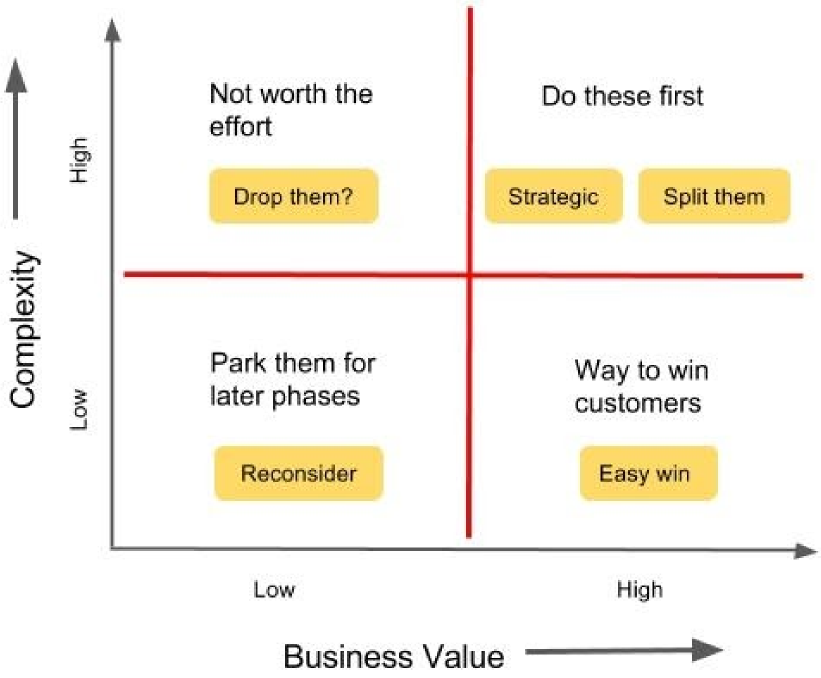

Figure 4 Value vs Complexity model (Kukhnavets, 2020)

The idea is simply to draw the figure as in figure four, and then place the projects on the figure based on their complexity and business value. The figure highlights so called "low hanging fruits" which are located on the low right corner. Those are easy to implement and have high business value. On the top right corner are the ideas that have big business value and are also complex. With this tool you can easily see which ones you should aim first. (Kukhnavets, 2020)

4 IMPROVED EUROFINS DIAGNOSTIC MODEL

This chapter explains the process of creating the operational excellence diagnostic model for Eurofins.

4.1 Maturity Model

Operational excellence maturity model is the most significant part of the diagnostic, as it structures the elements and topics to be evaluated. The purpose of the maturity model is to standardize the elements and topics that needs to be looked at. Based on the maturity model the areas that need most improvement can be identified and more depth analysis can be done.

The target is that the labs would also use the maturity model independently without group support to evaluate their current status and find the improvements areas. Therefore, the maturity model needs to be very self-explanatory and it has to work independently without other material.

4.1.1 Elements of the maturity model

There was more existing literature for operational excellence performance evaluation than expected upfront. The literature review consisted of 23 references where 14 were about Lean, seven for maturity models and two for leading the operational performance.

Based on the theory on chapter three four elements of Lean was chosen to be evaluated in new Eurofins diagnostic model. In addition to that certain key Eurofins topics were added based on Eurofins wishes, as those are key elements to drive waste reduction in Eurofins and are specific only for this company. Also Eurofins requested to be able to measure the status of digitalization in operations, and therefore digitalization was added to the topics to be evaluated. Therefore, the key elements to be evaluated during the diagnostic week are:

1. Culture
2. Systems
3. Tools
4. KPIs
5. Eurofins Specific
6. Digitalization

4.1.2 Topics of the maturity model

Once the six elements above were chosen, the key topics for each element needed to be chosen. Those elements were chosen based on the existing literature and based on the interviews of laboratory operational excellence program leaders. Eurofins Operational Excellence Leaders had quite clear view of each topic. The chosen topics for each element are listed below on table.

Table 6 Eurofins Operational Excellence Maturity Model Elements and Topics

Tools	KPIs	Systems	Culture	Eurofins Specific	Digitalization
1. Waste 2. Layout 3. Flow 4. Problem Solving 5. 5S 6. Standardization 7. SMED 8. Poka-Yoke 9. TPM	1. KPIs & Performance Boards	1. Performance management meetings 2. Operational Management Routines	1. Continuous Improvement Culture 2. Lean Culture	1. Labor planning and flexibility 2. Forecast of Demand 3. Support processes 4. Consumables management 5. Input Problems	1. Pre-registration 2. Sample Tracking & Paper-free lab 3. Data Transfer & Automatic Reporting

Table six above visualizes the six categories of maturity model and the total of 22 topics defined underneath them. The next step for building the maturity model is to break each one of the topic into five levels and define the requirements for each level.

4.1.3 Creating the structure and levels of maturity model

The maturity model is Excel based tool, as all of the labs have Excel and know how to use it. The ease of use is one of the key focuses on the maturity model.

As explained in chapter 3.9 the maturity model uses same 1-5 levels as every other model in Eurofins. The requirements to achieve each level are explained in depth in the maturity model itself. To achieve the next level in the maturity model the lab has to achieve all of the requirements of previous levels. The target is to make the maturity model work fully independently and without additional training or introduction. The level one always stands for minimum score where the subject has not been implemented at all. The level five stands for a score where the lab has fully implemented all the best practices of the subject being evaluated.

The order and sequence in the maturity model is the order which things should be evaluated on. First the tools and Eurofins Specific topics should be evaluated. After that the KPIs and how they are being managed through the standardized systems, should be evaluated. After systems the digitalization should be evaluated and the last but not least, the culture of the lab should be analyzed. All of the other topics are part of the culture of the lab, and therefore the culture has to be the last thing to be observed.

4.1.4 Defining the requirements for each level

The requirements and criteria for each tool and level were discovered through:

1. Existing literature
2. Interviewing the Program Leaders
3. Observations in many labs
4. Existing targets set for the lab through trainings and calls

Based on the four topics listed above the criteria for levels were created. The criteria for each level has been adjusted based on Eurofins requirements, current status and possibilities in lab. The target is to make very clear and concrete targets.

4.1.5 Maturity levels for Tools

The tools of maturity levels are listed in table six. For the tools the literature best practices needed to be adjusted based on Eurofins wishes, as there are certain limitations in laboratory environment. Also the group is focusing on certain topics that need to be implemented to the lab, and therefore the criteria reflects those.

Criteria for each tool and level are described below on table seven.

Table 7 Maturity levels and criteria for tools

Lean Maturity (Tools)	Level 1	Level 2	Level 3	Level 4	Level 5
Waste	-The concept of Waste is not known amongst the staff.	- The concept of Waste is understood amongst some members of staff. - No (or extremely infrequent, uncoordinated) efforts are made to eliminate it.	- The concept of Waste is understood amongst most members of staff. - There is evidence of Waste elimination but the effort is not rigorous, systematic, or widespread.	- The concept of Waste is understood amongst all members of staff. - A structured approach towards eliminating Waste exists but it is not rigorously applied.	- The concept of Waste is engrained in the Labs culture. - A systematic, structured approach exists to identify and eliminate sources of Waste. The approach is rigorously applied.
Layout	- Process steps are physically separated from each other typically divided into remote teams or departments and separated by walls with no or small windows. - Activities are clustered by equipment instead of by flow. A large amount of time is consumed transporting materials.	- Process steps are not close to each other. Teams and departments are separated by walls (multiple rooms) but there are doors and windows for easier visibility. - Equipment of the same type is not clustered but placed in some of the process flows. A large amount of time is consumed transporting materials.	- The layout includes walls, but there are many/big windows for easier visibility. - The Lab layout and process placement minimizes transportation~~,~~ and processes are linked together.	- The Lab has an open layout with only the walls required for technical reasons. There is full visibility across the processes. - Process steps are together in work cells containing the equipment required to perform most of the operations without transportation needs.	All the conditions in the cell directly left plus: - The walls and benches can be adjusted, so that the layout is flexible to adaptable to the changing demand.

Sample Driven production system (Flow)	- The Samples are not processed FIFO but are stored after registration and then sorted by due date. - Inventory of Samples is not visible (e.g. stored in refrigerators without glass doors, in storage areas which are removed from working areas, et.) - Samples are not sub-Sampled and are shared. - Samples are distributed or fetched by all/most staff when needed (normally per work lists). - Most distribution happens manually with boxes/trolleys in large batches at low frequency. - No flow/distribution Kanbans exist.	- Samples are mostly processed FIFO, however, in many cases it is required to sort and find urgent Samples among the inventory. - Inventory of Samples is only sometimes visible. - Some Samples for some (mostly high frequency) methods are sub-Sampled (when needed) to avoid being shared. - Samples are distributed or fetched by all/most staff when needed (normally per work lists). - Most distribution happens manually with boxes/trolleys in large batches at low frequency. - No flow/distribution Kanbans exist.	- In registration Samples are sorted per Rush level, but afterwards FIFO is followed without sorting. A due date check may be used to indicate if Some Sample requires sorting during processing to avoid delay. - Inventory of Samples is mostly visible. - Samples for most methods are sub-Sampled (when needed) to avoid being shared. - The concept of centralized distribution (e.g. runner, milkman, water spider, etc.) is known or occasionally applied. - Some evidence of Alternative distribution methods (e.g. conveyers, dumb waiters, etc.) exists. - most distribution still happens manually with boxes/trolleys but there is evidence that it happened in higher	- In registration Samples are sorted per Rush level, but afterwards FIFO is followed without sorting. A due date check may be used to indicate if some Sample requires sorting during processing to avoid delay. - Inventory of Samples is always visible but not necessarily stored in clearly marked areas. - Samples for most methods are sub-Sampled (when needed) to avoid being shared. - The concept of centralized distribution (e.g. runner, milkman, water spider, etc.) is applied but not yet rigorously followed. - Alternative distribution methods (e.g. conveyers, dumb waiters, etc.) are in place for higher frequency or high volume flows (where practically	- In registration Samples are sorted per Rush level, but afterwards FIFO is followed without sorting. A due date check may be used to indicate if some Sample requires sorting during processing to avoid delay. - Inventory of Samples is always visible and stored in clearly marked areas. - Samples for all methods are sub-Sampled (when needed) to avoid being shared. - The concept of centralized distribution (e.g. runner, milkman, water spider, etc.) is rigorously applied with high levels of visual management in place. - Alternative distribution methods (e.g. conveyers, dumb waiters, etc.) are in place for most/all flows (where practically possible).

			frequencies or in smaller batches. - Flow/distribution Kanbans are used occasionally.	possible). - The distribution of Samples has been adapted to allow for the distribution of smaller batches at high frequency. - Flow/distribution Kanbans are used in most areas.	- The distribution of Samples has been adapted to allow for the distribution of smaller batches at high frequency. - Flow/distribution Kanbans are used in all areas.

Systematic Problem Solving	- The majority of problems are only noticed by team members and result in superficial "quick fixes”. - Problems constantly reoccur and result in low process efficiency (productivity or equipment performance). - Some "knee-jerk" problem solving may be required from management, but only based on random issues of their choice with no understanding of root cause.	- Limited use of structured problem solving with root cause analysis by management and/or operational personnel for major problems. - Majority of solutions are still “quick fixes” leading to repetitive problems.	- Teams are (temporarily) formed to identify root causes utilizing a structured problem solving methodology and tools for major recurring problems only. - Increased focus on identifying and removing root causes through corrective measures. - Solutions are not always standardized (through visual standards, SOPs, or poka yoke). - A culture of identifying problems at process level is still predominantly driven by management.	- Teams are (temporarily) formed to identify root causes utilizing a structured problem solving methodology and tools for a wide range of recurring problems. - Emphasis is placed on identifying and removing root causes through corrective or preventative measures. - Solutions are mostly standardized (through visual standards, SOPs, or poka yoke). - A culture of identifying problems at process level instead of by management is in place.	- Teams are (temporarily) formed to identify root causes utilizing a structured problem solving methodology and tools for virtually all recurring problems. - Root causes are identified and removed through preventative measures. - Solutions are always standardized (through visual standards, SOPs, or poka yoke) and training documents updated (if relevant). - A culture of identifying problems at the lowest organizational level instead of by management is in place.
5S	- No workplace organization on the shop floor. - All areas are generally disorganized and dirty. - It is not clear what is needed (Samples, consumables,	- Workplace looks more organized, but it is difficult to determine what is needed and there are few markings to identify proper locations. - In general, the	- Clean, organized work areas. Locations for Samples, consumables, tools and equipment are mostly marked and followed. - Scrap/rework is clearly separated.	- Discipline is high on 5S follow-up. - Locations for materials, consumables, tools and equipment is marked and followed. - High levels of workstation standardization is applied. - 5S principles	All the conditions in cell directly left, plus: - 5S audits are periodically performed by staff (at all levels) with participation and review from management, including the Lab manager.

	tools and equipment).	cleanliness level is low.		are applied in the non-production areas also (offices, conference rooms, shared folders, etc.)	Audit results are recorded and identified deviations or improvement ideas are registered, evaluated and, if applicable, executed.
Standardization (SOPs, visual standards and works instructions)	- No standard operating procedures (SOP) are used. Line personnel work by experience. The same activity is performed differently by each staff member and across shifts.	- Basic work procedures exist but do not cover all key processes, are not easily accessible by team members but are not rigorously followed by personnel. - Standards include little or no visual aids e.g. pictures or diagrams).	- Standard operating procedures and/or standardized work forms for all critical processes have been developed. Standards are rigorous but are long or complicated with no or limited visuals. - Standards are not always rigorously followed. - Standards may not be available at workstations.	- Standard operating procedures and/or standardized work forms for the majority of processes have been developed. - Standards include visual explanations for easier understanding. - Standards are rigorously followed. - A process to review and update standards is in place but may not always be followed.	- Standard operating procedures and/or standardized work forms for all processes have been developed. - Standards are predominantly visual. - Standards are rigorously followed. - A structured process to review and update standards is in place and followed.
Single Minute Exchange of Die (SMED)	- Changeover processes has not been mapped out and described - Standard work for changes does not exist	- Changeover processes has been mapped out - The IED (input exchange of die) and OED (Output Exchange of Die) has not been defined. - Some if any standard processes has been created for changeovers	- Most of the changeovers has been mapped out - OED and IED actions has been determined and categorized - Actions to optimize the processes been taken	- OED and IED processes has been minimized - All OED actions are being performed while the machine is running - Improvements has taken place and the changeover times are at good level	- All changeover processes has been mapped - All IED and OED actions has been determined, timed and evaluated - Employees can show written standard work for all changeovers - Employee can describe the difference

					between IED and OED and knows how to optimize them
Poka-Yoke (Error-proofing)	- No error proofing takes place - Process quality is dependent on the employee actions and performance - Nothing prevents the employee to make a mistake (pipet more than required, pipet wrong liquid, etc.)	- Basic poka-yoke actions has been taken - Color coding is in place at some processes - 5S markings are in place	- Over 50% of the process steps are error proofed - Error-proofing is being developed continuously	- Reagents and other consumables are scanned before applying to the sample (System alarms if the consumable is wrong immediately) - Most of the process steps are fully error-proofed	´- 90% of the processes are error proofed - Employee cannot do mistake (E.g. Gasoline spout does not fit to diesel car) - Defect rate <1%
Total Productive Maintenance (TPM)	- TPM elements has not been implemented - Machines do not have maintenance plans, or they are not followed - Maintenance is ordered mainly when the machine is not working properly	- Maintenance plans are created for most of the equipment and they are being followed rigorously - Predictive metrics are not in place - OEE is not being measured	- Maintenance plans in place for all equipment - Predictive measurements available for some of the machines (System alarms even before the machine makes bad quality, as it can predict something is about to broke)	- Autonomous maintenance has been taught to operators, and they are aware of the machines - OEE is being measured for most of the equipment - Predictive maintenance tools are in place	- Autonomous maintenance is part of the regular work - OEE is being measured and followed - Unexpected break downs are extremely rare at the lab - Predictive maintenance is in place

As seen above on table sevev, each tool has more than one criteria that needs to be in place to achieve certain levels. All of the criteria are tangible and fairly easy to measure.

4.1.6 Maturity levels for Eurofins Specific

Eurofins specific topics are topics that are fully adjusted to fit high volume testing laboratories. Most of the topics have touch bases to existing literature but mostly they are defined based on the best practices developed by Eurofins.

All of the criteria and levels for Eurofins Specific maturity evaluation topics are listed below on table eight.

Table 8 Maturity levels and criteria for Eurofins specific

Lean Maturity (Eurofins Specific)	Level 1	Level 2	Level 3	Level 4	Level 5
Labour planning and flexibility	- Labour resources have no flexibility and such situation is accepted as the norm, with no plans in place to address it. - There is no proactive planning of labour in accordance with expected demand. Adjustments are made after problems occur.	- Labour resources have an undefined and limited flexibility, allowing certain non-systematic and partial adjustment of resources to Customer demand. - There is a certain mid-term proactive planning of labour resources based on the periods of the year.	- Labour resources have a certain flexibility including cross competences stated in a skill matrix and possibility of overtime. However, there is no target on skill matrix, no clear rules to enforce overtime, and no measurement or visibility of productivity and overtime done. - There is a continuous proactive mid- to long-planning of labour resources based on the demand forecast.	- Labour resources have a high flexibility including cross competences stated in a skill matrix, flexible time agreements and non-productive tasks done in low demand days. - There is a target on skill matrix and a certain measurement of productivity and flexible hours balance. - There is a continuous proactive long-term planning of labour resources based on the demand forecast, comparing required and planned labour resources.	- There is an updated training plan based on the gaps in the skills matrix and the process risk assessment. - Productivity is measured in real time so that labour can be adapted in case demand is low. - The impact of the different possible changes in resource planning can be evaluated. A tool exists to perform these analysis.

Forecast of demand	- The only forecast is the budget, with a low level of detail, i.e. monthly or less and completed without using historical data to anticipate seasonality.	- The forecast exists in the budget, with monthly detail, but with historical data analyzed and seasonality included.	- The forecast is done specifically for production planning with weekly detail using historical data and in case of big deviations it is reviewed.	- The forecast is done specifically for production with weekly detail using historical data and it is reviewed periodically to correct for deviations and to add commercial input.	- There is knowledge of the planned Samples from EOL (or similar tools), InterCo and own Sampling.
Support Processes	- All non value added and support activities are done by analysts, technicians and operational staff, in line, at the expense of Samples i.e. Samples are waiting.	- Some of the most common, Lab-wide support activities are completed by designated, non-technical staff, but they are not centralized and methods are not consolidated	- Some of the most common, Lab-wide support activities (e.g. washing glassware, general waste disposal, general cleaning, etc.) is centralized and optimized to ensure these processes to not negatively impact operations. - A structured approach exists to identify additional activities that can be centralized.	- More localized, department or method specific activities (e.g. washing of homogenization equipment, method preparation, etc.), is centralized and optimized to ensure these processes to not negatively impact operations. - Lean tools like SMED are introduced for equipment. - A structured approach exists to identify additional activities that can be outsourced.	- There is an extensive level of centralization of support activities including per-prepared maintenance packages for analytical equipment, etc. - Lean tools like SMED, OTED, etc. is extensively used for equipment and also for other analytical activities (e.g. extraction changeovers). - A structured approach exists to identify non-core activities that can be outsourced to external service providers or shared across multiple Sites.

Consumables Management	- No structured consumables management process is in place. - Analysts, technicians and operational staff manages (including potentially ordering) their own consumables - There is no effort to consolidate common/similar items.	- Some consumables management is in place for common, high volume items. - There is some effort to consolidate common items.	- A centralized consumables management process is in place for the main storage area and for smaller, area specific storage areas. - Most common items have been consolidated where possible - At workstations, analysts, technicians and operational staff are collect consumables from a smaller, area specific storage.	- A centralized consumables management process is in place for the main storage area and for smaller, area specific storage areas. - At workstations, analysts, technicians and operational staff are supplied with consumables based on a manual Kanban system or ordering list.	- An automated consumables management system (with min/max levels) is in place for the entire Site. - At workstations, analysts, technicians and operational staff are supplied with consumables at point of use based on either an automated re-ordering system or an IT based Kanban system.

Input Problems	- There is no defined procedure to identify, document and eliminate input problems, nor a measurement of their quantity.	- There is a procedure to identify, measure and eliminate most input problems. - An basic measurement of quantity and frequency exists.	- There is a clearly defined procedure and ownership to identify, measure and eliminate all input problems. - A clear measurement of quantity and frequency exists. - Some problems are not only solved but preventative measures are taken.	All conditions to the left plus: - Some solutions are communicated to other Customers causing or other Labs struggling with the same problem.	- Input problems KPIs is reviewed periodically. - Root cause analysis is performed systematically. - Solutions are standardized. - Solutions defined are communicated to all Customers which could present the same problem.
Management of Equipment Capacity	- There is no clear view on capacity. - Equipment is added when problems arise. - Bottlenecks sometimes exist in inexpensive equipment.	- There are some insights into capacity. - Equipment is added when problems arise. - Bottlenecks never exist in inexpensive equipment.	- There are detailed insights into capacity. - Capacity is compared to expected demand and proactive steps are taken to ensure that sufficient capacity is available. - Bottlenecks never exist in inexpensive equipment.	- Basic metrics (e.g. OEE) is determined for main analytical equipment. - Capacity is compared to forecasted demand to understand impact of stock on TAT for better decision taking and proactive steps are taken to ensure sufficient capacity is available. - Bottlenecks never exist in inexpensive equipment.	- Relevant detailed metrics including TEEP, OOE, OEE, Utilization Ratio or Scheduling Ratio, etc. are measured and monitored for all equipment. - Capacity is compared to forecasted or pre-registered demand and proactive steps are taken to ensure sufficient capacity is available. - Bottlenecks only exist in predefined locations (if needed) and is effectively managed.

4.1.7 Criteria and levels for KPIs and Systems

KPIs and systems will be presented under this same chapter, as they are closely connected. KPIs are the way to measure how the laboratory is performing and the systems are the way to observe, manage KPIs and steer the company to the chosen direction. The maturity levels and criteria for KPIs and Systems are described in table nine.

Table 9 Maturity levels and criteria for KPIs & Systems

Lean Maturity (KPIs & Systems)	Level 1	Level 2	Level 3	Level 4	Level 5
KPIs & Performance Boards	- No (or very basic) performance data is collected but not displayed	- Basic KPIs including Health and Safety, inventory, TAT-95 and TAT-R are collected but not displayed.	- Basic KPIs including Health and Safety, stock, TAT-95 and TAT-R are displayed, with detail per production line or department. - Some KPIs have targets. - Both current status and past performance is displayed on visible performance boards (digital or paper based). - Corrective actions are sometimes taken to improve performance but are not noted with owner and due date nor followed-up.	- More advanced KPIs including productivity and saturation are displayed. - All KPIs have targets. - Short term actions are noted with owner and due date, and followed-up. - Recurrent problems are not yet addressed or are only addressed infrequently. Problem Solving boards do not exist.	Quality metrics are also included. Cost metrics are displayed where relevant. - Recurrent problems are addressed using structured problem solving. Problem Solving boards exist. - A skill matrix is visible and updated. - A section exists for short term labour planning.

Performance Management meetings	- Meetings never run or only irregularly with varying attendance and unclear agendas. - Meetings are often viewed as a waste of time. - No actions are identified and tracked. - Several attendees make no contribution at all.	- Meetings run ad hoc with limited attendance. - A structured agenda is neither defined nor visible. - Discussions center around issues rather than resolutions. - Actions are taken away from meeting but often with no follow-up. - Meetings often only work in presence of senior leader.	- Meetings are conducted on a regular basis. - A complete meeting agenda and boards are defined, but they are not always followed. - Some actions are generated, but completion is not tracked. - Deviation from target is not always followed by corrective action.	- Meetings have a regular frequency and punctuality. - A complete meeting agenda is followed in detail. - Meetings are run by shop floor leaders without middle management and in absence of leader back-ups are known. - Deviation from targets lead to corrective actions or analysis. - Action completion is tracked.	All the conditions on the left, plus: - There is a cooperative atmosphere, including a challenging attitude. - Problem solving and root cause analysis is not done in the meeting, without data, but an owner is defined to do the analysis. - Meeting is completed efficiently.
Operational Management Routines	- There is no clear definition of management tasks and routines. - Ownership is based on hearsay, and is "known", not documented.	- There is a certain definition of management tasks. - Ownership for team leaders, BUMAs, department managers and Lab Managers are defined but not always rigorously followed.	- There is a clear definition of management tasks. - Ownership for team leaders, BUMAs, department managers and Lab Managers are defined but not always rigorously followed. - Task allocation is known by most members of staff and respected/updated. - Back-ups per task are defined. - Org-chart is visible.	- There is a clear definition of management tasks. - Ownership for all organizational levels are defined but not always rigorously followed. - Task allocation is known by most members of staff and respected/updated. - Back-ups per task are defined. - Org-chart is visible. - Defined routines exists for critical processes.	- There is a clear definition of management tasks. - Ownership for all organizational levels are defined and rigorously followed. - Task allocation is known by all members of staff and respected/updated. - Back-ups per task are defined. - Org-chart is visible. - Defined routines exists for all processes.

4.1.8 Maturity criteria and levels for digitalization

Digitalization is not a direct "Lean Tool" in the books. However proper digital tools reduce waste in the processes significantly. Many of the labs still do not use digital tools, but instead work with pencil and paper and number of static excels.

Eurofins has defined certain digitalization best practices for labs. Those should be especially evaluated during the diagnostic, as most of the tools described in table 10 have direct impact too the turn-around-time, development and quality.

The levels and criteria of digitalization is described below on table 10.

Table 10 Maturity levels and criteria for digitalization

Lean Maturity (Digitalization)	Level 1	Level 2	Level 3	Level 4	Level 5
Pre-registration	- Samples are not pre-registered by the customer. - Samples are registered at the lab when the sample arrives	- Sample pre-registration system (EOL or other) has been implemented, but less than 20% of the customers use it. - When samples arrive to the lab the information is still missing - Once samples arrive to the lab, registration has to insert information about the parcel to the system	- Up to 50% of the samples customer pre-register - Instead of just scanning the barcode at the registration, the registration personnel has to insert information to the system manually	- When samples arrive to the registration, the registration personnel only scan the barcode/QR-code - The barcode automatically fills up all the data to the registration system. - Up to 80% of the samples are pre-registered	- Up to 90% of the samples are pre-registered - Role of the registration is just to scan incoming samples and distribute them to the correct areas

Sample tracking/ Paper-free-lab	- Laboratory cannot track the sample during the process from their system at all - All information during the process is being written to a paper	- Laboratory staff inserts most of the data to the system manually during the process - High level tracking of the sample is available from the system (Sample registered, Sample in process, Invoicing)	- Laboratory uses scanners at each station to log in the data to the system - Low number if any papers needs to be filled during the entire process - Laboratory can see at all times the location and status of the sample from the system	- After scanning the barcode of sample the system displays all required information to process the sample - Full sample tracking available in the system	- Laboratory is totally paper-free area - Full sample tracking available from the system including automatic metrics and alarms if sample is in risk of being late - All working instructions and other information is automatically being displayed to the employee when he/she scans the barcode of the sample - System includes poka-yoke functions to prevent failures

Data Transfer & Automatic Reporting	- Data from analytical equipment is mainly processed and calculated manually for the reports - Laboratory does not have automatic reporting functions. All reports fully manually written on template	- Data is moved using USB sticks or other solutions in lab - Excel based tools has been created to do the basic calculations for the data	- Up to 50% of the reports are created automatically by the system - Reports are sent to the customer manually using email or other functions which requires an employee to operate	- Data is transferred automatically from analytical equipment to the system - Data is moved manually from the system too the reports - After data is moved to the system the report is created automatically and sent automatically to the customer	- All data is automatically being moved from analytical equipment to the system - System moves automatically data to the correct reports and creates the reports - System automatically sends the reports to the customer - Only QA and other special cases needs to be reviewed manually by an employee

4.1.9 Maturity criteria and levels for Culture

All of the tools and elements described above aim to reach a Lean and continuous improvement culture. Organization culture is something that develops over time, but there are several tools that can really speed up the development of culture and improve it to the Lean way.

The maturity levels and criteria are explained in table 11 below.

Table 11 Maturity levels and criteria for culture

Lean Maturity (Culture)	Level 1	Level 2	Level 3	Level 4	Level 5
Continuous Improvement Culture	- There is no method implemented to collect improvement ideas from the staff	- There is a standardized method how staff can submit their improvement ideas - The method however focuses to large scale improvements - Not many, if any ideas is being submitted each month	- There is a structured method to collect improvement ideas from all levels - The system supports and encourages staff to submit even the smallest ideas - Ideas are being reviewed and implemented systematically, and there is a clear process	- The system is well known within the staff - Average is 1 improvement idea per staff member per year - There is a KPI in place to measure the continuous improvement	- Standardized gemba walks are implemented at site, to go and collect the ideas from staff - Average improvement ideas reported by each of the staff members is 3< per year
Lean Culture	- Lean is not well known topic within the staff at the lab - There is no Lean trainings for the staff at the lab that they could participate	- Most of the staff has participated at least one Lean training - Staff is aware of the word Lean and what it means, but does not know how to Lean the processes	- Most of the laboratory employees can explain the 7 wastes and the purpose of the 5S - Lean is being implemented and improved by the team leaders, not only by the local lean manager	- Laboratory staff can explain and show the benefits of Lean in the lab - Staff is identifying waste from the processes while working and reducing it	- Lean training is part of the standard introduction plan at the lab. All new employees have to participate Lean introduction when joining the lab.

4.1.10 Consolidation of results

As different staff members working in different role can see the current status of the lab very differently. Therefore, for the excel tool created during this thesis includes a consolidation sheet, where all the different results from different employees can put into the sheet. That visualizes very well the difference between departments and staff members, and also automatically counts the deviation.

4.1.11 Maturity model result visualization

Numbers and levels do not always explain the whole story of the performance clearly. Therefore, literature suggests to visualize the maturity model using radar charts. A radar chart was created to the excel based tool created during this thesis. The radar chart created is shown in figure five below.

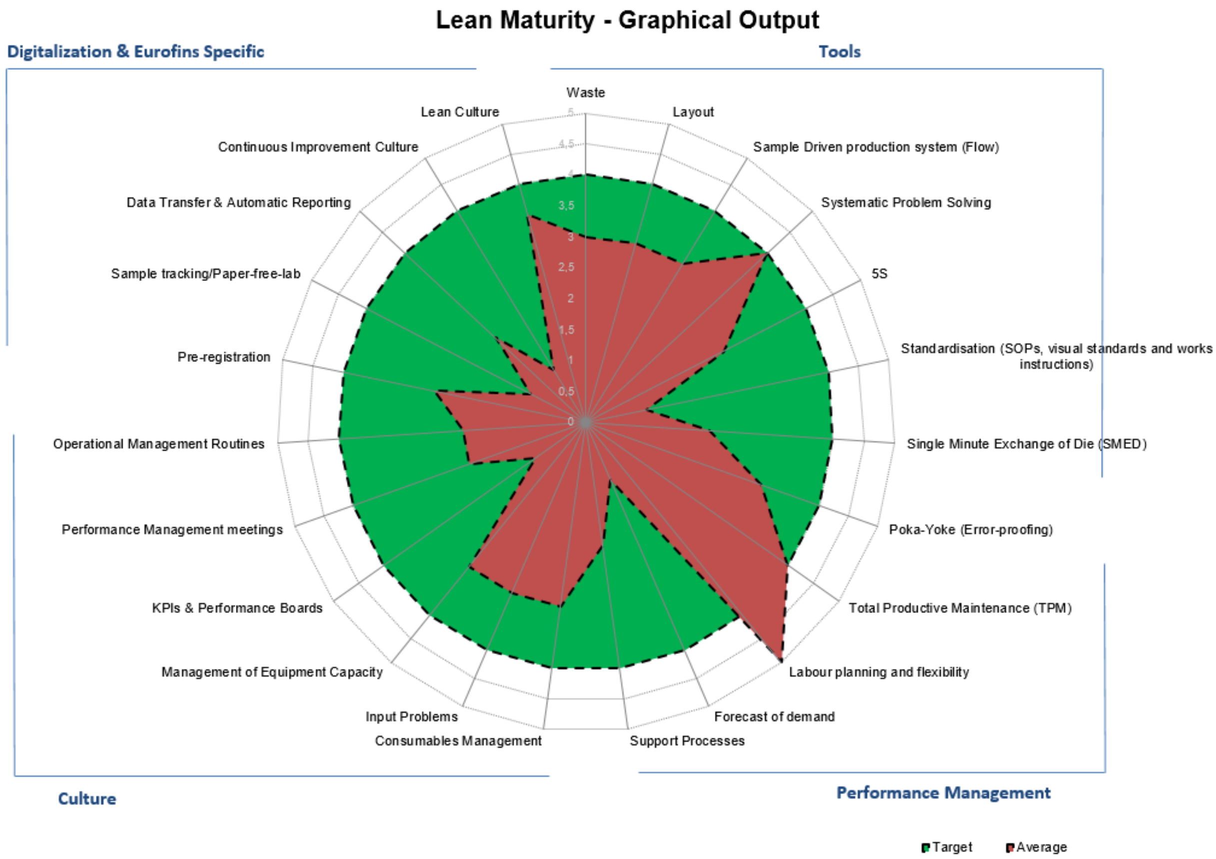

Figure 5 Lean maturity model radar chart (Ras, 2015)

On the radar chart on figure five the target level of the lab is shown on green layer. The red layer shows the current status of the lab, based on the current maturity levels. That way lab can set targets for certain areas of focus using the green layer, and also compare themselves to other labs. The radar chart visualizes the gaps and total performance very well. That way the opportunities for improvement are easily revealed.

4.1.12 Summary of maturity model

The complete maturity model is not delivered with this thesis, as it is confidential. It is an excel based tool which has been made very easy to use and is self-explanatory. The excel also has an introduction sheet on how to use the excel.

The maturity model overall is an extensive quick way to analyze entire lab in a structured way. It covers the topics to be evaluated and it works also as target setting tool. The tool describes which are the next steps to be achieved to improve the labs performance.

4.2 Diagnostic schedule

The diagnostic week is only five days, where Monday and Friday are usually couple hours shorter than regular working days due travelling. During these five days the total operational excellence performance of the lab needs to be diagnosed. During the diagnostic week the actual processes are not being improved or changed, but the improvement opportunities are just being identified. During the following weeks of diagnosis, the improvement plans are actually being made.

Based on the experience of the team, the diagnostic differs depending on the current status of the individual labs. Some labs have implemented most of the tools and they can be evaluated and improved significantly, and some labs have not even heard of the topics before. Therefore, the time needed for each topic varies significantly from few minutes to several hours. Also certain topics are more important for certain kind of labs than others, so time will be spent differently on different topics.

Based on the difference between the labs, the five-day schedule needs to be flexible. Eurofins already had a five-day schedule but based on the literature and interviews it needs to be updated. Based on the existing literature the diagnostic should also be more closely linked to the maturity model. Once the schedule is more closely linked to the maturity model, the diagnosis will have a structure, and the maturity model will work as a check list that each topic has been diagnosed.

Many of the tools are not observed individually. For example, *Waste* consists of number of different topics and layout and 5S are usually always being evaluated in parallel. Therefore, the schedule should not have tight time schedules for topics, but rather for the elements.

As the five-day diagnostic is created by the Eurofins, there is not existing literature presenting schedules. Shingo Institute evaluates the factories using number of evaluators at same time, where each evaluator focuses on their own topics. Therefore, the proposed schedule on figure six is created based on the interviews, existing schedule, maturity model, observations and experience.

Diagnostic Agenda

	Monday	Tuesday	Wednesday	Thursday	Friday
	High level view & trainig	**Tools**	**Eurofins Specific, KPIs**	**Systems, Digitalization, Culture**	**Wrap Up**
9h	Travel and logistics	Drawing of the High-level VSM/Flow Chart of the lab process	Evaluating the "**Eurofins Specific**" topics	Evaluating the "**Systems**" Maturity Model	Prioritize things to be improved during next weeks
10h		Detailed Lab observation: **Process Step 1**		Complete "**Systems**" maturity model Explain & Train about **Systems**	Complete the Summary of the Diagnosis
					Definition of next steps
11h		Detailed Lab observation: **Process Step 2**		Evalutating the "**Digitalization**" of maturity model	Wrap-up with Lab Mgmt
12h	Introduction and Welcome		Complete **Eurofins Specific** maturity Model		Buffer time & Documentation
	Lunch	Lunch	Lunch	Lunch	Lunch
13h	Introduction to lab and strategic needs understanding	Detailed Lab observation: **Process Step 3**	Explaining and Training the lab staff based on observations about the "Eurofins Specific"	Complete "**Digitalization**" maturity Model Explain & Train about **Digitalization**	Travel and logistics
14h	Diagnostic Review & Agenda Adjustment	Detailed Lab observation: **Process Step 4**		Buffer time	
		Buffer time	Buffer time	Evaluate the "**Culture**" (Includes lab staff interviews)	
15h	Visit to the lab/operative area Quick walk through of the overall process	Completing the "**TOOLS**" of Maturity Model	Evaluating the KPIs & Performance Boards		
16h		Explaining and Training the lab staff based on observations about the "**TOOLS**"	Complete KPIs maturity Model Explain & Train about KPIs	Complete "**Culture**" of maturity Model Explain & Train about the "**Culture**"	
17h	Buffer time & Documentation	Buffer time & Documentation	Buffer time & Documentation	Buffer time & Documentation	

Figure 6 Proposed agenda for the diagnosis week

The agenda is strongly connected to the maturity model. The elements of being in maturity model are in same order as in agenda to make it easier to follow both.

The idea is to on Monday focus on overall status of the lab. Before diagnostic the operational excellence program leader has not visited the lab before, and is not aware of the situation of the lab, other than the preparation calls held before the diagnostic. On Monday therefore the idea is to introduce each other, introduce what the lab does and understand the strategic needs and possible challenges. After that the program leader will walk through how the diagnostic will be performed, and if there is a need to adjust the agenda. After that it is important to have a high level walk and introduction at the lab to understand the overall process.

On Tuesday first the high level value stream map or flow chart will be drawn to understand the sequence and length of the steps. After that each step should be observed at the lab in depth to understand the status. This step varies between the lab, as some labs want to improve the overall situation of the lab that consists of 100 different tests that have nothing in common when in other hand some labs have few very standardized tests. After the observations of each step the "tools" element of the maturity model needs to be completed. After completion the program leader needs to explain the grading of each tool and what is in place and what is missing and which things should be improved and focused on.

Wednesday focuses on two elements: Eurofins Specific and KPIs. Eurofins specific is quite broad topic that has to be observed in depth. Mainly this is done at the office but also some topics include laboratory observations. After the evaluation the "Eurofins Specific" element of the maturity model needs to be completed. All of the grades needs to be gone through with the lab and explain what is in place and what should be improved or implemented. The same things in same order should be done to the KPIs after Eurofins specific.

On Thursday the same walkthrough will be done to Systems, Digitalization and Culture.

After all of the six elements of Maturity model are completed, on Friday the prioritization of observed improvements needs to take place which is explained in chapter 4.3. After prioritization the summary PowerPoint of the diagnostic needs to be filled and the next steps to be confirmed. The last thing is to wrap up and end the week with a summary to the lab management and observations, things to be improved and next steps.

4.3 Diagnostic week training material

Eurofins group arranges number of trainings during the year. However most of the sites only have very few employees trained in Lean. Therefore, during the diagnostic week after observing each element there is always need for short training about terms, topics and things that will be discussed. This training usually consists of one or two slides, just to get everyone aligned before going more into the improvements.

As Eurofins arranges number of different kind of training and has created thousands of slides of training material for those, the diagnostic week training material was created mainly out of the existing material. The training material consists of same topics in same order as in maturity model to make it easier to go through the material.

As the diagnostic week is not a pure training week, not all of the slides needs to be gone through. Only the topics that needs to be clarified and needs more insights at the site.

The training material created as part of this thesis is not shared with this thesis as it consists of confidential Eurofins material.

4.4 Prioritization of improvements

At the end of diagnostic week there should always be many different improvement topics discovered. After they are identified they need to be prioritized. Very often the laboratory management has a clear vision which one they want to implement first, but the ideas should always be prioritized systemically.

When the right prioritization tools were chosen for diagnostic, one of the main focus was on the ease of use. Most of the lab personnel are not familiar with the tools and they need to be easy to teach and execute in matter of minutes. Therefore, the suggested tools to use are either the ICE model or Value vs Complexity. Those tools are explained in depth in chapters 3.10.1 and 3.10.2.

After the projects are prioritized the chosen prioritization needs to be documented. So called "low hanging fruits" which are easy to implement and have high impact should be implemented first.

4.5 Creating the documentation of the diagnostic

During the diagnostic many topics, observations and ideas are gone through. A lot of time and money is also spent to do the whole diagnostic; therefore, it is important to document the observations and agreed steps well.

One of the observations of the group Lean team members was that during the diagnostic only the negative things are pointed out which makes the lab feel like they would be doing very badly overall. The reason why diagnostic has this negative feeling, is that during the diagnostic only things that needs to be improved are pointed out, listed and focused on, no matter if the site is overall doing very well and have already implemented number of things.

Therefore, the documentation will also list the positive things at the lab, that are already in place and managed well. But most of the documentation space will be used for clarifying the improvements.

The diagnostic documentation consists of ten phases. The first phase clarifies the targets and improvement needs the lab management has set. All of the targets should be measurable and tangible.

The next phase is the Lean maturity models. First the Lean maturity model radar chart which was completed by the lab staff and on the next slide the maturity model completed by the operational excellence program leader. That way it is easy to compare the difference in views between the lab and the operational excellence program leader.

The third, fourth, fifth, sixth, seventh and eight phases look almost the same. Each one of those are executive summaries about the different elements of maturity model (Tools, KPIs, Systems, Culture, Digitalization, Eurofins Specific). Each one of those first summaries the things that are good and going well with few bullet points. After that is an explained list of things in prioritized order about things that should be improved and shortly described how. These are the main deliverables of the diagnostic, as the purpose was to find the improvement ideas. This documentation is also the only document that will be handed to the lab. Therefore, all of the improvement ideas should be listed clearly.

The ninth phase will summarize the agreed next steps, including the next visit, things that lab should be working on in the meanwhile and possible additional agreed tasks.

The last tenth phase consists of all of the images, drawings and others that were created during the diagnostic week. All of them should be just pasted to the end of the PowerPoint, so they can be easily found when needed.

By following these ten phases the documentation will be fully structured and the lab will have a documentation that clarifies all of the improvement opportunities observed during the diagnostic.

During the next weeks of support more slides should be added to the PowerPoint and document all of the actions and observations to the same PowerPoint. That way there is one key document of the corporate support.

5 CONCLUSIONS

This chapter first summarizes the key findings and improvements of the diagnostic. After that all of the research questions will be answered. At the end of the chapter the potential future improvements will be listed.

5.1 Business challenge

Eurofins is a large global laboratory company who is driving implementation of Lean principles through group Lean team, which consists of ten highly experienced operational excellence program leaders. The program leaders travel to different labs globally and diagnose the current status of the lab, and after the diagnose they create an improvement roadmap for the lab.

Prior this thesis the diagnosis was done differently between different team members which is explained more in depth in chapter 2. The result of that was different team members created different kind of roadmaps, and did not always consider all of the Lean aspects at the site. The target of this thesis was to align the diagnosis performed by different team members and find the best practices from existing literature and from the team members to create one best practice diagnosis method.

5.2 Creation of the method

The new diagnostic method was created based on existing literature and interviewing highly trained operational excellence program leaders.

First the key elements of Lean had to be identified based on existing literature. The existing literature defined four key elements of Lean which were: Tools, KPIs, Systems and Culture. In addition to those two additional operational excellence methods were added based Eurofins wishes which were: Eurofins Specific and Digitalization. Both of the added elements are key strategic elements for Eurofins and therefore they need to be observed as part of diagnosis.

After the six elements were clarified the topics underneath each element were studied in depth. The elements are built out of the smaller topics, and the key topics were chosen together with the group Lean team members. The theory of each topic is explained based on existing literature in chapter three.

The theory was then combined with the existing best practices in chapter four. Most of the diagnosis in literature were made by using maturity model. The maturity model was created for

Eurofins and all of the supporting material required for it. The maturity model was created to work as an independent file guiding the user through diagnostic. All of the other material follow the same structure as the maturity model.

At the end of the thesis there were several documents handed to the Eurofins including: Maturity Model, Diagnostic week schedule, Diagnostic Summary Template, Diagnostic week training material and this thesis as the background of all of the materials.

5.3 Answering the research questions and deliverables

At the beginning of this thesis in chapter 1.3 the key research questions and deliverables were introduced. In this chapter it will be clarified if each one of those has been answered.

5.3.1 Answers to the research questions

In chapter 1.3 there were five key research question defined which were:

1. What are the things to be evaluated when evaluating the lab performance?
2. How the labs should be evaluated and graded?
3. What are the criteria and scales for each thing to be evaluated?
4. What are the criteria how the development projects are chosen and validated?
5. How will the results be presented?

The first key research question was about the key topics to be evaluated when evaluating the lab performance. This question is answered in depth in chapter 4.1 where each item to be evaluated is defined and explained. There is total of 6 elements that consist of 23 topics to be evaluated when evaluating the lab performance. A maturity model was created out of these key things which is also explained in depth in chapter 4.1.

The second question was about how the scale to be used when evaluating. The scale should 1-5 as most of the existing literature suggests that. Also other Eurofins evaluation forms use the 1-5 scale. If other scale would be used the Eurofins evaluation and maturity forms could not be combined and different scales would cause confusion. This is explained more in depth in chapter 3.9.

The third research question was about what are the criteria for each level. The criteria have been explained very tangible way in maturity model and in chapter 4.1. Each level has several criteria that the lab has to meet to achieve certain level.

The fourth research question is about how the identified improvements can be prioritized. The should be done using the ICE method or Value vs Complexity models, which are explained in chapters 3.10.1 and 3.10.2.

The fifth question asks how the results should be presented. The PowerPoint template for presenting the diagnostic results was created as part of this thesis. The results should be presented in ten different phases which are explained in depth in chapter 4.5.

By reviewing this chapter, we can confirm the thesis answers to all of the research questions that were set up front.

5.3.2 Research deliverables

There were five research deliverables defined when starting this thesis that were:

1. Lab evaluation template
2. Updated 5-day schedule which tells in which order the lab should be evaluated
3. Create/combine from the existing material one presentation that covers the entire evaluation week
4. Template to present the results
5. Extensive report on the background of the chosen things to be evaluated

The first deliverable is the lab evaluation template, which was created and is explained in chapter 4.1. The evaluation template is a maturity model which was suggested by most of the literature reviewed for this thesis. The maturity model consists of six elements and 23 topics that needs to be evaluated using the five level scale during the diagnostic.

The next deliverable was the 5-day schedule. The 5-day schedule was created and it is now more focused on the maturity focus that free topics now. The 5-day schedule is presented and explained in depth in chapter 4.2.

The third deliverable was the training material for diagnostic week. The training material was created based on thousands of training slides that Eurofins already had. Out of those slides were created a compact training material that explains each diagnostic topic in two slides. The creation of this training material is explained in chapter 4.3.

The fourth deliverable was a template to present and deliver the diagnostic results. The template was created with a PowerPoint with standard blocks that needs to be used. The template structures the diagnostic certain way where also the positive things already in place are being notified. The template is explained in chapter 4.5.

The fifth and last deliverable is this extensive thesis about the background of each decision made during the thesis.

Overall at the end we can confirm that all of the requested deliverables were delivered by the end of the thesis.

5.4 Further improvement needs

This thesis and the material delivered with the thesis should enable the team to run the diagnostic homogeneously all across the globe, and to different kind of labs.

The further improvements could take place after the method created during this thesis has been tested for several months. The writer thinks there may be need to adjust the schedule for certain kind of special laboratories, so standardized schedule may be needed to make for example labs that run research based projects. However, majority of the labs in Eurofins are test based businesses and usually the test based businesses request for corporate support.

Another potential improvement overtime is to add or change some of the topics in the maturity level, once the total level of Lean in Eurofins has improved. There are more digitalization tools coming out every year, so also adding those to be part of the diagnostic can be a possible improvement.

Overall as continuous improvement is one of the key topics in Lean, that should be also applied to the Lean team tools.

6 SUMMARY

This thesis had a very tangible business challenge where members of corporate Lean team performed the diagnostic differently which lead to variability in roadmaps depending on the expert who performed the diagnostic.

The current state was first discovered through number of interviews and reviewing the existing material available. Also the writer of the thesis is the member of the corporate Lean team and had observed other members in the team. During the current state analysis, the key challenges were identified that needed to be solved during the thesis.

After the current challenges were identified the existing literature were discovered in depth. Total of 29 resources were used during the literature study to identify the best practices for diagnostic. The existing literature identified four key Lean elements and up to 23 topics were chosen for the maturity model that was suggested by the literature.

The maturity model was created based on the literature and based on Eurofins wishes. The maturity model is very self-explanatory that can be used even without Lean knowledge. The maturity model uses levels from 1 to 5 where each one of the criteria for each level is described in depth. In addition to the maturity model the training material, diagnostic 5-day schedule and the presentation template was created.

Overall all of the research questions were answered and all of the deliverables were delivered. The thesis completed and closed the gap that the Eurofins was facing.

REFERENCES

ANDERSEN, E.S. and JESSEN, S.A., 2003. Project maturity in organisations. International Journal of Project Management, 21(6), pp. 457-461.

Alves Anabela; Kahlen Franz-Josef; Flumerfelt Shannon; Siriban-Manalang Anna. 2019. Lean Engineering for Global Development. Springer.

Gerhard, Plenert. 2017. Discover Excellence, An overview of the Shingo Model and its guiding principles. CRC Press

Bell, Mike & Zunich, Edward. 2016. PPI-5 Training Guide. Thermo Fisher.

Feld, William M. 2000. Lean Manufacturing. CRC Press.

Helmold Marc. 2020. Lean Management and Kaizen, Springer.

Huntsman, Jon. 2020, The Shingo Model, Shingo Institute.1-60 s.

Ice scoring Mode. 2019. Productfolio. Available at: https://productfolio.com/ice-scoring/

Isoherranen, V. Niinikoski, E.-R. Malinen, T. Jokinen, M. Kess, P. Karkkainen, M. K. 2016. Operational excellence evaluation model for SMEs and regional findings. IEE.

JORDING, T. and SUCKY, E., 2016. Improving the Development of Supply Chain Management Maturity Models by Analyzing Design Characteristics. In: R. BOGASCHEWSKY, M. ESSIG, R. LASCH and W. STÖLZLE, eds, Supply Management Research – Advanced Studies in Supply Management. Wiesbaden: Springer Gabler, pp. 97-119.

Karaivanov Dimitar. 25.3.2019. Lean KPIs for Business. Available at: https://kanbanize.com/blog/lean-kpis-for-business/

KLÖTZER, C. and PFLAUM, A., 2017-01-04. Toward the Development of a Maturity Model for Digitalization within the Manufacturing Industrys Supply Chain, 2017-01-04.

Kukhnavets, P. 2018. How ICE Score Method Helps to Choose Better Product Features. Hygger. Available at: https://hygger.io/blog/ice-method-helps-choose-better-product-features/

Kukhnavets, P. 2020. Value vs Cost and Value vs Complexity. Hygger. Available at: https://university.hygger.io/en/articles/1635183-value-vs-cost-and-value-vs-complexity

Lu, Dawei. Betts, Alan. Croom, Simon. 2011. Re-investigating business excellence: Values, measures and a framework. Routledge.

McCarthy Dennis; Rich Nick. 2004. Lean TPM: A Blueprint for Change. Elsevier.

METTLER, T., 2011. Maturity Assessment Models: A Design Science Research Approach. International Journal of Society Systems Science, , pp. 81-98.

PAULK, M., CURTIS, W., CHRISSIS, M.B. and WEBER, C., 1993. Capability Maturity Model for Software (Version 1.1). Pittsburgh, PA: Software Engineering Institute.

PROENÇA, D. and BORBINHA, J., 2016. Maturity Models for Information Systems - A State of the Art. Procedia Computer Science, 100, pp. 1042-1049.

Ras, Eduard et al. 2015. Lean Book. Eurofins.

SANTOS BENTO, G.D. and TONTINI, G., 2018. Developing an instrument to measure lean manufacturing maturity and its relationship with operational performance. Total Quality Management & Business Excellence: 20th QMOD Conference Selected Best Papers, 29(9-10), pp. 977-995.

Sayer Natalie; Williams Bruce. 2007. Lean For Dummies. Hoboken.

Steigerwald, K. 2019. Value vs Complexity. Productplan. Available at: https://www.productplan.com/glossary/value-vs-complexity/

Tapping Don. 2007. The new lean pocket guide XL: Tools for the elimination of waste!. MCS Media.

Vorne. 2020. Lean Production. Available at: https://www.leanproduction.com/tpm.html

Wright, Christopher. 2017. Fundamentals of Assurance for Lean Projects. IT Governance Publishing.

Pinto J. Quesado L. José; Matias O. João; Pimentel Carina; Azevedo G. Susana; Govindan Kannan. 2018. Just in Time Factory Implementation Through Lean Manufacturing Tools. Springer.