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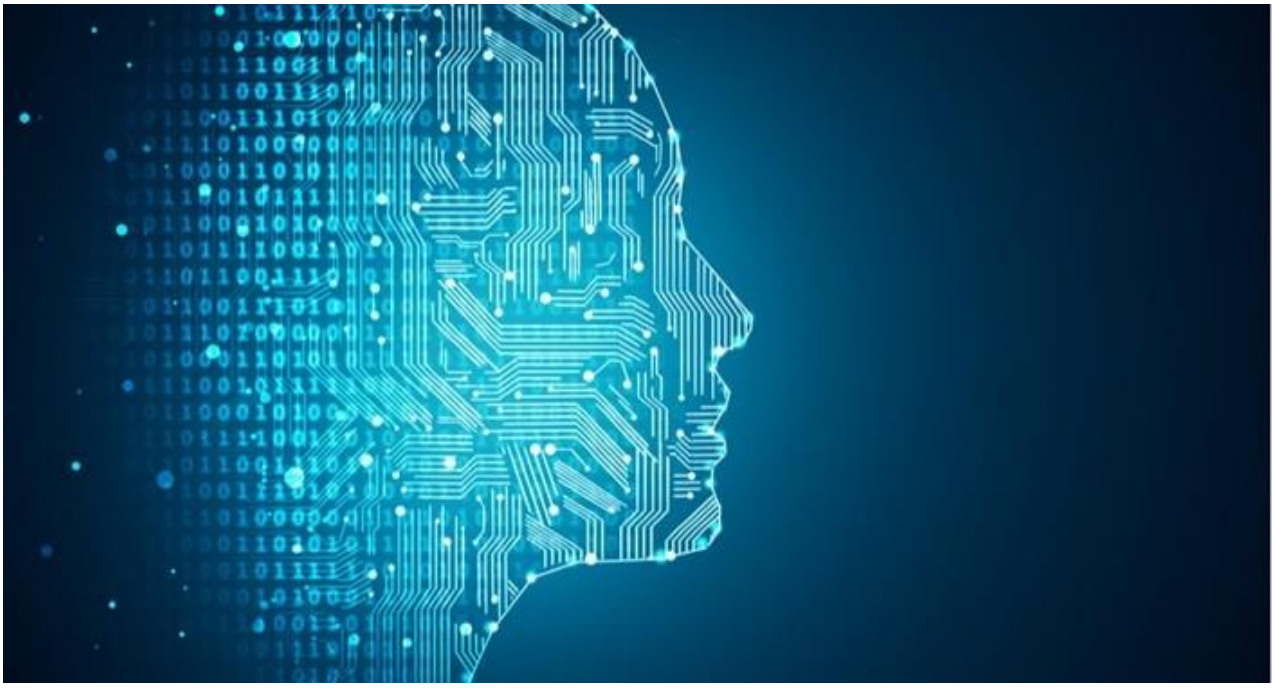
Best Practice Guidelene

Green Digital Transformation Initiatives and Best Practices in Manufacturing Industry

2020-1-TR01-KA226-HE-098393

Building Virtual Learning Platform for Environmentally-Friendly Digital Transformation Management



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INTRODUCTION

This guide has been prepared to analyze and disseminate good practices in digital transformation management by SMEs in their digital transformation processes. The guide identifies and analyzes good practices by combining digital transformation management with the perspective of 'green and environmentally friendly practices'. Thus, experiences and short directives will be presented to inspire and guide the digital transformation processes for SMEs. It will also enhance 'project-based learning' experiences in digital transformation management for students, academics and researchers interested in this field. This will allow stakelholders to produce real case studies that will help them understand their 'theoretical' knowledge in digital transformation management in practice.

Project-based learning (PBL) or project-based instruction is an instructional approach that provides students with opportunities to develop knowledge and skills through engaging projects based on challenges and problems they may encounter in the real world. The guide, created in line with the project-based learning approach, was developed in collaboration with experts from academia and industry. The guide analyzes and interprets best practices (original findings) in digital transformation management based on field analysis. The fact that this study is also prepared to address examples of the analyzed good practices in the Sustainable Development Goals and Green Transformation axis increases the innovative power and broad impact of the study. As a result, some of the examples in the guide are “direct” uses of digital technology (transformation) in the area of "*green digital transformation*."

The guide also includes several other applications that look at how digital tools indirectly contribute to green transformation.

Project-based learning (PBL) can have a significant impact on a digital transformation management curriculum by providing students with hands-on experience in applying digital technologies to real-world problems,

In the context of digital transformation management, this PBL based guidline can be used to teach students how to use digital tools and technologies to solve business problems, develop new products and services, and improve business processes.

This PBL-based guideline can also help learners gain a deeper understanding of the challenges and opportunities associated with digital transformation. By working on real-world projects, learners can experience firsthand how digital technologies can be used to create value for businesses and the environment

The guide covers a wide range of applications of different digital tools such as simulation technology, artificial intelligence, augmented reality, radio frequency identification and drone technology, including renewable energy, waste reduction, circular economy and reduction of carbon emissions.

The examples discussed in the guide demonstrated the added value that businesses realized in terms of reducing paper consumption as well as gaining speed and efficiency by using ERP systems. In addition, the examples given include examples with more complex and direct environmental impacts, such as the environmental impact that companies have on reducing carbon emissions through the use of simulation technology. In this sense, we hope that this guide, which presents a wide range of examples of the use of different technologies in different business processes, will guide companies and researchers, especially SMEs, who are planning to realize digital transformation. The best practices included in the guide also include examples such as the increase in speed and efficiency, the reduction of input costs, and the production of specialized products through the use of digital tools. Accordingly, it is understood that the strategies applied on the effects of digital transformation in the current literature can be applied in real-world production environments and provide practical advice and case studies to demonstrate their results. In this respect, the guide contributes simultaneously to the EU's "twin transition" target, which emphasizes the understanding of sustainability in sustainable development and economic growth. The guide provides concrete examples of how businesses can make investments in digital transformation. Highlighting the added value of digital transformation for both businesses and society, this study supports learners' ability to see the correspondences of literature knowledge in practice. As a result, this guide provides readers with concrete examples of which digital technologies can be used by companies seeking to achieve a similar effect.

This guide is innovative because it also helps students who are/will be studying management of digital transformation to see concrete examples from working life. As part of this study, each company we interviewed as part of the best practices analysis shared key information, documents, and visuals about the digital transformation process in their companies. Through a simulation demonstration, they shared with us very important information for their institutions. We would like to thank them again for their valuable information and hospitality. Without them, this work would not have completed. On this occasion, we want to send our thanks to our experts and researchers who participated in the fieldwork at Greater Manchester Chamber of Commerce (GMCC), and Istanbul Minerals and Metals Exporters' Association (IMMIB). We are grateful for their involvement in the completion of this work. We would also like to thank the whole Erasmus+ program, especially the officials and experts at the Turkish National Agency, for their financial and administrative support of the research. In this sense, we hope that the guide will be useful to academics, students, researchers and SMEs who want to implement digital transformation.

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Research Methodology and the Study's Background

The term twin transition refers to the intersection of two main priority areas of the EU in terms of its scope. These two priorities are the transition to a low-carbon and sustainable economy and the digital transformation of various sectors of the economy. The twin transition philosophy is to promote economic growth, competitiveness, efficiency and job creation while reducing greenhouse gas emissions and ensuring that economic development is environmentally sustainable. The twin transition policy is essential in terms of achieving the EU's goal of being a climate neutral continent by 2050, as well as ensuring sustainable economic growth and promoting competitiveness in the global economy. As a result, the twin transition promote the concept of sustainable development by aiming for businesses and economies to grow in a 'clean' manner. This concept, where the themes of green transformation and digital transformation intersect, has also been the key to these good practice analyzes. Therefore, this guide to good practice presents strong examples of how digital tools and digital transformation can be effective in the EU's journey to become a climate neutral continent. Researchers have seen how the impact of digital transformation on businesses' productivity and efficiency is revealed via company visits and digital maturity analyses. Additionally, it was stressed how digital technologies and change, whether direct or indirect, have contributed to the process of going green transition.

Accelerating the twin transition not only requires new technologies and greener practices, but also a reskilled workforce. According to the European Skills Agenda and the Recommendation of the Council on Vocational Education and Training, innovative learning and teaching methodologies are needed to meet the needs of sectors for digital and green skills. This guide is also a product of the idea to support this innovative learning methodology. Accordingly, by understanding the experience of digitally mature workplaces using different digital technologies, it is aimed to understand the practices that have an impact on environmental sustainability and green practices, as well as operational efficiency and productivity through the use of these technologies. Thus, it is also aimed to gain important insights on how the digital technologies in the existing literature can be used concretely. Accordingly, field visits were made to workplaces that were determined to be 'digital mature' by the experts in the project team. The workplaces that were deemed to have implemented good practices in digital transformation management, especially the examples that were found to realize "green digital solutions" through interviews based on visits or on-site observations, were included in the guide as the sample of the research. Accordingly, this guide provides the reader with the following:

- *Understanding the overall view of digital transformation, its benefits to businesses by understanding which digital technologies SMEs use, how and for what purposes.*
- *To provide an overview of the obstacles and challenges faced and available solutions related to the realization of digital transformation,*
- *Understanding the contribution of digital tools to environmental sustainability and green transition.*

The research is the result of an original study with important examples of the provision of a green and digital economy, called "Twin Transition". The guide was carried out in "5" sub-dimensions, specifically by visiting workplaces found to have reached digital maturity and studying their practices. Accordingly, the steps of this analysis of good practices are as follows:

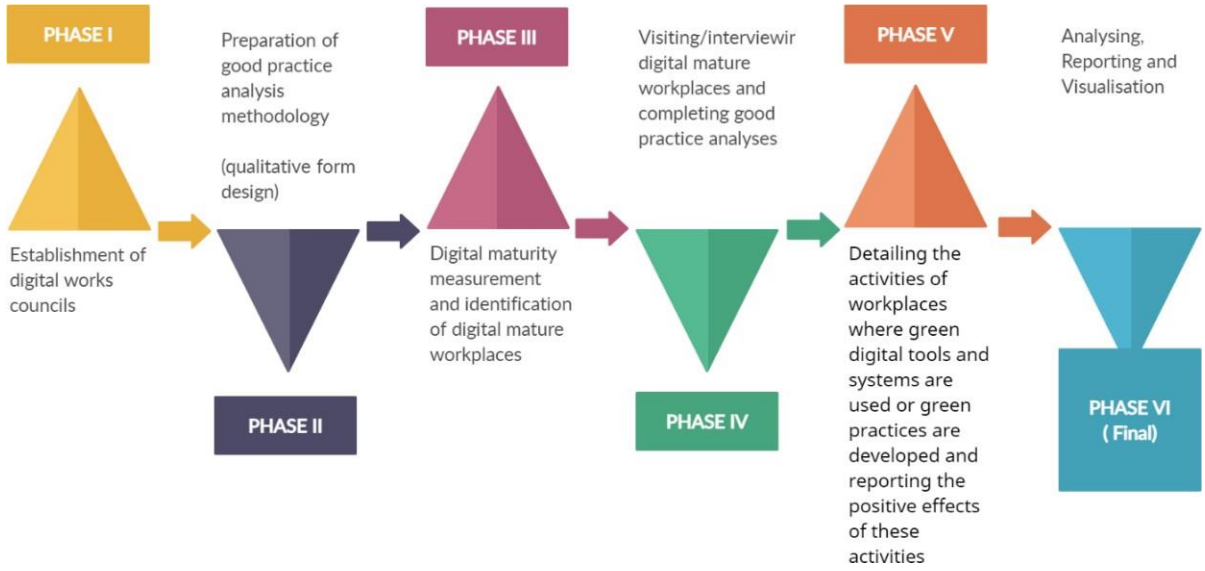

Figure 1. Guidline procesess flow diagram (by Authors)

The guideline was analyzed at the intersection of green and digital transformation themes, as well as good practice analyzes conducted under the leadership of the project's business partners, Istanbul Minerals and Metals Exporters' Association (IMMIB) and Greater Manchester Chamber of Commerce,(GMCC) and with the support of Istanbul University, University of Bedforshire and Bielefeld University. By making visits to businesses that were considered to be digitally mature, information about which tools and how these businesses used and what kind of transformation they have achieved has been obtained and was included in this guide. In addition, the innovative solutions (in-house) that these enterprises have realized within their own structure are also included in this report. Thus, striking examples of 'twin transition' examples in EU countries have been reached at the intersection of green transformation and digital transformation.

Figure 2. Intellectual Output Implementation Map (by Authors)

The field research area (scope) of the research is in the project partner countries of Turkey, Germany, and England. It has been observed that some companies interviewed did not carry out their best practices in the country where they have existing establishments but in a different country. This situation, found within the scope of the project, is an important example of globalization. Therefore, in this good practice analysis, various examples of good practice were reported from Turkey, the UK, and Germany, as well as from the Netherlands and Singapore.

Preliminary Information About Digital Maturity Graphs:

In guidline, graphical representations were prepared by the authors specifically for each example of good practices. The graph used for the good practices shows the digital maturity level of the companies that are the subject of the good practices analysis. The digital maturity representation is expressed as a 45-degree angle at the intersection of the "horizontal" and "vertical" axes. It is determined that the technologies located near the aforementioned 45-degree angle are fully integrated into the companies' business processes. The horizontal axis of the diagram cut at the 45-degree angle represents the area in which the digital technologies currently used by the companies are located. This area is between low level 1, and high level 5 in terms of the use of digital technologies. Accordingly, level "3" and higher refers to the "more mature" companies in terms of digital technology use. Levels 1 and 2 refer to less mature/immature businesses in terms of the use of digital technologies. The "vertical" axis of the diagram is used to show the level of digital maturity in terms of "business processes". It therefore indicates how advanced the adoption of digital transformation is in business processes such as the human resources organization, the administrative structure and the strategic structuring of the company. The vertical axis where the 45-degree angle starts is between "1-Low level" and "5-High level". A value of close to level 5 means that the digital transformation has been fully implemented in the company's organizational and business processes.

Accordingly, as the digital technologies on the horizontal axis approach the 45-degree angle, it refers to a situation where the business is integrated into the business processes. Considering that digital transformation is not only a technological infrastructure development process, but also that the technological infrastructure should be integrated into organizational processes; digital technologies, which are seen to be on the 45-degree axis, indicate that the business has "fully mature" digital transformation.

CASE STUDY 1:

Keywords: Enterprise Resource Planning (ERP), Internet of Things (IoT)

Sector: Textiles Services

Technical Textiles Services (TechTex) was founded in 1996 by David Beardsworth and Brian Whitney. The company has grown to become one of the UK's largest suppliers of healthcare and industrial fabrics – with two trading divisions focused on the manufacturing of a variety of products ranging from wet wipes to non-woven geotextiles. Based in Manchester they operate from a modern 70,000 square foot manufacturing and wholesale facility with over 3,000 tonnes of fabric passing through the facility each year. The company has an approximate turnover of £18m p/a and has worked alongside GM Chamber members Visual PM on their digital transformation strategy.

- **Digital Transformation Tools / Activites Used**

TechTex use an Enterprise Resource Planning (ERP) system to manage their main business processes and work flows. Despite the ERP system being an important tool for their business – the implementation of this system was an example of being 'over-promised' or 'mis-sold' by a Digital Transformation consultant. They had been informed that the ERP system itself would resolve the challenges they faced as a business, although it has become apparent that this system, while beneficial, is only one part of the process.

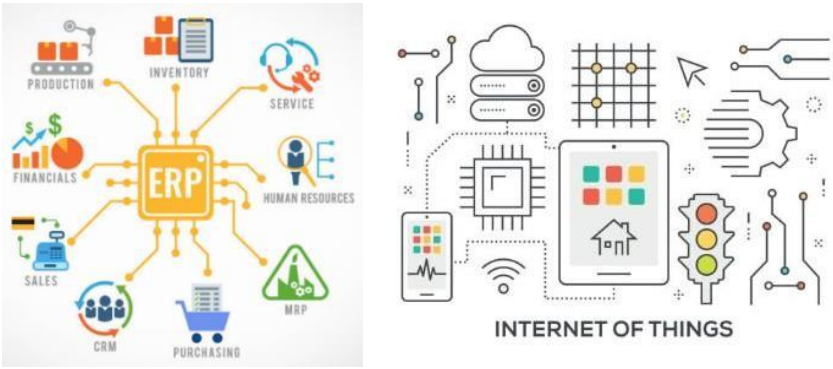

Figure 1. Current Tools

(CC)

The company also uses real-time live data monitoring through a combination of software and IOT sensors on the production line machinery. This supports real-time monitoring and opitmisation of systems and workflows to improve productivity and ensure maintenance of machinery. The implementation of these new forms of technology required training and upskilling of both the Management Team and the wider work force.

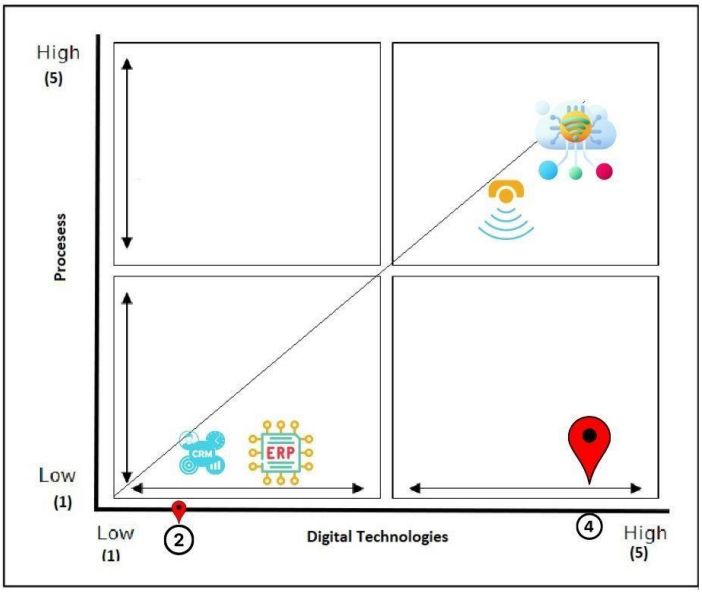

Figure 2. Techtex Digital Maturity Level Template
(preperad by Authors)

- **Digital Maturity Level**

Previously the company was using both an ERP and CRM (Customer Relationship Management) system that were not integrated. This resulted in additional manual processes and sharing of data via spreadsheets. Prior to the most recent Digital Transformation activity (detailed below) Techtex suggested that they would have placed themselves at a Digital Maturity Level of 2 – meaning that although they were aware of the need for technology within the business, this was very reactive, systems do not communicate and technology does not help them to increase productivity or avoid potential issues. However, since the implementation of the Digital Transformation activities below Techtex would now placed themselves at a **Digital Maturity Level of 4.**

- **Key Example of Digital Transformation**

Techtex have highlighted the introduction of Internet of Things (IoT) Sensors on their production line as the most impactful element of Digital Transformation completed by the business. These Sensors enabled additional automated quality control checks with the data gathered integrated to work in conjunction with the ERP System and production line robotics. This resulted in improvements to productivity and quality control while also resulting

in a reduction in waste and the ability for the company to produce better results with a leaner workforce. A noticeable improvement to the companies P&L was seen within a one-month period.

- ✓ *Improvements included – daily temporary worker requirements eliminated by 100%, on-time shipment orders improved to* 98.4%,

- ✓ *Order accuracy improved to 99.7%,*

- ✓ *Equipment availability increased to 91% - which resulted in further reduction of labour costs and 98% of the management team for the business completed a full 18-week training programme on the new technologies implemented.*

TechTex decided upon this technology by assessing the key objectives/requirements of the business. The Leadership Team of the business identified a focus on reducing the reliance on labour, improving speed/accuracy of shipment deliveries, reducing over-time requirements and increasing equipment availability as the main priority areas. Once the key focus areas were identified, TechTex then connected with external consultants to explore the best new technologies to support in achieving these goals. This process posed challenges, with initial conversations with consultants resulting in the purchase of incorrect software that did not achieve results required.

- **Challenges Experienced**

Other than the challenges outlined above in relation to consultants, other challenges experienced by Techtex were all linked to staff/people. The business was experiencing difficulties with staff retention – it became apparent from leaving interviews that staff were frustrated with the poor management system in place and out-dated technology throughout the business. This was most apparent in their previous productivity metrics such as 'order picking standards' – these outdated metrics were demotivating for staff and required revision. Once the process of implementation of the new technology was underway the main challenges related to training. Due to previous staff turnover most frontline supervisors within the business were new to their roles and therefore required detailed training/upskilling. It was also fundamental that training relating to the implementation of new technologies was provided for staff of all levels across the business to ensure staff embraced the new technologies and maximised their use.

CASE STUDY 2:

Keywords: Roadvent™, 3D CAD modelling, Simulation

Sector: Air Pollution Solutions

Pollution Solution was founded in 2014 in response to growing awareness of the challenges posed by air pollution globally. Since 2014 the business has focused over 30,000 development hours on working towards tackling air pollution and created a range of different products. Pollution Solution work across both the public and private sectors. In the public sector they assist local authorities, councils and governments as they strive to improve air quality. They focus on Air Quality Management Areas (AMQA), Ultra Low Emission Zones (ULEZ) and pollution hot-spots. In the private sector they assist companies who want to achieve safe and legal air quality levels for their staff, customers, and neighbours. The company is based in Hertford and has worked in collaboration with GM Chamber Members Wilde Analysis on their Digital Transformation journey.

They achieve this work through their primary product Roadvent™ which is designed to be placed within the road service at pollution hotspots to capture and clean exhaust emissions from slow moving or stationary traffic. This can be used at schools/nurseries, taxi ranks/bus stops, trainline crossings, toll booths, distribution centres, fuel stations and at drive throughs. Roadvent™ is a system that comprises of channels embedded in the road surface using a fan to draw air through the system from road level. This air is then passed through filters to remove harmful gasses and particulate matter before being released back into the environment. This technology is designed to be on the road surface and positioned as close as possible to the vehicle exhaust outlets to maximise the pollution capture rate.

- **Transformation Tools/Activities Used**

For the development of their Roadvent™ product, Pollution Solution have harnessed the use of digital technologies to support with product development. The business determined that using Computational Fluid Dynamics (CFD) through the Ansys Spaceclaim 3D CAD modelling software to create a ‘virtual drive through’ simulation ahead of real-world testing.

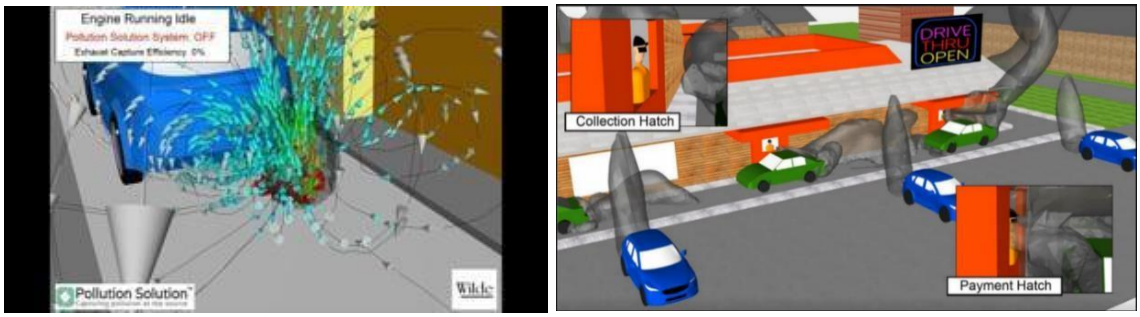

Figure 3. Video Contents of CFD Simulation of early stage analysis

- **Simulation Videos (Link):**
  - CFD Simulation - YouTube
  - Early Access CFD Simulation/ Simulation created with Ansys SpaceClaim technology - YouTube

- **Digital Maturity Level**

As a company that is at the cutting edge of technology, Pollution Solution perceive themselves to have a high level of Digital Maturity and would score themselves at a **Level 4**. They have full integration of their in-house platforms and use automation throughout the business. However, it is worth noting that they did not have the technical expertise in-house that was required for use of the CFD software and therefore had to obtain external expertise.

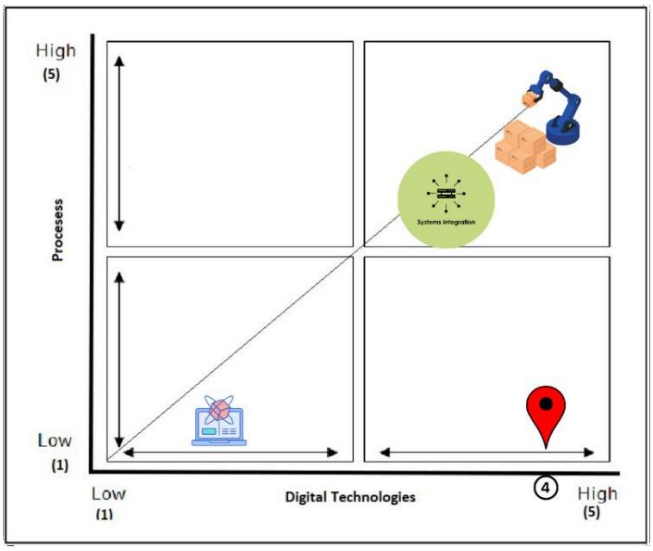

Figure 4. Pollution Sllution Digital Maturity Level Template (by Authors)

- **Key Example of Digital Transformation**

Pollution Solution had identified the need for the use of new technologies as part of the development of their Roadvent™ product. With the product focused on addressing air quality challenges relating to fossil fuelled vehicles, there were a host of challenges identified prior to product development and testing.

Although real-world testing would be required, physical testing of this new product would be expensive and impractical at the early concept stages. Along with the cost implications, it is also dangerous and damaging to the environment to perform create these physical tests over a sustained period. Due to this the company identified the use of Computation Fluid Dynamics (CFD) as the ideal technique to assess the proposed solution through simulation and modelling. After discussing this with consultants and exploring the market, they decided that Ansys SpaceClaim technology would be the preferred programme to assist with the 3D modelling required for this simulation process.

The simulation creation and development was a success with the CFD modelling enabling Pollution Solution to test time-varying levels of pollution. The simulation also allowed the company to test nine different vehicle models performing various cycles of acceleration/deceleration. The early stage CFD analysis predicted that exhaust capture of up to 97% occurred in calm conditions. The simulation also highlighted the high levels of pollution exposure suffered by staff working at the simulated business sites when there was not a Roadvent™ solution installed.

The use of the CFD simulation was extremely beneficial to Pollution Solution. It demonstrated the effectiveness of the Roadvent™ product in addressing a major pollution issue. It also predicted the current pollution rates around a representative drive-through site enabling a comparison with relevant guidelines and air quality legislation across Europe. This also provided valuable research which can be used to promote the product to both potential customers and investors.

Roadvent Product Featured as part of BBC’s Clean Air Day 2022 Programming

- **Challenges Experienced**

Although the process undertaken by Pollution Solution to utilise CFD simulation technologies during product development was a resounding success, it was not without challenges. Firstly, the company were required to identify investment in the business to support with the development of the CFD simulation. This is because the price of the external expertise needed for the creation of this technology and the length of time required for development involved. Upon completion of the simulated testing, real world testing was still required – this incurred further costs and highlighted some other challenges with the product, but these challenges were vastly reduced compared to full ‘real-world testing’ which would have been required had they not used the CFD simulation technology.

CASE STUDY 3:

Keywords: Artificial Intelligence, Simulation, DEFORM 3D, Robotics, integrated CRM/ERP systems

Sector: Non-ferrous forgings, Machined components

Cerro EMS is the United Kingdom's largest producer of commercial non-ferrous forgings and machined components in the UK. Having been established in 1836, the Birmingham-based business are considered business leaders in their field with a strong reputation for innovation through regular investment in state of the art manufacturing centres. Cerro EMS have developed a global customer base and now export to clients on four continents and, as of 2023, have machined over 5 million components. Although the business works across a wide range of sectors, the key industries for this organisation are Gas/Utilities, Electrical, Welding, Security, Health Care, Automotive, Marine, Defence and Hydraulics. Cerro EMS have worked in collaboration with GM Chamber Members Wilde Analysis on their Digital Transformation journey.

Cerro EMS pride themselves on delivering significant savings for their clients without compromising on quality by refining process and using innovative technologies. In this example Cerro EMS were looking at ways to improve efficiency in design processes while still meeting stringent product quality requirements.

- **Digital Transformation Tools/Activities Used**

Cerro EMS have gained a reputation for being industry leaders through innovation and due to this were keen to explore options to improve efficiency through simulation of the manufacturing process. This was particularly attractive to the business due to the significant cost savings whilst improving both product quality and tooling experience.

Figure 5. DEFORM 3D engineering software (Wilde Analysis, 2023)[1]

[1] DEFORM is specifically designed to simulate cold, warm and hot manufacturing operations for preform optimisation, tooling and product development, process troubleshooting and die stress analysis. Typical applications include forming, heat treatment and machining. Developed by SFTC, automatic remeshing

They enlisted the support of external consultants who were experts in simulation software and through these discussions they identified DEFORM 3D engineering software as the tool that would best serve the business needs. Alongside the introduction of DEFORM 3D for simulation purposes, the company also currently uses Artificial Intelligence, process robotics and integrated CRM/ERP systems within their operations.

- **Digital Maturity Level**

As previously mentioned, Cerro EMS are considered industry leaders due to their innovative approach to business. Due to their commitment to innovation the company regards itself as **Level 5** in terms of Digital Maturity.

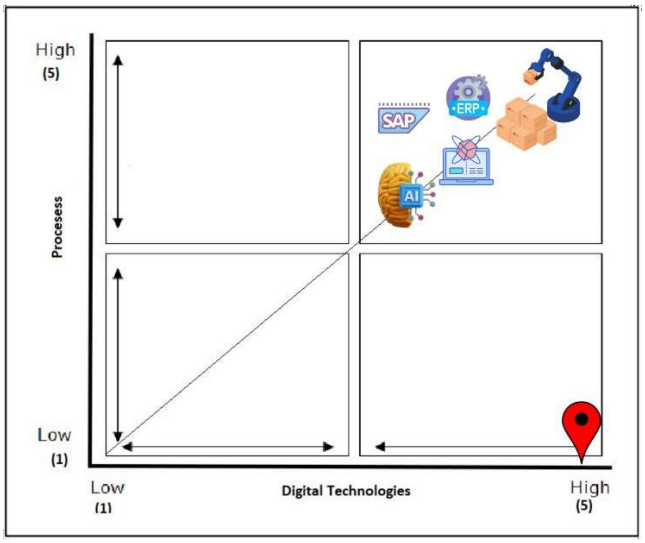

Figure 6. Cerro EMS Digital Maturity Level Template
(by Authors)

As they are continually at the forefront of innovation, they would consider themselves to be 'digitally strategic'. They have threaded digital activity throughout their business strategy – with AI, robotic process automation and simulation all now embedded in their daily business operations.

- **Key Example of Digital Transformation**

As a business that is continually striving to improve efficiency, the key example of digital transformation for Cerro EMS was the use of DEFORM 3D software. The primary benefit of the implementation of this software was a reduction in the costs of the manufacturing process – both due to reduced resource requirements and higher quality control. This cost saving has enabled Cerro EMS to increase profits whilst reducing the cost to clients.

capabilities and robust non-linear solvers enable extremely large deformation material flow and coupled thermal behaviour to be simulated efficiently and accurately.

They decided upon this technology through consultation with external Digital Transformation consultants – a key recommendation from the consultants was the combination of new technologies along with upskilling of existing staff members.

DEFORM 3D is designed to produce accurate simulations at speed with a focus on cold, warm and hot manufacturing processes. The programme enables clients to predict the material flow in industrial forming operations without the cost of delay and shop trials. This technology is used at the beginning of the manufacturing process to allow Cerro EMS to predict product behaviour (which in turn will optimise designs for clients), test innovative concepts and validate products. As this activity all takes place before the manufacturing begins this greatly speeds up production which saves time and money for the business. Cerro EMS uses DEFORM 3D to provide analysis of their metallic/non-metallic forming heat treatment, machining, and mechanical joining processes. A further benefit that Cerro EMS noted about the DEFORM 3D software was the ease of use. The user-friendly interface meant that the platform was accessible for staff members at all levels of seniority and technical expertise within the business. This was an important factor in staff engagement with the new software which aided faster adoption of the software.

Cerro EMS cited the move to using DEFORM 3D with a variety of significant improvements to company performance. Since using the platform there has been a reduction in sample times with the number of samples required reduced by c.50%. The improvement in quality control and eradication of design errors/faults has been significant – with the majority of laminations/folds in the design process tackled in the early stages of the virtual design procedure.

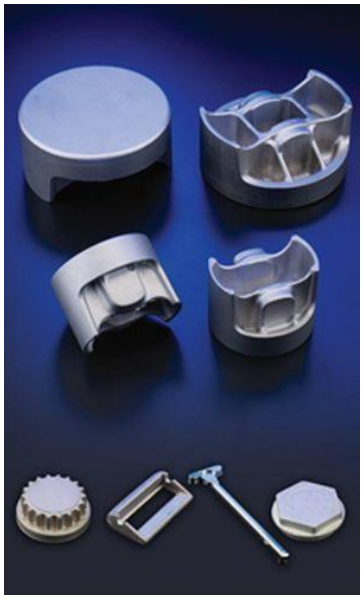

Figure 7. Image of components manufactured by Cerro EMS

In addition to this the thermal data that is gathered through the DEFORM 3D has revolutionised the way in which the business works regarding certain processes. The data recovered has been used to inform forging temperature parameters for low leaded brasses which in modern times have become prevalent in the water

fitting and valve market. This discovery has reduced material surface deterioration due to improved control of furnace and adiabatic temperatures. Interestingly, these adjustments and new parameters have gained attention from the wider industry – with Cerro EMS' suppliers now looking to replicate this way of working. Internally the greater confidence this has given the business in material volume and raw stock management has allowed for bulk purchases which result in more affordable materials and a reduction on initial lead times. Cerro EMS has now fully integrated DEFORM 3D as part of their die design procedure.

- **Challenges Experienced**

Due to the high level of digital maturity across the business, Cerro EMS felt that the integration of the DEFORM 3D software into their company processes was relatively smooth and without challenges. Despite this, the main challenge posed by the changes was the initial resource drain of training for all relevant staff. This was a short-term challenge as the impact of this training was far out-weighed by the benefits quickly realised by the introduction of the new software within the design process.

CASE STUDY 4:

Keywords: Robotic Automation

Sector: Wooden Packaging

Established in Bursa in 1978, the company operates in the field of Wooden Packaging. The company aims to achieve sustainable success by acting with a focus on efficiency in all its operational processes.

- **Problems & Solutions**

The problem areas experienced by Mebesa company were categorised under "3" headings from digital transformation. These are briefly

- ✓ Occupational Health and Safety (OHS) problems
- ✓ The need to produce higher quality products
- ✓ Low Efficiency

- **Digital Transformation Tools/Activities Used**

Robotic Pallet Nailing Project is the first project developed by Turkish engineering companies in this area. Operator only loads wood parts to fixtures and press start button. The gripper on the robot is designed for both nailing products and transporting manufactured products to the unloading area After receiving the start signal, the robot starts nailing product. After the front surface of the product is nailed, the positioner turns the product over and after that, the nailing process continues. After the nailing process is finished, the positioner returns to its original position. With the help of the robot gripper, the robot picks up the product and carries it to the unloading point. For the continuity of production, 2 loading and 2 unloading points have been prepared. The robot transports the product to the appropriate unloading point. It is very important to work with a supplier who can understand their needs. It is necessary to work on solutions that minimize human error. Infrastructure is also very important; an infrastructure preparation should be made accordingly in the implementation of the projects.

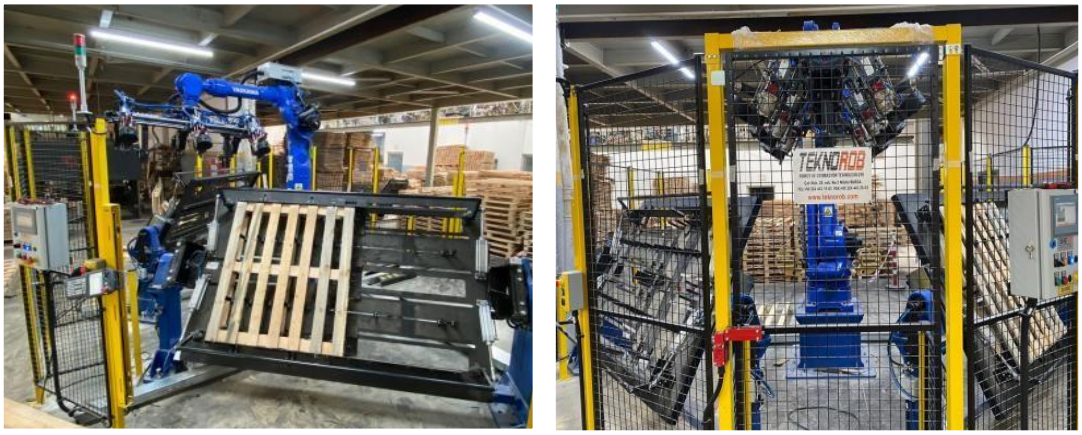

Figure 8. Working steps of the robot

- **Digital Maturity Level**

With this technology project, the organisation characterised its Digital Maturity at **Level 4.**

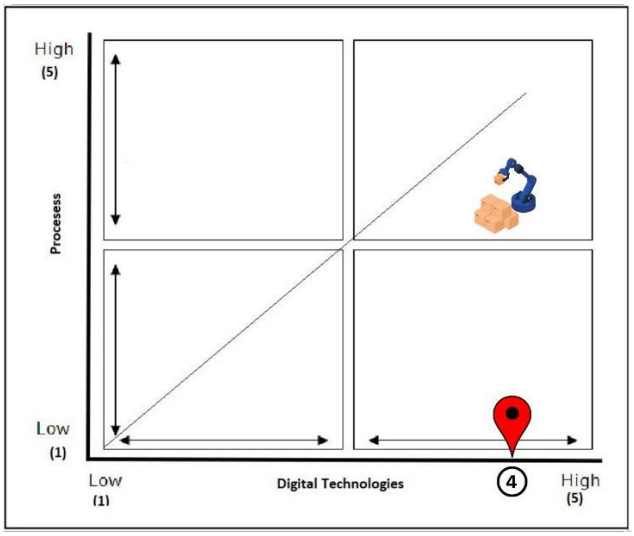

Figure 9. Mebesa Digital Maturity Level Template
(by Authors)

Goals Achieved

- ✓ *100% automation has been achieved, except for loading the semi-finished product and removing the produced pallet from the line. With 1 worker per shift, the entire process has become controllable.*

- ✓ *The number of products produced per shift was increased by increasing the production speed by more than 2 times. (According to field analyses, production times have been reduced from Pallet/190 sec. to Pallet/60 sec.)*

- ✓ *In products such as EPAL; which are subject to international standards, the number of nails, the position of the nails, etc; products that are 100% compatible with the standards were produced with low margins of error.*

- ✓ *Thanks to its flexible design structure, additional solutions specific to needs were developed and integrated.*

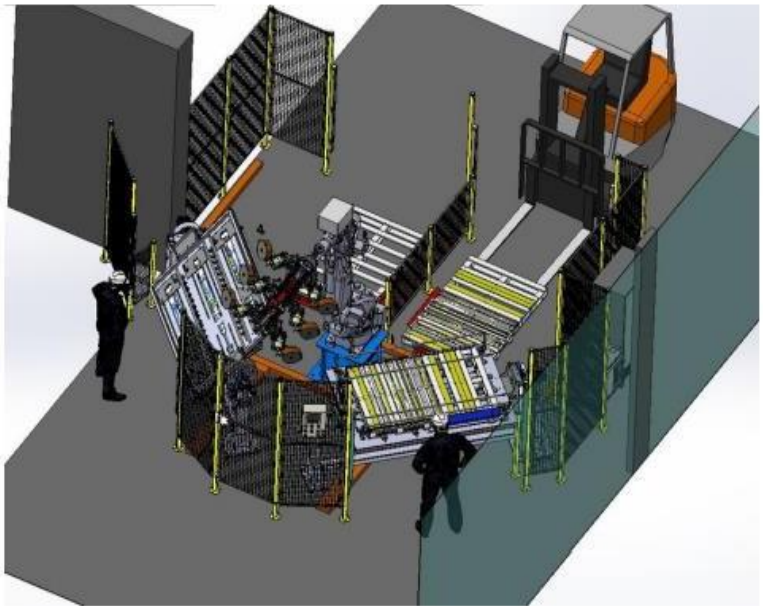

Figure 10. Robotic Pallet Nailing Project

- **Resource & Environmental Impacts**

A product obtained from nature is used and it was very difficult to recycle the product when faulty production was made in the period when it was not robotic. But with this technology, faulty production is prevented and excessive use of the material is prevented. As the faulty product decreases, the cost also decreases.

- ✓ There were air leaks before, but now the air consumption is reduced by 10-15% (not exact measurement).
- ✓ There is a minimal increase in electricity consumption due to the use of robots, but this can be tolerated with the efficiency gained.
- ✓ Since it minimizes the human factor in production, it greatly reduces the problems related to work accidents, diseases, etc.

CASE STUDY 5:

Keywords: CRM, ERP, Digital Integration and Data Management, Innovative Softwares

Sector: Engineering Consultancy

Wilde Analysis are a consultancy business who primarily work with a diverse range of engineering clients in a variety of industrial and academic sectors – these clients span all business size from newly-formed start-ups through to multi-national organisations. Through years of experience Wilde Analysis have formed partnerships with a stream of innovative software developers to ensure they are able to recommend the most relevant and adaptable solutions to the challenges faced by their clients. Alongside working with commercial clients, they are dedicated to supporting the next generation of future engineers through their work with academia. They are involved in providing year-in internships and also assisting schools with their STEM focused programmes. Wilde Analysis are owned by the PDSVISION Group. The PDSVISION Group consists of several independent companies based around the globe all of which play a role in assisting businesses with taking control of their Digital Transformation journey. The group particularly focuses on supporting business through engineering simulation (CAE), 3D design (CAD), Product Lifestyle Management (PLM), Service Lifecycle Management (SLM), Internet of Things (IoT) and Augmented Reality (AR).

- **Digital Transformation Tools/Activities Used**

Although Wilde Analysis use a host of different technologies for their clients, in-house they have focused their attention on a suite of 'Vision' software programmes which are developed by another organisation within the group. They use 'Gold Vision CRM' as their main Customer Relationship Management (CRM) software, 'Deltek Vision' as their primary Enterprise Resource Planning (ERP) programme, 'Vision Payroll' as their main finance system and various other digital platforms through Microsoft.

- **Digital Maturity Level**

Wilde Analysis consider the business to be at a Digital Maturity **Level of 4.** They thread technology through their customer experience and journey, it is a key component of their overarching business strategy, they use real-time insights/analysis to influence their operations and they gather data across all functions of the business.

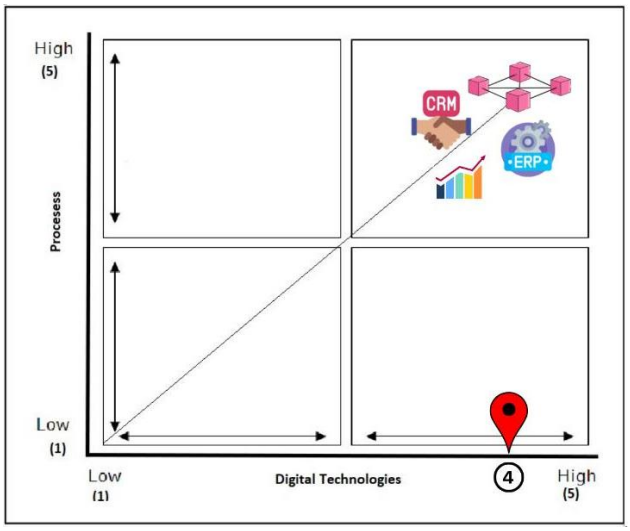

Figure 11. Wilde Analysis Digital Maturity Level Template (by Authors)

Due to their connections with PDSVISION they operate a fully integrated suite of programmes which allows them to analyse data with ease across their various departments. They admit that the move to becoming 'fully digital' has been accelerated by the Coronavirus pandemic with all training courses now held digitally, a work from home culture and 80% of meetings that were previously held in-person now taking place in a virtual environment.

- **Key Example of Digital Transformation**

When assessing the changes they have made to the business in recent years, Wilde Analysis feel that the element of Digital Transformation that has made the largest impact on the business is the implementation of a new Customer Relationship Management (CRM) system. The company had identified a need for improved management of activities and data relating to both existing clients and prospective clients. They felt it was vital that this investment in new software providing them with a platform that had the capability to be shaped to the companies requirements. Historically the company had kept records of engagements with clients/prospects in a secure manner but had lacked the functionality to properly assess this data and utilise the results to influence their wider Marketing and Sales strategy. Wilde Analysis explored various options on the market with a view to achieving the above requirements along with providing a cost-effective solution.

Following on from market research and discussions with individual software providers. Wilde Analysis opted to build their new CRM system with Gold Vision CRM. They decided upon this platform as previous basic CRM systems were out-dated and did not integrate well with their suite of software platforms. The company had identified a benefit to be had in a centralised approach to all contact details which would allow multiple departments to share a workflow. They also wanted a more intuitive platform that would support a Sales/Marketing function that was working ever-more remotely due to the pandemic. This platform provided them with security and confidence in the recording of data with the ability to produce dashboards for further analysis. It also provided an accessible and user-friendly interface which minimised the need for staff training and encouraged accurate use from all divisions within the company. Other benefits included the fact that it was

responsive both on desktop and mobile devices and, as mentioned previously, was fully customisable meaning it can develop/grow as changes are made to the organisation. Other key factors for this platform included the full integration with Microsoft Exchange – meaning that all client emails/calendar invitations could be tracked at the click of a button.

Results from the use of this new technology emerged quickly – with an improvement in analysis of the sales pipeline through the concept of 'lead scoring'. This allowed the company to focus greater energy on clients that are likely to be more commercially productive. This improvement in resource management instantly changed the way in which the company approach their sales strategy – creating a more efficient workflow. This was supplemented by the programmes ability to structured targeted marketing campaigns/campaign management. This more personalised approach ensured clients/prospects were being contacted with more relevant information and not becoming desensitised to content from the business. An environmental benefit to the business was achieved through the full integration of this software with other programmes within the organisation – this resulted in less reliance on paper records, less need for storage and, therefore, lower energy costs. This, accompanied by a movement to cloud servers, greatly reduced the companies carbon footprint.

- **Challenges Experienced**

A primary challenge was creating both a sense of engagement and ownership from the Senior Management and Operational Teams. Whilst both groups understood the importance of modernising work processes, there was a feeling that change may cause problems, upset processes and fundamentally be "more trouble than it was worth". This was resolved through open communication of the perceived benefits of the new platform and how this directly relates to the role of the individuals or departments that these colleagues were either working in or responsible for. This example of communication skills and transparency ahead of implementation of new technologies is a very valuable lesson – if the company had not taken the time out to discuss this with relevant staff then there is a risk that the CRM platform would not have been used correctly and data would not have been gathered in a useful manner. With a platform such as a CRM system a lack of engagement, and therefore correct usage, from the workforce can render the software ineffective and, in some cases, even problematic.

As with the introduction of any new 'management system', a challenge experienced was the migration of existing data to the new platform. Although the Gold Vision system was intuitive and supportive of the introduction of new data, there was a requirement from the company perspective to cleanse and assess existing data held on other sources ahead of migrating this to the new platform. This was an important piece of work as they did not want to replicate the challenges with data previously experience by bringing the data across in full. This took up some staff time, but a clean and correct database on the new Gold Vision platform greatly assisting with the engagement of the wider team when the programme was rolled out to staff. This also assisted with another challenge that was fundamental to the success of the platform – which was embedding the use of the new CRM system processes into all workflows for the business.

CASE STUDY 6:

Keywords: Ansys technology (enginering simulation), Advanced automation

Sector: Manufacture and commercialisation of its hydrogen refuelling products

NanoSUN is a world-leading, award-winning engineering company headquartered in Lancaster, UK. The business is focused on the development, manufacture and commercialisation of its hydrogen refuelling products. The company has a clear focus on accelerating hydrogen transportation and mobility across the UK and Europe – they specialise in the supply/development of mobile hydrogen refuelling stations using their own innovative cascade technology. This work aims to facilitate mobility of hydrogen and the rapid and low-cost deployment of the support infrastructure needed to encourage the adoption of hydrogen vehicles through various industries (including, but not limited to – buses, heavy duty trucks, trains, vans and construction/material handling equipment). The businesses' core product offering is their mobile Pioneer Hydrogen Refuelling Systems (HRS) which is a mobile, self-contained refuelling solution that provides a portable method of delivering transportation-grade hydrogen directly to the point of use. This system enables efficient, safe and rapid dispensing of hydrogen.

With concerns over climate change ever increasing, there has been an increased focus on the role that hydrogen can play as an alternative to fossil fuels. Hydrogen offers near zero CO2 emissions when produced using renewable energy sources such as electrolysis of water to release hydrogen or, alternatively, solar-based processing. With such a high value to the environment, this led to creation of NanoSUN in 2017. NanoSUN have worked with Greater Manchester Chamber of Commerce members Wilde Analysis for support in the Digital Transformation of their business to assist with their important work.

- **Digital Transformation Tools/Activities Used**

As part of their journey in striving for innovation, NanoSUN joined the Ansys Start-up Programme. This programme provides startup businesses with access to Ansys technology to help to grow while mitigating the initial investment required. This programme was set up as a part of Ansys' commitment to partnering with future industry leaders and playing a key role in their journey. The programme primarily supports businesses who wish to utilise the power of simulation to assist with innovation and product development. Through the programme NanoSUN have been granted access to a range of Multiphysics simulation software including Ansys Fluent Computational Fluid Dynamics (CFD) simulation.

NanoSUN was established in 2017 out of a desire to bridge the gap between hydrogen suppliers and fuel cell users with the key mission of developing high-pressure, mobile and cost effective hydrogen storage, distribution and dispensing solutions to the transport industry. Naturally there is a great deal of safety concerns when

working with hydrogen storage/distribution. Effective ventilation is essential to avoid the risk of fire and observation for any potential leaks is vital. From conversations with Wilde Analysis and Ansys, it quickly became apparent that the CFD Simulation software could play a key role in establishing safety, while also monitoring the refuelling stations.

- **Digital Maturity Level**

Despite working in market-leading/innovative technologies and holding a wealth of engineering/scientific expertise, NanoSUN are still a young company having only been established in 2017. Due to this they feel that prior to joining the Ansys start-up programme they would have considered their Digital Maturity Level to be at a level 3. They were conscious of digital responsibilities and digitally purposeful in terms of documenting IT plans/budgets etc. However, there is a strong argument that the more recent introductions of Ansys systems to their way of working has increased this to a **Level 4** – where they are proficient in key technologies and using an ever-increasing level of advanced automation.

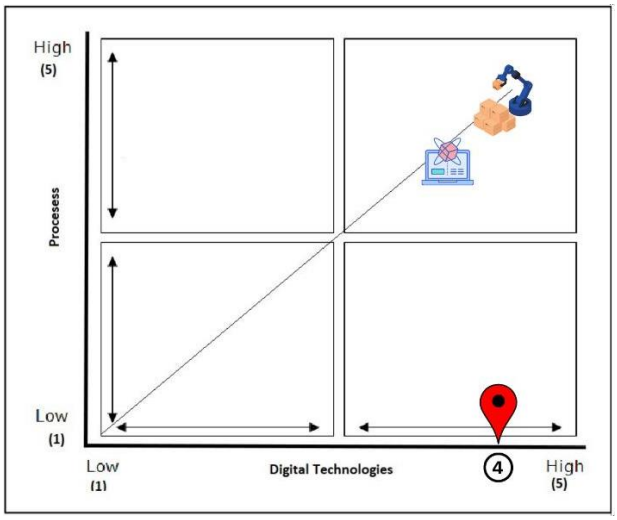

Figure 12. NanoSUN Digital Maturity Level Template (by Authors)

- **Key Example of Digital Transformation**

As outlined above, the introduction of NanoSUN to the Anasys start-up programme greatly accelerated their capabilities to progress development. This is due to challenges around funding which would have prevented access to this software had it not been from the programme. Quickly after joining the programme it quickly became apparent that utilisation of Computational Fluid Dynamics (CFD) simulation would be vital for the business. The company started to use Ansys Fluent (CFD Simulation software) to model scenarios such as hydrogen releases/leaks and potential combustion points throughout all stages of development. This is a challenging exercise with hydrogen being the lightest element and dispersing at such a rapid rate. The business used CFD Simulation to replicate the buoyancy of hydrogen and observe for a leak based on the expected flow within the refuelling systems and throughout the various cylinders of the system. In addition to this, they also

started to analyse potential combustion points to understand and gauge the direction and magnitude of potential releases. This would therefore indicate the magnitude of potential flames caused by these releases allowing calculation of proper hazard distances and ensuring that they would adhere to related hydrogen safety standards as outlined by the British Compressed Gas Association (*5 metres from flammable gas storage, sources of ignition and fuel gas vent pipes; and 8 metres from employee offices or congregations of people, flammable liquids and ventilator air intakes*).

Figure 13. This diagram depicts decent technology (left) versus cascade technology (right). NanoSUN uses cacade for hydrogenrefueling

Figure 14. This diagram illustrates the advantages of NanoSUN's mobile Pioneer Hydrogen Refuelling Statiton (HRS) solutions (furthest left) in comparison to fixed HRS solutions (center and right)

An example of this in action is the use of CFD Simulation to model thermal pressure relief devices (TRPDs) to anticipate the temperature at which a fire may erupt due to a gas release. The simulation can be used to calculate horizontal distances between the point of hydrogen release and people working nearby. As a part of these thermal measurements NanoSUN are then able to able to forecast probabilities for injury, exposure durations and thermal radiation intensities. Through these analyses, they are able to predict, monitor and prevent catastrophe.

Figure 15. Temperature profile illustrates the termal release of nine cylinders

Figure 16. Radiation profile illustrates the termal release of nine cylinders

- **Challenges Experienced**

As a recently formed company, NanoSUN experienced challenges around funding and cost to deploy new technologies. Although they managed to navigate this challenge through the benefits of the Ansys start-up programme, it is important to recognise that this is all-too-often a barrier which prevents other businesses from utilising the most relevant/effective technologies.

Due to the rapid scaling-up and growth the business (alongside the niche industry that the organisation works in), NanoSUN benefitted from the fact that many of their staff had experience of using CFD simulation technologies through their studies at University. Coincidentally, many UK Universities work in partnership with Ansys technology – which gave the company a head start in terms of proficiency with the technology. This avoided a key challenge that would have been the upskilling of internal staff to use complex technologies. This also, once again, reduced the drain of financial resources that would have been required by either bringing in external expertise either through recruitment or for training.

Another challenge for the business was compliance. While the CFD simulation software has its strengths, it is vital that the information provided is correct. Due to working with hydrogen, NanoSUN must work in collaboration with government agencies and regulatory associations to meet safety standards due to the high flammability of hydrogen coupled with the lower ignition energy.

CASE STUDY 7:

Keywords: Simulation, Bigdata, Software Integration

Sector: Commercial vehicle spare parts manufacturing

Sampa was established in 1994, with origins dating back to 1950. Sampa successfully develops, tests, and manufactures high-quality automotive parts at a 150.000 m2 integrated manufacturing campus.

For over 50 years, Sampa has offered quality parts that conform to UK and European ISO quality certificates, assigning market experts to roles in manufacturing, procurement and sales, operations and distributing centre departments. Simply put, Sampa independently runs the company as a leading commercial vehicle spare parts manufacturer and distributor.

Sampa's expansive vision for the future includes the opening of new sales hubs and warehouses around the world, with distribution to 160+ countries and offering fast and efficient provision of high-quality parts wherever they are needed. This global expansion has led to the inception of Sampa UK & Ireland Ltd, founded in Manchester in 2020. Sampa UK & Ireland has built a solid reputation as a reliable manufacturer offering high-quality parts for commercial vehicles and trailer businesses, with its Manchester base housing an environmentally friendly, integrated and fully operational warehouse and a centralised logistics centre – allowing for control over all logistics, sales, and services operations.

- **Digital Transformation Tools/Activities Used**

Sampa takes great pride in its 1500 m2 state-of-the-art research and development centre – CAMP. CAMP was launched at an initial cost of 12 million euros and is funded each year through approximately 2.5% of Sampa's annual turnover. Equipped with high-tech tools, machinery, and 5 departments with over 200 scientists and technicians, CAMP is constantly in pursuit of the latest innovative products, processes, materials, and methods.

In the Product Technologies division, technical personnel are assigned and mobilised according to strategic product groups, whilst materials design and development activities are carried out in the Material Technologies division. Coordination and reporting of all projects carried out and reported in CAMP are provided by Project Management, whilst the Intellectual Property team carry out the research, application and registration processes of CAMP's patent, brand and industrial designs. The Mould & Equipment Design division carries out the design

works regarding moulds, machines, and equipment development projects within CAMP. These departments include:

- ✓ Laboratory and Material Technologies,
- ✓ Product Technologies,
- ✓ Engineering & Method,
- ✓ Mold & Equipment Design,
- ✓ IP & Project Management

Sampa places a huge amount of emphasis on its testing capabilities and in-house technologies.These include, but are not limited to…

- ✓ Universal Mechanical and Tribology Testing
- ✓ Stress Relaxation and Creep Systems
- ✓ 3D Scanning
- ✓ Dispergrader
- ✓ Melt Flow Index
- ✓ Corrosion Test Chamber

- **Digital Maturity Level**

Sampa's vision to continually strengthen their R&D infrastructure, and therefore increase their competitiveness globally, combined with a sustained and substantial investment in 'real world' testing capabilities, places Sampa as a high **Level 4** on the Digital Maturity scale. In addition to Sampa's enviable testing facilities and production capacity, their focus on recruiting the very best minds from the likes of Amazon and Google has only enhanced their Digital Maturity score further.

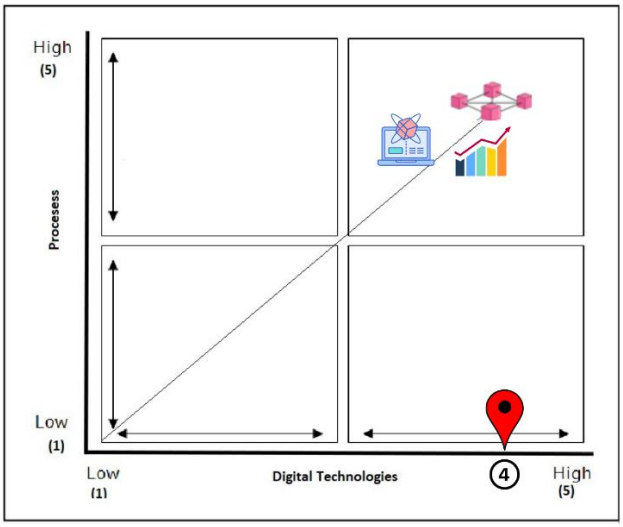

Figure 17. Sampa Digital Maturity Level Template (by Authors)

The CAMP R&D team works closely with the marketing team to communicate news on innovative new products and developments that are made. To further strengthen their Digital Maturity, Sampa regularly cooperates with universities and private enterprises in the region.

- **Key Example of Digital Transformation**

When testing their products, Sampa simulates the challenges posed by real road and weather conditions by using salt-corrosion resistance metres from CAMP's high-tech equipment and rare testing machines such as MTS. Thanks to the road data that Sampa collect from their customers around the world and these high-tech devices, they have the opportunity to monitor and perfect products in all possible conditions. Sampa have always attempted to integrate big data into every aspect of their operations.

Figure 18. MTS test lab

The research work conducted at CAMP helps Sampa comprehend the exact needs of customers. Furthermore, it also makes great contribution to fit these needs by developing new and improved products and services. In this way, CAMP has a fundamental effect on the interaction with their customers.

- **Challenges Experienced**

Real world field testing is very expensive, time-consuming and doesn't allow for "in-service" inspection. To save time and offset delays in development, Sampa supplement field testing with cost-effective mechanical testing in the high-tech MTS test lab, capable of providing greater testing speed, control and repeatability.

The MTS test lab ensures precise alignment with original parts, enabling Sampa to bring safer, more durable and fuel-efficient products to market faster and at a lower cost.

CASE STUDY 8:

Keywords: Simulation technology

Sector: Energy

RJM International is a specialist provider of a range of innovative and technologically-sophisticated products and services aimed at the power, industrial plant, biomass and Waste to Energy sectors. RJM supplies leading global power generators and other large combustion plants, such as refineries and steelworks. The company is recognised for its ability to deliver innovative solutions to help customers operate as efficiently and cost-effectively as possible whilst meeting the latest governmental emissions regulations.

Simply put, RJM designs, manufactures, and installs a vast number of technologically sophisticated products. They range from the wholesale replacement of a plant's entire set of burners to the replacement of individual oil injector components.

- **Digital Transformation Tools/Activities Used**

RJM frequently helps its global generator customers resolve operational challenges such as slagging, fouling, combustion imbalance or instability, poor efficiency, steam temperature issues and other issues such as fuel switching, fuel blending and co-firing. In today's energy market, providing fast and cost-effective combustion solutions to reduce emissions, improve efficiency and increase reliability is critical to new and aging combustion plants. Engineers must verify product integrity, ensuring it can successfully operate across a range of real-world operational conditions prior to prototyping.

The scale, complexity and costs involved for supporting these high value assets requires RJM International's use of cutting-edge simulation driven by high-performance computing (HPC). RJM International's engineers use Ansys HPC to analyse customers' existing operational systems and quickly solve large and complex Ansys Fluent simulations during an overnight run. This enables engineers to run more design variations and develop a complete analysis prior to prototyping. As a result, global power generators and other large combustion plants leverage enhanced designs that reduce emissions and improve efficiencies. With the introduction of Ansys HPC, simulations that previously required a week can now be completed within a day, enabling an 86% reduction in development time.

In addition, RJM employs some of the industry's top combustion modellers and has developed its own enhanced, proprietary combustion modelling code for a wide range of coal, biomass and waste fuels to provide even greater levels of accuracy. This enables predictions to be very closely matched by actual post-upgrade

performance. RJM also uses DEM (Discrete Element Method) modelling and Physical Modelling for understanding multi-component biomass fuel flow behaviour and builds dynamic to-scale physical fuel/air models of PF flows to identify imbalances in fuel/air delivery to the burners.

RJM has an extensive range of QA-approved fabricators that manufacture its own range of power plant technology, including burners, complete firing systems and material handling equipment. They are based in the UK and overseas, many of whom we have worked at RJM for over 25 years.

- **Digital Maturity Level**

The highly technical and critical nature of RJMs modelling and simulation technology places them at a **Level 4** on the Digital Maturity chart. This technology is at the very heart of RJMs strategic roadmap for tackling challenges faced by their customers, and is carefully maintained by experienced individuals at the company. RJMs Head of Process Engineering is a sector expert who co-authored the UK's Best Practice Guide to power station safety.

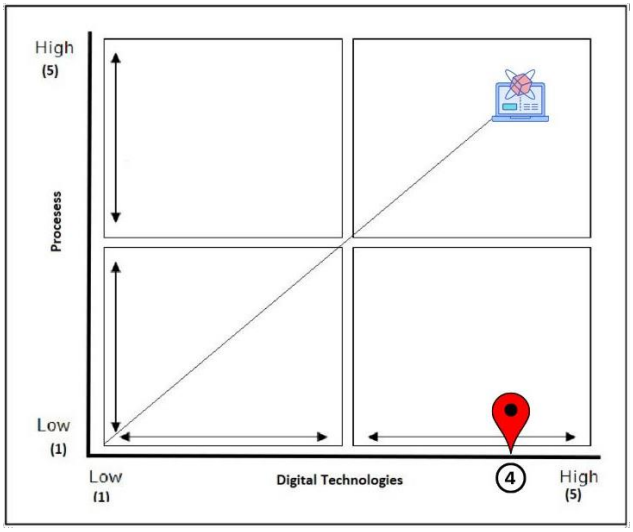

Figure 19. RJM Digital Maturity Level Template (by Authors)

- **Key Example of Digital Transformation**

As part of Kosovo's accession planning to join the European Union, its 680MWe lignite-fired power station, Kosovo B, needed to be brought up the latest EU standards. This meant that NOx emissions must be significantly reduced, from around 700-800 mg/Nm3 to less than 200 mg/Nm3 at 6% O2, with SNCR, and dust emissions from 300-700 mg/Nm3 to 20 mg/Nm3. Overall plant efficiency also required improvement.

Using its tried and tested approach, RJM international surveyed in great detail every aspect of the plant and conducted numerous CFD-based fuel / air flow and combustion modelling assignments to arrive at a solution that has at its heart RJM-designed and manufactured ultra-low NOx burner components as well as a range of other upgrades.

- **Challenges Experienced**

RJM follows a strategic roadmap for tackling combustion challenges. However, RJM is heavily reliant on the Ansys high performance computing to solve complex simulations.

The knowledge of world fuels and fuel behaviour is the cornerstone of RJM's ability to solve complex combustion issues; without their vastly experienced and loyal workforce, RJM may struggle to deliver for their highly technical customer base.

CASE STUDY 9:

Keywords: Robotic Automation, Integrated System, Big Data, Internet of Things (IoT), Sensor Technology

Sector: Rail depot equipments

GBR Rail (formerly known as Garrandale Rail) is the UK's leading provider of specialist rail depot equipment. They deliver projects world-wide to meet the needs of the rail industry. The company design, manufacture and maintain carriage wash systems, fuelling stations, controlled emission toilets, lubricating and monitoring systems.

Established in 2009, GBR Rail is focused on supporting in all areas of rolling stock maintenance using innovative practices which has led to them being considered industry experts in Carriage Wash Machines, Controlled Emission Toilet (CET) Systems, Fuelling and Ad-Blue Systems.

They have an impressive portfolio of previous projects including Sydney Metro North-west, Network Rail Greater Anglia, Hitachi Rail Europe working with high profile clients such as Siemens, Network Rail and Spencer Group. GBR Rail have extensive experience in working to ensure optimal safety and reliability of their operating systems. For over thirty years GBR Rail have delivered innovative solutions to the rail, engineering and chemical sectors including fabrications to high specification, safety critical components for the transportation, petrochemical, oil and gas industries. They worked with GM Chamber Members Wilde Analysis.

- **Digital Transformation Tools/Activities Used**

GBR Rail use a host of different Digital Transformation tools across their range of products and projects – primarily for the purpose of automation. In relation to their Carriage Wash Systems (which is the area of the business we mainly focused upon), the company uses a range of IoT (Internet of Things) sensors as part of their installation to ensure automated processes are in place. Sensors are used to ensure correct placement of the washing jets in relation to the rolling stock carriages to ensure that the automatic roof, eave and skirt washing is completed correctly. These sensors provide data in relation to levels of dirt/debris and length of clean required – this information is fed into intelligent operating systems which are designed to assist their clients in optimising the cleaning process and ensuring a swift return of clean rolling stock carriages back into the transport network. As part of this intelligent data gathering, GBR Rail also utilise sensors for speed monitoring and stock logging – with all data then assessed by remote diagnostics and data monitoring systems. Each system build is bespoke and due to this GBR Rail are always striving to be at the cutting edge of new technological developments.

- **Digital Maturity Level**

Due to the integration of their existing internal programmes, along with implementation of these systems within their projects which enable clients to assess real-time data and diagnostics. GBR Rail would consider themselves to be at a **Level 5** in terms of Digital Maturity. They view their work as digitally strategic with their digital focus forming a key part of their business strategy with robotic automation and integrated data collection forming a vital part their work.

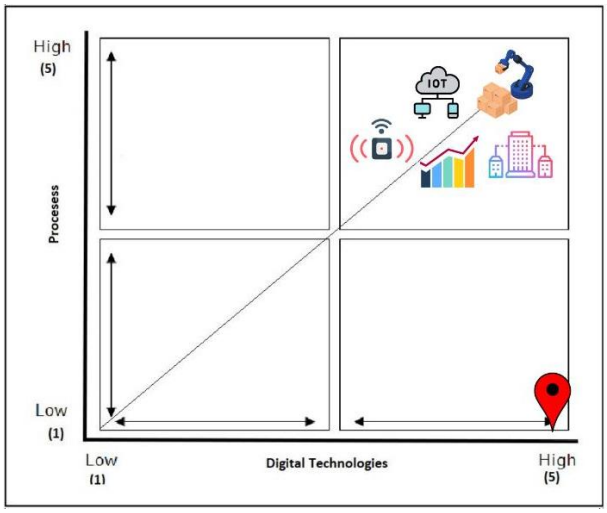

Figure 20. GBR-RAIL Digital Maturity Level Template (by Authors)

- **Key Example of Digital Transformation**

The primary example of GBR Rail undertaking digital transformation came in relation to Carriage Wash System design for a project at Old Oak Common Depot located to the West of London Paddington Train Station. The installation of a new wash depot followed designs that the company had been involved with the installation for at other sites throughout the UK with two Carriage Wash Machines that form part of the entry into the depot washing train carriage as they enter. The same train lines are used to exit trains from the depot, however a wash cycle is not required on exit. The two Carriage Wash Machines may operate both individually and simultaneously dependent on requirements. When a train passes over a sensor on the track on route into the depot a wash sequence activates. Each carriage was then having five stages to clean and rinse the train.

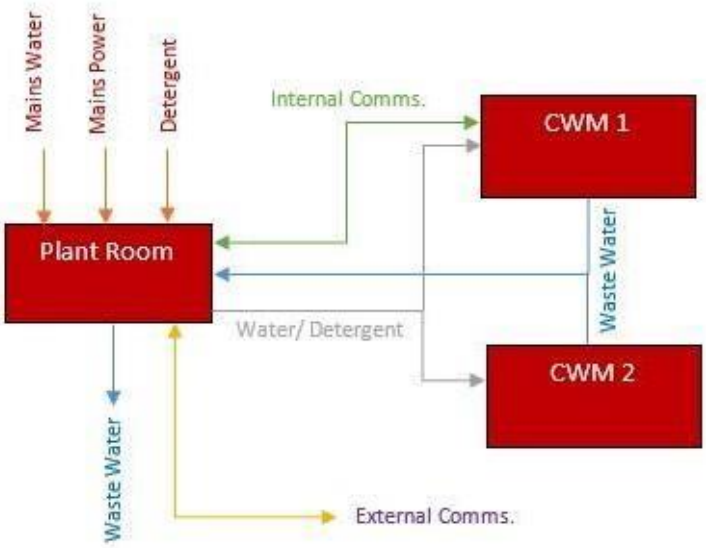

Figure 21. Functional Block Diagram showing connections between Carriage Wash System (Courtesy: GBR Rail)

As part of the design process GBR Rail were required to provide evidence and supporting information that the new Carriage Wash Systems would meet their client's specifications. To achieve this they needed to provide necessary performance data and input for the completion of a Reliability, Availability, Maintainability and Safety (RAMS) assessment. This process was achieved through performing three separate analyses using ReliaSoft's Synthesis Software.

The ReliaSoft Synthesis Software is a reliability engineering enterprise platform which was developed to allow synthesis of discrete reliability program activities into a continuous knowledge enhancement process. This is achieved by leveraging classical reliability engineering methodologies and existing best practices, coupled with a new and intelligent approach to integration based on Object Based Reliability Modelling (OBRM). The OBRM approach captures and shares information across activities while at the same time abstracting activity-level complexity to share knowledge in a manner that is relevant and of value.

In this instance the ReliaSoft Synthesis software was used to perform-:

- *Maintenance Task Analysis (MTA) to identify repair times for planned maintenance activities*
- *System Reliability Assessment to calculate availability based on planned and unplanned maintenance activities*
- *Failure mode and Effects analysis to identify single point failures*

- ✓ Maintenance Task Analysis (MTA)

The Maintenance Task Analysis identified the planned maintenance tasks that are expected to be performed on the system. This was performed using the maintenance manual to identify duration and frequency. Accounting for planned maintenance only, operational availability is 99.1% - which sits above the required 98% threshold.

- ✓ System Reliability Assessment

To calculate the system reliability and account for any unplanned maintenance, a model was created to assess individual items using Reliability Block Diagrams using a system led modelling package from the same suite of services called ReliaSoft BlockSim. Failure rate data was collected for each component in the system and represented as a 'block' in the diagram. These blocks were then connected based on their 'reliability-wise' configuration to account for the redundancy in the system. The process enabled the calculation of a Failure Rate and Mean Time Between Failure values. The maintenance tasks from the earlier MTA were considered to calculate the availability of the system with corrective maintenance and spare part usage. Once again this calculation showed availability above the requirement of 98%.

- ✓ Failure Mode and Effects Analysis (FMEA)

Finally, to identify single point failures of the system a Failure Mode and Effects Analysis was performed. This is a systematic bottom-up process that considers the failure mode for each component in the system, its effects and potential causes. The effects of failure are described in a manner that aligns with a Customer symptom (eg – poor wash quality) to assist with future diagnostics of plant failures.

As part of this process two single points of failure were identified that would both result in the Carriage Wash Machines being unavailable and one single point of failure that would result in just one of the machines becoming unavailable. Other subtle failures were also identified resulting in either no end effect or some degree of degraded wash, this was attributed to the large amount of redundancy within the system.

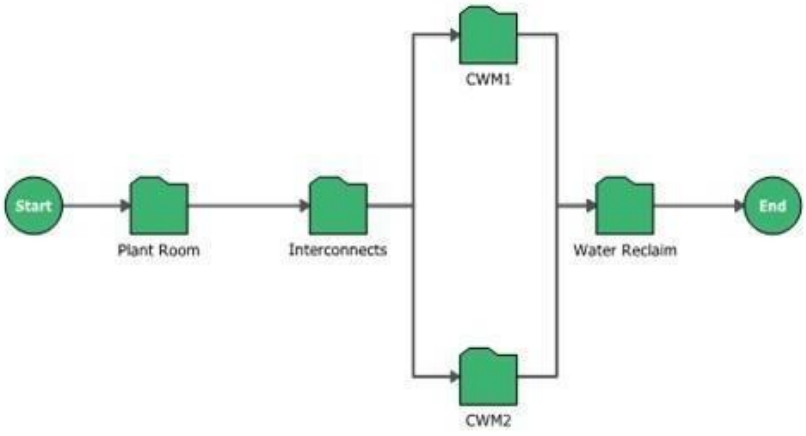

Figure 22. Top Level RBD for CWS with requirement for one CWM to be operational (Courtesy GBR Rail)

- **Challenges Experienced**

GBR Rail required external support and expertise to mobilise the development of these models at pace, which was essential in securing the business from the client. There was a cost associated with bringing in external support, however in this case this aided the company in securing the contract – which therefore paid for the costs associated. A further benefit for GBR Rail is that this process allowed them to develop systems that are re-usable and upskill internal staff to use these programmes going forward to help analyse both existing and potential new projects. This development is of great benefit to the business as innovation is key in this field with the aerodynamic nature of rolling stock causing difficulties in keeping them clean, which creates a constant challenge for innovation in this space.

CASE STUDY 10:

Keyword: Bigdata

Sector: Doors and Home Accessories Manufacturer

Crystal Doors manufactures bespoke vinyl wrapped doors and accessories for Kitchen, Bedroom and Bathroom retailers. Since 2010, Crystal Doors have occupied a factory located in Rochdale, Greater Manchester, and were honoured with a prestigious Queen's Award for Enterprise for Sustainable Development in 2021, recognising their pioneering approach to achieving net zero manufacturing.

- **Digital Transformation Tools/Activities Used**

After being inspired by a visit to Siemens' high-tech factory, Managing Director Richard Hagan has since embarked on a relentless journey to embed Industry 4.0 technology into his business, and has tied it to ambitious environmental goals.

Crystal Doorss biggest investment to date is a self-learning dust extractor system which autonomously monitors 24 machines, ensuring smart energy consumption and maximum environmental performance. The system can predict maintenance needs and is even able to identify which machine is making the most money for the company. The system has five inverters that allow 19 different machines in the factory to run at different fan speeds as and when required, ensuring optimal energy usage. It is the first time an extraction system of this kind has been installed in the UK.

The continuous monitoring system is fully automated and self-cleaning, and includes an alarm system to inform staff when the silo is full or if there are any issues with air quality. The extracted wood dust that ends up in the silo is then fed into a biomass boiler as fuel, creating a constant loop turning waste into usable heat. The huge 980kW waste-fed biomass boiler was installed back in 2015 and has made significant improvements to the sustainability of the business ever since. Carbon emissions have also been reduced through programmes like onsite solar generation, smart sensors for lighting, LED retrofitting and material efficiency.

- **Digital Maturity Level**

Crystal Doors have spent over £1 million on market-leading, energy saving technology, including a £580,000 investment into the aforementioned state of the art dust extractor. Whilst this digitisation is helping to boost

Crystal Doors operational efficiency, by their own admission, they have a long way to go to achieve their aim of becoming carbon neutral by 2030.

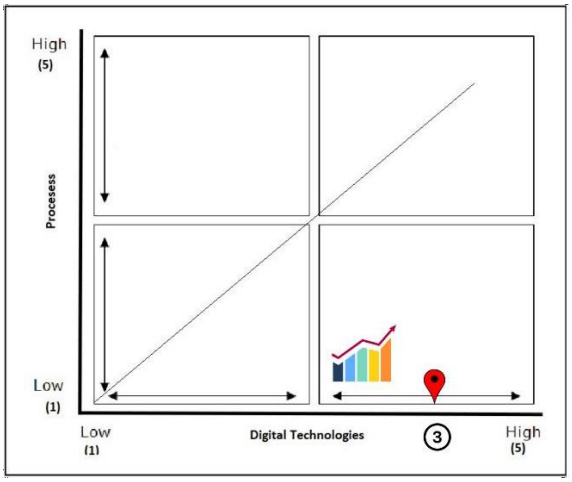

Figure 23. Crystal Doorss Digital Maturity Level Template (by Authors)

Therefore, their Digital Maturity score is currently at **Level 3**. The ability of Crystal Doors automated systems to continually monitor performance and integrate with other machines is a great example of the emerging benefits of Big Data for manufacturers. Further investment in industry 4.0 technology, and plans to integrate and implement ISO 14001, 19001 and 18001, will boost their Digital Maturity score further.

- **Key Example of Digital Transformation**

Since 2015, Crystal Doors have invested in many digital technologies as part of their road to net zero vision. Their factory-wide network of smart sensors allow Crystal Doors to track efficiency, energy consumption and d carbon emissions on a publicly available dashboard, providing a clear online visualisation of how the factory is performing in real-time. Digitalisation is crucial to their pursuit of ‘lights-out’, fully sustainable manufacturing. The data analytics available through their digital systems allows us to analyse not only their factory efficiency but also its carbon impact.

Being able to measure the footprint of each area of Crystal Doors operations, in real time, allows them to identify where we need to focus their efforts. Digitalisation also plays a key role in directly reducing emissions by increasing factory efficiency, reducing waste, and unlocking new capabilities.

CASE STUDY 11:

Keyword: 4G Sensor, Data Analytic, IoT

Sector: Mechanical and electrical maintenance services

The Thermatic Group was established in 1971, providing mechanical and electrical maintenance services to building owners and facilities managers across the United Kingdom & Ireland. Thermatic deliver technical services including energy management and remote monitoring to a vast array of customers such as Aldi, Boots, Royal Mail and JD. The Thermatic Group comprises of Thermatic Technical FM, Thermatic Energy Services and Thermatic Homes; priding themselves on offering a combination of cutting edge technology and experienced, highly skilled engineers.

- **Digital Transformation Tools/Activities Used**

Thermatic work directly with end-user clients to help them achieve their energy management targets. One of the ways in which Thermatic support their customers in reducing their energy consumption is via a Building & Energy Management System (BEMS). A Building & Energy Management System (BEMS) is responsible for the control and regulation of buildings key systems, such as heating, ventilation, cooling, lighting and much more.

Thermatic have invested in Internet of Things to create truly smart BEMS for their customers. As BEMS technology has evolved, it has allowed buildings to be better optimised for the comfort and security of Thermatics customers, in addition to being able to better control energy costs. However, due to some of the constraints of BEMS, it might not have always been possible to add on additional improvements without them being cost-prohibitive. This is where Thermatic's investment in IoT comes in.

Within multisite estates, not every building can give back the return on investment on a full-blown BEMS, however, Thermatic have identified an IoT solution that keeps install and monitoring costs down. In addition to remotely being able to access and control sites that had previously not been on the radar, customers can also utilise the huge range of sensors available to the IoT market, reducing install costs through the benefits in wireless systems and add further monitoring to existing BEMS sites.

- **Digital Maturity Level**

It is clear that Thermatics ongoing investment in technology and focus on improving the energy performance of their customers through IoT and data analytics has proven to improve their service offering. The wide-ranging use and implementation of this technology places Thermatic at a score of 3 on the Digital Maturity scale.

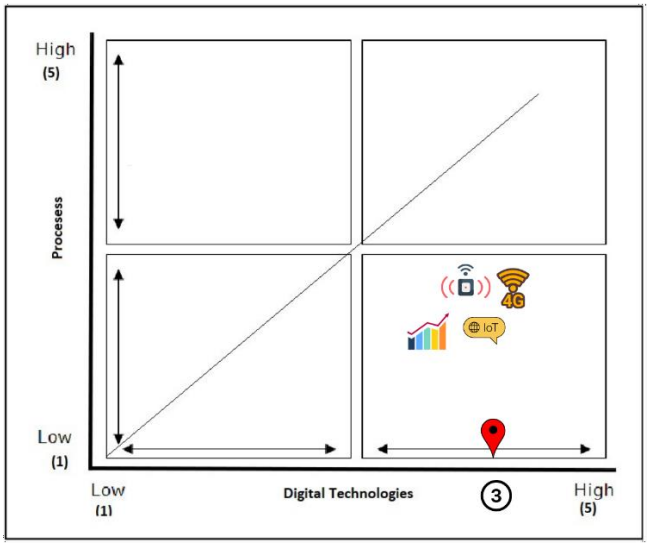

Figure 24. ThermaticDigital Maturity Level Template (by Authors)

(Level 3) for Thermatic to improve their score, they could embrace more complex technology to drive further efficiencies and reduce costs for their clients.

- **Key Example of Digital Transformation**

Having identified a problem with server rooms overheating at multiple customer sites, the Thermatic envisioned a system of mobile, Internet of Things (IoT) enabled sensors that could be retrofitted to existing assets to help track and predict overloads remotely. The 4G-connected sensors required were simple, easy to install and low cost, but have had a transformative impact in terms of customer care and competitiveness.

- **Challenges Experienced**

Thermatic have faced a variety of challenges with the introduction of IoT across their BEMS portfolio, including problems at a specialist retailer client with over 400+ stores across the UK. Within each store, there are critical areas that require specific temperature monitoring. The client has a huge drive towards net zero, so it was key that the internal store environment is controlled as efficiently as possible. There were a number of issues that Thermatic faced when implementing IoT sensor technology for the client, including:

- ✓ Sensors panelled over in refits.
- ✓ Sensors being damaged and not replaced.
- ✓ Items that give off heat or cooling are located around the sensors i.e. lighting, kettles, products
- ✓ Sensors end up being at the wrong height.

On occasion, sensors have also been known to read hotter than they should, causing excessive cooling or heating and leading to discomfort for employees and customers.

More Details and Cases: https://thermaticenergy.co.uk/case-studies/bems-recommission/

CASE STUDY 12:

Keywords: Bigdata, AI, Horizontal-Vertical Software Integration, Sensor Technology, IoT

Sector: Textile Manufacturing

Ünlü Tekstil was established in 1992 as a manufacturing facility. Located in Istanbul, the company has managed to cultivate a manufacturing structure in an area of 26.000 m2 annually manufacturing, using state of the art technology, more than 2.500.000 textile items including garments such as jackets, trousers, blouses and skirts.

- **Problems**

The company's data was not manageable.

The source of the problems encountered could not be clearly identified. This resulted in a significant problem for efficiency and quality.

- **Digital Transformation Tools/Activities Used**

It was noticed that the textile industry business uses a variety of digital technologies simultaneously. This business has successfully incorporated digital technology into its business processes because it employs them in an integrated way. As a result, the business was adept at using a variety of technologies, such as sensor technology, artificial intelligence, Internet of Things, horizontal and vertical software integration, and big data.

- ✓ Real-time data collection and sharing
- ✓ Ensuring the flow and transparency of all data

The data has started to be collected digitally and instantly. Real-time data is shared with the customer and can track customer orders in real-time. This is also used for horizontal integration. All data flow and transparency are ensured. In addition, each product has a unique QR code. Thanks to this, a very detailed impression of the product can be obtained, such as when the product was produced, by whom it was controlled, from which supplier and when the materials were obtained. This is very important in terms of transparency principle. The entire team, from production to management, is in the role of implementer in this process.

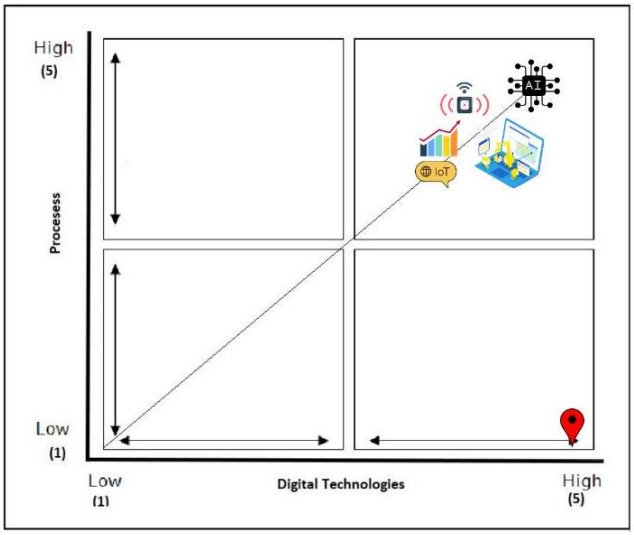

Figure 25. Ünlü Tekstil Maturity Level Template (by Authors)

In this respect, the digital maturity level of the company, which uses many digital technologies at a networked and professional level, was set at level 5.

✓ Goals Achieved

Really important factors that reduce productivity were identified and thus the root cause of the problems was solved. Although the product variety produced by the company is very high, the productivity rates are also quite high. This shows that if the company's product range was less, its productivity could be even higher. To put it more clearly, the productivity has reached up to 2 times the sector. The process also made the internal structure transparent. Employee motivation has also increased.

Figure 26. Ünlü Tekstil Factory & Sample Product

There is no direct raw material effect. However, indirectly some factors (e.g. water reduction) affect energy consumption. Businesses must be made measurable and managed by collecting data from each unit. Accordingly, they can make improvements and develop themselves with report analysis. If it cannot be measured, it cannot be managed.

CASE STUDY 13:

Keywords: Artificial Intelligence, Internet of Things (IoT), Horizontal-Vertical Software Integration, Sensor Technology

Sector: Waste Management

Fazla was established in 2016 with the mission to halve carbon emission caused by food waste in Türkiye. Company's main motivation was to create an exemplary business model serving UN SDGs. (2- Zero Hunger, 11- Sustainable Cities and Communities, 12- Responsible Consumption and Production, 13- Climate Action and 17- Partnerships for the Goals). Thanks to technology-based holistic solutions, Fazla makes it possible to reduce waste and easily manage the waste generated.

- **Problems**

✓ Carbon emissions from food waste were high.
✓ There were a need for fair and sustainable systems to reduce inequalities.
✓ There were no resource-oriented solutions in waste management.
✓ Technology-based holistic waste management solutions
✓ Operational speed in Fazla Waste Management System
✓ Data analytics providing insights to reduce the waste generation
✓ Completely transparent, traceable and documented business processes
✓ Effortless waste tracking and management

Fazla Market: Online liquidation platform enables secondary sales of products that are out of the standard sales channels for any reason. Hence, both sellers and buyers contribute to reduction at source. Considerable products such as food, and textiles are sold or purchased through Fazla Market.

Fazla Donation: Surplus products that are at the risk of becoming waste but in good conditions to be consumed are donated with Fazla Donation service. Through its technology-based national infrastructure and wide food banking network, Fazla creates more than just social value with these products.

Fazla Animal Feed: Surplus products that are not suitable for human consumption are utilized with the Fazla Animal Feed service to be utilized as raw materials in animal feed production, reducing resource requirements in this area.

Fazla Recycling: Surplus products that are not suitable for human consumption are recovered by the Fazla Recycling service that determines the recycling and recovery methods with the highest value for all waste streams including food, textile, packaging and chemical and waste oil.

Smart Scale System: This system developed for professional kitchens reduces waste generation at source. Reports generated as a result of the measurements provide a full picture so that necessary waste and cost reduction actions can be identified.

Fazla App: It brings HoReCa businesses, markets and end consumers together to reduce waste. Businesses such as restaurants, patisseries, cafes, markets list their overproduction in the app with a discounted price.

Fazla Sustainability Consultancy: With its expert staff, Fazla helps companies meet their sustainability goals and create long-term, positive impact through its Sustainability Consultancy service.

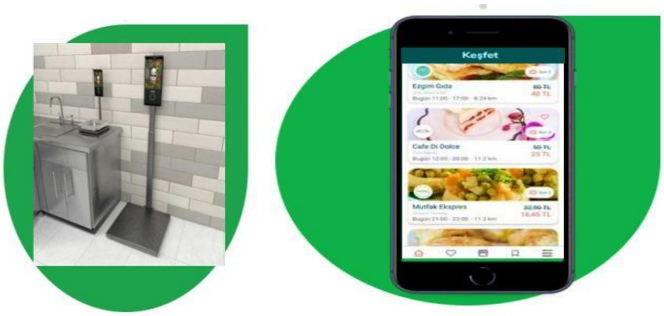

Figure 28. Fazla's Mobil App and Office

- **Digital Transformation Tools/Activities Used**

It has been observed that the company operating in the textile sector uses many digital technologies simultaneously.

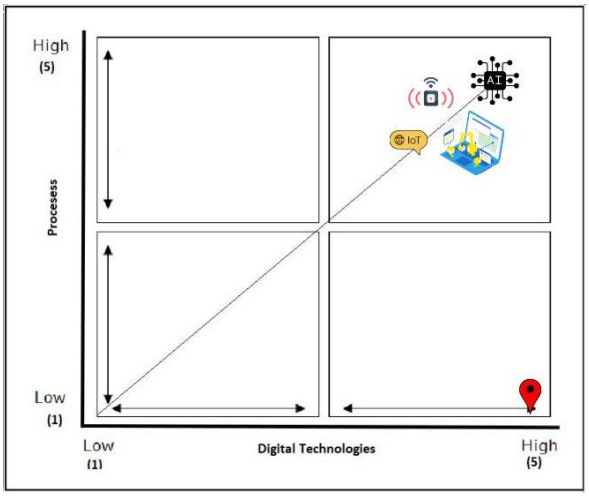

Figure 28. Fazla Maturity Level Template (by Authors)

The company, which uses digital technologies in an integrated way, actively uses sensor technology and horizontal-vertical software integration solutions, especially artificial intelligence and the internet of things. In this respect, the digital maturity of the enterprise is defined as level 5.

- **Goals Achieved**

Fazla made it possible to reduce and easily manage the waste generated thanks to technology-based solutions. Reduction at source:

- ✓ Avoiding waste with Data Analytics
- ✓ Secondary Sales Marketplace: Fazla Market
- ✓ Smart Scale System
- ✓ Fazla Application
- ✓ Fazla Sustainability Consultancy
- ✓ Donation operations were carried out with more than 150 food banks across Türkiye.

It is one of the requirements of the age to follow and be aware of the developments experienced locally and globally. This is very important in terms of both shaping the future and protecting workflows. On the other hand, lifelong learning must continue. It is necessary to be open to learning, to receive and process information and to evaluate it in the best way for everyone. With this approach, it is possible to show great adoptability which is an important aspect in today's world.

CASE STUDY 14:

Keywords: Horizontal-Vertical Software Integration, Virtual Reality, Simulation

Sector: Lightning Protection and Earthing Fabricator

Since 1953, Radsan has been carrying out its work under the titles of production, sales, commitment, consultancy, training consultancy and project service. It is an export company based in Istanbul.

- **Problems**

✓ Inefficient technical training process
✓ Time and place dependent technical trainings, high-priced instructor load
✓ Occupational accident risk during on-the-job training
✓ Product promotion problem in organizations such as fairs

Thanks to the VR simulation, the Thermowelding experience in the construction site can be used independently of time and place without the risk of work accident. An experience that is impossible to present in various physical areas such as the fairground is presented with advanced technology VR experience. With PC support, simulation can be experienced without the need for any hardware other than a computer.

- **Digital Transformation Tools/Activities Used**

Tekstil sektöründe faaliyetini gösteren firmanın pek çok dijital teknolojiyi eş zamanlı olarak kullandığı görülmüştür.

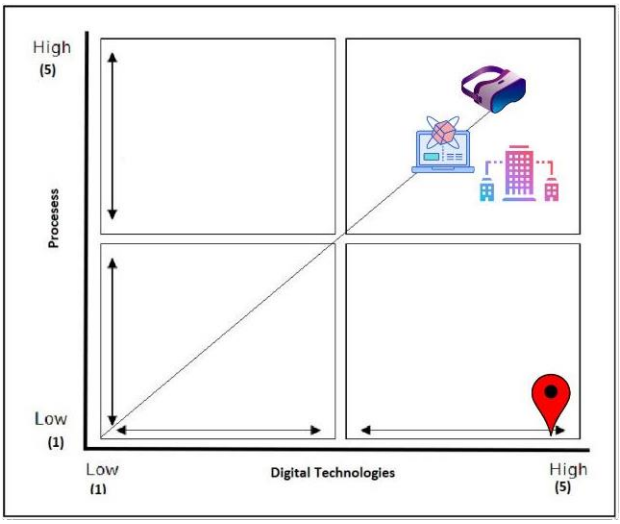

Figure 29. Radsan Maturity Level Template (by Authors)

The company, which uses digital technologies in an integrated way, actively uses horizontal-vertical software integration and simulation technology solutions, especially virtual reality technology. In this respect, the digital maturity of the enterprise is defined as **Level 5.**

Figure 30. VR simulation experience and fairground

- **Goals Achieved**

Within the scope of training activities, time spent by experienced engineers and craftsmen, and expenses such as travel and accommodation were saved.

A positive contribution was made to the image of the company by promoting the virtual reality training application at the fairs attended.

Thanks to the web-based application, certificates were sent to more than 250 technical people by providing continuous training.

During these works, priority was given to increasing women's employment.

It is not a harmful application that greatly affects the environment. Thus, it has no direct environmental impact.

It was a training that could not be done in environments such as fairs, seminars, offices, but now the chance to practice in an office environment was created for technical people.

To carry products and services advance, such applications must be included and now should be seen as basic needs. Return on investment in this area is much faster than it was expected. Digital investments must be made in areas that will support the own sales process of SMEs.

CASE STUDY 15:

Keywords: Sensor Technology, Robotic System, Horizontal-Vertical Software Integration

Sector: Polyester Yarn Production

Korteks, a Polyester Yarn Production company, was established in 1989 in Bursa. KORTEKS, largest integrated polyester yarn producer and exporter of Europe, continues to create added value for Turkey with its nearly 2200 employees. Their investment of Polymer Recycling Plant, which is a first in Turkey, has been completed and started production. They will produce RPET Chips, which is the raw material of recycled polyester yarn, from PET bottles and yarn wastes and transform them to polyester filament yarn.

Problems & Solutions

- ✓ Inefficient use of existing warehouse capacities
- ✓ Long delivery times

Automatic Warehouse System

- It is a 2022 Efficiency Award-winning Project.
- Automated warehouse systems provide logistics management that minimizes unwanted costs and risks, but high-speed storage and warehouse management in loading and unloading operations ensure efficiency.
- Robot stacker-crane is preferred in high-altitude pallet racking systems where input-output speeds are very high.
- Storage can be made up to 40 meters high. The access capacity is high.
- There is no need for operators in the storage area.
- The time of preparation of orders is reduced.

Figure 31. Korteks Automated Warehouse

- **Digital Transformation Tools/Activities Used**

It has been observed that the company, which works in the field of polyester yarn production and therefore in the manufacture of textile products, uses many digital technologies simultaneously.

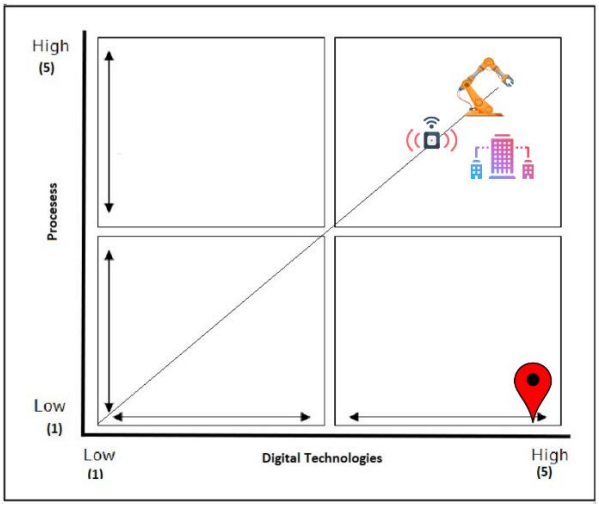

Figure 32. Korteks Maturity Level Template (by Authors)

The company, which uses digital technologies in an integrated way, actively uses sensor technology and horizontal-vertical software integration solutions, especially artificial intelligence and the internet of things. In this respect, the digital maturity of the enterprise is defined **as Level 5**. According to company Korteks, it is very important to analyze and determine the needs correctly. Targets should be determined according to these needs and so the right investments should be made.

- **Goals Achieved**

Efficient use of space, fast stock control, fast order preparation and much leaner business processes have been achieved.

Thanks to the vertical growth advantage of the automatic warehouse instead of the horizontal storage area, higher capacity has been achieved in less square meters.

Approximately 10% improvement has been achieved in packaging.

With warehouse efficiency, expenses such as heating, cooling and lighting have been reduced, and carbon emissions have been minimized.

Human resources have become more efficient.

- **Simulation Video (Link):**

https://www.youtube.com/watch?v=DXTTP4TTTVA

CASE STUDY 16:

Keywords: Horizontal-Vertical Software Integration, Drone (Automation), Big Data

Sector: Organized Industrial Zone

GEBKİM – Kocaeli Gebze V (Chemistry) Specialized Organized Industrial Zone, which was established with the gathering of distinguished representatives of the chemical industry in Turkey, aims to be a pioneer in the chemical industry of our country and to create an ideal investment and trade environment. GEBKİM Legal Entity was created by its participations:

- ✓ Investment Monitoring Coordination Department
- ✓ Gebze Chamber of Commerce
- ✓ Chemical Employers Organized Industrial Zones Association

- **Problems & Solutions**

Emergency action plans were not always ready and when teams arrived on the field, they could not find the data they needed.

- ✓ Lack of Communication and coordination among employees
- ✓ Lack of accessing the information simultaneously.

Emergency Response Software

- ✓ It is a software designed to prevent possible accidents and to intervene before fires grow and it has a 2022 Efficiency Award.
- ✓ The data has been transferred from hardcopy to digital so that it can be accessed from any point. A drone has also been added to this software, so images are sent to the emergency teams before they arrive. The drone also has a thermal camera, it can also see and transmit information from the temperature difference.
- ✓ The magnitude of the situation can be seen before arriving at the scene, and it provides advantages such as correct positioning and correct team orientation.

- **Digital Transformation Tools/Activities Used**

It has been observed that GEBKIM, which uses digital technologies in an integrated way, integrates drone technology with horizontal-vertical software solutions. In addition, the fact that active data collection process is carried out during the scanning process from the sky has been a good example of the use of big data, even if it is partially. Considering the diversity of existing digital technologies and the area of use of technologies. Level 3 maturity level has been qualified.

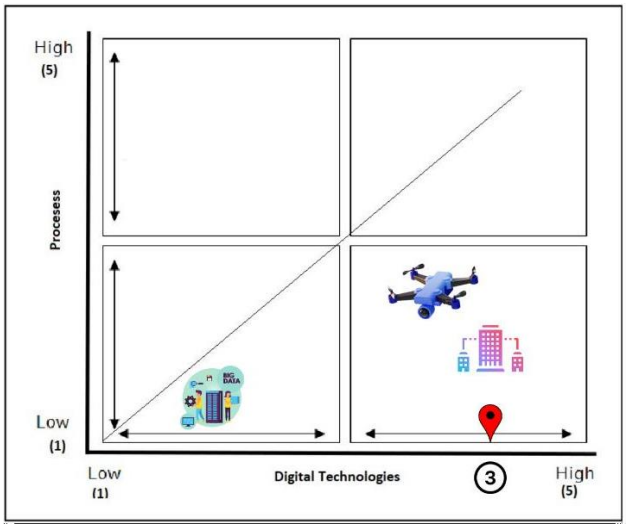

Figure 33. GEBKIM Digital Maturity Level Template (By Authors)

- **Goals Achieved**

1812 people were given training on emergency response preparation - emergency response planning, first aid, etc. Four exercises were conducted regarding the application of the software. With the exercises, the faulty parts were seen, and improvements were made accordingly. A collective emergency study was carried out with the participation of AFAD and the metropolitan fire department. The coordinates of the factory have been entered into the software, and the drone can perform automatic flight accordingly and send images from the scene.

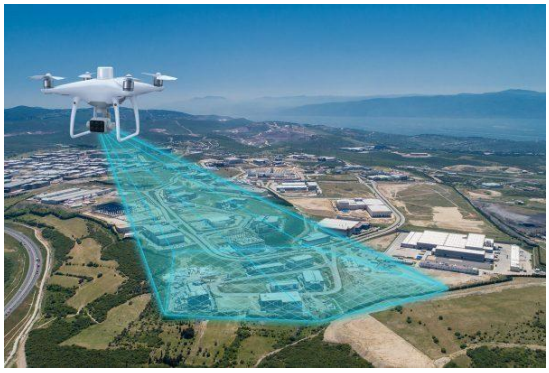

Figure 34. GEBKIM Drone Simulation

There are various chemicals in the chemical industry, if the emergency team did not know about them, the size of the fire would grow due to wrong intervention. Due to the fact that the chemical factories in the region were side by side, more than one factory could be affected. With this project, environmental damage was also minimized. Companies should attach great importance to occupational health as well as production. All possibilities of technology should be used in the prevention of accidents and first response processes. If the companies do not give special attention to work accidents and fires, it will result in the destruction of the products produced in a possible fire. This will cause adverse effects on resource use (raw materials, energy, time, etc.). In addition, this situation will cause businesses to produce the same products again and to use additional energy and raw materials. For this reason, taking occupational health and safety measures by using digital technologies not only increases the efficiency and safety of the enterprises, but also contributes to environmental sustainability.

CASE STUDY 17:

Keywords: Internet of Things (IoT), Robotic System

Sector: Automotive sub-industry

AK-AR was established in 1969 in Istanbul. In its establishment, it started with the production of sheet metal parts for the safe deposit box lock, TV and auto sub-industry, and the production of sheet metal parts and plastic injection parts for companies producing electrical household appliances were added.

- **Problems & Solutions**

The company produces serial products. It was not possible to do this with human power in terms of cost and time. The main problem was a waste of time and lack of quality.

- ✓ Collaborative robots started to be used, so the number of personnel working in 5 units decreased from 10 to 2.
- ✓ All production lines work automatically and without errors.
- ✓ Robots can work side by side with humans, have sensors everywhere and can stop themselves. At the same time, they can also communicate with each other. (IoT)

- **Digital Transformation Tools/Activities Used**

It has been seen that AKAR, which uses IoT technology and Robotic Technologies in an integrated manner, first used the digital transformation with a focus on productivity increase. With the use of digital technologies, it has been seen that the company produces more with lower kW consumption. Considering the technologies used, the digital transformation of the business **is described as Level 3.**

Figure 35. Collaborative Robots (Cobots)

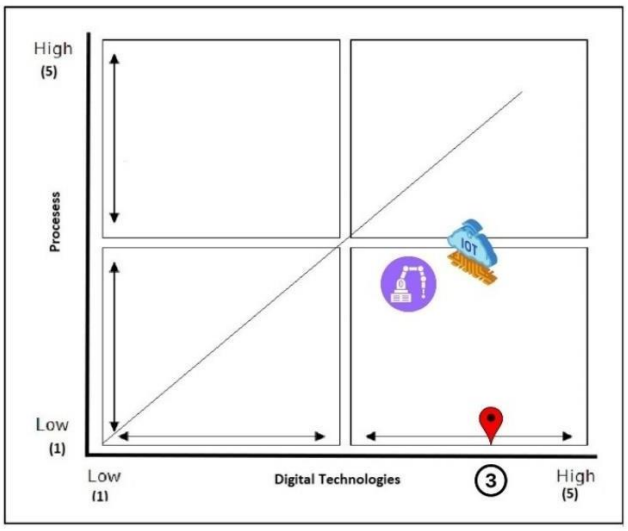

Figure 36. AKAR Digital Maturity Level Template (by Authors)

- **Goals Achieved**

Thanks to robots, hanger production by 1 machine was increased from 1057 to 1800 per hour. Productivity increased. Previously, 2 workers were working on a single machine while now 2 of them work on 5 machines. This also gives them an opportunity to experience different fields in the company.

CASE STUDY 18:

Keywords: Supply Chain Optimization

Sector: Automotive sub-industry

Operating in the field of Engine Control and Distribution Panels, the company was established in Istanbul in 1980.

- **Problems & Solutions**

The source of the problems could not be clearly identified.

Information from the end user cannot be filtered.

- ✓ An after-sales function has been developed to find the source of the problems and manage the information flow. This is a user-friendly barcode system.
- ✓ After the product returns to the factory, transactions are made through this barcode at every step. Therefore, all information such as the time of receipt of the product, the waiting time, the source of the error, the response given to the customer, the response time from the customer can be kept.
- ✓ Only the after-sales function of a system that digitizes production processes (such as warehouse records, OEE calculation, machine occupancy rate calculation) and makes supply chain information (such as supplier raw material usage, stock amount, test-reports) shareable between the customer and the supplier has been implemented.

- **Digital Transformation Tools/Activities Used**

Kerim Elektromotor uses green supply chain optimization for its “resource productivity” and “indirect energy efficiency” targets in its digital transformation management process. SMEs generally have the infrastructure to implement this technology. Products need to have a coding system and almost all SMEs have this system. The system must be followed by the engineer. The production chief can also operate it, it is not very technical. Considering the technology used, the digital maturity of the enterprise **is described as Level 3.**

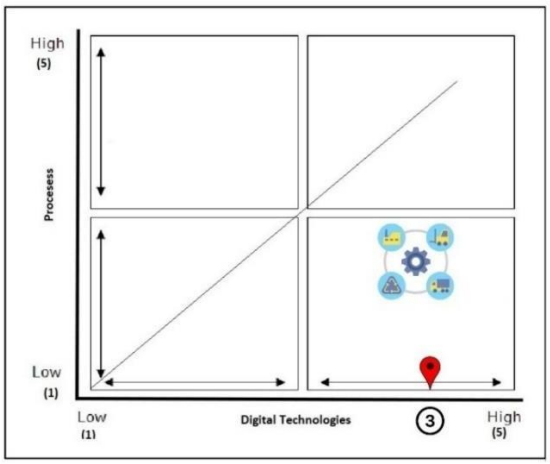

Figure 35. Kerim Elektronik Maturity Level Template (by Authors)

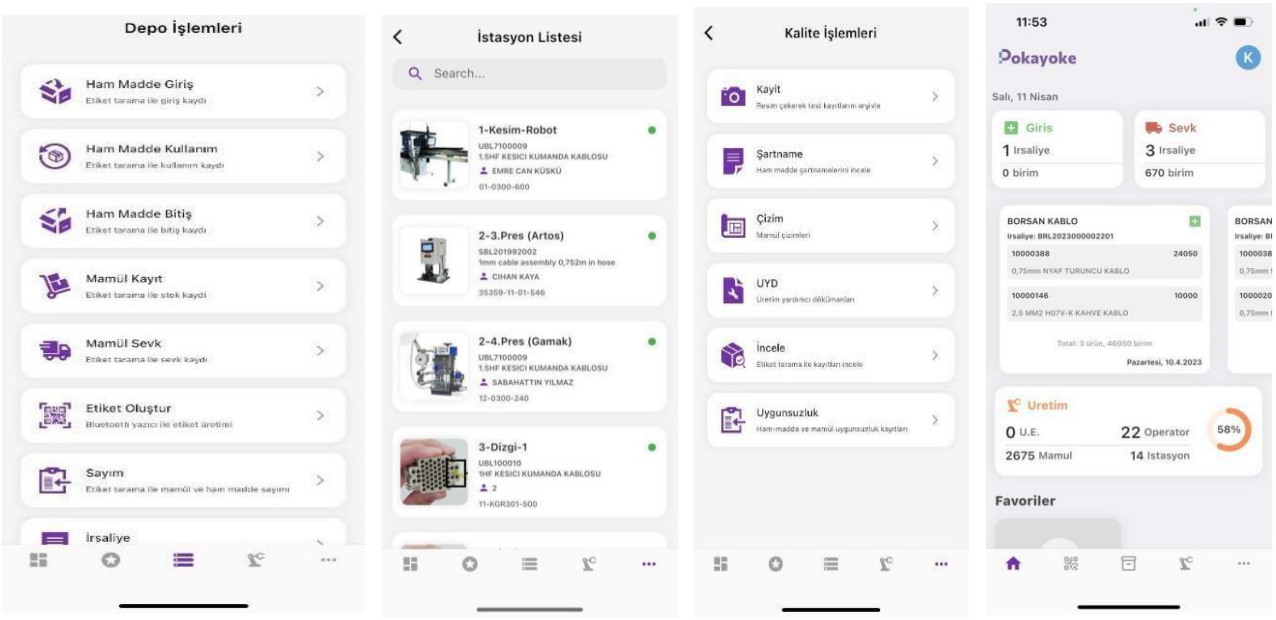

Figure 36. System Details (Warehouse Operations, Station List, Quality Operations)

- **Goals Achived**

Better recognition of customers and their needs.

It turned out that 80% of the problems that arose were due to the lack of information from the customer. In this way, customers were better informed about the product.

It was understood that company-related errors occurred at the level of 2%.

Flowing usage and fault information from the end user was ensured to flow directly to the manufacturer.

It is aimed to understand how many failure returns are from the products sold annually (they do not have this data because they have been tested for 1 month yet)

CASE STUDY 19:

Keywords: Mobil-App, Big data, Internet of Things (IoT), Deep Learning

Sector: Waste Management

Founded in 2022, "Köstebek" is an organization that allows people with broken/unused electronic devices to play an active role in the recovery process of their devices. The "Köstebek" mobile application enables the registered collection of unused electronic devices with the electronic waste recognition system it contains and offers an ecosystem where people can earn points for the devices they want to recycle and use these points on the donation platforms they want. Established as a green initiative, the company contributes to environmental sustainability by transparently presenting the recycling process of electronic waste to the customer and making the user an active participant.

Problems & Solutions

Köstebek's problem concerns creating a 'measurement-based' digital infrastructure for waste management. Thus, it is aimed to minimize the illegal records of electronic wastes and focuses on establishing a data-information system that will strengthen the digital waste passport application. Based on the business idea of “Nothing that cannot be monitored and measured cannot be managed”, Köstebek focuses on establishing a digital infrastructure for the monitoring of waste. Aiming to establish an end-to-end system while doing this, Köstebek ensures that the process of which product is reintegrated into production, from the disposal of a waste to the recycling process, is followed. Köstebek provides the opportunity to "understand", "monitor" and "manage" the wastes of manufacturing industry enterprises (especially electronics, automotive industry, etc.) at the end of the production year. Moreover, the waste passport, which enables the traceability of the waste process in this process, allows an electronic part/item with waste status at this moment to be reused in a device of which brand in the future. To this end, Köstebek also offers demos that allow companies that are manufacturers of electronic products or indirectly use electronic products to perform a waste inventory.

The company first conducted a survey to question the reasons for the inadequacies and problems in the collection of electronic waste. Based on the insights obtained from the surveys it conducted, the company has determined that there are no recycling points near the people, that they cannot make an individual profit by recycling, and that there is a lack of information about what electronic waste is. Köstebek aimed to solve this problem by developing a mobile application that works with a waste recognition system based on image

processing technology. Then, the field operation is managed end-to-end in order to collect the requests in the most sustainable and efficient way, together with the route optimization algorithm.

Digital Transformation Tools/Activities Used

Having a visual identification system with Deep Learning technology, the company starts the waste management process after identifying the existing waste (for example, cable) and identifying the waste cable with "Unique ID". This relevant cable, for example, turns into a cable with the code of "waste0102" and when that code is received and entered on the platform, the process of the waste can be monitored.

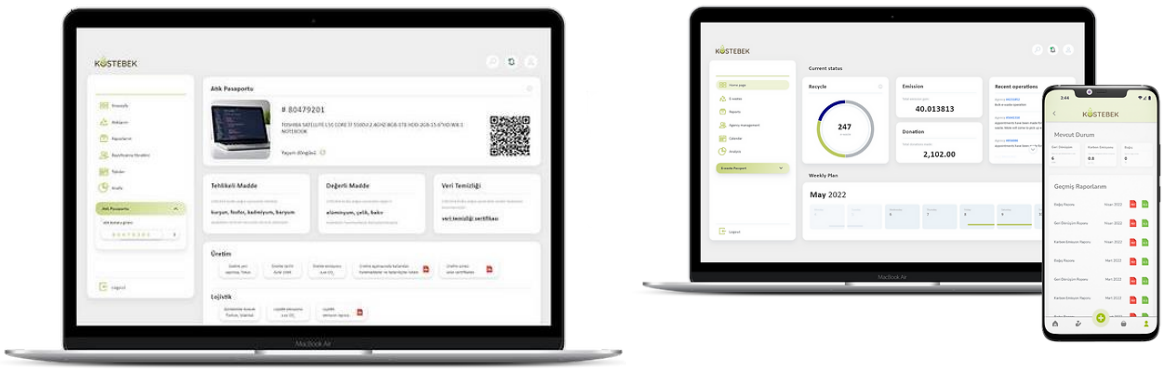

Figure 37. Köstebek Kontrol Paneli

For example:

- ✓ Which facility did the waste go to?
- ✓ Which raw material was obtained from this waste?
- ✓ What is the disposal rate if there is dangerous raw material?
- ✓ What is the recovery rate if it has valuable raw materials?
- ✓ The above-mentioned type of information can be examined systematically.

The company, which has its own data set, thus aims to establish a specialized e-waste library. This company, which specializes in electronic waste management, thus operates as a candidate to become a single branch for all electronic wastes. Working integrated with the mobile application developed by Köstebek, Köstebek Panel ensures that both the e-waste customer and the recycling facility are followed in a transparent manner on both sides of the e-waste. While businesses can receive detailed carbon emission reports as a result of the transaction, they can record their emission reductions in order to declare them in the carbon market. With the tracking feature of the waste transport box with the Internet of Things (IoT) system, which works integrated with the Panel, the company can instantly see where the customer's electronic device is, and can also see the information on opening and closing the box and entering the transaction via the platform. Köstebekk manages

the e-waste process from end to end by providing services such as panel application, E-Waste Inventory, Emission/Donation reports and archive, Dealer/Agent E-Waste Management and *Digital Waste Passport*

With the infrastructure prepared in accordance with the Product Passport proposal included in the Circular Economy Action Plan of the European Commission on March 30, 2022, the capacities of manufacturers and exporters operating in carbon-intensive sectors are increasing for the regulation of “carbon tax at the border”.

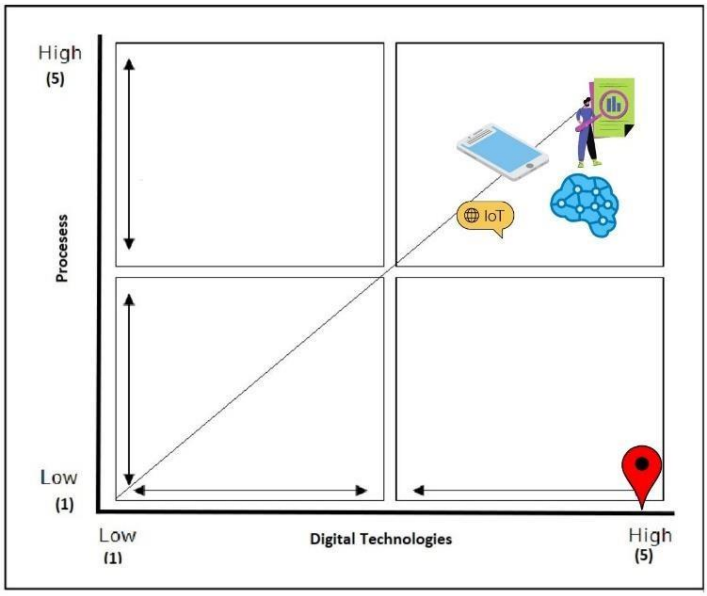

Figure 38. Köstebek Maturity Level Template (by Authors)

- **Goals Achived**

Köstebek recycled 2406 pieces (950+ KG) of electronicwaste, that prevented 29.5 MT CO2 emissions. 100 people donated their electronic waste for social benefits through the Köstebek application, which enables social benefit-oriented works to be carried out with the income obtained from Electronic Wastes. The company's carbon reduction activities have contributed to the protection of 1,864 pandas that are endangered by climate change. The team was the winner of the Tübitak 1512 Individual Entrepreneurship Program and has received numerous awards for promoting entrepreneurship. The company continues to do social benefit-oriented works in many areas, such as food donations, educational support, and sustainability training.

CASE STUDY 20:

Keywords: Bi gdata, RFID, IoT, ERP, Sensor, Artificial Intellegence, Mobil-App

Sector: Waste Management

Evreka is a company established in Ankara Teknokent in 2014 to provide "intelligent waste management" solutions for the "waste" management processes of local governments and businesses. Although the company was established in Istanbul, it carries out its operations in countries such as the Netherlands, Germany, Israel, Brazil and Singapore, where waste management chains are relatively more important. The good practice within the scope of this research has been prepared based on the examples of waste management processes implemented in Germany and the Netherlands.

Evreka's management system platform provides end-to-end waste management solutions, including waste collection path optimization, fleet management, real-time monitoring of waste levels and data analytics. The company, which helps to increase waste collection “efficiency”, “traceability” and “transparency” with the use of digital technologies and reduce operating costs for customers, is an important example of “green digital transformation” in this sense.

- **Problems & Solutions**

The company offers digital-based smart solutions in waste management, especially digital waste. Evreka application starts with making a “call” for individuals to initiate the recycling process of their digital wastes at home. The calls that appear in the Evreka application appear in the system of the company that performs waste management. Evreka's innovativeness emerges when the waste management company makes "route planning" by evaluating the "calls" received within itself. While this evaluation saves time and energy, it also minimizes the use of human resources in waste management. Accordingly, Evreka provides an end-to-end solution in waste management by analyzing the whole process, such as when, where and by whom the waste is taken, the type of waste, which facility the waste goes to and how it is sorted. Thus, Evreka provides both B2B and B2C activities by establishing a bridge between both individuals and companies in the waste separation and recycling process. The company works in the mission of "Producer Responsibility Organization" with the applications it carries out. Thus, a process in which the recycling responsibility is reflected "from the consumer to the producer" is implemented.

- **Digital Transformation Tools/Activities Used**

Evreka actively uses technologies such as sensor technology, RFID reader and artificial intelligence (camera) in garbage containers; It integrates different digital technologies such as big data, IoT, and ERP in the waste monitoring process. With the integrated use of these technologies, the digital maturity of the enterprise has been defined as **"Level 5"**.

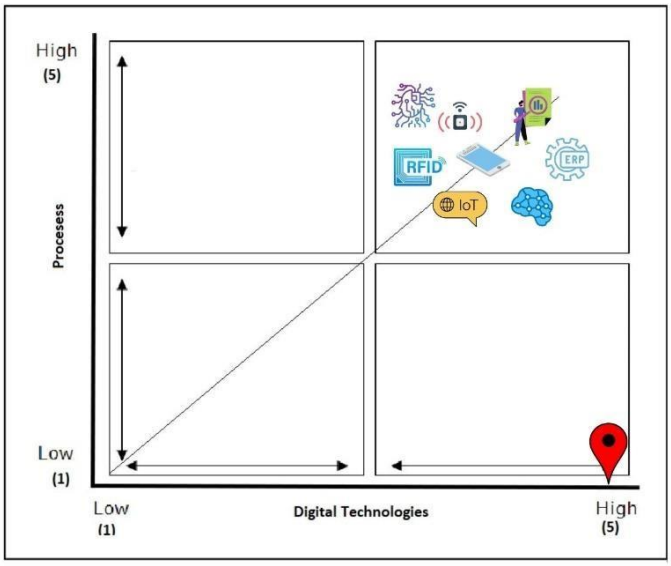

Figure 39. Evreka Maturity Level Template (by Authors)

The waste management process of the company, which shows its activities as an example of green digital transformation, consists of the following steps:

- Individuals' identification of waste through the mobile application,
- Identification of the shortest route with waste route optimization as a result of the call received,
- Receiving waste with sensor technology or artificial intelligence cameras
- Determining the received waste and determining which separation facility/company it will go to,
- Monitoring of waste recycling process.

• Goals Achived

The company offers digital-based solutions in line with the optimization of waste management, increasing efficiency in waste management and reducing carbon footprint. Evreka has halved the use of garbage trucks and containers in local municipalities with its smart waste management applications (fleet management and container management) and waste collection path optimization.

Unnecessary visits to empty or underfilled containers are prevented by means of container fullness sensors. In this way, the waste collection of the municipalities was optimized with less energy (fuel consumption) and less human resource. By optimizing waste route monitoring, new trips to the streets and container visits were avoided. This not only reduced fuel consumption, but also reduced carbon emissions generated by the trucks. It is indicated that this situation reduces the carbon footprint by 22-25 per unit on average.

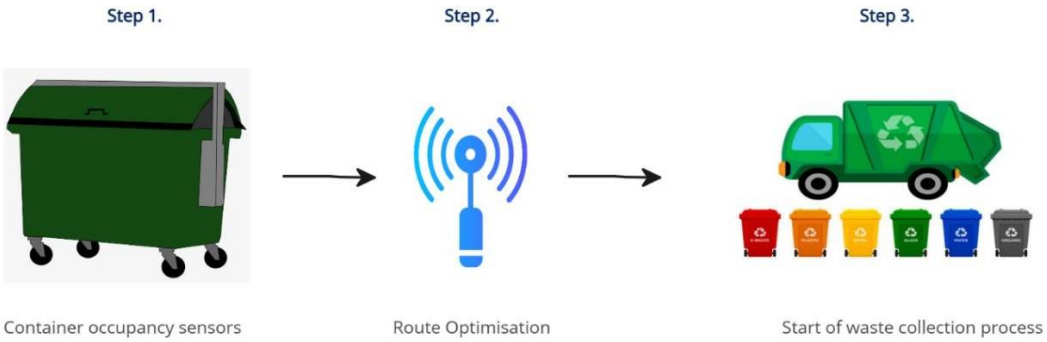

Figure 39. Evreka's Waste Management Process (By Authors)

Accordingly, the waste management process briefly consists of the following steps:

1. Instant measurement of the fullness of waste containers with container fullness detection sensors,
2. Instant processing of data collected through sensors and calculation of "route optimization",
3. Simultaneous sending of daily created routes to trucks' navigation systems

Note: Due to the confidentiality of customer data, the names of the local municipalities where the applications took place in Germany and the Netherlands are not given.

CASE STUDY 21:

Keywords: Yapay Zeka, 3D Yazıcı

Sector: Filament Üretimi

Filametto was founded in Şanlıurfa by entrepreneurs who are graduates of Hamdi Ulukaya Initiative, InnoCampus and GiGap Program. The company's main field of activity is the idea of producing recycled filaments for 3D printer users. The company, which is engaged in the production of recycled filaments, also conducted intensive studies during the pandemic period to produce "visors for healthcare workers" using recycled filaments via a 3D printer. For this reason, it was selected as a good example of how recycled products can be used in the production process with 3D printing. This example shows how digital tools can be used in the ecological production process with the help of a 3D printer.

Problems & Solutions

The filaments used in 3D printing processes are primarily thermo-plastics, with the most popular being acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA). As shown in Figure 1, the production process, which starts with the recycling of plastic waste, especially pet bottles, turns into personalized products with the "additive manufacturing" method, which also expresses the working logic of 3D printers, of recycled filaments obtained from plastics at the final stage. While the said production process contributes to the "zero waste" goal through the reuse of plastic waste, it also contributes to the production of personalized products, which increases the sustainability of the products. Considering the contribution of the product life cycle and the working principle of 3D printers to environmental sustainability, as explained above:

- ✓ Contribution to the reduction of carbon emissions,
- ✓ Minimum input in energy consumption,
- ✓ Recycling and re-production of waste,
- ✓ Longer usage time of personalized products by consumers

Figure 40. 3D printing with recycled building materials

It contributes to sustainability at different stages with the effects mentioned above. In this context, with the use of 3D printers in production processes, a process that will cause many different environmental effects arises both in the production and consumption stages. In this example of good practice, an interview was held with Filamento Limited Company as part of the field research and the filament manufacturing they carried out and the effects of these filaments with 3D printers were examined.

Phase 1: Uploading Sample Design

The first design phase is carried out by loading the sample visor model into the Autodesk program.

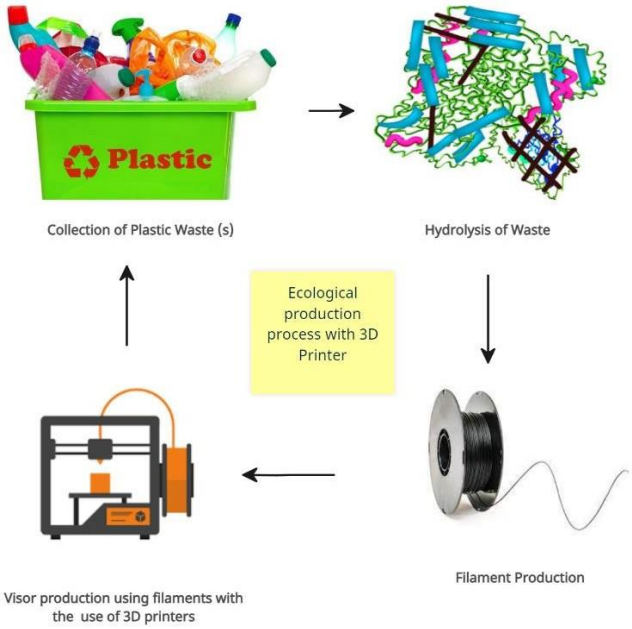

Figure 41. Filamentto's Eco Production Process with 3D (By Authors)

- ✓ **Manufacturing Process:**

Phase 1: Uploading Sample Design

The first design phase is carried out by loading the sample visor model into the Autodesk program.

Phase 2. Determination of the Most Appropriate Visor Model

Based on the past experiences of artificial intelligence technology, alternative new designs are produced. At this stage, the design phase is carried out with the understanding of “human-oriented design”. Accordingly, considering ergonomics and similar factors, the most suitable visor is determined by artificial intelligence technology.

Phase 3. Production

3.1. Production of recycled filaments with 3D printers.

3.2. It is ensured that 3D printers are used for the production of visors through the reuse of filaments obtained by recycling plastic waste.

- **Digital Transformation Tools/Activities Used**

Filamentto uses "3D printer" for digital tools and "artificial intelligence-based" software for visor design processes. With the use of these technologies, the digital maturity of the enterprise has been defined as "**Level 3".**

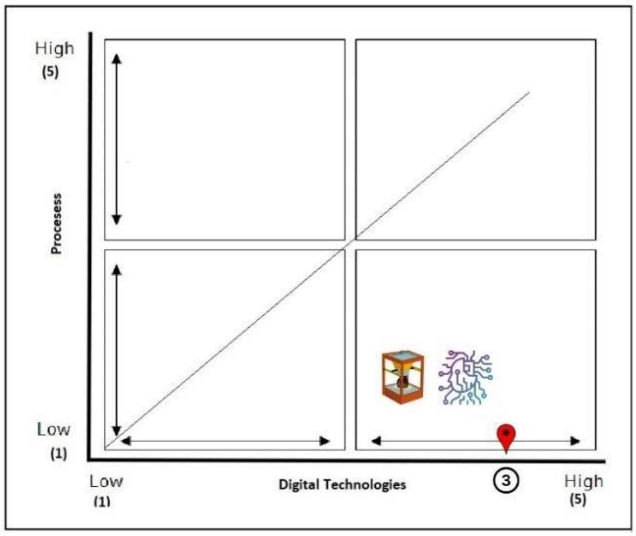

Figure 42. Filamentto Maturity Level Template (by Authors)

- **Goals Achived**

As summarized in the mentioned application flow, it has been observed that the company has an impact on sustainable development by using digital tools from a “zero waste” perspective, primarily through the recycling of plastic waste. The company also produced visors with the recycled filaments and produced free visors, especially for healthcare workers, during the Covid-19 pandemic. Accordingly, the effect of the company using 3D printers is summarized below:

1. Contributing to the reduction of environmental pollution by collecting and reprocessing 500 KG of plastic waste per year, ensuring both environmental and cost effectiveness through the efficiency of 3D printers in energy use,
2. To set an example for the principle of reuse and zero waste by converting the collected plastic waste into filament. Using the obtained filaments in the production of visors by 3D printing method,
3. Ensuring social impact through free distribution of the produced visors to healthcare workers.

This company uses 3D printers to recycle solid plastics, bringing the input cost closer to “0” (zero) in the production of visors. This situation is a good example for the company to increase its profit margin and to strengthen the corporate social responsibility processes of the company by distributing the produced visors to healthcare workers free of charge.

CASE STUDY 22:

Keywords: Artificial Intelligence, Machine Learning, Cloud Technology, Big Data, ERP, GIS

Sector: Energy (Distribution) Management

Envelio is an awarded "Clean Technology" software company from the Germany. In April 2017, Envelio was established as a spin-off of RWTH Aachen. Envilo have been pursuing a common mission: "*With our product, the Intelligent Grid Platform, we want to drive forward the energy transition on a global scale by making life easier for distribution system operators and grid customers*". Envilo, developing a software platform for energy grids that helps to integrate renewable energy sources and new types of energy consumers like e.g., charging points for electric vehicles into our energy system. The company, which shows its activities in line with the Sustainable Development Goal (7) "Affordable and Clean Energy" target, has been selected in this guide as one of the important practices for green digital transformation.

- **Problems & Solutions**

Envelio is a start-up company based in Germany that is using digital technology to revolutionise the energy grid. The company's software platform enables utilities to manage and maximise the efficiency of the distribution of energy from renewable sources such as solar and wind. Envelio's platform uses artificial intelligence and machine learning to forecast energy production and consumption, manage energy flows and maintain grid balance. By optimising energy distribution, Envelio can help reduce energy waste and the carbon footprint associated with the production and distribution of electricity. Envelio's digital tools include a cloud-based platform that integrates with existing grid infrastructure and enables real-time monitoring and control of energy flows.

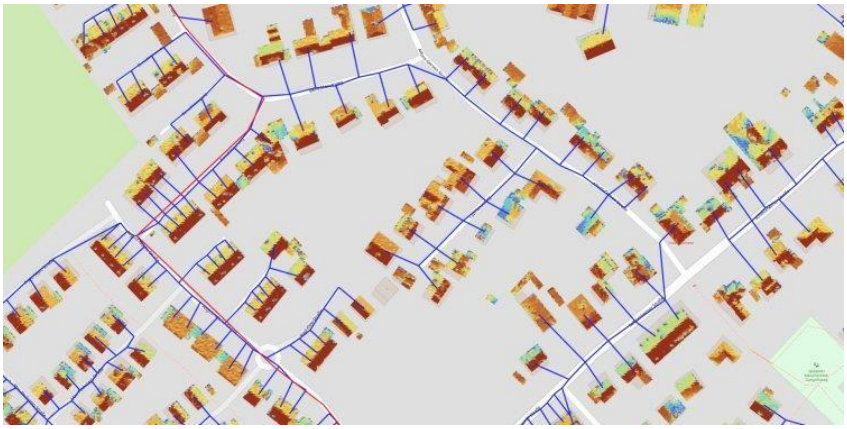

Figure 43. Sample Energy Distribution (from Impakter)

- **Digital Transformation Tools/Activities Used**

Envelio is a start-up company that integrates digital technologies into its "Smart Grid Platform" solution, specifically artificial intelligence and machine learning, as well as cloud technology. For the distribution of the power grid (especially distribution from renewables), this platform acts as a "digital hub". The relevant grid platform is designed as an intelligent system to manage end-to-end energy distribution. The system generally works as follows:

1. Data-driven automation of the grid connection process,

2. Teaching data and preparing supply requirement scenarios using machine learning technology,

3. Modeling the processed grid data and creating grid estimates

The company was defined as "Level 5" in terms of digital maturity with its integrated use of digital technologies.

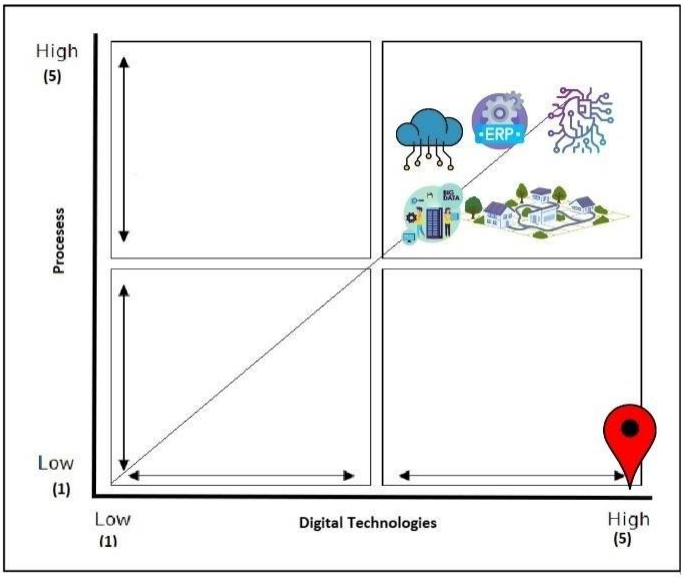

Figure 44. Envelio Maturity Level Template (by Authors)

- **Goals Achived**

As summarized in the mentioned application flow, it has been observed that the company has an impact on sustainable development by using digital tools from a “access to clean and affordable energy” perspective, primarily through intelligent energy distribution systems. The application also has the following socioeconomic implications.

- ✓ Improving electricity access by connecting people who do not have electricity (Bangladesh application)
- ✓ Reducing the cost of electricity distribution,
- ✓ Ensuring transparency and sustainability in electricity distribution

CASE STUDY 23:

Keywords: Mobile Application, Machine Learning, Sensor

Sector: Smart Thermostat Solutions

Tado is a Munich-based start-up that provides smart thermostats and air conditioning controls that can be controlled remotely via an app on a smartphone. The company's technology uses sensors and machine learning algorithms to optimise heating and cooling based on occupancy patterns and weather forecasts. This helps users save money on their energy bills while reducing the amount of energy wasted.

Problems & Solutions

Tado was founded on the idea of intelligent management of home energy systems. Thus, it aims to reduce energy costs (losses) in the home. With the Tado mobile application, people have the ability to remotely control the temperature in any room of their home. This prevents unnecessary heat consumption and saves more energy. The application provides its users with instant insights into energy consumption and savings online. It also provides the user with personalized energy saving ideas. In this way, it encourages people to consume less energy and contributes to sustainable development. The application, which interacts with digital tools such as machine learning and sensor technology to detect and estimate the temperature of the house, also alerts the user in case of a possible problem/malfunction risk in the control of the heating of the rooms. This helps to avoid malfunctions that may occur.

Digital Transformation Tools/Activities Used

Tado uses machine learning and sensor technology to integrate mobile apps. Tado's digital maturity level is described as "Level 4" with its business solution. Tado's digital tools include a "hosted in the cloud" platform that enables real-time monitoring and control of heating and cooling systems. In addition, Tado offers an app that provides insights into energy usage patterns and tips for reducing overall energy consumption. Tado's technology is considered an example of green digital transformation, as it enables more efficient energy use, reduces carbon emissions and promotes a sustainable lifestyle.

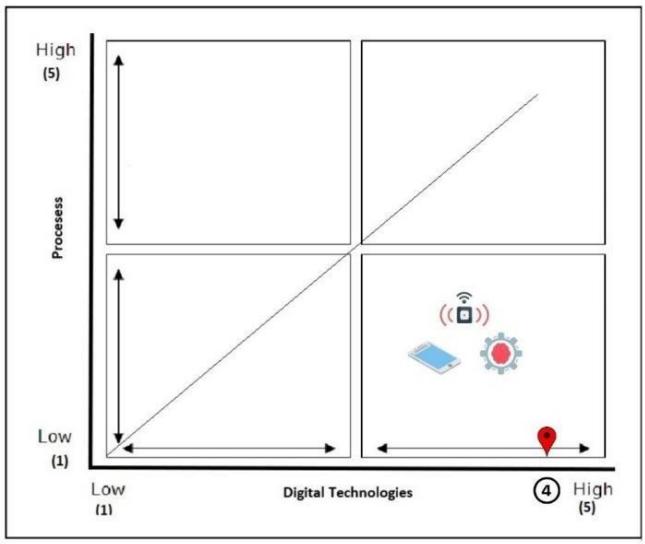

Figure 44. Tado Maturity Level Template (by Authors)

- **Goals Achived**

As summarized in the mentioned application flow, it has been observed that the company has an impact on sustainable development by sensor tecnology and machine learning from a “energy-saving ” perspective, primarily through using mobile applications for home based energy management. Tado has reduced individual energy consumption by 28% with the energy solutions they have realised.

CASE STUDY 24:

Keywords: Simulation, Cloud Technology

Sector: Eco-Plastic Manufacturing

Traceless is a start-up company based in Hamburg that is developing "*alternatives to plastic*" that are made from biodegradable materials derived from agricultural waste and founded in 2020. Traceless is multidisciplinary and diverse team of passionate experts, united by pioneering spirit. Company mission based on "*a world where the materials we use impact positively on the planet, making pollution and waste history.*"

- **Problems & Solutions**

The technology developed by the company utilizes a method known as hydrothermal carbonization, which converts waste materials like rice husks and straw into a biodegradable material that can be used to make products like packaging, cutlery, and straws.

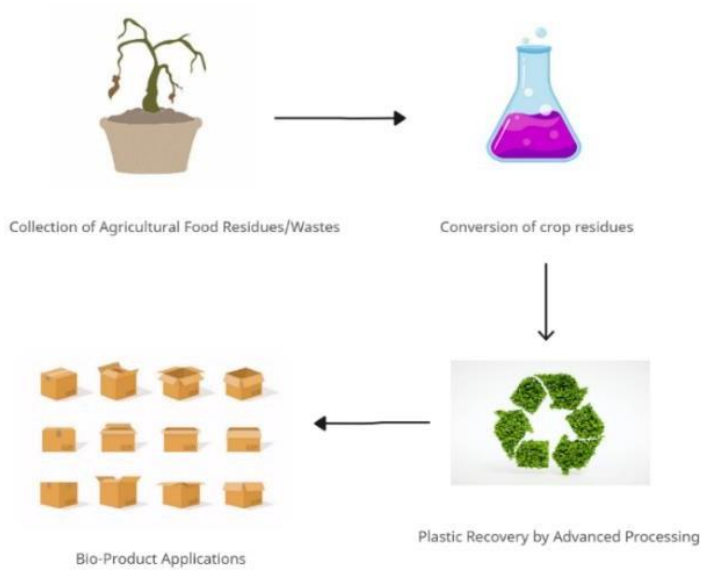

Figure 45. Traceless Bio-Production Process (By Authors)

Because it offers a sustainable alternative to conventional plastic materials, which can take hundreds or even thousands of years to decompose and contribute to environmental pollution, the digital transformation known as traceless is considered to be environmentally friendly.

- **Digital Transformation Tools/Activities Used**

Traceless uses digital tools such as simulation software and a cloud-based platform that enables real-time monitoring and control of the production process to optimize the hydrothermal carbonization process and reduce waste. Traceless uses mobile integrating simulation and machine learning in the recycling of agricultural waste. The digital maturity of Traceless is described as **"Level 4"** with its business solution.

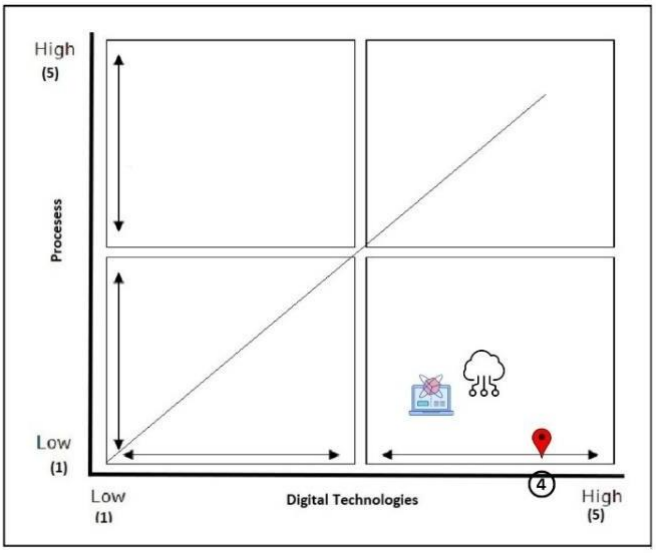

Figure 46. Traceless Maturity Level Template (by Authors)

- **Goals Achived**

With their business models, Traceless has been able to produce from recyclable materials instead of standard plastic materials that take thousands of years to recycle the materials they produce. Thus, plastic waste, which takes a long time to mix with the soil, has been prevented. In addition, it prevented carbon emissions and contributed to reducing the carbon footprint by contributing to the reduction of raw material/energy use in the production process.

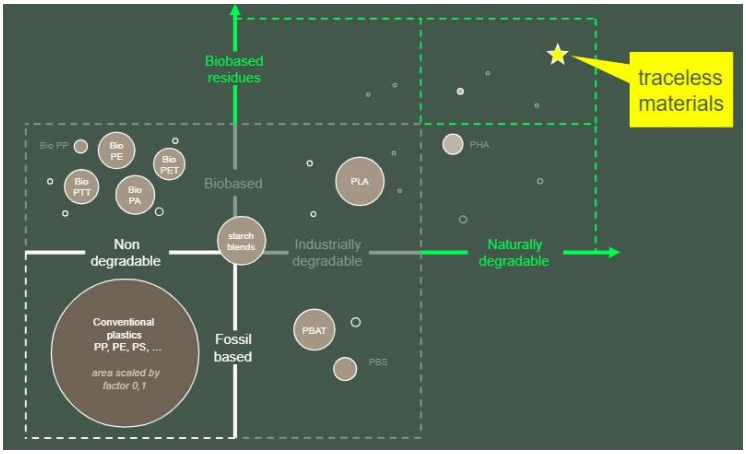

Figure 47. Traceless Bio-Production Process (from traceless.eu)

The company:

- Offered production of more sustainable plastic substitutes as bioplastics,

- 83% of fossil energy saved in production,

- 58.91 GJ of fossil energy saved,

- In 2019, it had a positive effect on the energy consumption of 8,800 kWH of individuals in Germany.

CASE STUDY 25:

Keywords: Arduino, 3D Printer, Artificial Intelligence

Sector: Facade Cladding Production and Prototyping

Ledshow TR is a company operating in the electronics and machinery manufacturing sectors of Tekno Sove Ltd. It was established in 2010 in Istanbul in the field of manufacturing electrical and electronic products. As of 2015, it has been operating in the field of jamb cutting machines and 3D styrofoam production.

Problems & Solutions

In addition to the production of jamb cutting machines, the company produces exterior cladding (panel) needed by homes and workplaces through jamb cutting machines. In this example of good practice, the company focuses on the idea of developing limited design models in the field of exterior cladding on the market. The company, which works as a supplier, serves as a supplier of "special design exterior cladding" by using various raw materials, especially styrofoam, to companies that make exterior cladding. It uses artificial intelligence technology to produce innovative designs and increases the print quality and diversity by using 3D printers in the printing process. The company also contributes to environmental sustainability by providing recyclable prototype products by using it in 3D printing and jamb cutting machines.

Digital Transformation Tools/Activities Used

The raw material used by the business is styrofoam. Because styrofoam foam is expanded polystyrene (EPS), 90 to 95% of its total content is air. Using special techniques, this air can be removed from the styrofoam and the styrofoam itself can be turned back into polystyrene for recycling.

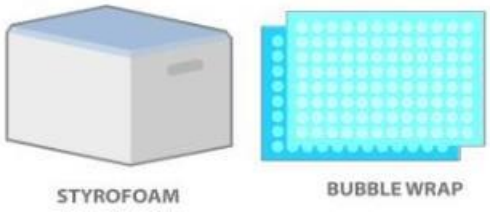

Figure 48. Styrofoam and Bubble Wrap Sample

Ledshow TR contributes to the recyclable product production process by using this styrofoam as a raw material. With artificial intelligence technology, the company generates new design ideas and produces innovative form products through both 3D printing and 3D printers.

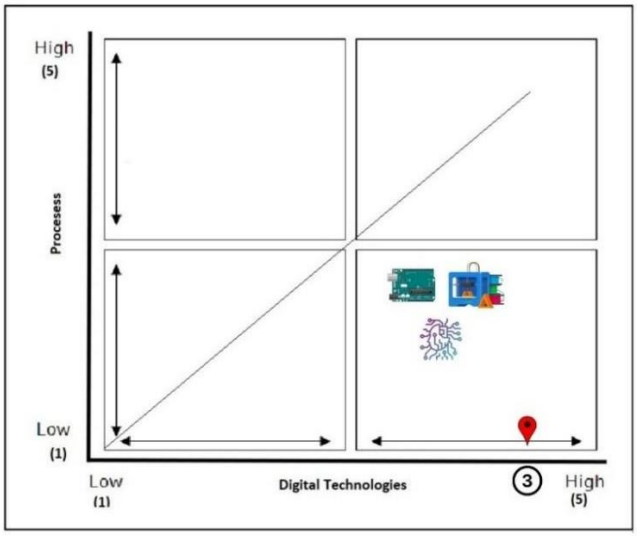

Figure 49. Traceless Maturity Level Template (by Authors)

Although it uses artificial intelligence technology together with 3D printing and printers, digital maturity has been determined as "Level 3", which is the average level. The company also builds LED lighting system for 3D printers using Arduino cards and uses it to offer tutorials and forums to help get started with using Arduino in 3D printing. However, since it is not an integrated process, this technology is not included in the leveling of digital maturity.

- **Goals Achived**

LedshowTR has been able to achieve innovative designs in which raw materials, especially styrofoam, are designed with artificial intelligence, through their business models. Accordingly, the following effects have emerged with the digital transformation activity carried out by the enterprise;

- ✓ Contributing to the production of innovative designs,
- ✓ Reducing design costs,
- ✓ Reducing the waste rate that occurs during the design process,
- ✓ Production of personalized products with 3D printing,
- ✓ Minimalization in waste reduction with the use of 3D printers in production,
- ✓ Minimizing the energy use of buildings with Styrofoam coating.