WORKING PAPER

Eurofound

Digitisation in the workplace

Case study:

3D printing at KLM Engineering and Maintenance (Schiphol)

Digitisation in the workplace

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Related report: *Digitisation in the workplace*

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Case summary

In 2018, pre-existing 3D-printing initiatives were accelerated within KLM Engineering & Maintenance (E&M – NACE code C.33.16) to develop new tooling for airplane maintenance and to reduce plastic waste. The E&M division of the Dutch airline KLM has approximately 5,000 employees and is located at Schiphol, Amsterdam.

The primary reason for accelerating and introducing the technology further in E&M was to build 3D-design capacity and awareness of the possibilities of 3D-printing among KLM employees. The technology is mostly used to develop new tooling for airplane maintenance and to reduce plastic waste. Due to this acceleration starting in 2018, at the beginning of 2020 KLM had eight local 3D-print offices within Engineering and Maintenance (E&M).

The most important changes for the organisation relate to issues of efficiency in maintenance cycles, rather than changes in the overall processes undertaken by the employees. Each 3D print office could save around €500,000 annually because having the capacity and capability to make custom-made tools results in more efficient maintenance. An added benefit is less dependence on external suppliers of tools. KLM E&M was also able to improve plastic recycling by converting empty plastic bottles from customers into printing material. During COVID-19, the 3D printing facilities have also enhanced the safety of the workplace as the staff have been able to design products which reduce the number of surfaces needed to the touched during maintenance work.

3D printed tools have taken away frustrations about certain aspects of maintenance (for example doors falling open when conducting maintenance, damaging the airplane). Access to 3D printing allows for different approaches to problem solving and opens up the opportunity to change the potential solution to a problem to one which can reduce time and effort for the same high-quality results in maintenance and repair.

The 3D printing related tasks are not considered part of the regular job profile but come on top of other assigned tasks and need to be performed during down time. The newly acquired skills do not result in an immediate change in prospects or earnings within the company. They do create some divide between workers: especially for the older technicians who find it more difficult to acquire the new skills given the schooling they received or the competences they possess.

As 3D printing did not fundamentally change the engineering tasks, it was seen as the introduction of a new tool for those employees who were keen on experimenting, and no formal approval of employee representatives was deemed necessary. There was interaction between employees and management on aspects of the technological change process that could be improved, to discern the best ways in which the technology could support their work, which e.g. resulted in knowledge sharing sessions.

Introduction

Background and objectives

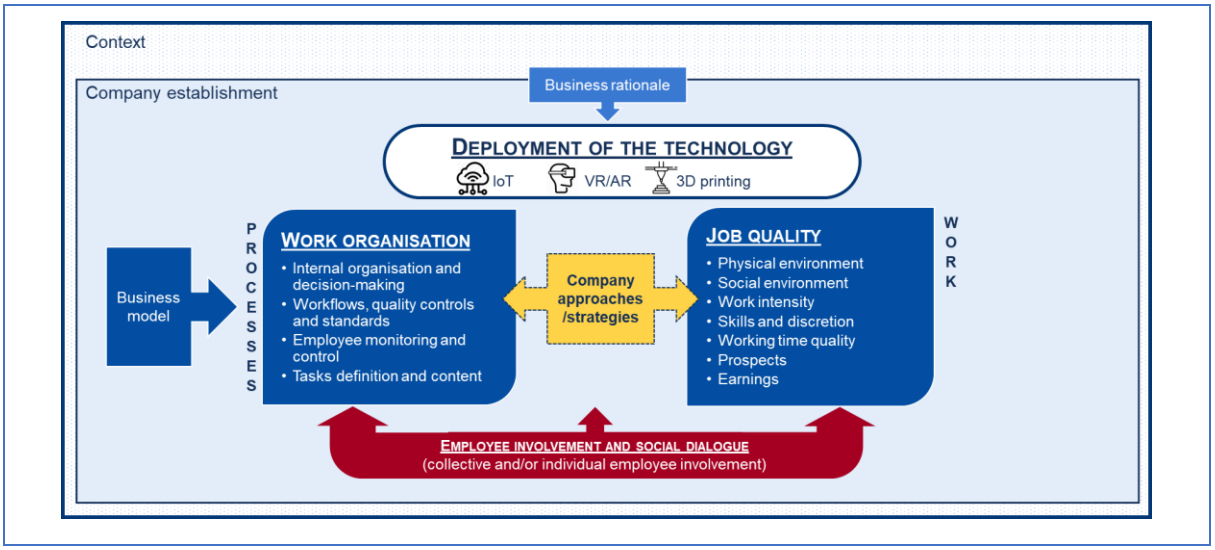
This working paper illustrates the case of KLM Engineering & Maintenance (E&M) (the Netherlands) in relation to the introduction and deployment of 3D printing technology. The working paper explores the impact of 3D printing technology on work organisation and job quality, as well as the extent of the employee involvement in relation to the digitisation process.

This case study has been conducted in the context of a Eurofound research on the impact of digitisation on the nature of work. This research is set against a conceptual framework elaborated by Eurofound (Eurofound, 2018a), which differentiates between three vectors of change, of which one is digitisation and is associated with three digital technologies, being additive manufacturing or 3D printing, the Internet of Things and Virtual and Augmented Reality.

According to Eurofound's conceptual framework on the digital age (Eurofound, 2018a) the effect of digitisation is most direct on working conditions, as it involves a change in the work environment and the nature of work processes. It also involves changes in tasks and occupations and has an indirect effect on employment conditions and industrial relations.

Based on this conceptual framework, Eurofound has developed an analytical model (reproduced in Figure 1) that serves to guide the analysis of all 10 case studies (including the case of the KLM E&M division) conducted for this research. According to this model, the nature of work consists of two core dimensions, namely work organisation and job quality. Employee participation and social dialogue is a cross cutting dimension as it can both influence and be influenced by the way the technology is deployed in the workplace. Typically, the technology changes the establishment's business model, which in turn impacts the work organisation and elements of job quality (partly depending on how the technology is applied in the workplace). Both contextual factors and establishment or company specificities may drive the digitisation efforts. These factors should be taken into account for a better understanding of what has either constrained or facilitated the digitisation process within each establishment.

Figure 1 Conceptual model of the study



Source: Technopolis & Eurofound (2019)

The current case study focuses on one of the three business divisions of KLM, that is Engineering & Maintenance (E&M), located at Schiphol Airport (the Netherlands). This case study provides insights into the introduction of 3D printing technology in a large company and illustrates the importance of a well-defined vision on technology implementation and the added value of employee consultation before implementation. It also depicts the particularities of introducing a new technology in a risk-avoidant sector. This case study draws primarily on qualitative interviews conducted with two employees (a senior ground engineer and junior equipment engineer), two managers of KLM (innovation and programme manager), a representative from the KLM Works Council and a 20 minute consultation of the trade union NVLT and desk study of secondary sources such as the company website, annual reports and blog posts.

Reason for selecting this particular case

KLM E&M has a well-defined approach to innovation but is also set in a risk-avoidant sector and has a relatively old workforce. This case study therefore not only provides learning about the process of introducing a 3D printing technology within a large organisation and the impact it has on the employees that have to work with the technology, but it also illustrates the use of 3D printing within a risk-avoidant sector and the impact on a workforce that is not used to changing work practices. This case study also adds the perspective of a company that is actively looking for solutions where 3D printing is of added value, in particular by developing maintenance tooling. As the 3D printing technology was gradually further introduced to the KLM E&M division in 2018, in addition to some other scattered initiatives in E&M, the case study mostly focuses on the initiation phase of developing a company vision on additive manufacturing and the first steps towards the implementation of the technology.

Report structure

In the following chapters more context will be provided by describing the KLM E&M division in more detail (chapter 1), the introduction and implementation of the technology (chapter 2), the impact on the business model, work organisation and job quality and the extent of employee involvement in the process of change (chapter 3). The working paper ends with lessons learned drawn from this specific case and takeaways.

1. Establishment profile

Type of entity and ownership structure

KLM Engineering & Maintenance (E&M) is part of KLM Royal Dutch Airlines and provides aircraft, engine and component maintenance to KLM, Air France and other airlines, as well as engineering support.

KLM Royal Dutch Airlines was founded in 1919 with home base Amsterdam, Schiphol Airport. KLM is part of the KLM Group, which includes KLM, KLM Cityhopper and the wholly-owned subsidiaries Transavia and Martinair. In 2004, KLM Group was merged with Air France in the Air France-KLM Group. Both companies retained their own identity, trade name and brand. The Group plays a pioneering role in the European air transport industry and in 2019 was listed number one on the Dow Jones Sustainability Index.

Supervision and management of KLM is structured according to a two-tier model, consisting of a Board of Managing Directors that is supervised by a Supervisory Board. The Supervisory Board supervises management and general performance of the company, provides the Board of Managing Directors with advice, discusses KLM Group's strategy and approves management decisions.

KLM is managed by an Executive Team, which is made up of the Board of Managing Directors and representatives of the different business areas of KLM. The Board of Managing Directors in 2019 consisted of three members: the president-director, financial director and operational director. Functions and business areas that are represented in the Executive Team are: Customer Experience, Transformation, Cargo, Engineering & Maintenance, Inflight Services, Flight Operations, KLM Benelux, Information Services, Human Resources & Industrial Relations and Corporate Centre.

Activities and geographic location

Engineering & Maintenance (E&M – NACE code C.33.16), located in Schiphol, is one of the three main business divisions of KLM. The other two are passenger business and cargo. The aim of Engineering & Maintenance (E&M) is 'to be a significant player in the field of Maintenance, Repair and Overhaul (MRO)' (2020). More concretely, the division provides KLM and other airlines with aircraft, engine and component maintenance, as well as engineering support. In terms of maintenance operations, KLM E&M is the second largest provider of these services globally. In its attempt to improve its services provision, KLM E&M uses 3D printing to produce maintenance tools.[1]

Next to the three business divisions mentioned above, KLM has also a central division called KLM corporate. Part of this division is the Central Transformation Office, responsible for change processes within KLM. The Transformation Office has its own Radical Innovation Team, which is responsible for orchestrating the innovation-ecosystem of KLM. The initiative to accelerate the already existing 3D printing within KLM E&M originated from this Radical Innovation Team.

[1] KLM E&M is not entitled to fabricate airplane parts because of legal requirements and commercial/intellectual property restrictions.

Size and workforce composition

In 2019, the company had 36,600 employees, of which 28,615 employees are permanent and 1,957 are temporary staff. KLM E&M has a total of 5,000 workers, mainly divided over the four biggest units:

- Engine Services
- Airframe
- Component Services
- Engineering

Each of these departments again has sub-units.

Form of employee representation

Within KLM overall, there are three different formal forms of employee representation.

1) At the level of KLM E&M there are several group committees. The group committees ensure agreements in the collective labour agreement (CAO) are upheld. Examples are the group committee component services, the group committee on quality assurance and the group committee engineering. Members of the group committees are elected by the employees. The group committee boards are in contact with trade unions, the E&M division board and the overall KLM Works Council.
2) The KLM E&M division board is an extra board between the KLM Works Council and the group committees, for issues that encompass several committees. Representatives from the group committees are chosen to take part in the division board.
3) The company's Works Council operates at the overall KLM level and was established in 1950. The Board of Managing Directors meets with the company's Works Council on a regular basis. During these meetings, a number of topics are discussed, such as the company's strategy and financial results. The topic of conduct and culture within KLM is also addressed. The KLM Works Council has 25 members, who are elected. Finally, there is also a European Works Council, for matters concerning Air France-KLM.

Furthermore, there are several different trade unions that represent KLM E&M staff. These are the Dutch Union for Airplane Technicians (NVLT), the KLM Unie and the broader Christian National Union (CNV) and Federation of Trade Unions (FNV). Employees that are a member of (one of) these trade unions can be elected for the three bodies described above.

2. Introduction and deployment of the technology in the establishment

Motivation for the introduction of the technology

According to the management, the main reason for introducing the 3D printing technology was to build 3D design capacity and raise awareness of the possibilities of additive manufacturing within KLM. When talking to interviewees, three underlying motivations can be discerned.

Firstly, by building 3D design capacity, KLM can prepare for the future and keep up with its competitors (learning by doing). An example is Lufthansa Technik (the maintenance, repair and overhaul division of Lufthansa) which opened its own additive manufacturing centre in 2018 to develop 3D printed aerospace parts. Together with Oerlikon, a partner company that develops additive manufacturing solutions, the company is also investing in the standardisation of additive manufacturing technologies. In order to keep up and be able to match future standards within the aviation business, KLM needed to start with deployment of the technology as well.

A second reason to start working with 3D printing is the fact that since 2017, KLM has reached its ceiling of 500,000 flights per year. One of the things the company is doing to deal with this limit is to optimise operational processes (for example saving on procurement of parts, better inventory control, integrating processes of different departments). Budget and time savings are important. In this case, with 3D printing being applied within KLM E&M, maintenance and reparation material expenses as well as time per procedure can be decreased.

Thirdly, KLM is continuously investing in sustainable and innovative products and processes to reduce its carbon footprint. The company has a goal of reducing the volume of its waste by 50% in 2030 (in comparison to levels in 2011). The 3D printing is part of a recycling loop, where KLM recycles waste and uses it again to create tools for engineering and maintenance.

Place in the workplace for the technology and its embeddedness

The 3D printing technology has been gradually accelerated in KLM E&M since 2018. This deployment took place in the shape of so-called 3D print offices. Each department received its own local 3D print office consisting of one printer (the Ultimaker S5), four trained staff members (mostly junior engineers and mechanics) and material for a year. Because of this gradual roll-out, the level of technology readiness differs per department. While the departments of engine services and component services have been working with 3D printing for quite a while now (2+ years, TRL 8/9), implementation within airframe is still relatively new (1-2 years, TRL 7/8).

The first 3D print office was considered a demonstrator. It took around a year to open this print office: convincing people within KLM E&M that it was worthwhile to do this, train people and get the office up and running. Once the office was in use and it became clear that the printed tools were of added value to the work within KLM E&M, opening up other offices was easier. According to interviewees, with each new office, the implementation process became more efficient.

The 3D printing technology is mostly used to develop new tooling for airplane maintenance as well as introducing circular concepts to reduce plastic waste. When an employee has a new idea to improve the tools used, a prototype is made and tested in maintenance operations. If the prototype proves to be of added value for maintenance activities it becomes a part of the official maintenance tools.

Timing of the introduction and progress thus far

The acceleration of the 3D printing technology started with the Radical Innovation Team, part of the Central Transformation Office of KLM. Additive Manufacturing was already performed in several parts of Engineering and Maintenance but efforts were not coordinated and knowledge was not being shared among those projects. This was the key role of the Radical Innovation team of the Transformation Office. Thus supporting and aligning efforts that already were being made and accelerate them.

The sheer size of KLM Royal Dutch Airlines requires orchestration of innovative activities and change processes in the company. A large number of employees throughout the company are working with innovation and it is of added value to KLM to connect these people to each other, so that innovation can be put to use for the entire company. The Radical Innovation Team have a central overview and connect the different stakeholders within the organisation working on innovation.

In late 2017, 3D printing was already being tested within the engine service department. This development was picked up in the Radical Innovation Team and a person responsible for additive manufacturing (also called the topic owner) was appointed within the Radical Innovation Team. At this point the Team started to scale the use of 3D printing across KLM E&M.

At the same time, KLM was thinking of recycling the plastic bottles used by customers in the airplane. It was suggested to use the material from these plastic bottles for 3D printing.

The first step towards introduction of the technology was to organise workshops with employees within Engineering and Maintenance. During the workshops, employees were asked how they would like KLM to implement additive manufacturing if it had unlimited resources. Subsequentially, the different perspectives that were put forward during the workshops with employees were shared in a workshop with management, consisting of the different vice-presidents of KLM E&M. The result of this final workshop was a vision for additive manufacturing in KLM E&M. Furthermore, a *capital investment plan* (business plan) had to be drawn up. This was seen as a blueprint to be re-used to open up consecutive 3D print offices.

After finalisation of the vision in 2018, the first local 3D print office was set-up within component services in 2019. In all, opening the first local 3D-print office took around a year. During this time there was some resistance from employees who voiced their concerns over whether it would be possible to use 3D printing within their work and whether it would be of added value. Employees were mostly concerned that 3D printing could only be used for printing airplane parts (KLM E&M is only allowed to repair and maintain parts, not to produce new ones). This required additional explanation of the goals and uses of the 3D print offices.

Once the first local 3D print office was set up, others soon followed. Through the first 3D print office the potential of the technology and added value (especially increased productivity) was demonstrated clearly to the employees, which made it easier to convince others of its worth for their

own department. This was done by organising knowledge-sharing workshops, in which the added value of 3D printing for the employee (how their work would become easier) was explained. By now, in 2020, KLM has eight local 3D print offices within Engineering and Maintenance:

- Component Services: 2 local 3D print offices
- Engine Services: 1 local 3D print office
- Airframe: 3 local 3D print offices
- Central Engineering: 2 local 3D print offices

KLM developed a Roadmap for Additive Manufacturing which foresaw another 18 initiatives around 3D printing, including the addition of three more 3D print offices over the next five years. Unfortunately, the COVID-19 pandemic has had a major impact on KLM. As an airline, KLM was immediately impacted by this crisis. The long-term impact for KLM and its change processes around 3D printing cannot be foreseen. At the moment, further scale-up of additive manufacturing within KLM has been put on hold.

Initial expectations of the introduction of the technology

When the KLM Radical Innovation Team started with the development of a vision for additive manufacturing within Engineering and Maintenance, the initial expectation of the team was to build 3D-design capability within KLM E&M with a small investment. By building this capability, the idea was that employees would become less reluctant to use the technology and gain further insights in its potential use. Above all, it was considered a necessary capability to remain competitive within the aviation industry in the future.

Employees themselves were sceptical. There were three reasons for this scepticism. 1) Engineers working within KLM Engineering and Maintenance are only allowed to execute repairs and maintenance and cannot produce any new airplane parts. Because most employees had the preconception they could only use 3D printing to produce parts, for many of them the first response was that it was not possible and not allowed, as KLM does not have the rights to produce airplane parts. 2) KLM's number one priority is safety of its passengers, resulting in little room for trial and error. Interviewees feel that this safety culture, combined with the high average age of KLM E&M employees (53 years) results in them being more risk-avoidant and having difficulty with changing their work practices. 3) A final factor that resulted in scepticism from employees, was the fact that 3D printing would be done using plastic, while they are used to working with off the shelf metal tooling.

Initial positive responses towards the use of 3D-printing mostly came from a small group of younger staff members, mostly junior engineers and technicians. Other employees first needed convincing that it was possible to use 3D printing for engineering and maintenance and that it would actually help to make their jobs easier. Namely, by printing custom-made supportive tools that will not be integrated in the airplane, but that make the maintenance process easier and more efficient.

Once engineers realised that with 3D printing could solve issues they had run into for years in a row their mindset started changing.

Initial strategy for the introduction of the technology and adjustments during its deployment

The KLM Transformation Office aims to improve the efficiency of KLM, across all business areas. Innovative ideas that come from within the organisation are identified by the Radical Innovation Team, after which different people within the innovation ecosystem are put in contact with each other and a vision and strategy are created together to ensure broader implementation of the innovation in the organisation. This innovation ecosystem includes among others representatives from the different KLM E&M departments (both engineers and directors), senior leadership of KLM E&M and external parties such as the companies providing 3D printing material and training and knowledge institutes that have up-to-date knowledge on applications of the technology.

When the Radical Innovation Team started with coordinating the development of additive manufacturing within KLM, there initially was no strategy. This was created after consultation workshops with employees from KLM E&M on the potential of the technology. The consultation started at the initiative of the Radical Innovation Team, to gather input from employees that would have to work with the technology and were considered to have the best insights in what possible uses of the technology could be. Once the vision was finished, local print offices could be opened up.

So far, there have been limited to no changes in the implementation strategy to set up 3D print offices in the different E&M departments. The implementation strategy consists of a roadmap for the implementation of 3D print offices. Furthermore, for every 3D print office that is set up four employees receive training, a printer is purchased, and printing material is provided.

Involvement of employees in the decision-making process

In the decision-making process, there was little to no involvement of employees. Employees were consulted to map the possible applications of 3D printing within KLM E&M and subsequently inform management, but decisions to open up local print-offices were made without involvement of employees.

Involvement of formal employee representation is limited. Group committees can be involved in investment decisions, in this case the investment in a 3Dprint office. Only when developments result in the decision to let go of a certain number of employees or when investments of over a million euros are done, the overall KLM Works Council becomes involved.

3. Impact of the technology in the workplace

Changes to the business model

The 3D printing has not resulted in any major changes to the business model of KLM E&M, as the technology has been introduced recently following a gradual process starting in 2018 and still ongoing. Nevertheless, the instalment of the 3D print offices has had very promising results. According to KLM, each 3D print office could save around €500,000 annually because custom-made tools result in more efficient maintenance. One example is the expensive polyurethane tape that earlier would be used to protect turbine blades and rim holes when painting over a Boeing 737. Since the opening of the 3D print offices, it was possible to use cheaper and more reliable 3D-printed housings or plugs to prevent the rim holes from being painted over. Sometimes 3D printing also results in time savings, as only one instead of two employees are needed to conduct a certain part of maintenance. Another example is maintenance to the overhead lockers in the cabin, which can now be kept in place by a 3D printed tool, while before, one employee had to hold it while the other made necessary adjustments.

Furthermore, 3D printing helps KLM to use its plastic waste. Prior to opening the 3D print offices, KLM was already recycling PET-waste. Empty water bottles from airplanes are collected once they arrive at Amsterdam Schiphol Airport (each day, KLM Catering Services manually sorts about 15,000 bottles) and sent for recycling into filament. The companies Morssinkhof Rymoplast and the filament manufacturer Reflow support KLM with the plastic circulation. The filament is now used as a base material for 3D printing. Before KLM started recycling plastic bottles, it bought premium materials at €60 per kilo, while production of recycled filament costs about €17 per kilo. Recycled filament is therefore also more financially attractive. Of course not all 3D printed tools can be made from recycled material but a large portion can. Furthermore, the production of filament has helped KLM to work toward its goal of reducing plastic waste by 50%. In 2018, the amount of waste was reduced by 9% and 28% of the remaining waste was recycled.

During the COVID-19 pandemic the 3D print offices also came in handy. A challenge was set up to print tools that could help prevent the spread of COVID-19 in the workplace. Tools that were created ranged from special levers for taps to new doorknobs.

Impact on the work organisation

Internal organisation and decision making

The introduction of 3D printing has had no impact on the internal organisation nor decision making within KLM E&M. Formal tasks of employees have remained the same, there have been no new hires or dismissals because of the technology and no restructuring of the internal organisation. The technology has so far mostly had an impact on maintenance processes, with reduced time and material costs needed for maintenance. Interviewees do not foresee the introduction of 3D printing resulting in fewer people being needed in the near future.

Workflow, quality controls and standards

The first employees that were trained in 3D design[2] and have now been printing for about 1-1,5 years, are considered largely autonomous. Together with colleagues, they come up with new ideas and start printing prototypes on their own, without further encouragement or support needed from management. The possibility for employees to produce new tools did at some point result in several different departments within KLM E&M printing new tools with little coordination and monitoring on quality.

At a certain point in time, this issue was raised by employees from the central engineering team responsible for certification and quality control. Subsequently, a knowledge-sharing session between different employees was organised to make agreements about the quality management of 3D printing within E&M departments. Since then, the central engineering team is involved in the process and when needed ensures that all necessary steps are completed, including making an official drawing of the tool, classifying the tool and registering the tool in a data management programme.

It does at times remain a challenge to ensure tools do not 'get lost' within the organisation and to keep the number of tools under control and registered, especially since most of the time several revisions of a tool are printed. Before the COVID-19 pandemic, KLM initiated 'Plant X', an innovation lab where technicians could go to with their ideas, to explore, test and validate them and where the central engineering team could be involved to help with the quality processes. The physical space where engineers could work on new solutions greatly benefited the interaction between the central engineering team and the different E&M departments. With the initiative put on hold because of the pandemic, interviewees foresee that it will become more difficult again to get in touch with technicians working on 3D printing in the different departments, as there is no longer a central place where they can meet each other.

Employee monitoring and control

According to interviewees there is limited employee monitoring within KLM E&M. New tools and 3D printing related projects are put in the project management database. It is therefore possible to keep track of the number of prints that were made during a certain time period. However, at the moment, this is not monitored.

Task definition and content

The formal task definition of employees has not changed. The official tasks of employees have remained the same and they are only allowed to work on 3D printing when their official tasks have been completed. Nevertheless, it is possible to discern some informal changes to the work profiles of employees that work with 3D printing. An example is the fact that, because 3D printing is not yet well known within the organisation, employees working with the 3D printers also function as 'ambassadors'. They explain to other employees why the 3D printing technology is of added value to their work and convince others to contribute to prototyping activities. According to management this can be quite difficult, as these are often young employees (mostly junior engineers, between 18-35 years old), in comparison to the average age (55 years old), and they need to explain to other

[2] In June 2020, a total of 58 E&M engineers had been trained, with different educational backgrounds.

more experienced staff what the added value of the technology is. Interviewees indicate that ambassadors are starting to feel more confident with this new role.

Impact on job quality

Physical environment

3D printing has made the work for technicians at KLM E&M easier. Examples are tools that enable maintenance with one instead of two engineers or new tools that save time, such as the plugs that ease the painting process of the turbine blades. Furthermore, the creation of local print offices has resulted in employees having a dedicated physical place to work on 3D printing, which ensures focus and also facilitates the 3D printing process. The interviewed employee representative expects 3D printing to reduce the number of physical risks employees face, as there might be less need to use welding equipment and lathes.

One interviewee mentioned that he was initially a bit concerned about working with 3D printers and the ultra-fine particles that could be released during the printing process. After bringing this up during a training session, the trainers from Makerspace were able to provide him with academic papers and reports that lifted his concerns. KLM E&M has a risk unit that checks if the work environment is safe and ensures proper air extraction and protective equipment are available and used.

Social environment

Employee engagement and motivation is boosted when they see problems that they have run into for years being solved in a few hours or days through rapid prototyping. One example is the foldable tables that are part of the business class seats. The tables need to be calibrated, which requires disconnecting the table by removing several different screws in a fixed order. Repeating this for each individual table is a lot of work. With 3D printing technology it was possible to create a tool that ensured removal of the individual tables was no longer necessary. This way, frustrations about certain aspects of maintenance (for example tasks that require a lot of time or are very repetitive) are taken away by the 3D printed tools. Some employees also indicate that their mental wellbeing has increased, as they have now learned a new skill and enjoy doing it.

Another effect on the social environment is the fact that colleagues are starting to become more open to sharing experiences and knowledge. Employees have gotten to know colleagues that they did not know before. A 3D printing community has evolved, and sessions are sometimes organised to exchange knowledge. There is still a large group of employees that are risk-averse and hesitant to change their work practice. Changing the mindset within the whole of KLM E&M will take time. When employees working with 3D printing however receive positive reactions from colleagues, this is again considered a positive stimulus.

Work intensity

For the KLM employees that are actually printing tooling in 3D, it does sometimes result in working overtime. Especially as these employees only work with 3D printing on a part-time basis. Therefore, it can take some time to remember the details of the design and printing process. It is an extra task they have to do next to their regular tasks. Furthermore, prototyping new tooling is a process of trial-and-error. Staff in E&M see the added value of 3D printing when a new tool is created that works

and that is able to solve a structural issue in the maintenance process. The staff that do not work with the 3D printers themselves, but are able to use the developed tooling, already profit from some increased efficiency in their work, where the tools help to save time or enable them to conduct a maintenance job with one instead of two engineers.

Skills and discretion

At the start of the project, information sessions were facilitated within the different E&M departments. Employees from the different E&M departments that were interested to learn more about 3D printing were invited to join a presentation and subsequently asked if they would like to work with 3D design. Of those employees, a group was selected that would receive training. A selection of four employees per 3D print office was made by the respective manager. This decision was based on interest and competences of the employee, in particular if someone had affinity with design and would be able to combine it with their current job.

Often these people were already familiar with 2D design or had done some 3D printing for leisure, at home. The training was provided by the company MakerPoint, that also supplied the 3D printers. Most employees received the basic 3D design training, a few (for example equipment engineers that have experience with making drawings and modelling) received more advanced training. In the first round of training, 58 people were trained in 3D design. Before the COVID-19 pandemic, KLM was planning to provide a second round of training, but this has currently been put on hold.

During the first training, it became apparent that not every technician can master 3D design. It is a different skill from doing technical maintenance on the aircraft and requires creativity and affinity with design. Most employees within engineering and maintenance are technicians that were educated to conduct maintenance on an airplane but have received no training in 3D printing. Some older employees are familiar with 2D design but only the young technicians have received some 3D modeling during their studies.

Other skills that are needed are:

- Knowledge of modelling and making 3D-drawings
- Content knowledge of the printing process, such as printing with plastics, powder, etc.
- Knowledge about the software, to be able to turn a 3D model into something the printer can print
- Spotting opportunities and creative thinking, for example noticing where in the maintenance process a new 3D printed tool could be of use.

To become confident in 3D printing, time investment is also needed after receiving training to learn and further develop these skills. Motivation and affinity with 3D printing as well as persistence and not being afraid to make mistakes is therefore a must-have. At the moment, while receiving the same training, the skill levels of employees differ with some staff being more active in 3D printing than others. These are often younger staff that are willing to invest extra (over)time in learning by doing.

Working time quality

Within KLM E&M, working on 3D printing (3D design, printing and prototyping a tool) is not part of the formal task description of employees and it is something employees do during down time, when they have finished their priority tasks, for example at times when less maintenance is needed. As

noted by one interviewee, this involves putting in extra time (outside working hours) to work with the 3D printer, on the employee's own initiative. According to employee representatives this is often the case within KLM and it is part of a lean way of working. The decision to free up extra staff and to allocate additional resources is taken only when a new task starts to take up too much time and it becomes clear that extra FTE are needed.

Because employees cannot work on 3D printing full-time, interns from Delft Technical University, Amsterdam University of Applied Sciences and Eindhoven University that join KLM E&M for around six months are a major asset. The intern is fully dedicated to the 3D printing and can help KLM E&M employees. These can be employees that do not know anything about 3D printing but have a good idea for a tool, for example an aircraft mechanic that knows very well how the maintenance process works, and for whom the intern is able to quickly translate the technical specifications into a 3D design. Interns also help those employees who have received training but may have forgotten something, and for whom the intern can answer questions about the software or printer, something that would take the employee more time to figure out him or herself.

Prospects and earnings

The use of 3D printing and employees learning how to make a 3D design has not resulted in changed prospects or earnings for these employees within KLM E&M. The new skills could however be of added benefit to employees when applying for jobs elsewhere.

Employee involvement and social dialogue

Within KLM Engineering & Maintenance, there has been some employee consultation before the technological change process. However, apart from investment decisions regarding the 3D print offices, formal representation and involvement of workers in the decision-making process has not taken place. Consultation of employees was considered important to discern the best ways in which the technology could support their work. The final decision-making process is something that is considered to be a role of management, not employees.

Consultation with employees before the opening a local 3D printing office has mostly taken place at the initiative of the management. The employee consultation was instrumental to develop a vision on additive manufacturing. According to interviewees, this initial process has facilitated a more positive mindset towards the use and added value of 3D printing. Many technicians had good ideas on how 3D printing could be put to use, in particular to create tools for maintenance, and this input was taken into account when establishing the vision on 3D printing within KLM E&M.

During the technological change process, there was no explicit employee involvement or consultation. After the technological change, when several 3D print offices were opened up in different departments of KLM E&M, interaction between employees and management mostly occurred on an informal basis and mostly upon the initiative of employees themselves. This was for example when the central engineering team responsible for certification and quality control initiated a knowledge-sharing session on quality management of 3D printed tools within E&M.

Lessons learned and conclusions

Business model and work organisation

At the moment, 3D printing has limited impact on the business model and work organisation of KLM E&M, which actually makes it a 'safe' technology to introduce: its introduction will not immediately change work practices within KLM E&M and investment costs are small. Work organisation (the way work is planned, organised and managed) has not changed, as priority is still given to formal maintenance tasks and 3D printing is an activity that is done in spare time, without a change in the function descriptions of employees. In the meantime, introducing the technology ensures that KLM E&M is ready for the future and keeps up to speed with its competitors. Positive aspects of the introduction are awareness and capacity building amongst employees and time and financial savings for KLM engineering and maintenance. If, in the near future, 3D printing becomes the standard within the aviation business, KLM E&M will have a foundation on which to build.

Job quality

The introduction of 3D printing has had some impact on the job quality of the employees working with 3D printing. New tools have resolved some of the structural issues that technicians of KLM Engineering & Maintenance face on a daily basis (for example tasks that require a lot of time or are very repetitive), lifting frustrations and for those actively designing new 3D models resulting in greater variety of intellectual tasks. Of particular benefit is the fact that the technology has enabled knowledge-sharing on maintenance and 3D printing within the organisation. The introduction of the technology also showed that 3D design is a particular skill that does not fit all airplane engineers. The actual modelling, drawing and printing is therefore often done by the younger employees that are motivated, not too afraid of making mistakes, and willing to invest extra time without receiving extra earnings or prospects from KLM.

Employee involvement

Consultation with employees mainly occurred before the technological change process within KLM and according to the interviewees it was of added value. It was considered important to discern the best ways in which the technology could support the work of the concerned employees. It has helped defining opportunities and a vision on additive manufacturing within KLM E&M. Employees have not been however involved in any formal decisions regarding the technology.

Strategy for the roll-out and of the technology

Employee consultation was instrumental to prepare KLM's 3D printing strategy. The company's vision for additive manufacturing was based on the input from employees; the Radical Innovation Team played a significant part in this by actively involving all the different stakeholders from the innovation ecosystem (for example, representatives of the KLM E&M departments, senior leadership of KLM E&M, external partners providing 3D printers, training and printing material) in the implementation process. Once the vision was established, the management implemented the strategy and accompanying roadmap for the roll-out of the technology. There was initially some scepticism among employees regarding the use and added value of 3D printing. Changing the

employees' mindset is a continuous process. Within KLM E&M this is now partly done by the 3D printing 'ambassadors' that showcase their work to other engineers and mechanics. The case also shows that within a large organisation, having a strategy that was informed by consulting employees does not necessarily take away this resistance. For this, further employee involvement in the process and actively making them part of this change is required.

Conclusions and takeaways

The KLM E&M case study offered insights into the introduction of a new technology at a company that operates within a risk avoidant sector and that has a relatively old workforce. The case study concerns a top-down implementation strategy of the technology with consultation of employees at the start playing an important role in the development of this strategy. This consultation ensured that the technology provides added value to KLM E&M and that it was introduced in such a way that scale-up is easily done. It also shows that within the aviation business and within a company with a relatively high average age, changing practices is difficult. Most of the people working with the new technology are young employees or interns. With KLM E&M in general, employees are only able to work on 3D printing part time, supported by a full-time intern. Convincing other employees of the added value of 3D printing and making time to help 3D specialists to develop new ideas and tools often first requires a demonstration that the technology and the tooling developed with it actually work.

The case study also shows that innovation is fragile and that crises can have a major impact. At the moment, the sustainability of 3D printing within KLM is uncertain. When the COVID-19 pandemic hit off, KLM had to put innovation-related initiatives on hold, including expansion of the number of local 3D print offices. The 3D print offices that were put in place before will remain and still have their use for the company. The technology proved to be versatile during the COVID-19 crisis as it made it possible to print protective equipment. On the other hand, mostly younger employees with short-term contracts know how to work with this technology and chances are that these persons will be the first to lose their jobs if KLM needs to make further cuts to survive.This could result in the necessary skills and knowledge on how to use the technology leaving the company.

References

All Eurofound publications are available at www.eurofound.europa.eu

Acemoglu, D. and Restrepo, P. (2017), 'Robots and jobs: Evidence from US labor markets', NBER Working Paper.

Arrow, K. J. (1962), 'The economic implications of learning by doing', *The Review of Economic Studies*, Oxford Journals, Vol 29, No. 3 pp. 155-173.

Austrian Federal Government (2017), *Realising potentials, increasing dynamics, creating the future. Becoming an Innovation Leader*, Vienna.

Bowyer, J. and Christensen, C., *Harvard Business Review* (1995), 'Disruptive technologies: Catching the wave', available at https://hbr.org/1995/01/disruptive-technologies-catching-the-wave

Carayannis, E. G. and Campbell, D. F. J. (2010), 'Triple helix, quadruple helix and quintuple helix and how do knowledge, innovation and the environment relate to each other? A proposed framework for a trans-disciplinary analysis of sustainable development and social ecology', *International Journal of Social Ecology and Sustainable Development,* Vol 1, No. 1, pp. 46-69.

KLM Royal Dutch Airlines (2020), KLM Corporate. Retrieved from: https://www.klm.com/travel/nl_en/corporate/index.htm on 14-07-2020

KLM Royal Dutch Airlines (2020), *Annual Report 2019,* Amstelveen. Retrieved from: https://www.klm.com/travel/nl_en/images/KLM-Jaarverslag-2019_tcm542-1063986.pdf

KLM Unie (2020), KLM Unie. Retrieved from: https://klm.unie.nl/ on 14-07-2020

Local Makers (2020), '3D printed KLM houses' Retrieved from: https://www.localmakers.com/portfolio-item/3d-printed-klm-houses/ on 9-07-2020

Medium (2019), '3D printing in KLM or How to fix a plane using a plastic bottle.' Retrieved from: https://medium.com/@top3dshop_com/3d-printing-in-klm-or-how-to-fix-a-plane-using-a-plastic-bottle-8d94ce16c71a on 9-07-2020.

NAG (2020). KLM Engineering and Maintenance. Retrieved from: https://nag.aero/members/klm-engineering-maintenance/ on 20-07-2020

NVLT (2020), Nederlandse Vereniging voor Luchtvaart Technici. Retrieved from: https://nvlt.org/ on 14-07-2020

Stil, H. (2019), KLM'ers zijn nog altijd niet gerust op de plannen van Ben Smith. Retrieved from: https://www.parool.nl/nieuws/klm-ers-zijn-nog-altijd-niet-gerust-op-de-plannen-van-ben-smith~b53d04b0/?referrer=https%3A%2F%2Fwww.google.com%2F on 08-09-2020

Vialva, T. (2018), Lufthansa Technik opens additive manufacturing center to develop lightweight 3D printed aerospace parts. Retrieved from: https://3dprintingindustry.com/news/lufthansa-technik-opens-additive-manufacturing-center-to-develop-lightweight-3d-printed-aerospace-parts-141537/

Vialva, T. (2019), KLM Royal Dutch Airlines recycles water bottles to make 3D printed tools. Retrieved from: https://3dprintingindustry.com/news/klm-royal-dutch-airlines-recycles-water-bottles-to-make-3d-printed-tools-163810/ on 9-07-2020

VKP (2020), Vereniging van KLM Professionals. Retrieved from: https://www.vkp-belang.nl/ on 14-07-2020

VNV (2020), Vereniging Nederlandse Verkeersvliegers. Retrieved from: https://www.vnv.nl/ on 14-07-2020

Annex A Definitions used in this report

Table 1. Definitions

Definition	Explanation
Ambassador	A representative or figurehead for promotional purposes
Digitisation	The process of converting existing information from a physical format into a digital one
Flagship	A single item from a related group that can be considered as the most important
Innovation Ecosystem	A group of players, stakeholders and community members that are critical for innovation
Rapid Prototyping	A group of techniques used to quickly fabricate a scale model of a physical part or assembly.
Roadmap	A planning technique to support strategic and long-range planning by matching short-term and long-term goals with specific technology solutions
3D printing	Machines that can create physical objects from three-dimensional digital models, generally by laying down successive layers of material.

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