DON'T FORGET THE HUMAN IN HUMAN ROBOT COLLABORATION

Ensuring job quality in human robot collaboration – three manufacturing use-cases

1 Introduction – why we should not forget the H in HRC

Robots change our work – just like machines have been doing

Machines coming to the aid and replacing humans
Ever since the first industrial revolution[1], machines have come to our aid to make up for the workers' limitations. The first industrial revolution brought us machines that replaced the workers limited muscle power, the second industrial revolution is bringing us machines that are replacing additional worker capabilities in the area of information processing, brain power so to speak.
So, we see machines being able to do more and more and becoming ever more autonomous, the latter being the robots.

Fears
Machines replacing workers have always been met with fear and anxiety. Is the machine safe? What will happen to my job if the machine can do things quicker, without complaining, without getting tired? The word "sabotage" can be linked to Belgian textile workers stopping machines by placing a clog (sabot) in the mechanism.

Humans and robots are necessary
In mass production where task content has generally been low, the threat of losing a job to a robot is higher than in jobs that contain more tasks and elements of decision making, requiring capabilities that belong to the workers' strengths: flexibility and reasoning. Much production is changing into low volume, high mix requiring flexible production schemes. The 'human worker' will remain necessary in these production environments. And even in mass production, the worker has not been fully replaced, nor will he be in the near future. The human therefore remains a critical factor in production processes. Because robots too are critical to many production processes, the focus is increasingly on developing so-called collaborative robots, or cobots, that can work safely alongside humans or even together with humans.

Changes
Like all forms of robotization, collaborative robots change the work done by humans. Changes in itself provide the best opportunities to improve job quality. But there are more reasons to pay attention to job quality in these changes. The nature of robotization and its associated fears and safety risks, require special attention. Job quality also requires attention to avoid the worker becoming the robot's aid or being given the left-overs: tasks robots cannot do, which do not necessarily present a coherent and satisfying set of tasks. Lastly, human-centered management practices provide a competitive advantage as they are more difficult to copy than technology-only approaches[2].

About Rossini
Rossini is a European project focused on expanding the range of collaborative robots. To date these cobots have limited payloads and speeds for obvious safety reasons. The Rossini project is

[1] Brynjolfsson & McAfee (2014) make the distinction between first and second industrial revolution
[2] Neumann et al (2021) in their article on Industry 4.0 and the human factor

developing an inherently safe industrial robot and robot environment, allowing for higher payloads and higher speeds. At the same time the project is developing tools to help engineers safeguard job quality when designing a collaboration environment for robots and humans and to monitor job quality parameters in operation with which it is possible to schedule robot and worker tasks in an optimal way, in terms of productivity and worker wellbeing.

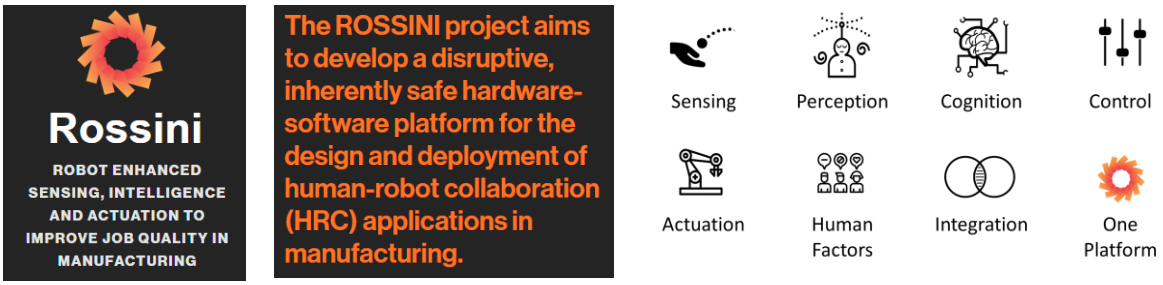

Figure 1: Rossini's goal and the platform elements, see: https://www.rossini-project.com/

About job quality

Job quality, more or less, describes the goodness of a job. It is multidimensional, as shown by the well-established framework on job quality, published by the Organization for Economic Co-Operation and Development[3] (OECD, 2018) and illustrated in Figure 2. According to this framework, job quality comprises three main areas: earnings quality, labor market security, and quality of the working environment. OECD also states that quality jobs are an important driver of increased labour force participation, productivity and economic performance. In short: workers with quality jobs are more productive and healthier than those with lower quality jobs.

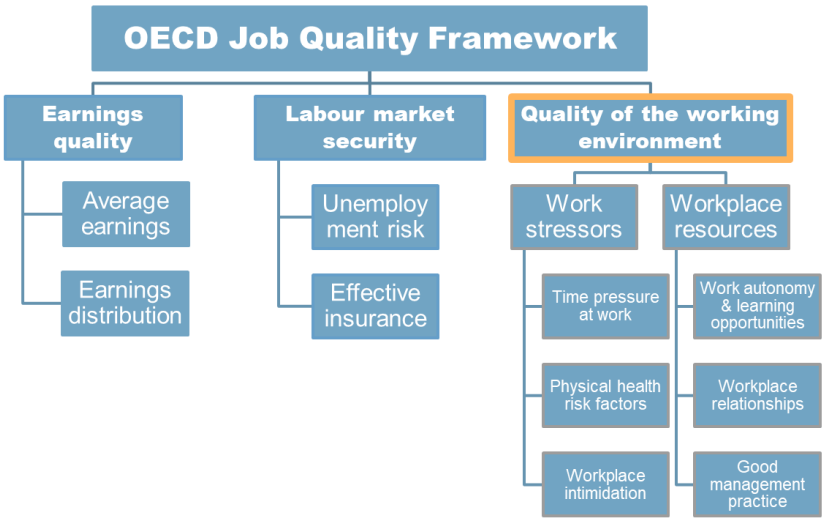

Figure 2: The OECD Job Quality Framework based upon Cazes et al. (2015)

Job quality in Rossini

Obviously robotization is not necessarily directly connected to earnings and labor market security. However, robotization is closely related to the quality of the working environment, directly in the sense that using a robot may reduce lifting, pushing and pulling and can pose a direct safety risk and indirectly as changing tasks and introducing a robot at the workstation, most likely require adjustments to the workstations. Further, collaboration with robots requires attention to task

[3] https://www.oecd.org/employment/job-quality.htm

allocation: who does what, when and for how long. This is to prevent work from becoming e.g. a source of too much stress.

Rossini use-cases - three examples of how cobots can have a positive effect on JQ

Rossini's use-cases present three different applications of collaborative robots, each with their own direct benefits from the robot and challenges with respect to job quality. In the following chapter we will briefly present each use-case by sketching the current situation, the direct benefits from using a robot and remaining/specific challenges with respect to job quality.

2 Whirlpool - counterweight assembly washing machine

2.1 Current

Almost all washing machines contain one or more concrete counterweights to prevent the machine from going for a stroll when the laundry is spun. These parts typically weigh 12-14 kg and are mounted manually on an assembly line. Because of the continuous flow nature of the production line, using a lifting aid would be too slow. Workers therefore manually take the weight out of a storage bin, inspect and mount them with a tact time of 30 seconds. Because of this, the company has limited working on this line for each individual worker to 2 x 2 hours a day. The company also has a second production line that is stop and go. Here the lifting aid can be used. However, because it is cumbersome in its use, operators are tempted to lift manually.

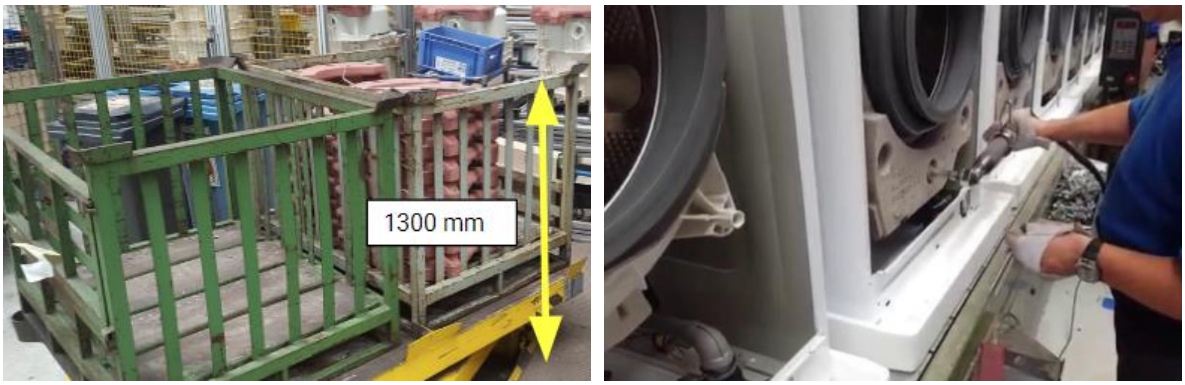

Figure 3: Left - the bins from which the counterweights are picked up; right - fixating a counterweight to the washingmachine

2.2 Rossini HRC solution

As full automation is not yet possible, a solution in which a robot and a human worker collaborate, is sought to reduce the risks for the worker while maintaining productivity. The counterweight's mass exceeds payloads of currently existing cobots, therefore the Rossini platform is used to create a safe solution with an industrial robot. The idea is that the robot brings the weight to its mounting position at which time the operator takes over. While the operator secures the weight with bolts to the machine, the robot moves back to pick up a new weight.

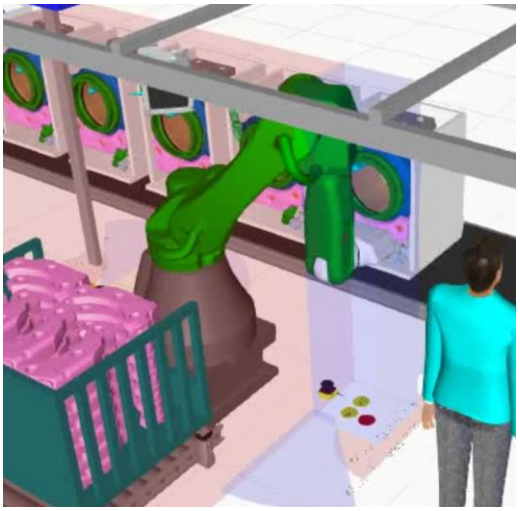

Figure 4: The robot is busy positioning the counterweight on the moving washing machine; once finished the operator fixates the counterweight after which the robot returns to pick up the next

2.3 How the robot can improve aspects of job quality

The biggest gain from using the robot is of course a reduced risk for musculoskeletal disorders. Further, because worker strength is no longer a prerequisite, the task becomes available for a more diverse population, including an aging workforce. Because the robot is quick enough, the worker is no longer tempted to pick up the weights by hand. The available time from not having to pick up the counterweight can be used to complete one or two additional assembly actions, thus expanding the work content, even though only slightly.

2.4 Challenges

While the robot takes away heavy lifting, thereby reducing the health risk, this may not be appreciated by all workers, as some workers like to be physically active. Health risks are not necessarily felt which makes it less intuitive to act upon. Therefore, having workers participate in the redesign of their jobs is important. They may have good ideas for instance on which substitutive tasks can be done in the available time.

The change can further be used to take a look at the supply chain. If a robot is used to present counter weights from a storage bin, a similar robot may also be used to create a robot-friendly storage of counterweights in the same storage bin.

3 IMA - Reel exchange on packaging machine

3.1 Current

A teabag packaging machine requires regular exchange of reels with packing and labelling material. The reels are at three different levels on the machine, two of which are unfavorable for lifting: one at knee level and one at shoulder level. Unfortunately, the reels with the largest weights need mounting at these levels.

An operator typically operates 2-4 machines, exchanging reels, clearing micro-stoppages and performing small maintenance tasks. The reels weigh appr. 4 kgs for the middle reel, 8 kgs for the upper reel and from 10 to 13 kgs for the lower. The lifting that is done while exchanging reels is considered acceptable according to health guidelines. Nevertheless, the back and shoulder load from these lifting positions (low and high) may still form a risk. For this reason, the company

operating the machines seeks to eliminate the lifting as much as possible, to be able to accommodate an aging workforce and to have more flexibility in reel size and packaging materials.

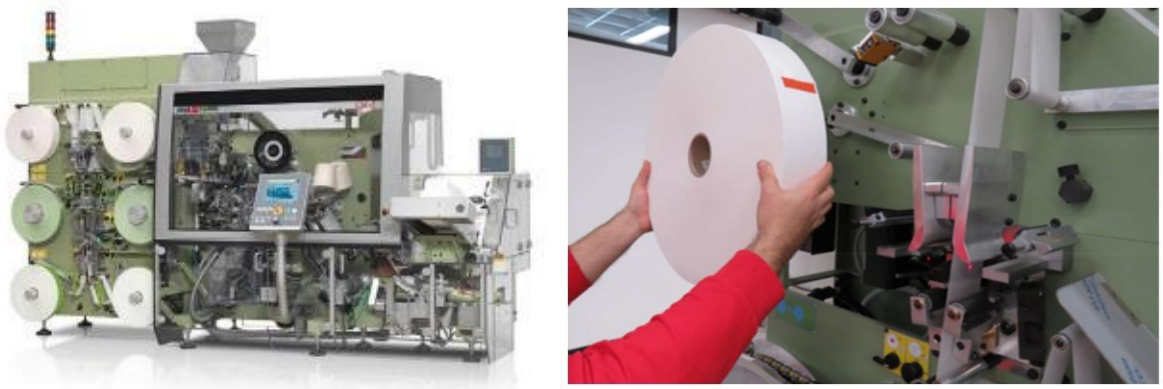

Figure 5: C24-E tea bag packaging machine - lifting a reel to the upper position.

3.2 Rossini HRC solution

The solution is a robot arm mounted on an AIV, autonomous intelligent vehicle. To date no collaborative solutions exist that are autonomous in their movements on the work floor, have two robot arms and work safely alongside operators with sufficient speed. The Rossini solution aims to be capable of detecting the reels that need exchanging, moving to reel storage locations, taking the required reels and exchanging them on the machine. These tasks will be monitored by modular dynamic safety sensors that will lead human operators, automatic machines and robots to work side by side. In the future each operator will be helped by two mobile robots covering ten machines.

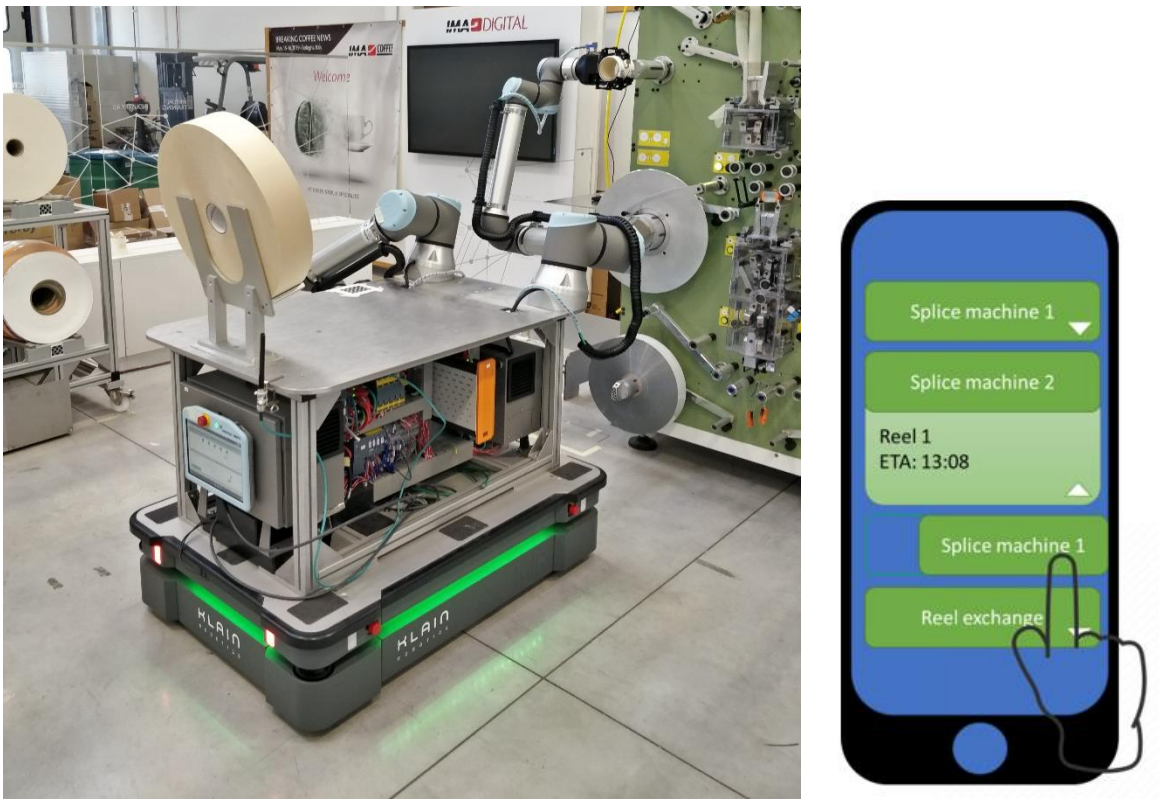

Figure 6: The current set-up – the ROSSINI IMA platform during a reel core removal– an idea of what the interface could look like. It provides an overview of all planned tasks, both for robot and operator, and with it the operator can accept, decline and delegate tasks.

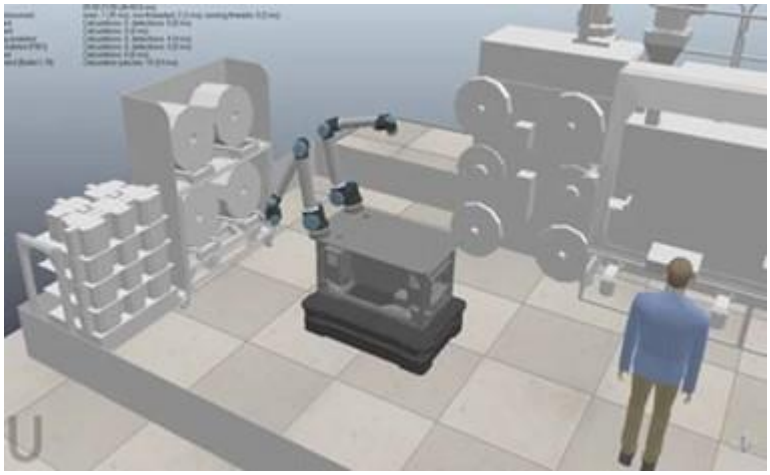

Figure 7: Simulation performed by UNIMORE to test the motion planner.

3.3 JQ improvement

Besides a productivity gain, the physical aspects of job quality will improve. The operators will still do occasional lifting, yet predominantly to the middle reel, with an optimal height. This is not necessarily detrimental to health. With this, the work should also become more accessible to workers with limited strength, such as many older workers. While the operator is at work, special software, developed in the Rossini project will monitor all lifting actions and will be able to reassign tasks to either human or robot, depending on monitoring results, thus providing an additional safeguard.

3.4 Challenges

The company operating the teabag machines very well recognizes that handing over tasks to the robots and increasing the number of machines for an operator, should take place gradually. Initially, working together with the robot might lead to some stress as the worker might not feel confident about the robot's reliable execution of the task. Once confidence is built, and the robots behaviour becomes more predictable, the worker will have learnt all control options and start feeling more relaxed. The operator's span of control can then be widened. The robot's predictability is also increased by early involvement of operators in the task allocation between operator and robot(s) and through Rossini's human robot interface leading to an optimal human robot understanding.

4 Schindler - lift panel assembly

4.1 Current

The lift panel assembly line is a typical example of a high mix low volume production line. Almost all panels are unique, reflecting the size and identity of the building they are built for.
Current work is divided over four types of workstation: kitting, assembly 1 and 2 and packing. This set-up requires intermediate buffering and parts packaging to reduce the risk of mistakes. Schindler would like to eliminate packing and unpacking as the activities are non-value added. Considering that parts are generally unpacked again within the hour, sometimes even within 10 minutes, Schindler would also like to reduce material waste. With respect to quality of the working environment, the kitting area design could be improved. Further, assembly contains some repetitive screwing tasks operators which could be performed by a robotic aid.

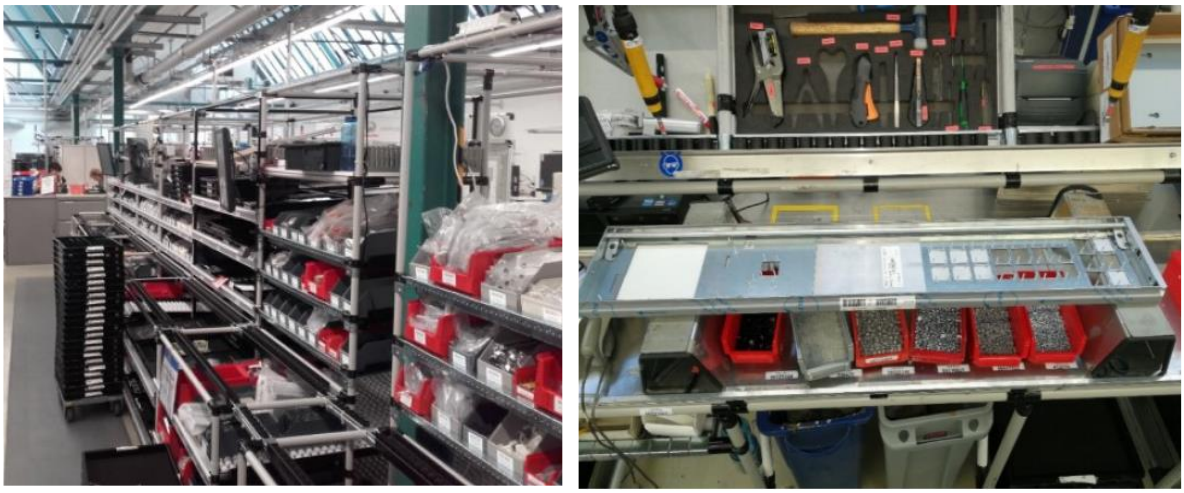

Figure 8: Current set-up with seperate kitting, assembly and testing workstations

4.2 Rossini HRC solution

The aim is to transform the production area into several dedicated workstations were (almost) all activities from the four current workstations are combined. The robot will be used to assist the worker in panel assembly by performing certain assembly tasks and by supplying the right parts at the right time from a workstation specific warehouse, thus reducing quality risks. As optional extension the Rossini interface can be connected to a software/hardware package that projects work instructions onto the assembly area and shows where the robot is going to be active (see Figure 9)

Figure 9: Workinstrucations projected on the assembly area, also showing where the robot will be active

4.3 JQ improvements

Workers will assemble and test a complete product. This is often regarded as beneficial to job satisfaction as work content is higher, therefore cycle-times are longer, and the worker does not have to hand-over an unfinished product to the next workstation. The robot takes over screwing tasks which are not only tedious but also unpleasant as operating the torque screwdriver leads to jerky forces around the wrist. The unfavourable working height and reach distances in the kitting area are eliminated by an optimal workstation design.

4.4 Challenges

Currently the operators rotate across the different workstations. This not only provides some change in work but also in work posture, as e.g. the kitting is done walking. If the new workstation is a sit-only workstation, the average daily sitting time of operators will increase together with the risks commonly attributed to sitting. For Schindler it is a challenge to create sit-stand workstations that allow workers to sit and stand alternatively. Because of the robot and its warehouse / supply tasks, this is even more difficult.

Another challenge lies in keeping waiting time for the operator to a minimum while the robot is performing a task on a panel. This could lead to a two panel set-up or the human helping the robot to quickly perform his tasks.

5 Conclusion

The Rossini examples described here, show that human robot collaboration is not just a method to improve productivity, it can (and should) also be used to positively affect job quality. The examples show that with the Rossini platform safe solutions can be created that would otherwise lead to less safe or less productive results. At Whirlpool and in the IMA use-case the collaboration eliminates heavy lifting for the operator, at Schindler the operator is relieved from some tedious tasks and from the riskful operation of torque tools. However, in all use-cases there are also challenges which, if not addressed, may affect other aspects of job quality in a negative way.

To achieve an optimal solution, it is important to look at the work system as a whole of which both operator and robot are elements. Human factors should therefore be taken into consideration when redesigning work into a collaborative human-robot setting. This is an important element of the Rossini-project.