Due to confidential reasons, some diagrams and data are not shown. The following is the summary of my 4th year capstone design project at Department of Mechanical Engineering, Dalhousie University.

The objective of this capstone design project is to incorporate collaborative robots (COBOTS) and mobile robots into the manual production lines at Neocon International.inc, a plastic car mat manufacturer located in Dartmouth, Nova Scotia, Canada. The existing production lines at Neocon are entirely manual, and the project aims to introduce automation for improved efficiency.

The original production line contains following workstations:

1. Thermoforming machine: takes in raw plastic sheets and thermoforms them into pieces with desired shapes and patterns (118 seconds). The machine can process two sheets simultaneously, and the thermoformed pieces are rolled out back to the entrance of the machine.
2. Trimming station: trimming worker is responsible for feeding raw plastic sheets to the thermoforming machine and transferring the formed pieces to the trimming station. The trimming worker trims out any unwanted parts on the formed pieces before passing them to the next station (97±23 seconds).
3. Velcro station: a Velcro worker is deployed at the Velcro station. The Velcro worker glues 4 to 12 Velcro pairs (depends on the specified product type) onto the trimmed pieces (97±23 seconds). Once the Velcro is glued, the entire piece is placed into a lid-equipped equipment called the Velcro press. The piece is pressed under the lid until the glue dries and the Velcro is securely fixed (43±7 seconds). Afterward, the Velcro press table is opened, and the piece is transferred to the packaging station by the packaging worker.
4. Packaging station: the packaging station comprises a packaging table and a thermal sealing machine. The packaging worker takes the piece from the Velcro press table, packs it into a plastic bag, and seals the bag using the thermal sealer. The packed product is then palletized into finished product containers by the packaging worker (81±6 seconds).
5. Containers: there are two main types of containers in the production line: raw material containers and finished product containers.

Due to the thermoforming machine's capacity to process two plastic sheets simultaneously, two sets of production lines are deployed next to one thermoforming machine. Each set includes six workers. The takt time of the production of one mat is 145±16 seconds.

The project was mainly focusing on transferring manufactured pieces between workstations with robotic manipulators (a robotic arm mounted on a mobile robot) and using robotic arms (COBOTS) to replace the Velcro worker at Velcro stations. The Omron TM-12 robotic arm and LD-90 mobile robot were selected based on the production line's dimensions and the product requirements.

The Velcro station is redesigned for a pair of two production lines. The new automated Velcro station will contain 3 robotic arms. A top view of the new Velcro station, drawn in Solidworks, is as following:

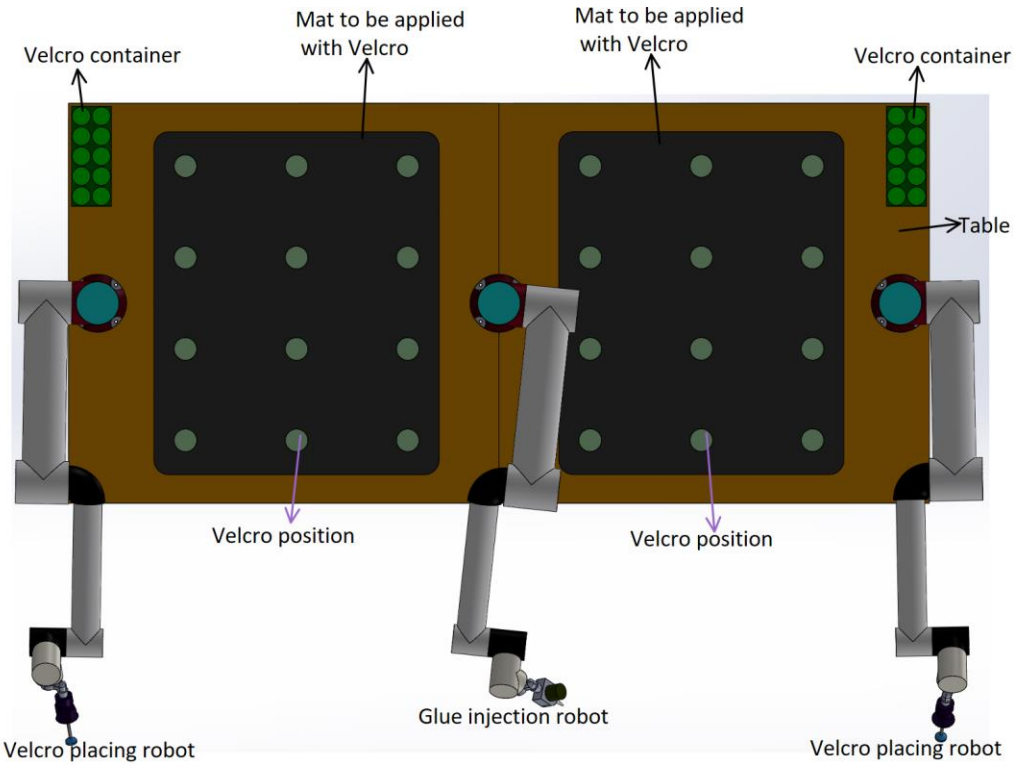

Figure 1: Top view of automated Velcro station

As shown in Figure 1, two Velcro placing robots are deployed at the right and left side of the station and one glue injection robot is deployed at the middle. Two Velcro containers are placed on the top right and left corners of the station. Two sheets will be transferred from the trimming stations by robotic manipulators. For demonstration propose, the mat is considered as a plastic sheet with dimension of 1000mm*1200mm*10mm with a maximum mass of 3kg, which is a typical size of the company's product. 12 Velcro positions are distributed on the surface of the sheet.

The Velcro placing robots are equipped with Robotiq EPick gripper (as shown in Figure 2A) to pick up the Velcro pairs from the Velcro container and place the Velcro onto the desired points on the sheets.

As shown in Figure 2B, the glue injection robot is equipped with glue injection module to inject glue onto the desired points on the sheets.

Robotic arms are equipped with computer vision system to identify the Velcro positions and Velcro containers (not included in the scope of this project).

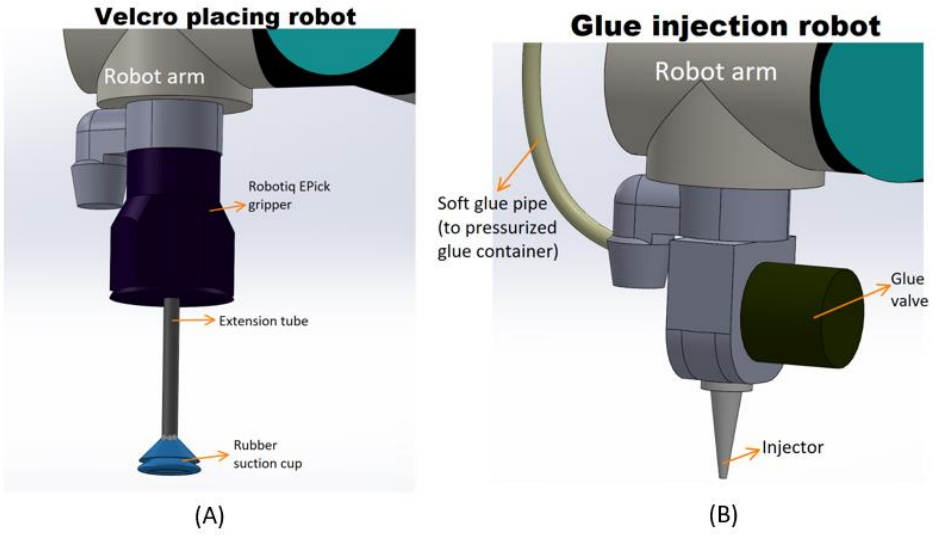

Figure 2: End-of-arm equipment for Velcro placing robot (A) and glue injection robot (B)

To allow the Velcro placing robots to grab Velcro pairs easily, the Velcro container is designed as shown in figure#. The container can contain 120 pre-assembled Velcro pairs assembled by another worker. One Velcro assemble worker will be assembling Velcro pairs and refill Velcro containers. Based on time calculation, one Velcro assemble worker can handle 3 production lines (e.g., 0.33 worker per production line).

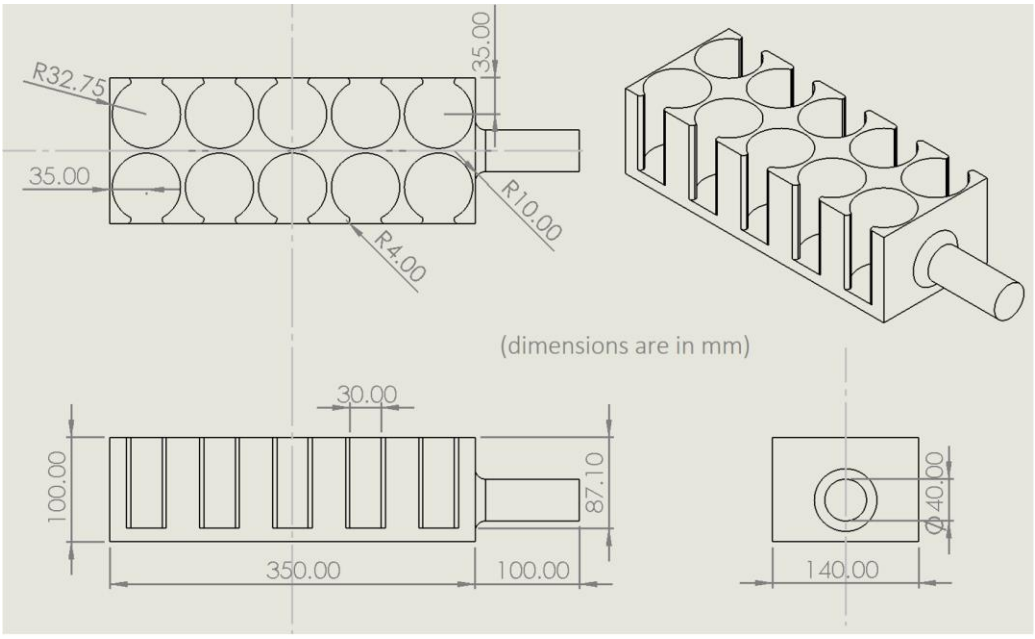

Figure 3: Drawing of model of Velcro container

When operating, routes of the three robotic arms are designed under this specific scenario to avoid interfering between robots:

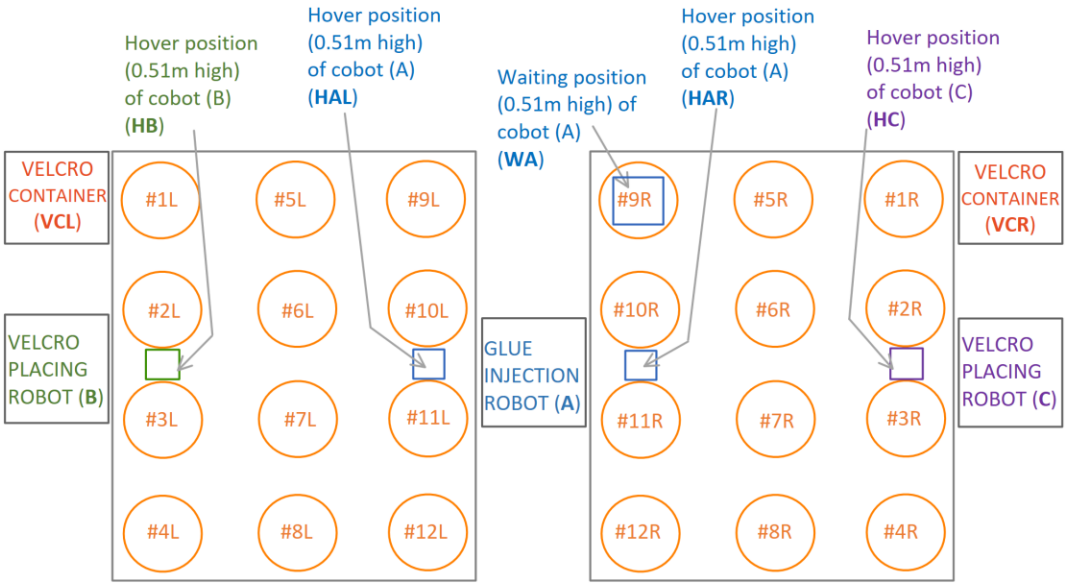

Figure 4: Schematic of Velcro and robot arm positions

Table 1: Robotic arm routes on Velcro workstation

Robot	Route
Glue injection robot (A)	HAR-HAL-#1L-#2L-#3L-#4L-#4R-#3R-#2R-#1R-#5L-#6L-#7L-#8L-#8R-#7R-#6R-#5R-#9L-#10L-#11L-#12L-#12R-#11R-#10R-#9R-WA-HAR
Left Velcro placing robot (B)	HB-VCL-#1L-VCL-#2L-VCL-#3L-VCL-#4L-VCL-#5L-VCL-#6L-VCL-#7L-VCL-#8L-VCL-#9L-VCL-#10L-VCL-#11L-VCL-#12L- HB
Right Velcro placing robot (C)	HC-VCR-#4R-VCR-#3R-VCR-#2R-VCR-#1R-VCR-#8R-VCR-#7R-VCR-#6R-VCR-#5R-VCR-#12R-VCR-#11R-VCR-#10R-VCR-#9R-HC

With automated Velcro station and designed route, the time taken by the Velcro placing step is reduced to less than 100 seconds in the most complicated case.

With robotic manipulators and new automated workstations implemented, the new production line is shown in Figure 5:

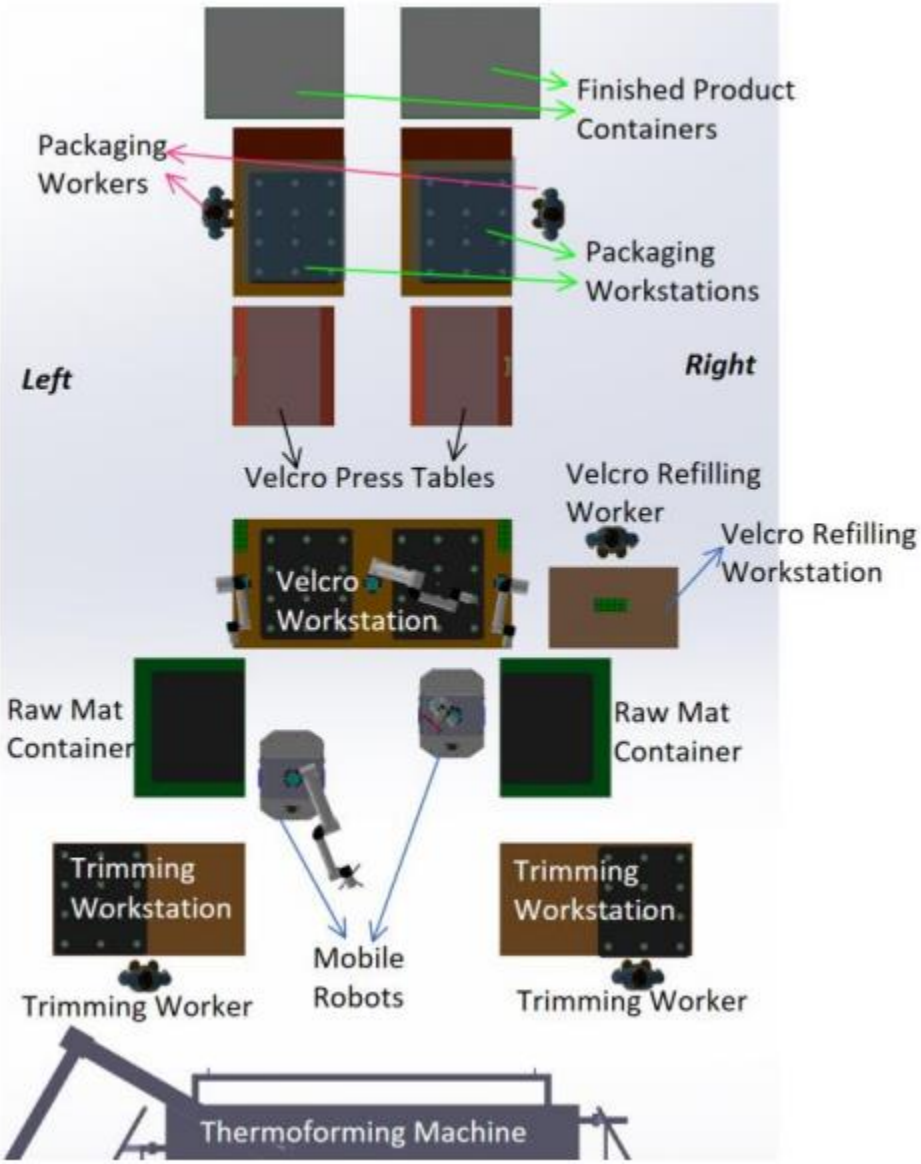

Figure 5: Top view of the new production line

The route of two mobile robotic manipulators is also designed based on serval stops set in the production line to avoid interfering and improve the efficiency:

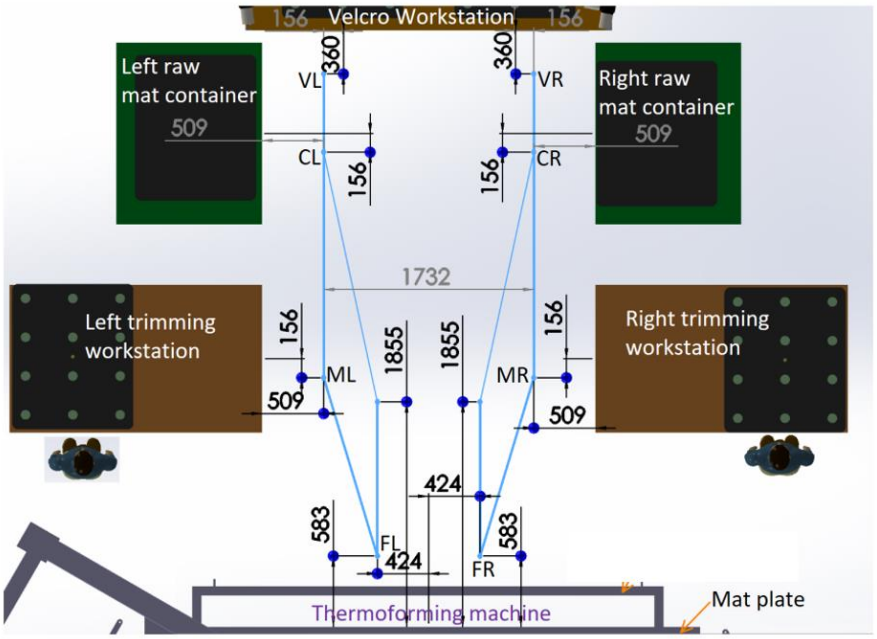

Figure 6: Robot stops planned based on production lines configurations

In the redesigned semi-automated workflow, the robotic manipulator takes on several tasks previously performed manually. It transfers raw plastic sheets into the thermoforming machine, moves thermoformed pieces from the thermoforming machine to the trimming station, and transports the trimmed pieces to the Velcro station. By automating these transfer tasks, the trimming workers now have more time to focus on their trimming tasks since they no longer need to shuttle between the thermoforming machine and the trimming station.

Additionally, the packaging workers' responsibilities have been expanded. They are now responsible for pressing the parts with Velcro and sealing them into plastic bags, in addition to their existing packaging duties.

Overall, the semi-automated production line has shown improved productivity. In a three-hour session, the semi-automated line can produce 79 mats, compared to the original line's production of 71 mats in the same timeframe. Additionally, the introduction of automation has resulted in a reduction of 0.67 workers per production line, indicating increased efficiency and potential cost savings.

Note: The numbers provided are hypothetical and used for illustration purposes. The actual performance of the semi-automated production line may vary based on the specific implementation and operational conditions.