Product: Railly Clean
Team: Dalektable

Abstract

Railly Clean is a train sanitising robot that clears and sanitises train tables while the train is in, or out, of transit to save waiting time at stations and reduce risk to employees and customers.

We have four goals for creating the Railly Clean demo:
1. Move down aisles. Moving straight down an aisle and rotating in any direction.
2. Detect vacant tables and clean them. Use camera/IR/radar to detect vacant seats at a table. Use a robotic arm to sweep then sanitise the table.
3. Detect people and move out of way. Use camera/IR/radar to detect people and move to the end of the carriage.
4. Move from carriage to carriage by opening doors. Press the door button (and sanitise it while pressing). Move across the carriage connection area.

With a number of smaller goals after these to polish off the final project (return to charging port at low battery, move into unoccupied seats when needed, connection to a simple analytics app/website, general aesthetics).

1. Goal description

Our robot system solves the problem of cost pressure of keeping train services clean, which has increased as a result of COVID-19. Our robot aims to alleviate this by autonomously cleaning rubbish from train tables, sanitizing them, and cleaning door buttons as the robot moves from carriage to carriage, all while the train is in motion.

1.1. Relevance of the system

In July 2020, Northern Rail published a campaign article specifying the effort it put into cleaning trains during COVID-19. 430 staff were employed, everyday cleaning 6000 door buttons and 400 train toilets multiple times, removing 20 tonnes of rubbish, covering a total of 15km of trains placed end-to-end, as well as requiring 510 man hours per night (Hellam, 2020). Using the current lowest national minimum wage of £6.45 for age 18 and above, it would cost Northern Rail at least £5547 a day to employ 430 people each working 2 hours during the day. Given Northern Rail's current fleet of 333 trains, a fleet of £300 robots working 365 days, each covering a whole train, cost less than £300 to run a day (excluding charging and maintaining costs) (Northern Railway). We believe that just by relegating the task of cleaning train tables (clearing rubbish and sanitizing) and door buttons to robots, a smaller workforce can be employed during the day, significantly alleviating the current cost pressure on keeping in-service trains clean, while minimizing viral exposure to staff.

Moving outside of the United Kingdom, we believe there already exists a potential market for railway-train cleaning robots, as a 1995 research paper detailing East Japan Railway's prototype for robots cleaning commuter railcars' floors shows (Yaguchi, 1995). The cited reason for the development was Japan's aging workforce. More recently, as a result of COVID-19, we have also seen Hong Kong MTR (Mass Transit Railway) deploy specially designed autonomous robots to sanitize its subway cars with disinfectant, citing "extra protection for passengers and staff" as a reason (MTR). MTR's robot "operates automatically by pre-setting the floor plan of the designated area," which we believe can be utilized in our robot system design (Briginshaw, 2020). While subway cars and railway cars are distinguished by their frequencies of use and usage environments, we believe the layouts and movement operations are similar enough that we can reference some of the design choices and mechanics of MTR's robots in our train cleaning robots. Both East Japan Railway and Hong Kong MTR cases show not only the potential market for the use of robots to clean and sanitize trains, but also the feasibility of such a system.

If we expand the scope of the potential usage of our robot system further, we have also noticed the adoption of autonomous robots to clean train stations as a result of COVID-19. St. Pancras train station in London started deploying cleaning robots called Eco Bot 50 in September 2020 (St Pancras International). East Japan Railway also tested and unveiled the CLINABO CL02 at its new Takanawa Gateway Station in July 2020. Just as East Japan Railway stated its intention to extend the functionality of the robot to "sanitiz[ing] the inside of train cars in the future," we believe it is reasonable that after train stations, train operators will be interested in robots cleaning their train carriages where travellers will spend most of their time, the cleanliness of which the operators are directly responsible for (The Japan Times, 2020).

We have identified some extended benefits of our robot system. The use of cleaning robots while train is in motion will cut down on waiting times at train stations, as less cleaning work needs to be done at the stations, allowing train operators to run more frequent services as well as providing more reliable, on-time services. As shared by Northern Rail in March 2020, one of its focuses in trying to revive the brand was "resetting standards and [. . .] remind[ing] everybody what a good railway looks like" (Newton, 2020). To that extent, we believe a fleet of cleaning robots to regularly sanitize tables and door buttons throughout train services is in the interest of train operators, going a long way in maintaining the cleanliness of train cars. Another benefit is that the fleet of robots can serve as a contingency plan during pandemics, during which train operators are pressured to quickly reopen services with stricter cleaning standards. Robots to help cleaning trains more regularly can enable train operators to keep services running early during pandemics and cutting down on revenue loss.

1.2. High-level description

The user problem we are solving:

In order to remain sanitary, trains must be cleaned continually at great expense to the operator. The current method (as expanded on above) involves employing hundreds of cleaners. As highlighted by the COVID-19 pandemic, limiting the number of people who come into contact on a train is highly desirable.

The Railly Clean will be a cleaning robot that will have several hardware components that enable it to move and clean. These components will receive input from sensors on the robot. The hardware will be controlled by code written in Python.

Railly Clean is solving the problem of cleaning while the train is in operation without increasing chances of transmission, using a robot cleaner to clean tables in the train. The Railly Clean will move along the aisle of the train while it is in operation, using its sensors it will identify and avoid obstacles. The robot will be able to balance itself against the movement of the train and remain upright and at a similar height to the tables to allow it to access them easily.

To avoid cleaners having to complete the repetitive task of cleaning tabletops the robot will be able to clean them using a cleaning solution and cloth mounted on a robotic arm. Railly Clean will be able to identify tables that are clear of items using its sensors, it will also be able to remove small objects (rubbish such as crisp packets, sandwich boxes etc. . .) before cleaning if necessary. Furthermore, Railly Clean will be able to identify tables that do not have passengers sitting at them, again using its sensors.

For a train to remain clean it should be cleaned regularly. By moving through the aisle at scheduled times the Railly Clean will be cleaning tables as quick as they're vacated. Once its scheduled cleaning is complete or the battery is below a certain level, the robot will return to a charging station to recharge. Overall, the Railly Clean will be a low-cost cleaning system which can be used to augment cleaning staff and encourage the confidence of passengers in the cleanliness of public transport to return. As a result of the COVID-19 pandemic all public services will be held to a higher standard of cleanliness and we believe that the Railly Clean can be a key asset for train operators in achieving these standards.

User stories:

- As a train operator I want my passengers to feel safe so that people continue to travel by train.
- As a business owner I want to minimise the running costs of the train to make my business sustainable in the long term
- As a train operator I want the robot to be able to operate with minimum changes to the train.
- As a passenger I want the train to be cleaned regularly so it is hygienic.
- As a passenger I want the robot to move out of the way so I can get to my seat.
- As a passenger I don't want the robot to interfere with my journey, by getting in my way when I'm seated at a table.
- As the ticket collector I want the robot to stay out of my way so I can get on with my job with access to the aisle.
- As a cleaner I want the robot to clean tables so I can spend more time on other areas in the train.
- As the train Health and Safety officer I want the robot to have a clearly designed emergency protocol so in an emergency passengers can exit the train quickly and safely.

2. Task planning

2.1. Milestones

Our team set out the following milestones for the project. The goals are in planned chronological order.

1. **Moving along the aisle** - by 31/01/2020

   The first step needed to be addressed before the higher functions of the robot are implemented is the robot's ability to move in the carriage while the train is also moving. It will be demonstrated by a Webots simulation of the robot moving through a modelled carriage. Given that the a train carriage is a relatively simple environment, and that at this point the robot does not need to cross carriages this is easily achievable.

2. **Sanitizing tables** - by 13/02/2020

   This is the basic function of the robot and the original idea. At first we assume the table to be free of objects. The robot needs to recognize and disinfect the table while moving through the carriage. It also needs to recognize if a table is occupied and skip those tables to avoid disturbing passengers. Demonstrated by a Webots simulation and code for the recognition.

3. **Clearing tables** - by 26/02/2020

   The robot now identifies if there is debris on the table that it should clear before sanitizing the surface. An advanced functionality is to recognize possible valuables. Demonstrated by a Webots simulation.

4. **Detecting people moving down the aisle and moving out of the way** - by 13/03/2020

   This is another important milestone to minimize disturbance to passengers. Demonstrated as general object recognition and avoidance in Webots

5. **Clean door buttons and use buttons** - by 22/03/2020

   This is an advanced functionality of the robot. Sanitizing the often touched door opening buttons on the wall would greatly improve the usefulness of the product. The ability to use buttons is needed for the following milestone, but easier to implement at this part by simply adjusting the pressure during cleaning.

6. **Crossing carriages** - by 29/03/2020

   This milestone would generate the biggest increase in the value of the product, as only one robot would be needed per train, instead of one per carriage. However, this would also be the most complex, as this part would greatly differ between train types, and could not be solved just by preset parameters. This requires us to make some assumptions about our target market - the age and setup of trains whose operators would consider investing in an autonomous cleaning robot.

2.2. Task decomposition

The task decomposition for our project is shown in Table 3. The milestones have been broken down into fundamental tasks which could be easily distributed amongst our group's internal teams. The estimated days are given based on how many real days we believe it will take from beginning to completion of a task. This often includes multiple team members working on the task in parallel. The Gantt Chart in Figure 4 shows a visual representation of the time allocated to specific tasks split by colour into their relevant milestones. Ad shown by the Gantt chart, work on tasks from different milestones often overlap as our internal teams may begin work on their tasks from the next milestone while the previous milestone is in progress. We have also included testing in our task decomposition in order to ensure that we dedicate time to ensuring that the different elements of a particular milestone work together before declaring that a particular milestone has been accomplished.

2.3. Resource distribution

After the completion of two weeks we have approximately 163 hours available per person. There are 20 hours of workshops left in the semester, and two group members must attend each one, so we have estimated the time spent to be 5 hours per person. We have arranged one weekly meeting with the whole group and our mentor, and another weekly meeting for each of the sub-groups working on tasks like Research & Documentation, Modelling, Navigation, Image Recognition, Testing. This amounts to 18 hours of weekly meetings per person, throughout the semester. There are four demonstrations, which every group member must attend. We have estimated each demonstration at one and a half hours per person, to allow for time to reflect on the feedback given, totalling 6 hours overall. The online Trade Fair's timing and many other details not yet provided but we are blocking the whole working day, i.e. 8 hours for any last minute fixes, preparation and presentations. The remainder of the time, i.e. 126 hours will be spent on either software (recognition, navigation, cleaning), modelling and testing. This is labelled as R&D in Figure 1 to show the time distribution.
Table 1 shows the detailed breakdown of tasks, the members allocated to them based on their skills and preference as shown in Figure 2, and the estimated number of hours we assume each assigned member to spend on it.

2.4. Risk assessment

The risks we have identified with pertinence to our project have been listed down in the form of a table in descending order of importance and likelihood, with the first five in relation to the robot itself and the last two in relation to the dynamics of the group (Table 2).

The number one challenge that this project faces is that of navigation around the train with passengers on board and the potential of it being a hazard, coming in the way of an evacuation procedure. As this is an important exception, we have considered alternative designs which do not have the robot moving along the floor but instead having it roof-mounted and extendable. In either case, we will have to confer with the experts on the viability so as to having a functional hardware in the end.

3. Group organisation

1. **Specific roles of group members**

   In order to build the robot successfully, our team has separated into 5 different groups. Some team members might belong to two different groups in order to make our development process run smoothly. Our team includes: 1) Research, Documentation and Presentation 2) Vision and Detection 3) CAD (Computer-aided design) 4) (Robot) Movement 5) Testing groups.

2. **Meetings**

   Our team has two different forms of meetings with different purposes. The first form of meeting is a weekly meeting on Microsoft Teams. The second form of meeting is the follow-up meeting on Facebook Messenger after the after the workshop or client meeting. During planning and designing stage, weekly meeting

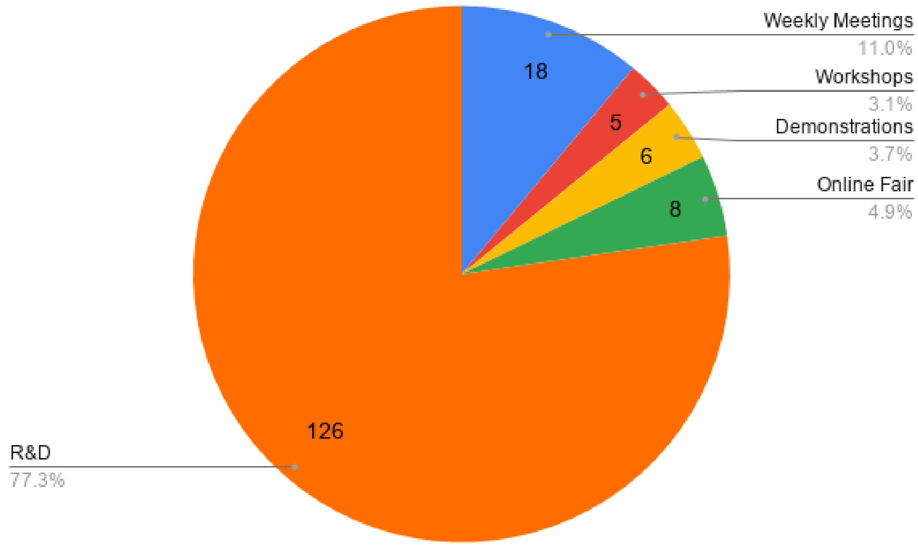

Figure 1. Resource distribution per team member.

will focus on how we plan to approach the project while assigning the roles and tasks to the members. In developing stage, the aim of weekly meeting is to report the process of each group and raise any questions or uncertainties which we can solve together as a whole. The meeting ensures each group meets the progress and do not slip behind. Our mentor will join our weekly meeting that we can stay in touch with the project and seek feedback and advices.

3. **Communication**

   Our team uses Facebook Messenger for the announcement, regular chat and any kind of discussion. This is the primary source where our group communication takes place. We also use GitHub for documentations, minutes and the sharing ideas.

4. **Code sharing and progress checking**

   Our team uses GitHub for version control in our project. We created an organisation which has all the members and share public repositories within our group. All the code of each task will be stored within these repositories. Meanwhile, we exploited the benefit of project management tool in GitHub which allows us to check the progress by having a dashboard for To-Do, In Progress and Done. Our team adopts agile development process. Each iteration we focus on adding one milestone feature and improve after client's feedback. We will create the weekly milestone on GitHub and add the issues for the task that we need to accomplish. The assigned tasks will be added to the To-Do on the dashboard and everyone can see which goals we are achieving and what have we done so far. GitHub also provides a visualisation for the milestone we set, and we can check our progress before the meeting. Our team also has a rule that every work should be ready on 12pm in the submission day for a final check before submission.

5. **Task allocation**

   Our team allocates tasks based on the strengths and weaknesses in the skill matrix (Figure 2) and personal willingness. Skill matrix is a way to let maximise our strengths when choosing our tasks and the things we enjoy working. Our task decomposition (Table 3) allows the team-mates to focus on working their specific area and prevent collision with other groups.

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Proficiency Scale	5 - Expert	4 - Proficient	3 - Competent	2 - Advance Beginner	1 - Novice						
Name	Python programming	Market research	Project management	Organisational skills	Machine learning	Report writing	Public speaking	Robot hardware	Design and modelling	Commmunication Skills	Vision/Detection
Daniel Spencer	3	4	2	4	3	4	2	1	1	4	1
Anh Nguyen	3	2	2	3	3	3	3	1	1	3	1
Apurv Mishra	5	1	3	2	4	1	4	1	1	4	3
Austin Cheang	4	3	3	2	4	3	2	1	1	2	2
Máté Stodulka	4	3	3	4	4	4	4	2	1	4	2
Arnav Desai	3	3	3	4	3	4	3	1	1	4	1
Suhas Narreddy	4	2	1	1	3	5	5	3	1	4	3
Caitlin Mcdougall	4	1	3	4	3	4	5	3	2	4	3
Sean Memery	5	2	3	4	4	2	2	4	3	2	2

Figure 2. Skill matrix

Week	Milestone	Tasks	Members	Estimated hours	Notes
3	Aisle Navigation	Modelling carriage	Daniel, Arnav	3	
		Hardware modelling	Daniel, Arnav	5	
		Model tables	Daniel, Arnav	2	
		Robot Stability	Daniel, Arnav	3	
		Robot Movement	Sean, Austin, Anh	5	
		Carriage End Recognition	Caitlin, Máté, Apurv, Suhas	15	
		Demo testing	Sean, Daniel, Arnav	2	
		Demo report prep	Suhas, Anh	10	Due Feb 1
4	Table Sanitisation	Model rubbish	Daniel, Arnav	2	
		Model valuables	Daniel, Arnav	3	
		Model arm	Daniel, Arnav	15	
		Table Recognition	Caitlin, Máté, Apurv, Suhas	10	
		Empty Table Identification	Caitlin, Máté, Apurv, Suhas	5	
		Disinfectant Spraying	Sean, Austin, Anh	5	
		Table Wiping	Sean, Austin, Anh	15	
5	Table Sanitisation	Model passengers	Daniel, Arnav	10	
		Hardware modelling	Daniel, Arnav	10	
		Table Recognition	Caitlin, Máté, Apurv, Suhas	12	
		Empty Table Identification	Caitlin, Máté, Apurv, Suhas	8	
		Disinfectant Spraying	Sean, Austin, Anh	5	
		Table Wiping	Sean, Austin, Anh	15	
6	Table Clearing	Rubbish Detection	Caitlin, Máté, Apurv, Suhas	12	
		Hardware modelling	Daniel, Arnav	10	
		Object Removal	Sean, Austin, Anh	5	
		Valuables Detection	Caitlin, Máté, Apurv, Suhas	15	
		Demo testing	Sean, Daniel, Arnav	2	
		Demo report prep	Suhas, Anh	10	Due March 1
7	Avoidance of public	Model butons	Daniel, Arnav	2	
		Hardware modelling	Daniel, Arnav	10	
		Obstacle Detection	Caitlin, Máté, Apurv, Suhas	10	
		Obstacle Avoidance	Sean, Austin, Anh	15	
		Location Return	Sean, Austin, Anh	10	
8	Avoidance of public	Obstacle Detection	Caitlin, Máté, Apurv, Suhas	10	
		Hardware modelling	Daniel, Arnav	10	
		Obstacle Avoidance	Sean, Austin, Anh	10	
		Location Return	Sean, Austin, Anh	5	
		Demo testing	Sean, Daniel, Arnav	2	
		Demo report prep	Suhas, Anh	10	Due March 15
9	Button Manipulation	Model more carriages	Daniel, Arnav	10	
		Hardware modelling	Daniel, Arnav	15	
		Button Detection	Caitlin, Máté, Apurv, Suhas	8	
		Button Disinfection	Sean, Austin, Anh	10	
		Button Pressing	Sean, Austin, Anh	5	
10	Carriage Crossing	Inter-Carriage Navigation	Sean, Austin, Anh	20	
		Hardware modelling	Daniel, Arnav	15	
		Demo testing	Sean, Daniel, Arnav	2	
		Demo report prep	Suhas, Anh	10	Due March 29

Table 1. Resource allocation for the system

No.	Risk	Actions to minimize	Contingency plan
1	Running into passengers/obstacles in its path	Using visual sensors to detect obstructions and backtracking to move out of the way	Try making the robot more compact and have it move into vacant spaces between seats instead of the ends of the carriage
2	Cleaning a table with passenger's items on it	Using visual sensors to detect presence of items not to be considered as waste.	Have a human check the table for such items before having the robot clean the table
3	Contact interaction with surfaces.	Map the area of the table and clean its surface using a cloth	Have a human monitor the cleanliness of the table if the robot does not clean to a satisfactory degree
4	Maintaining cleanliness of robot itself	Implementing a mechanism to dispose off the cloth after use (since we use disposable cloths)	Have a human clean it at the end of the journey
5	Inability of movement between carriages due to varying surfaces	Have "tank tracks" instead of traditional wheels as the mechanism	Work on just one carriage as a use case
6	Lack of experience with specific software/hardware	Allocate extra time to learning its ins and outs	Work with materials provided by the course, ensuring a solid support system.
7	Disagreements between members of the group / Running over time	Measure progress for each task against its initially projected time to complete	Have a vote (overseen by project manager) if there is not an immediate consensus and distribute workload with other members who are ahead of their tasks.

Table 2. Risk assessment

Task Name	Milestone	Estimated Days	Dependency	Rough description
Robot Body Model	Aisle Navigation	5	-	Basic model able to withstand train motion.
Carriage Model	Aisle Navigation	3	-	Modelling the train carriage aisle and door
Robot Movement	Aisle Navigation	2	-	Basic movement forward and backwards
Carriage End Recognition	Aisle Navigation	5	-	Recognise reaching the end of the carriage.
Demo preparation	Aisle Navigation	3	-	Report Writing and Demo Video Creation
Testing	Aisle Navigation	1	-	Testing of Aisle Navigation
Arm Model	Table Sanitisation	7	-	Model the arm for use in Webots
Table Model	Table Sanitisation	3	-	Model carriage tables and chairs
Table Recognition	Table Sanitisation	5	-	Recognise when it is next to table
Empty Table Recognition	Table Sanitisation	2	-	Recognise a table is empty
Disinfectant Spraying	Train Sanitisation	7	-	Mechanism for spraying disinfectant.
Table Wiping	Train Sanitisation	10	-	Wiping entire table using correct pressure
Testing	Table Sanitisation	1	-	Testing of Table disinfection process
Item models	Table Clearing	2	-	Model rubbish and valuables for clearance
Rubbish Detection	Table Clearing	5	-	Able to detect rubbish on a table
Rubbish Removal	Table Clearing	5	-	Able to Remove Rubbish from the table
Valuables Detection	Table Clearing	5	-	Detect valuables to stop binning.
Demo preparations	Table Clearing	3	-	Writing report and creating video
Testing	Table Clearing	1	-	Testing of Table Clearing
Obstacle Detection	Avoidance of public	3	-	Detect humans or obstructions in aisle.
Obstacle Avoidance	Avoidance of public	5	-	Move to suitable area away from aisle.
Location Return	Avoidance of public	5	Obs Avoid	Return to previous location after avoidance.
Button CAD modelling	Avoidance of public	2	-	Modelling of buttons
Demo preparation	Avoidance of public	3	-	Report Writing and Demo Video Creation
Testing	Avoidance of public	3	-	Testing of behaviour when obstruction
Button Presser Model	Button Manipulation	3	-	Model appendage for button pressing.
Button Detection	Button Manipulation	5	-	Detect buttons on the wall of the train.
Button Disinfection	Button Manipulation	2	-	Disinfect/clean the buttons in the train
Button Pressing	Button Manipulation	3	-	May press buttons for going through a door.
Testing	Button Manipulation	2	-	Testing of Aisle Navigation
Model updates	Carriage Crossing	1	-	Any additional updates to design
Cross Carriage	Carriage Crossing	4	-	Able to move from one carriage to another
Demo preparation	Carriage Crossing	3	-	Report Writing and Demo Video Creation
Testing	Carriage Crossing	3	-	Testing of ability to cross carriages

Table 3. Task decomposition for the system

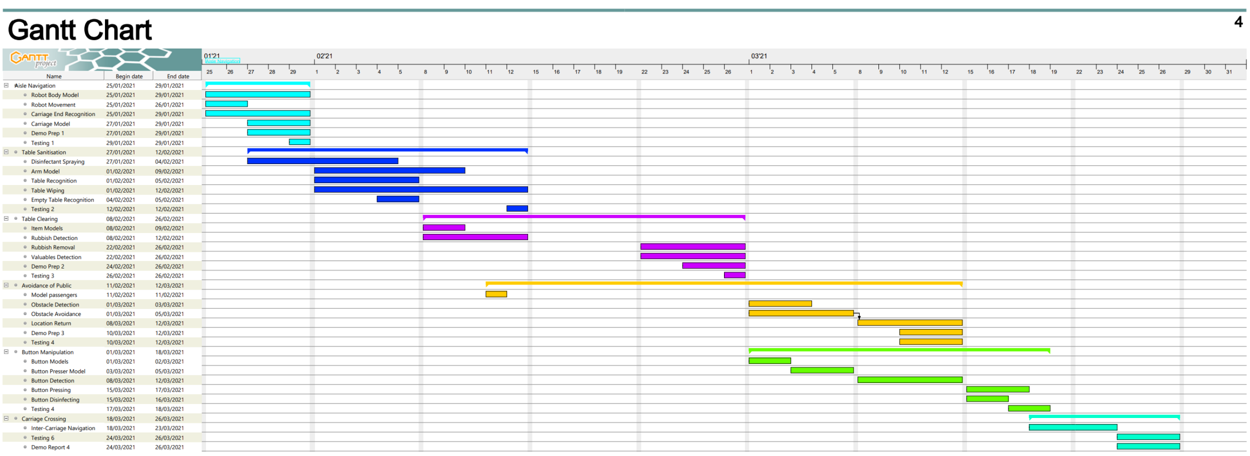

Table 4. Gantt Chart