Door-mounted Hand Sanitizer Dispenser “INNOVA", and a sophisticated leap to control the risk of COVID19-

إعداد

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Abstract

In the context of Covid19-, various organizations like the Centers for Disease Control and Prevention (CDC) of the United States of America, have identified high-touch surfaces as a potential vector of transmission of Covid19-, which comprise doorknobs, light switches, handles, and similar surfaces.
Additionally, recent findings from the Commonwealth Scientific and Industrial Research Organization (CSIRO) suggest that Covid- 19 can survive 28 days on smooth, non-porous surfaces at ambient temperatures, showing that disinfection frequency for high-touch surfaces is not enough and far from optimal.
According to this problem, the present project «INNOVA» has identified the need to provide hand sanitizer near high-touch surfaces and remarking that most common surfaces are located near the entrances, it is proposed to implement a solution on the doors. It has been identified an important need to offer a solution that is not bulky and obstructive like existing solutions in the market, specially adapted for applications in small places like houses, residential buildings, small businesses/offices, and social areas. As a result of the work carried out, it was determined that using a linear and retractable motion system for the Door-mounted Hand Sanitizer Dispenser will allow the product to be used in rooms with limited space, in a compact and safe manner.

Keywords: INNOVA, hand sanitizer, innovation, science, family care, sustainability, development

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1 Introduction

Currently, a large number of countries are experiencing a rapid increase in the cases of infection due to Covid19-, which has generally been called the Coronavirus second wave.
Consequently, the different measures have implemented mandatory biosecurity protocols for all economic and social activities, including primarily hand hygiene, since it is the main proven defense against covid19-. This circumstance has imposed the development and redesign of a range of products to meet specific health requirements (Obaid,2022). For this aim, we have proposed to design a Door-mounted Hand Sanitizer Dispenser "INNOVA". This product would benefit various domestic and economic sectors by allowing them to better implement propagation control measures against Covid19-. The main objective of "INNOVA" is to develop a product by going through all its phases as part of the Design Methodology, under the premise that the engineering design methodologies are undoubtedly the main tool to outline ideas and turn them into a tangible product under the best practices.

2 Project Statement

In the context of Covid19-, various organizations like the Centers for Disease Control and Prevention (CDC) of the United States of America, have identified high-touch surfaces as a potential vector of transmission of Covid19-, which comprise doorknobs, light switches, handles, and similar surfaces [4].

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Additionally, recent findings from the Commonwealth Scientific and Industrial Research Organization (CSIRO) suggest that Covid19- can survive 28 days on smooth, non-porous surfaces at ambient temperatures [6], showing that disinfection frequency for high-touch surfaces is not enough and far from optimal. From this, and additional considerations, the following short comings are identified:

High-touch surfaces are potential vector of transmission of Covid19-. It can 'survive' from 7 to 28 days at ambient temperature (30-20 °C).
Disinfection frequency for high-touch surfaces is not enough.
Obstructive solutions take up space in smaller places.
Handwashing, the main defense against Covid19-, is required after opening and closing doors.

Based on the above problem, the present project has identified the need to provide hand sanitizer near high- touch surfaces, and remarking that most common surfaces are located near the entrances, it is proposed to implement a solution on the doors.
It has been identified an important need to offer a solution that is not bulky and obstructive like existing solutions in the market (fixed stations with hand sanitizers, automatic doors, touchless systems, and similar solutions. See Figure 1)

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Figure 1: Bulky fixed stations with hand sanitizers

3 Clarification of the Task

In order to address the design challenge of the Door-mounted Hand Sanitizer Dispenser "INNOVA", it is necessary to know the needs, requirements, constraints and important factors for each user in contact with the system throughout its life cycle. All the above must be translated into Product Design Specifications (PDS). The generation of these specifications is carried out in two stages, where first the Quality Function Deployment (QFD) method is applied to understand the problem and translate the requirements into engineering characteristics that satisfy them as product specifications, and then these specifications are organized and classified by means of the list of specifications.

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3.1 Needs Identification and Quality Function Deployment (QFD)

Four types of product stakeholders ("who" part of the QFD), both direct and indirect, were identified for this project:

End-users: Regular user, and person with disabilities. Direct client: Owner/buyer.

Indirect clients: HSEQ team.

Based on the previous product stakeholders, the needs and requirements ("what" part of the QFD) were defined. The rest of the requirements were obtained from the other possible users, as well as certain requirements that arise in part from the analysis of the technical survey and the current commercial offer of this type of products. The QFD summarizes all the above.

Subsequently, they were translated into engineering characteristics.

3.2 Requirements List and Product Design Specifications

Based on the results of the QFD, the specifications and target values are established and presented in this section. Figure 2 shows the requirements and specifications related to the geometry and dynamics.

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Type of Requirement	Requirement	Engineering Specification (PDS)	Target Values (uncertainty of +/- 30%)	% of import.
Geometry	Take the Least space possible.	Overall dimensions of the device.	30 cm (L) x 13cm (W) x 13cm (D)	9 %
Geometry	Geometrical compatibility for mounting.	Flatness tolerance with respect to the door.	< 0.5 mm	1.8 %
Kinematics	No contradiction with the movement of the door.	Degree of opening with the device installed.	90° (approx.)	4.9 %
Kinematics	No sudden movements during the operation.	Settling time and overshoot.	< 3 s	5.3 %
Kinematics	The dispenser must be ready for use in a short period of time.	Durations in the kinematic profile.	< 5 s	5.3 %
Forces	The dispenser requires minimal forces to operate.	Force to push the dispenser.	< 20 N	4.1 %
Forces	The structural integrity of the door should not be affected.	Loads on the door.	< 150 N	2.3 %
Forces	Avoid complex prime movers (actuators).	Mechanical output power.	< 40 W	5.2 %

Figure 2: Product Design specs. – Geometry and Dynamics

Additionally, Figure3 shows the specifications related to the installation, manufacturing and materials. Finally, Figure 4 shows the specifications on operation, ergonomics, safety and aesthetics.

Type of Requirement	Requirement	Engineering Specification (PDS)	Target Values (uncertainty of +/- 30%)	% of import.
Installation	Easily Installed by the customer (not technical).	No. of components & manual assembly operations.	< 8	4.1 %
Installation	Compatible with different types of doors.	Number of changes to achieve adaptability.	< 5	5.7 %
Manufacturing	Low manufacturing costs	Cost of the materials and the manufacturing processes.	< 110 €	7.8 %
Materials	Should be able to work with different sanitizers.	Design compatibility with hand sanitizer Products.	-	8.1 %

Figure 3: Product Design Specifications - Installation, manufacturing and materials

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Type of Requirement	Requirement	Engineering Specification (PDS)	Target Values (uncertainty of +/- 30%)	% of import.
Operation	Low waste of sanitizer.	Wasted volume of sanitizer per operation.	19 ml/750ml of sanitizer <	4.1 %
Operation	Provides easy access for sanitizer replacement.	No. of operations to replace the sanitizer.	< 8	1.2 %
Operation	The re-filling frequency is as low as possible.	Sanitizer storage capacity.	250 ml >	5.7 %
Operation	Low noise operation.	Sound pressure level (A-weighted).	< 70 dBA	1.4 %
Ergonomics	Shape compatibility with the hand.	Match average hand size.	195 mm (approx.)	5.7 %
Ergonomics	Easy access to its location (accessibility).	Accessible height and location.	100 - 150 cm	9.4 %
Safety	The device doesn't have sharp edges.	Fillets and chamfers dimensions.	< 7.5 mm	5.2 %
Aesthetics	Match the aesthetics of the door (if possible).	Quality of the materials (neutral architectonic design and color).	According to standard door finishing	3.8 %

Figure 4: Product Design Specifications - Operation, ergonomics, safety and aesthetics

4 Conceptual Design

4.1 Functional Analysis and Preliminary Concepts Generation

This section formally begins with the conceptual design of the Door-mounted Hand Sanitizer Dispenser “INNOVA”, where the general design methodology is further developed. Firstly, the functions that the product must have in order to achieve the global performance defined by the product specifications (PDS) are identified. In this case, the general function is to provide sanitizer to a person entering a room with reduced space by means of a compact solution installed on the door. From this general function, it is possible to identify those sub-functions

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that allow it to be fulfilled, which are shown in Figure 5.

N	Subfunction	Means of solution			
1	Mounting	Bolted	Permanent joining (bonded)	Permanent joining (welded)	
2	Mechanical power supply	Potential energy source	Electric motor	Pneumatic actuator	Manual
3	Triggering action	Door handle	Door motion	Proximity sensor	Push button
4	Mechanical transmission	None (direct coupling)	Reduction gear	Flexible transmission	
5	Deployment mechanism	4-bar mechanism	Linear slider mechanism	None (no deployment)	
6	Stopping mechanism	Rubber stopper	Geometrical constraint	Position controller	None
7	Retraction mechanism	Manual	Kinematic retraction	Motion inversion (controller)	None
8	Store sanitizer	Mounted bottle	Non-mounted storage		
9	Supply sanitizer	Manual	Pump bottle	Pump	

Concept 2 Concept 1 Concept 3

Figure 5: Functional analysis, morphological chart and concept generation

4.2 Concept Selection and Analytic Hierarchy Process (AHP)

The evaluation of the QFD matrix and the requirements were taken into account for the selection of criteria. The conclusion was that the most important criteria for the design of the product are the following:

Low overall cost of the product
Low overall dimensions of the device
High design flexibility/adaptability for installation.
Low design complexity (working principle)
High accessibility of the device (layout)

The criteria mentioned above were compared with each

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other with a relative importance based on the percentages of importance obtained from the QFD, so it is possible to establish the respective weights of each criterion.

This is done applying the Analytic Hierarchy Process (AHP). The analysis and results for the criteria are shown in Figure 6. Recall that If the (CR) is less than or equal to 0.1 the matrix has admissible consistency, and if it is greater than 0.1 the inconsistency is not admissible [3].

Figure 6: Criteria assessment, weighting and consistency matrix

CRITERIA COMPARISON MATRIX [C]						CRITERIA WEIGHTS [W]
	Low overall cost of the device	Low overall dimensions of the device	High design flexibility/adaptability for installation	Low design complexity (working principle)	High accesibility of the device (location)	Criteria weights [%]
Low overall cost of the device	1	0.33	0.20	3	0.33	8.9%
Low overall dimensions of the device	3	1	0.33	5	1	20.1%
High design flexibility/adaptability for installation	5	3	1	9	3	48.2%
Low design complexity (working principle)	0.33	0.20	0.11	1	0.33	4.5%
High accesibility of the device (location)	3	1	0.33	3	1	18.2%
Sum (column)	12.3	5.53	1.98	21	6	

CONSISTENCY CHECK FOR [W]				
a) Weighted sum vector [Ws]	b) Consistency vector [D]	c) Lambda value	f) Consistency relation	
0.449	5.051	5.124	n	5
1.037	5.148		RI	1.115
2.484	5.151		CI	0.031
0.229	5.080		CR	0.028
0.946	5.190			

Following the AHP methodology, a similar procedure to the previous one is applied to evaluate each concept variant with respect to the different criteria. Thus, it is also evaluated in what percentage relative to the rest of the solutions satisfies a criterion. For each case, the weighting and its consistency are also evaluated. Figure 7 shows the results of the analysis

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for the criterion 3, which has the highest weighting among the criteria. For the sake of simplicity, only criterion 3 is shown in this document, but the rest criterion is evaluated using the same approach.

CRITERION 3
High design flexibility/adaptability for

	Concept 1	Concept 2	Concept 3	Criteria weights [W]
Concept 1: 4-bar	1	0.3	0.5	16.4%
Concept 2: slider	3	1	2	53.9%
Concept 3: fixed	2	0.5	1	29.7%
Sum	6	2	3.50	

a) Weighted sum vector [Ws]	b) Consistency vector [D]	c) Lambda value	f) Consistency relation	
0.492	3.004	3.009	n	3
1.625	3.015		RI	0.525
0.894	3.008		CI	0.0046043
			RC	0.009

Figure 7: Solution assessment, weighting and consistency for each criterion (for simplicity only criterion 3 is shown)

Finally, with the evaluation of each solution against each criterion and the assessment of the criteria, it is possible to combine everything to make the global evaluation of the design concepts, which finally allows to select the alternative that consistently satisfies the different needs. The global results are given in Figure 8. Based on the analysis above, the solution concept 2 is selected.

	Criteria weights (W)						
	8.9%	20.1%	48.2%	4.5%	18.2%		
	Low overall cost of the device	Low overall dimensions of the device	High design flexibility/adaptability for installation	Low design complexity (working principle)	High accesibility of the device (location)	Total	
Concept 1: 4-bar	0.020	0.021	0.079	0.009	0.042	0.172	
Concept 2: slider	0.016	0.052	0.260	0.009	0.127	0.464	Selected
Concept 3: fixed	0.053	0.128	0.143	0.027	0.013	0.364	

Figure 8: Global solution assessment and selection

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5 Embodiment design

5.1 General architecture of the product

The following figure shows the product architecture, with the subsystems of "INNOVA".

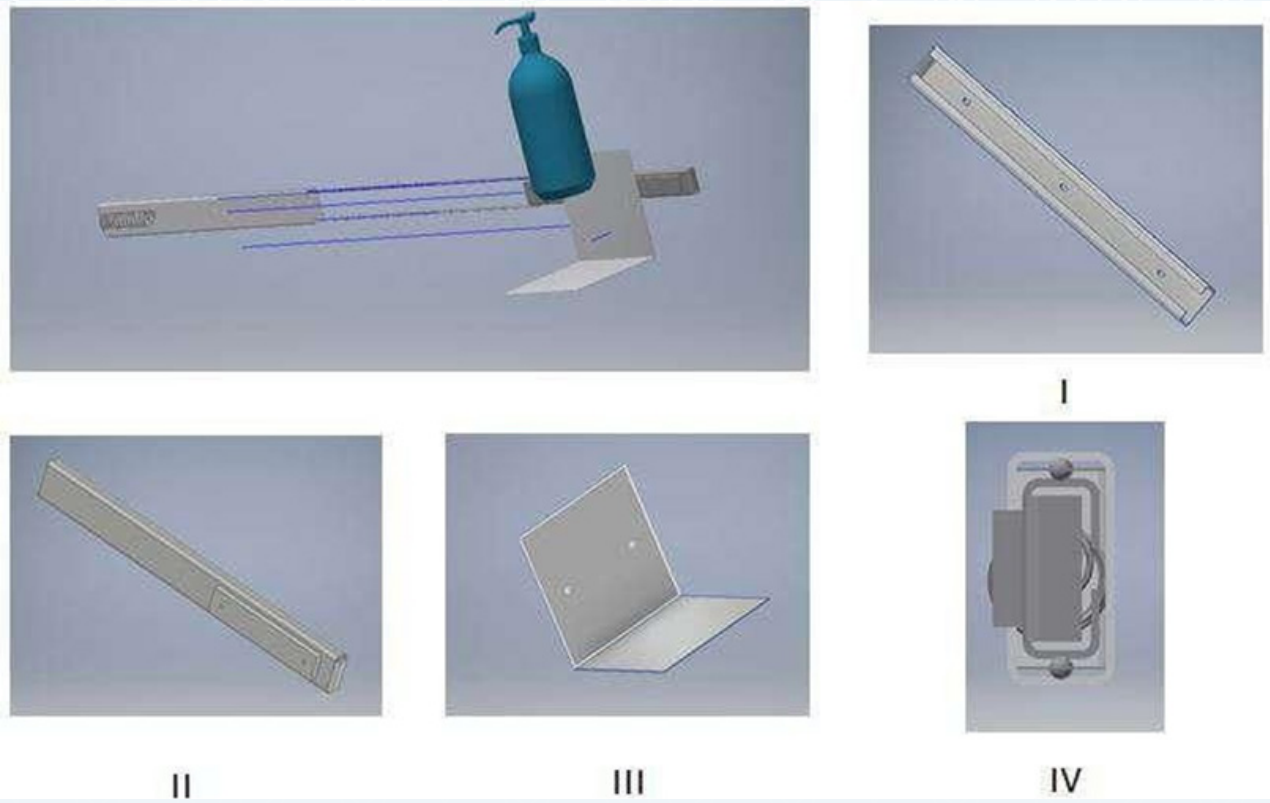

Figure 9: Main components of the Door-mounted Hand Sanitizer Dispenser

5.2 Material selection

The material selection process used is based on three aspects [1]: first, the desired characteristics are expressed as functions and constraints of each component. Then, the process of screening, ranking and choice of candidate materials are carried out. Finally, the selection is completed based on specific project considerations.

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Figure 10 shows the functions and restrictions of the main components of "INNOVA". It can be seen that the rail is mainly subject to bending due to the transverse load generated by its own weight and the moment generated by the weight of the bottle. This not only induces static loads but also flexural vibration during movement. The loading conditions are similar for the carriage, since the constraints of stiffness, length and width are linked to each other by the functionality of the motion. Then, as far as possible, the height of the guidance system is used as a free parameter.

Based on the above analysis, it was determined that a stiffness- limited design at minimum mass and a vibration-limited design should be considered. This allows the choice of appropriate material indexes, for both beam and plate/panel type components, to optimize the selection of materials for each one. The indexes established for the selection process, together with the objective of the selection are given in Figure 11.

FOR STIFFNESS-LIMITED DESIGN AT MINIMUM MASS

Functions and constrains	Index	Objective
Beam (loaded in bending) Stiffness, length, width constraint; height free	$E^{1/3}/\rho$	Maximize
Plate (flat plate, loaded in bending) Stiffness, length, width constraint; thickness free	$E^{1/3}/\rho$	Maximize

VIBRATION-LIMITED DESIGN

Functions and constrains	Index	Objective
Beams Length and stiffness constraint	$E^{1/2}/\rho$	Maximize
Panels Length, width and stiffness constraint	$E^{1/3}/\rho$	Maximize

Figure 11: Indexes and objectives for stiffness-limited and vibration-limited designs [1]

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After the proper material indexes are selected, these are applied to rank the materials by optimizing the index in the corresponding Ashby's materials selection chart, as shown in Figure 12.

From this figure it is identified that the most appropriate materials, both for stiffness-limited and vibration-limited design of panels/plates and beams, are the following: Metals, polymers and composites. other materials are discarded due to attribute limits. After selecting the appropriate family of materials for the product, additional criteria can be used to select subcategories of materials. In this case, another criterion of interest is to reduce the cost, so these are compared in Figure 13. In particular, aluminum and steel alloys have lower price compared to most polymers and composites and are easier for manufacturing purposes related to mechanisms.

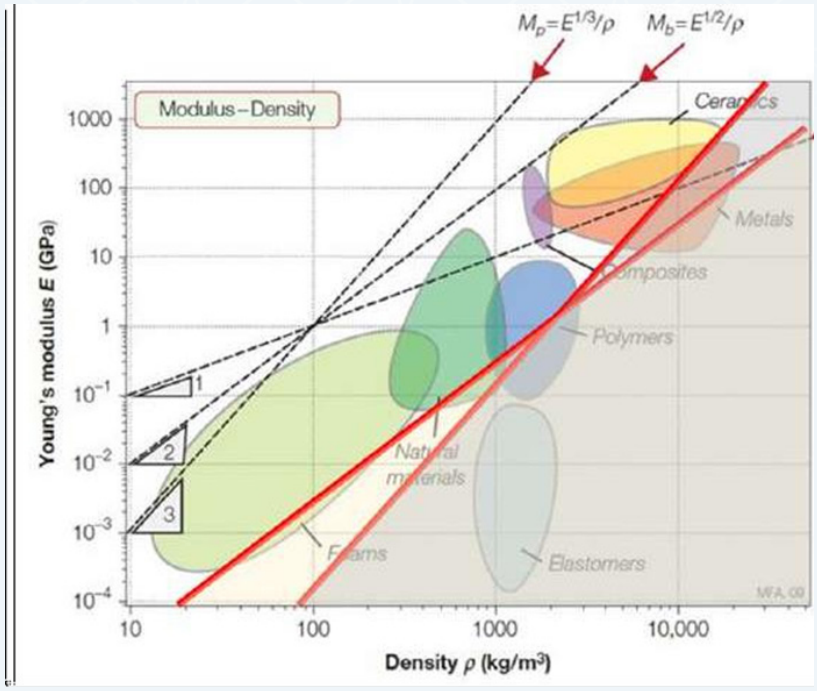

Figure 12: Analysis and attribute limits, based on Ashby's materials selection chart [1]

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5.3 Manufacturing processes selection

This section focuses on the selection of the manufacturing processes for the main components of the Door-mounted Hand Sanitizer Dispenser "INNOVA". Considering the selection of materials (metals), and the geometry of the components (i.e. prismatic non-circular shapes, 3D solids and plates), process selection charts are used. As a result, the recommended manufacturing processes for the components are: conventional machining, sheet forming, and extrusion. This is summarized in the Figure 14.

Part	Material	Shape	Manufacturing process
Slider/carriage	Metallic	Noncircular prismatic	▪ Conventional machining ▪ Sheet forming ▪ Extrusion
Bottle support	Metallic	Flat sheet	
Rail	Metallic	Noncircular prismatic	

Figure 14: Recommended manufacturing processes for the main components

Assembly Analysis and Design for Assembly (DFA)

A. General Guidelines for Manual Assembly

The major factors affecting the assembly operations of the design are analyzed in this section.

Handling:

Provided rollers inside the rail in order to prevent jamming of parts and for smooth movement.

Parts are handed easily, no slippery, sticky or fragile parts were used. Insertion and fastening:

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Chamfers in the rail's fasteners locations in order to make it easy to install and attach it to the door.
A guide for fasteners in the back of the rail is provided, also for the sanitizer supporting back plate.

Ease of access:

Easy access to all locations of the components in assembly and disassembly.
Complex components are pre-ensemble.
Assembling from "above" principle was used. Kinematics and adjustments.

B. Quantitative Assessment of the DFA

After the qualitative guidelines of DFA were applied, a quantitative methodology was revisited to assess the product. In Figure 15, the operation time for the assembly of the main components is calculated based on the manual insertion time, manual handling time and the number of operations. Using these results, it is possible to calculate the efficiency of the assembly:

$$Efficiency = \left(\frac{N_{min} \times T_a}{T_{ma}}\right) = \frac{5 \times 6}{48.5} = 62\%$$

(5.1)

It is noted that efficiency is limited by the use of screws, which have the highest operating time of all the components of the assembly. However, this is an acceptable restriction on design,

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as the choice is based on consideration of the stability of the rail fastening and the type of materials involved in the joint. Thus, all other components are considered to be within acceptable efficiency and the end result is a balance of different design constraints (not only assembly, but mechanical).

Part	Theoretical min. # of parts	Operation time [s]	Manual insertion time [s]	Manual handling time [s]	Number of operations, consecutively	Part no.
Rail	1	10	1	9	1	1
Screws (to door)	0	11.2	1.5	1.35	4	2
Spring mechanism	1	3.04	1.2	1.84	1	3
Slider/carriage	1	5	1.5	3.5	1	4
Bolts (to bottle support)	0	5.7	1.5	1.35	2	5
Mechanical trigger	1	10	1	9	1	6
Cover for mechanism	1	3.56	1.2	2.36	1	7

Figure 15: Quantitative assessment of the assembly

6 Detail Design

6.1 Description of the detail design in this section the description of the final design obtained as well as the related results are given (see Figure 16). At this stage of the design, standard components were selected wherever possible to facilitate the manufacture of the product. Also, the Bill of Materials (BOM) is provided.

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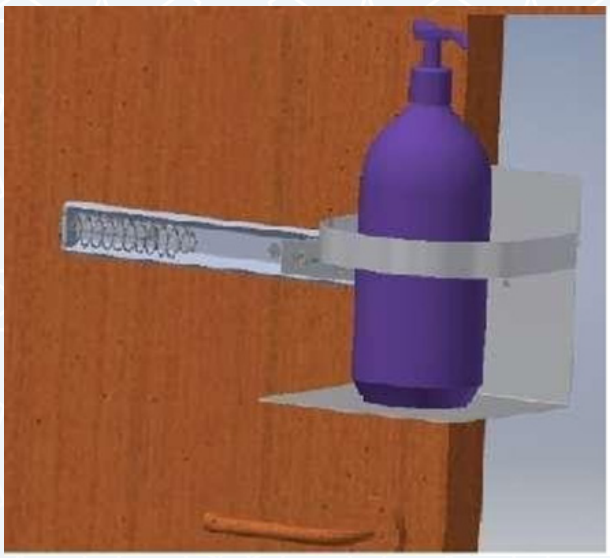

Item	QTY	Part
1	1	Trigger
2	1	Spring Lock
3	1	Spring
4	1	Internal Door
5	1	Extension
6	1	Bottle Support
7	1	Bottle Holder
8	1	Sanitizer Bottle
9	1	Linear Slider
10	1	ISO 1207 M5x6
11	2	ISO 1207 M5x10
12	2	ISO 1207 M2x12
13	2	IS 2636 M2

Figure 16: General assembly of the design and Bill of Materials (BOM)

For the rail and carriage, the Commercial Linear Guide from PBC linear, specifically the CR30 reference, was used. This system is shown in the following figure. This complies with the selected materials and the selected manufacturing processes in the embodiment design. For instance, roll formed rails made of steel sheet for low cost and corrosion resistance application are used. On the other hand, the machined slider body is made of aluminum alloy and anodized for corrosion resistance. Finally, the steel rollers are made of 52100 chrome steel, hardened and ground, lubricated for life, and sealed against contamination.

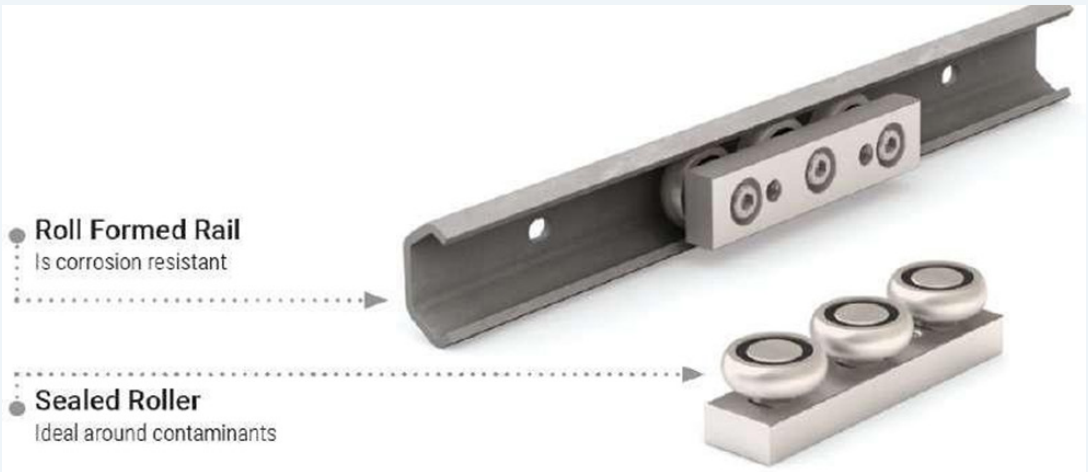

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Figure 17: Standard rail and carriage for linear guide system, from PBC Linear, CR30 reference

Trigger Mechanism

After having designed the Linear Slider to the desired specifications, a trigger mechanism is needed to actuate the system when the door opens. Many options where studied, and it was obvious that a simple mechanical system fits the requirements the best. An electrical trigger was considered, but the cost was incoherent with our product, so it was over-ruled directly. The trigger mechanism adopted consists of a hinged bar with a torsional spring, and attached to the spring with an elastic wire (in green). When the door is closed, the bar is parallel to the door and lying on the door frame/wall, and hence the wire is not in tension and the spring is compressed and sitting in the spring lock indent. When the door opens, the torsional spring releases the bar which becomes perpendicular to the door, making the distance from the spring and the tip of the bar higher, which lifts the spring out of the lock through the wire and releases it to push the Linear Slider forward. When the slider is retracted (manually), the spring falls back is the lock, and the door closes bringing back the trigger bar to its horizontal position, reducing the tension in the wire.

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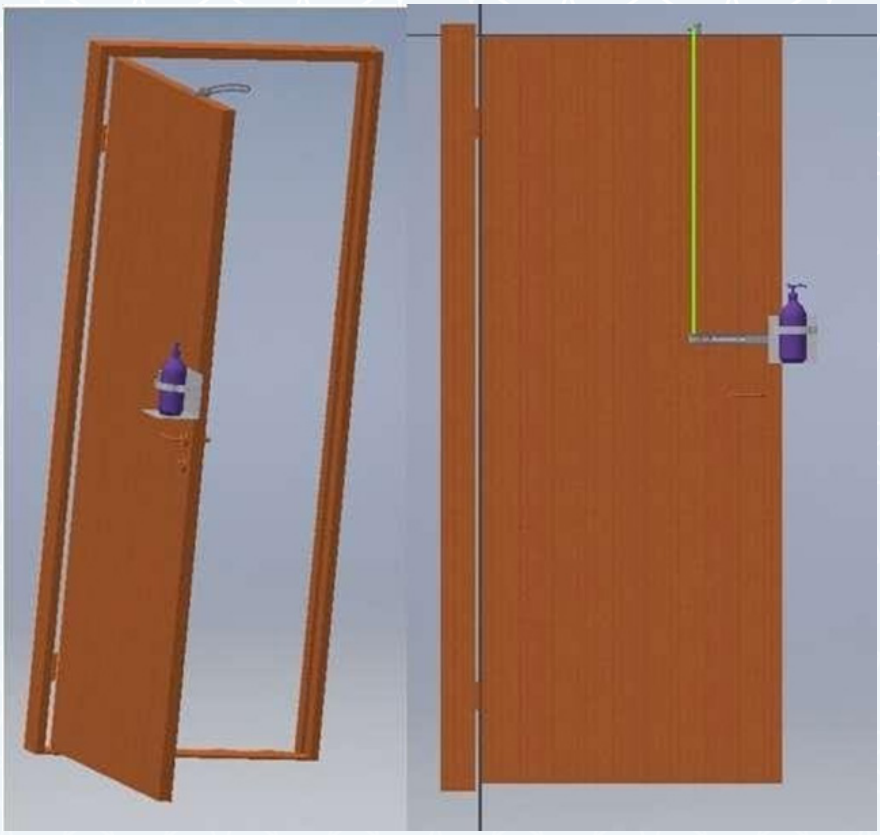

Figure 18: Trigger Mechanism

6.2 Loading calculations

Rail and slider/carriage

The equivalent load on the slider is due to the weight of the bottle (1.5 kg), as the inertial loads act in a perpendicular direction and are small due to the low operating speeds of the mechanism. This force acts in the radial direction, and is well below the load ratings (see Figure 19), so the design is safe. Fastening For a high factor of safety we consider at least 3 screws. Calculations for choosing the screws:

Shear Force: (F shear) Total Load = dispenser + slider mechanism = 1.5 kg + 0.4 kg = 1.9 kg.

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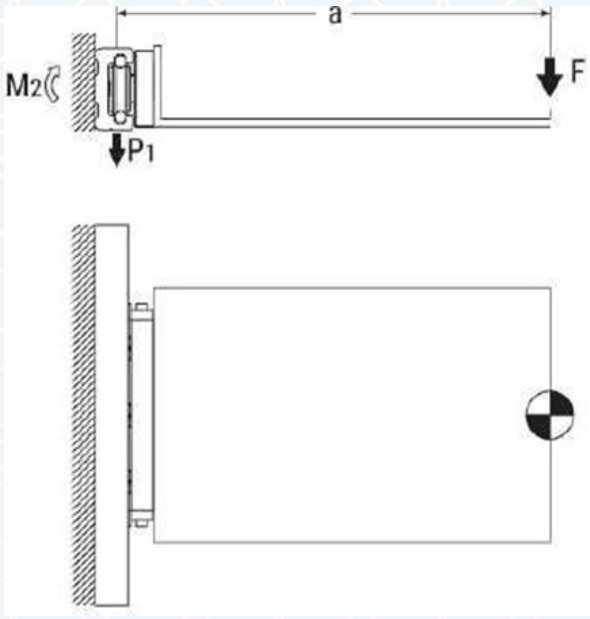

Load Ratings

Part No.		Fd N	Fy N	Fz N
Steel	CR20	280	210	160
	CR30	800	610	420
	CR45	1740	1330	930

Figure 19: load on the carriage due to the sanitizer bottle and Load ratings of the carriage

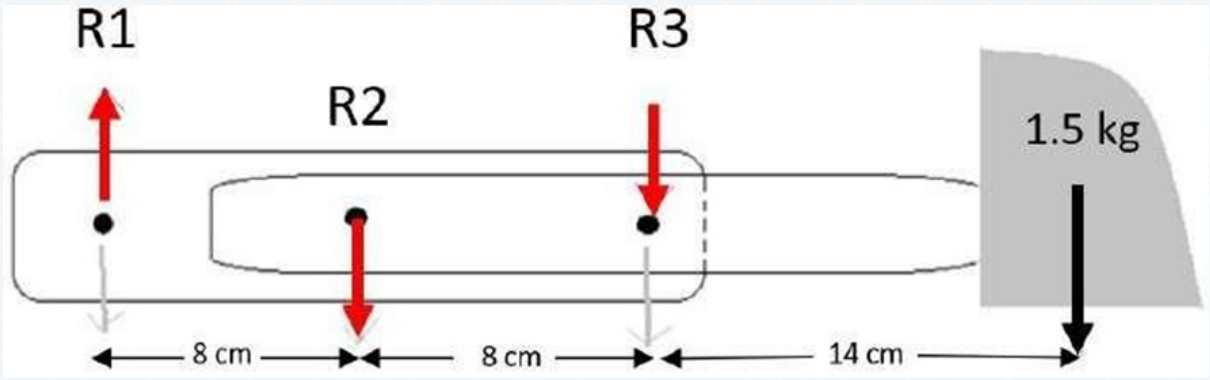

Figure 20: Free body diagram of the system

Shear Force (V) = load / no. of screws = (6.2 = 3 / (9.8 * 1.9 N. Torsional effect: (F torsional) Max Torque = F * arm = 9.8 * 1.5 * 3.234 = 0.22 N.m = 3234 N.mm.

The torsional force on the right screw is given by: F (orcetorsional) = (T(max) * r)/(r 20.2125 = (0.082 + 0.082)/(0.08 * 3.234) = (2N.

The screw that will sustain the max stress is the one on the right as the resultant force of the forces are both in the negative y- direction, so both the shear force and the torsional effect will

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make the biggest impact on it, summing up the resultant we get: Max Forces on the mentioned screw = = 20.2125 + 3.234 23.4465 N.

Considering Factor of safety = 35 = 1.5 * 23.4465 N.

These results can be compared to the previous load ratings. For the specifications of the fasteners refer to the figure below, which include the tightening torque. Spring For the spring calculations actuating the motion in the slider guide, doing calculation for a compressed spring in the slider guide Using Hooke's law, force needed to place the guide back in position should be minimal so that exerted force by human being is sufficient to overcome the stiffness of the spring.

The general equations while Opening: MX" = KX - μMg While closing: MX" = F - KX - μMg

Mounting

Slide	CR20/CRSS20	CR30/CRSS30	CR45
Slide mount screws (Socket head cap)	M5	M6	M8
Tightening torque (IN/Lb.)	25	43	103
Tightening torque (N-m)	3	5	12

Rail					
	Clearance		Suggested Fastener	Head Height*	
Size	inches	mm	(Button head cap)	inches	mm
CR20	0.115	2.921	M4	0.087	2.2
CR30	0.158	4.0132	M5	0.108	2.75
CR45	0.256	6.5024	M8	0.433	11

*Head height dimensions meet ISO 7380

Figure 21: Specifications for the mounting including tightening torque for fasteners

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To have the minimal force, the least stiffness should be selected, on that base taking into account only the force exerted by human, because from the above equation the effect of the friction will make the spring stiffness goes even higher so neglecting it to obtain safer Values: Note that the obtained value of the force is the average maximum force exerted by a single finger of a human being to push an object = 45 N.

6.3 Installation General installation

The drawer slider mechanism has a higher radial than axial load capacity, so the load is applied in the radial direction. This is a general guide to load the mechanism only in the radial direction.

A. Handling

Proper handling to ensure specified product performance, product life and to prevent accidental injury.

B. Lubrication

To ensure long life, it is necessary to have a thin film of lubrication on the raceway/railway at all times.

- Initial Lubrication (during installation): all components are pre- lubricated by the manufacturer.
- Periodic Lubrication/Maintenance: the lubrication interval is dependent on many operating and environmental conditions, such as load, stroke, velocity, acceleration, mounting position/ orientation, type of lubrication used, temperature, humidity etc. The actual lubrication interval should be determined by tests conducted under actual application conditions. The following guidelines can typically be used as a starting reference point under normal

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conditions: Re-lubrication every 1000 km of motion; 50000 cycles or six months (whichever occurs first).

Safety guidelines If the linear arrangement is designed, handled, installed, and maintained correctly, then they do not give rise to any known or direct hazards.

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