Enhancing Public Health: The Impact of Door-Mounted Hand Sanitizer Dispenser in Addressing COVID-19

Mehmed asch-Schaalan

Abstract— In the context of COVID-19, 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 COVID-19, 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 research 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—Hand sanitizer, innovation, science, family care, sustainability, development

I. INTRODUCTION

Currently, a large number of countries are experiencing a rapidincrease in the cases of infection due to COVID-19, and its scary consequences.

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 COVID-19. This circumstance has imposed the development and redesign of a range of products to meet specific health requirements. For this aim, we have proposed to design a Door-Mounted Hand Sanitizer Dispenser. This product would benefit various domestic and economic sectors by allowing them to better implement propagation control measures against COVID-19. The main objective 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]

This research covers the conceptual design, embodiment design and detailed design phases of a Door-Mounted Hand Sanitizer Dispenser, following the guidelines provided in the design methodology. The study of the research started with the problem statement, the review of the state of the technology, and the definition of requirements and specifications using the Quality Function Deployment (QFD) method. Next, the functional decomposition and synthesis of the system was carried out, the respective subfunctions were identified, and three alternative solutions were developed taking into account different solution concepts for the defined subfunctions.

The alternatives were evaluated following a Hierarchical Analytical Process (AHP). Finally, the embodiment and detailed design of the selected alternative was prepared. 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.

II. PROJECT STATEMENT

In the context of COVID-19, 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 COVID-19, which comprise doorknobs, light switches, handles, and similar surfaces. [4]

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 [6], showing that disinfection frequency for high-touch surfaces is not enough

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and far from optimal. From this, and additional considerations, the following short comings are identified:

- Biosecurity protocols are now mandatory for all economic and social activities, including hand hygiene.
- High-touch surfaces are potential vector of transmission of COVID-19. It can 'survive' from 7 to 28 days at ambient temperature (20-30 °C).
- Disinfection frequency for high-touch surfaces is not enough.
- Obstructive solutions take up space in smaller places.
- No 'universal' solution: different types of doors.
- Handwashing, the main defense against COVID-19, is required after opening and closing doors. [9]

III. CLARIFICATION OF THE TASK

Based on the above problem, the present research 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), specially adapted for applications in small places like houses, residential buildings, small businesses/offices, and social areas. With these considerations, the main characteristics of interest are:

- Compact size when retracted (e.g. suitable for small apartments, student housing).
- Mountable at different heights depending on the users (e.g. children at schools, people with special needs or disabilities).
- Reduce the risk of COVID-19 spread by triggering users to apply sanitizer when entering a new place (e.g. buildings, rooms).

Figure 1: Bulky fixed stations with hand sanitizers

In order to address the design challenge of the Door-Mounted Hand Sanitizer Dispenser, 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. In the same process, the target values of each of the specifications are established.

3.1. Needs Identification and Quality Function Deployment (QFD)

For the QFD please refer to the Appendix:
Four types of product stakeholders ("Who's?" part of the QFD), both direct and indirect, were identified for this research:

- 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 (shown on the top of the QFD) that allow these requirements to be met.

In the lower part of the QFD it is possible to observe the percentage of importance of the specifications for each user, which represent the priority in the development of the product. In this case the most important are precisely the parameters related to: 1) Accessible height and location, 2) Overall dimensions of the device, 3) Material compatibility, 4) Cost of the materials and the manufacturing processes, and 5) Number of changes to achieve adaptability (design flexibility). Similarly, target values are established, which in initial specification stages have approximately 30 percent uncertainty. In the lower part of the QFD we observe in green the most important factors in a global way.

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. Table 1 shows the requirements and specifications related to the geometry and dynamics.

Additionally, Table 2 shows the specifications related to the installation, manufacturing and materials. Finally, Table 3 shows the specifications on operation, ergonomics, safety and aesthetics. Please note that these specifications are flexible for design and not all are necessary (i.e. they are desirable).

TABLE I
PDS. – GEOMETRY AND DYNAMICS

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 %

TABLE II
PDS - INSTALLATION, MANUFACTURING AND MATERIALS

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 %

TABLE III
PDS - OPERATION, ERGONOMICS, SAFETY AND AESTHETICS

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 %

IV. 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, 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 that allow it to be fulfilled, which are shown in Table 4. [7]

TABLE IV
FUNCTIONAL ANALYSIS, MORPHOLOGICAL CHART AND CONCEPT GENERATION

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

At this phase, the mechanical conceptual synthesis is usually done to define the mechanical principles that will be used in the product. This includes a synthesis of typology and of scale. It is important to mention that the synthesis processes can be iterative, due to the very nature of the design. In this sense, in the conceptual design phase the preliminary mechanical synthesis is undertaken and during the embodiment and detailed design phases this are further rectified and/or modified to meet the specifications, as other factors (possibly of a non-mechanical nature) are incorporated into the design. This is considered for each concept next.

A. Concept 1: Dispenser deployed by 4-bar mechanism

The main components, layout and dimensions of the variant 1 are shown in Figure 2. The fundamental characteristics of this concept are:

- 4-bar linkage wall mounted.
- Integrity of the door is preserved.

- Direction parallel to the user's motion for less obstruction.
- Deployed using a trigger mounted to the door, under the influence of the bottle weight.

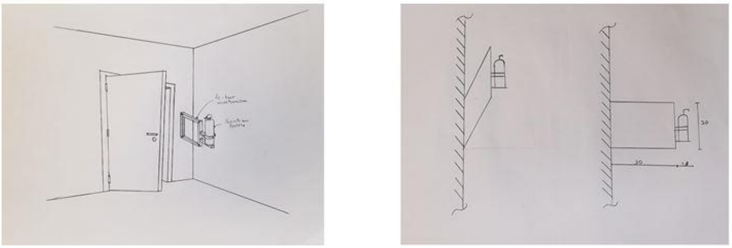


Figure 2: Conceptual sketch 1 - Dispenser deployed by 4-bar mechanism

B. Concept 2: Dispenser deployed by slider mechanism

Now the second variant is presented. Again, the principal components and disposition are shown in Figure 3.

The characteristics are:

- Door mounted sliding mechanism.
- Totally concealed behind the door when retracted.
- Provides sanitizer for users going in and out of the room.
- Deployed using a pre-stressed spring.

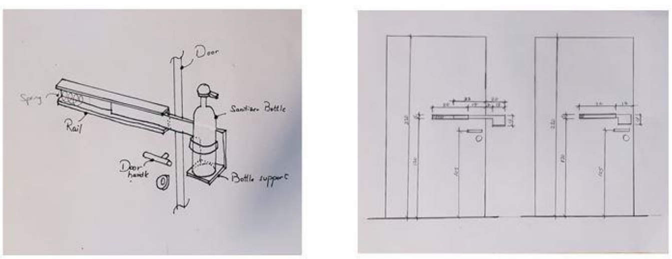


Figure 3: Conceptual sketch 2 - Dispenser deployed by slider mechanism

C. Concept 3: Fixed dispenser

Finally, a third variant was considered, which have the following characteristics (see Figure 4):

- Door fixed compartment.
- No mechanism needed (easier production).
- Fits multiple bottle sizes and shapes.

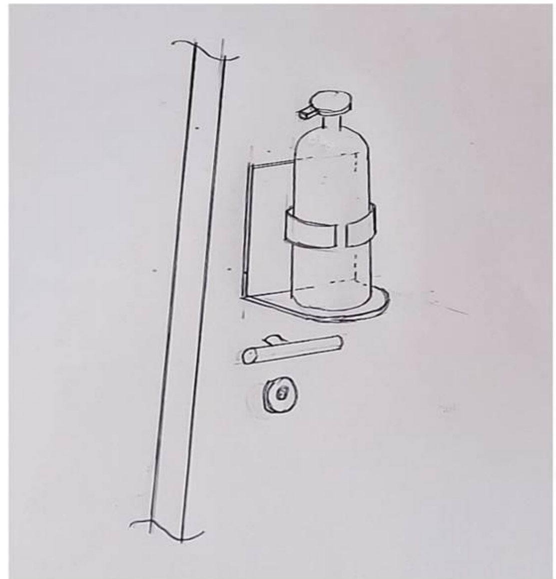


Figure 4: Conceptual sketch 3 - Fixed dispenser

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:

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

The criteria mentioned above were compared with each 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 Table 5. 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]

TABLE V

CRITERIA ASSESSMENT, WEIGHTING AND CONSISTENCY MATRIX

CRITERIA COMPARISON MATRIX [C]						CRITERIA WEIGHTS [W]	CONSISTENCY CHECK FOR [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 [%]	a) Weighted sum vector [Ws]	b) Consistency vector [D]	c) Lambda value	f) Consistency relation	
Low overall cost of the device	1	0.33	0.20	3	0.33	8.9%	0.449	5.051	5.124	n	5
Low overall dimensions of the device	3	1	0.33	5	1	20.1%	1.037	5.148		RI	1.115
High design flexibility/adaptability for installation	5	3	1	9	3	48.2%	2.484	5.151		CI	0.031
Low design complexity (working principle)	0.33	0.20	0.11	1	0.33	4.5%	0.229	5.080		CR	0.028
High accesibility of the device (location)	3	1	0.33	3	1	18.2%	0.946	5.190			
Sum (column)	12.3	5.53	1.98	21	6						

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. Table 6 shows the results of the analysis for the criterion 3, which has the highest weighting among the criteria. For the sake of simplicity, only criterion 3 is shown, but the rest criterion is evaluated using the same approach.

TABLE VI

SOLUTION ASSESSMENT, WEIGHTING AND CONSISTENCY FOR EACH CRITERION (FOR SIMPLICITY ONLY CRITERION 3 IS SHOWN)

		Concept 1	Concept 2	Concept 3	Criteria weights [W]
CRITERION 3 High design flexibility/adaptability for	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

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 Table 7. Based on the analysis above, the solution concept 2 is selected.

TABLE VII

GLOBAL SOLUTION ASSESSMENT AND SELECTION

	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	

V. EMBODIMENT DESIGN

5.1. General architecture of the product

The following figure shows the product architecture, with the subsystems of the Door-Mounted Hand Sanitizer Dispenser. Each one is described below and the embodiment principles are applied afterwards. Note that the numbering corresponds to the one shown in Figure 5.

1) Rail: is composed of the rail and the connections to the door. The function is to work as the mounting of the system, and also serve as the guide for the motion system.
2) Slider/carriage: this subsystem includes the carrier on which the bottle support is mounted, and transmits the motion of the linear motion system to the bottle itself.
3) Bottle support: the support is connected to the carriage and also allows to fix the bottle to the system.
4) Linear motion system: here the action component (spring) and the slider are included. They guarantee the linear motion of the product.

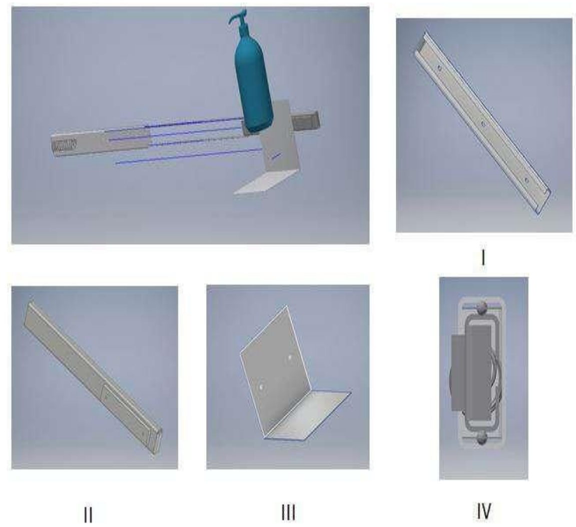


Figure 5: Main components of the Door-Mounted Hand Sanitizer Dispenser

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.

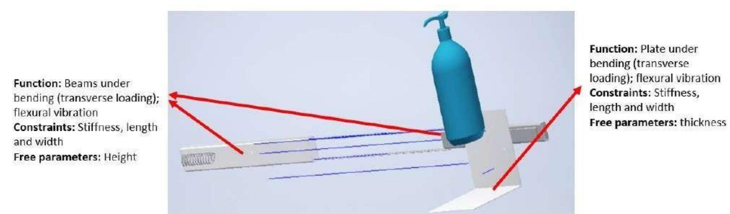


Figure 6: Shows the functions and restrictions of the main components

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 Table 8.

TABLE VIII
INDEXES AND OBJECTIVES FOR STIFFNESS-LIMITED AND VIBRATION LIMITED-DESIGN [1]

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

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 7.

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.

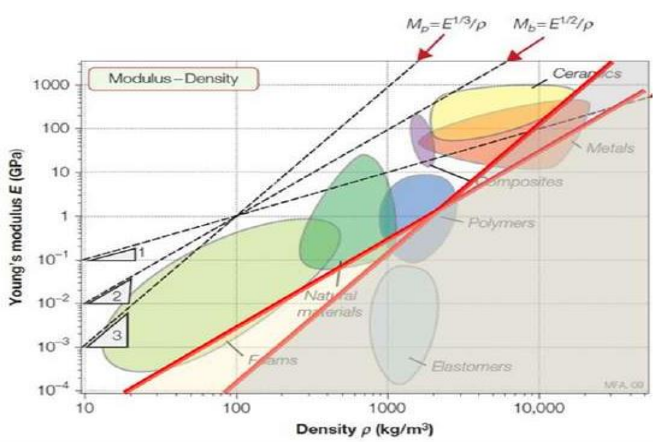


Figure 7: Analysis and attribute limits, based on Ashby's materials selection chart [1]

In this case, another criterion of interest is to reduce the cost, so these are compared in Figure 8. In particular, aluminum and steel alloys have lower price compared to most polymers and composites and are easier for manufacturing purposes related to mechanisms.[8]

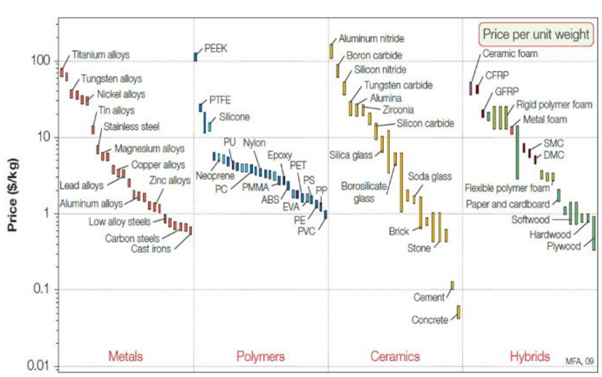


Figure 8: Possible choices based on price: aluminum and steel alloys [1]

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. 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 Table 9.

TABLE IX
RECOMMENDED MANUFACTURING PROCESSES FOR THE MAIN COMPONENTS

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

5.4. Assembly Analysis and Design for Assembly (DFA)

A. General Guidelines for Manual Assembly

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

1) Handling:
   a) Provided rollers inside the rail in order to prevent jamming of parts and for smooth movement.
   b) Parts are handed easily, no slippery, sticky or fragile parts were used.
2) Insertion and fastening:
   a) Chamfers in the rail's fastener's locations in order to make it easy to install and attach it to the door.
   b) A guide for fasteners in the back of the rail is provided, also for the sanitizer supporting back plate.
3) Ease of access:
   a) Easy access to all locations of the components in assembly and disassembly.
   b) Complex components are pre-ensemble.
   c) Assembling from "above" principle as 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 Table 10, 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:

$$Efficiency = \left(\frac{N_{min} * T_a}{T_{ma}}\right) = \frac{5*6}{48.5} = 62\% \qquad (5.1)$$

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, 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).

TABLE X

QUANTITATIVE ASSESSMENT OF THE ASSEMBLY

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

VI. DETAILED DESIGN

6.1. Description

The description of the final design obtained as well as the related results are given (see Figure 9). 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.

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 9: 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. [5]

The dimensions of the rail and carriage for linear guide system are given below:

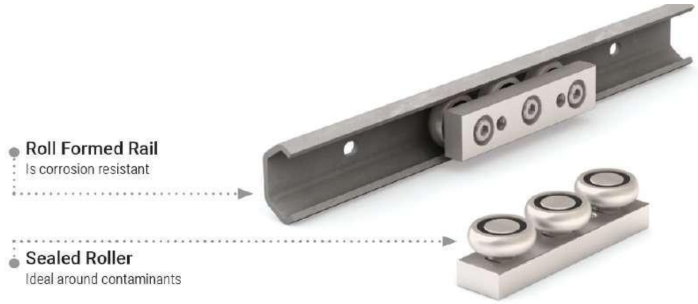
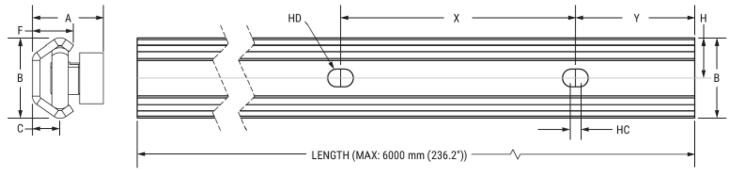
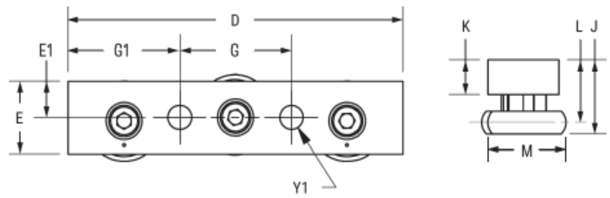


Figure 10: Standard rail and carriage for linear guide system, from PBC Linear, CR30 reference



Part No.	A	B	C	F	H	HC	HD	X	Y	Rail Wt. KG/M
CR30	26.5	30	10	15	15.0	2	5.5	80	40	0.95

Figure 11: Dimensions of the rail



Part No.	A	B	C	D	E	F	G	G1	J	K	L	M Ø ref	Y1	Thread Pitch	Weight KG
CR30	26.5	30	10	80	19.1	15	35	22.5	20	10	16.5	22.8	2x Ø 5.0 thru all	M6 x 1.0	0.1134

Figure 12: Dimensions of the carriage

A. 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.

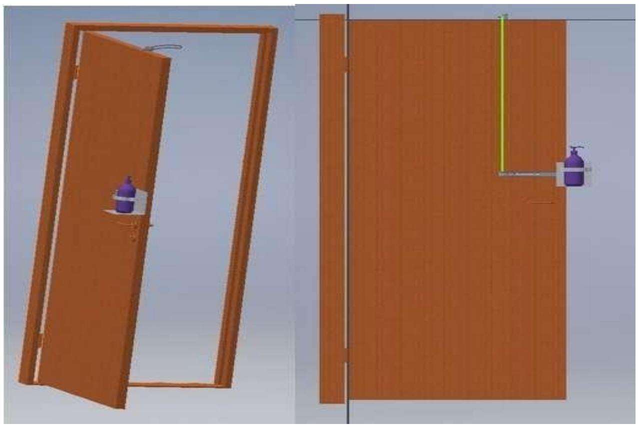


Figure 13: Trigger Mechanism

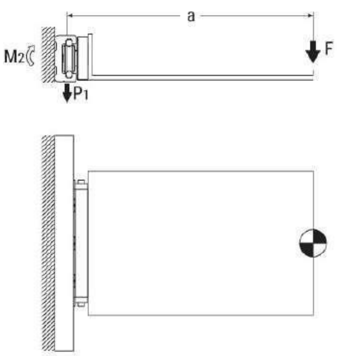
6.2. Loading calculations

A. 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 14), so the design is safe.

B. 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.



Load Ratings

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

Figure 14: Load on the carriage due to the sanitizer bottle and Load ratings of the carriage

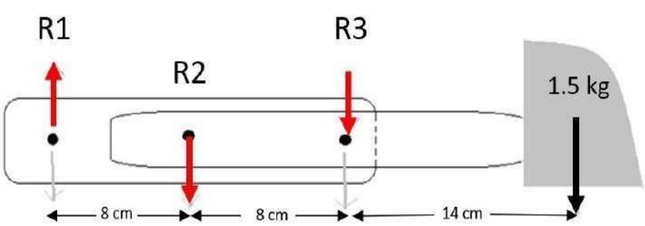


Figure 15: Free body diagram of the system

Shear Force (V) = load / no. of screws = (1.9 * 9.8) / 3 = 6.2 N.
Torsional effect: (F torsional) Max Torque = F * arm = 1.5 * 9.8 * 0.22 = 3.234 N.m = 3234 N.mm.
The torsional force on the right screw is given by:

F (orcetorsional) = (T(max) ∗ r)/(r 2)) = (3.234 ∗ 0.08)/(0.082 + 0.082) = 20.2125 N.

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 make the biggest impact on it, summing up the resultant we get:
Max Forces on the mentioned screw = 3.234 + 20.2125 = 23.4465 N.
Considering Factor of safety = 23.4465 * 1.5 = 35 N.

These results can be compared to the previous load ratings. For the specifications of the fasteners refer to the table below, which include the tightening torque.

C. 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 ,
And while closing:
MX” = F - KX - µMg

TABLE XI
SPECS FOR THE MOUNTING INCLUDING TIGHTENING TORQUE FOR FASTENERS

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 (Button head cap)	Head Height*	
Size	inches	mm		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

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: $K = \frac{F}{X} = \frac{45}{0.01}\ 4500\ Nm^{-1}$

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

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. For example, preloading the slider it will move freely if it's not kept horizontally a plastic level is supported to ensure it's horizontal.

B. Lubrication

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

1) Reduces wear.
2) Reduces stress on the contact surfaces.
3) Reduces friction (and therefore heat build-up).
   - 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 conditions: Re-lubrication every 1000 km of motion; 50000 cycles or six months (whichever occurs first).

C. 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. Misapplication, improper handling, improper installation, or improper maintenance may lead to premature product failure, which may have unintended consequences.

VII. Business Development

Door-Mounted Hand Sanitizer Dispensers emerged as a practical solution during the COVID-19 pandemic to promote hygiene and reduce the spread of the virus. This analysis compares their costs and benefits against other hygiene solutions such as traditional Wall-Mounted Dispensers, Standalone Sanitizing Stations, and Personal Hand Sanitizer Bottles.

A. Costs

1) Initial Investment:
   - Door-Mounted Dispensers: Typically, competitive due to specialized design and installation requirements.
   - Wall-Mounted Dispensers: Generally cheaper and easier to install.
   - Standalone Stations: Higher cost due to the need for additional space and construction.
   - Personal Bottles: Low initial cost but require continuous individual purchases.
2) Maintenance:
   - Door-Mounted Dispensers: May require more frequent refilling and maintenance due to higher usage.
   - Wall-Mounted Dispensers: Similar maintenance but often more accessible for refills.
   - Standalone Stations: Higher maintenance due to the need for regular cleaning and refilling.
   - Personal Bottles: Minimal maintenance; users are responsible for their own supplies.
3) Durability:
   - Door-Mounted Dispensers: Potentially more durable if designed well.
   - Wall-Mounted and Standalone: Similar durability concerns.
   - Personal Bottles: Prone to breakage and loss.

B. Benefits

1) Accessibility:
   - Door-Mounted Dispensers: Easily accessible as they are installed directly on entry points, encouraging use.
   - Wall-Mounted Dispensers: Also, accessible but may be overlooked if not positioned strategically.
   - Standalone Stations: Require additional space, which might not be feasible in all locations.
   - Personal Bottles: Convenient for individuals, but not universally available in public spaces.
2) Encouragement of Hygiene Practices:
   - Door-Mounted Dispensers: High visibility can promote regular use and improve public health compliance.
   - Wall-Mounted Dispensers: Effective but may not have the same direct impact as Door-Mounted options.
   - Standalone Stations: Effective but can be ignored if not placed at entry points.
   - Personal Bottles: Relies on individual responsibility, which can be inconsistent.
3) Infection Control:
   - Door-Mounted Dispensers: Directly addresses the need for hand sanitization upon entering and exiting spaces.
   - Wall-Mounted and Standalone: Provide sanitization but may not enforce immediate use as effectively.
   - Personal Bottles: Less effective in communal spaces, as users may forget or neglect to sanitize.

The elaboration of concept's design must always be followed by a market price and material costs study to be effective. The price is often too neglected in the design strategy. The consequences can be fatal: bad pricing is unfortunately one of the top reasons why start-ups and innovative projects fail. The cost price is the basis for determining the selling price and is therefore crucial to the success of the product. In order to ensure speed and efficiency, several components of the design will be purchased and not manufactured in order to arrive at the most cost-efficient product.

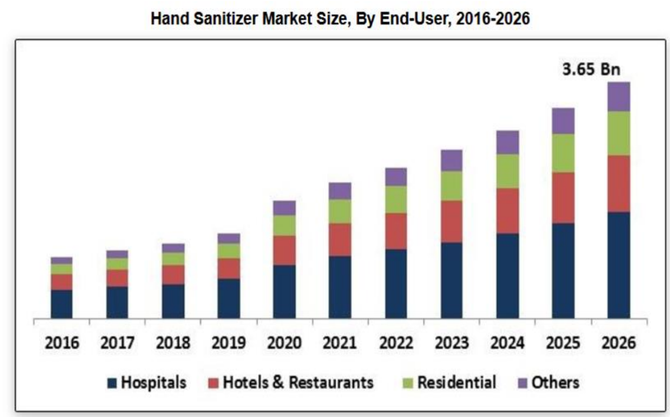


Figure 16: Hand Sanitizer Market Size, By End-User, 2016-2026

The market is relatively large and keep increasing, particularly with the spread of the coronavirus. It is projected that the market will reach a cap of around 3.65 billion dollars by 2026, which is quite big. In order to compete with the already existing concurrence, and keep the cost low, we searched on different manufacturing sites the components with the best prices that could meet our requirements.

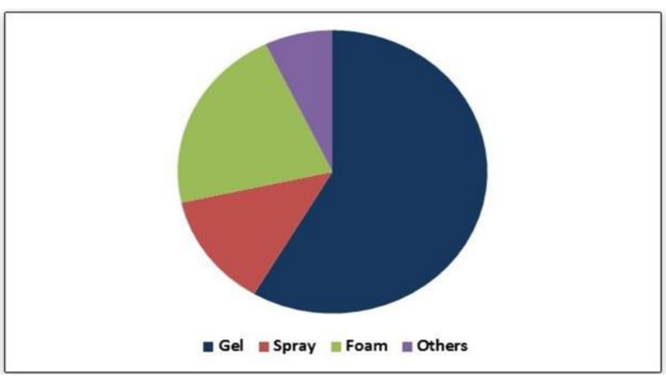


Figure 17: Usage proportion of different types of sanitizers

7.1. Components prices

The main goal of this section is to present the selection and price of the different elements used in the Door-Mounted dispenser:

A. Plate

Relatively cheap component, the most important constraint of the plate is the capacity to carry a load of more or less 1.5 kg.

B. Slider/Wheels

The slider turns out to be an essential component, being the most expensive of the device we had to look for the device to achieve our objectives but at the lowest cost. It is composed in part of a succession of wheels allowing the device to be held at the door and allowing it to move only transversely.

Among the different choices we had to find the most cost efficient one. Rail is use as a support to the door. In view of the relatively low price, a standard rail of sufficient length was chosen to meet the various requirements. The choice was for a 250 mm rail.

TABLE XII
COMPETITIVE COMPONENT'S PRICE

Component	Material	Quantity	Total Price
Rail	Carbon steel	1	5,98€
Wheels/Rollers	Chrome Steel	3	55,57€
Few bolts	Steel	4	5€
Plate	steel	1	0.2kg *0,6039 €/kg=0.12€
Spring	Carbon speed steel	1	5€
Trigger	Steel	1	2.5e-5 m3*7500kg/m3*0.603€/kg = 1.13€

VIII. Discussion

The ongoing COVID-19 pandemic has profoundly reshaped our understanding of transmission vectors, particularly regarding high-touch surfaces. As identified by the Centers for Disease Control and Prevention (CDC), surfaces such as doorknobs, light switches, and handles serve as significant potential pathways for viral transmission. The recent research from the Commonwealth Scientific and Industrial Research Organization (CSIRO) further underscores this concern, revealing that the SARS-CoV-2 virus can persist on smooth, non-porous surfaces for up to 28 days under ambient conditions. This longevity suggests that conventional disinfection protocols may be insufficient, highlighting a critical gap in our biosecurity measures.

The implications of these findings are multifaceted. Firstly, the mandatory implementation of biosecurity protocols across all sectors of society necessitates a renewed emphasis on hand hygiene practices. While handwashing remains the cornerstone of infection control, the proximity of high-touch surfaces to human interaction dictates that additional interventions are warranted. Given the prolonged survival of the virus on surfaces, the frequency of disinfection must be reevaluated and possibly intensified.

Moreover, the practical challenges associated with traditional disinfection methods cannot be overlooked. For instance, the presence of bulky cleaning equipment can be cumbersome in smaller spaces, leading to operational inefficiencies. Additionally, the variability in door designs and configurations precludes a one-size-fits-all approach to disinfection solutions. This variability further complicates the development of universally applicable interventions.

In light of these challenges, the necessity for hand sanitizers situated near high-touch surfaces becomes evident. The strategic placement of dispensers, particularly at entrances where the highest foot traffic occurs, can facilitate immediate hand hygiene actions upon contact with potentially contaminated surfaces. This approach not only enhances the overall efficacy of biosecurity measures but also promotes a culture of safety and vigilance among users.

To effectively address the design challenge of a Door-Mounted Hand Sanitizer Dispenser, a comprehensive understanding of user needs, requirements, and constraints throughout the product's lifecycle is essential. Translating these considerations into Product Design Specifications (PDS) will ensure that the final solution is not only functional but also user-friendly and adaptable to various settings. Engaging with stakeholders, including end-users, facility managers, and health experts, will be crucial in refining the design parameters and ensuring that the dispenser meets the practical realities of its intended environment.

IX. Conclusion

The integration of hand sanitization solutions into the architecture of our daily environments is a necessary evolution in the fight against COVID-19. By addressing the identified shortcomings and leveraging insights from current research, we can develop effective interventions that minimize transmission risks and promote public health safety in the new normal.

Moreover, the implementation of touchless dispensers in high-traffic areas could alleviate concerns surrounding surface contamination. By employing motion sensors or foot pedals, these dispensers can promote a hands-free experience, thereby minimizing the need for physical contact with potentially contaminated surfaces. This innovation not only addresses hygiene concerns but also encourages greater compliance with hand sanitization practices among the public, fostering a culture of health awareness and personal responsibility.

Furthermore, the scalability of this approach is noteworthy. Installing these dispensers in various settings, such as shopping malls, public transportation systems, and office buildings, can create a comprehensive network of hygiene stations that empower individuals to protect themselves and others. This proactive measure can be instrumental in mitigating the spread of infectious diseases, particularly in densely populated areas where traditional hygiene practices may fall short.

In summary, the expansion of door-mounted hand sanitizer dispensers to other high-touch and touchless areas offers a multifaceted solution to public health challenges. By prioritizing accessibility and user-friendly design, these adaptations can play a crucial role in safeguarding public health, enhancing community resilience, and ultimately contributing to a more hygienic environment in the face of ongoing and future health threats.

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