

# Crowdsourcing homemade facemasks: 772 U.S. health facilities' responses to personal protective equipment shortages in the first half of 2020

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## Abstract

**Purpose:** We examined 772 U.S. health facilities' responses to Personal Protective Equipment (PPE) shortages in the first half of 2020, as they crowdsourced face coverings from volunteer makers to be used as respiratory protection during crisis surge capacity. The purpose was to examine facemask specification requests from health facilities and develop a framework for crowdsourcing last resort PPE.

**Design/methodology/approach:** Homemade facemask donation requests from health facilities in 47 states systematically recorded in a public database maintained by public health graduate students at a major U.S. university were analysed. Open coding was used to content analyse facemask types and specifications, intended uses, delivery logistics and donation management strategies.

**Findings:** Our analysis revealed information gaps: Science-based information was scarce in 2020, leading to improvised specifications for facemask materials and designs. It also revealed the emergence of a crowdsourcing structure: Task specifications for volunteer facemasks makers, delivery logistics, and practical management of donations within the pandemic context. In anticipation of future pandemics and localised PPE shortages, we build on this empirical evidence to propose a framework for crowdsourcing science-informed facemasks from volunteers. Categorized within (a) logistics and workflow management, (b) task specifications and management, and (c) practical management of contributions

functional areas, the framework outlines the required tasks and specifications for crowdsourcing.

**Originality:** A novel empirically derived framework for crowdsourcing homemade facemasks is proposed, based on empirical analysis and crowdsourcing system design strategies. Our findings and the framework may be used for refining crisis capacity guidelines, as part of strategic planning and preparation for future pandemics that disrupt supply chains and cause shortages in protective equipment.

#### KEYWORDS

crowdsourcing framework, crowdsourcing workflow, facemask, last resort PPE, pandemic planning, surge capacity

#### Highlights

- At least 772 health facilities in 47 U.S. states experienced Personal Protective Equipment (PPE) shortages in 2020.
- During crisis surge capacity, they crowdsourced homemade masks from volunteers.
- The database shows information gaps and an emerging crowdsourcing structure.
- A crowdsourcing framework is essential for effective sourcing of homemade face coverings from volunteer makers during pandemics and surge capacity.

## 1 | INTRODUCTION

In mid-April 2020, as the World grappled with the spread of COVID-19, many health facilities in the United States depleted their available stock of Personal Protective Equipment (PPE) and were unable to fill PPE orders. They shifted to 'crisis or alternate' PPE conservation strategies<sup>1</sup> (para. 7) and sourced improvised PPE from volunteers. Volunteers needed instructions on materials, designs, production, and handling of masks, however little official guidance was available. According to CDC,<sup>2</sup> PPE shortages caused by the COVID-19 pandemic posed 'a tremendous challenge' to the U.S. health facilities, which had 'difficulty accessing the needed PPE' and 'had to identify alternate ways to provide patient care'<sup>2</sup> (para. 2). By March 2020, there were severe shortages of equipment needed to care for patients.<sup>3</sup> Months later, PPE shortages continued as health workers still reused or rationed single-use PPE.<sup>4</sup>

### 1.1 | PPE and surge capacity

Medical masks (e.g., surgical, procedural) are generally worn to protect the medical personnel from contact with blood and other body fluids during procedures and to limit the transmission of biological contaminants from staff to patients.<sup>5</sup> Respirators form a tight facial fit (seal) and are highly efficient in filtering airborne particles.<sup>6</sup> They go through rigorous certification process and are fit-tested with each user. Because PPE is especially important in infection control settings, it is in high demand and short supply during pandemics.

Surge capacity is defined as organizational ability to obtain the needed resources during the time of increased demand.<sup>7,8</sup> To address shortages, CDC<sup>9</sup> offers strategies for optimising PPE use, based on a 'continuum of options using the framework of surge capacity when PPE supplies are stressed, running low, or absent'<sup>(para.1)</sup>. The three levels of surge capacity are conventional, contingency, and crisis.<sup>9–11</sup> CDC<sup>9</sup><sup>(para.2)</sup> emphasises that the crisis capacity, during which suppliers cannot provide enough PPE, 'does not commensurate with U.S. standards of care'. Crisis capacity for masks includes conservation strategies such as cancelling elective procedures, using expired masks, reusing masks, etc.<sup>2</sup>

As a last resort, CDC<sup>2</sup> recommended that health personnel used homemade masks, which were not considered PPE as their protective capacity is unknown. Homemade facemasks may or may not meet the filtration efficiency or fluid barrier standards and are generally not intended for medical purposes.<sup>6</sup> Citing CDC recommendations, in April 2020, FDA authorised an emergency use of cloth facemasks by the public and by health workers in healthcare settings as source control.<sup>12</sup> Many U.S. health organisations responded to crisis surge capacity by crowdsourcing homemade masks, mobilising local crafters, community organisations, and volunteer groups; and engaging social and news media.<sup>13,14</sup>

## 2 | PURPOSE AND OBJECTIVES

The purpose was to develop a framework for crowdsourcing last resort PPE by health facilities during PPE shortages. To define the tasks and functions required for effective crowdsourcing, our objective was to analyse homemade facemask specifications and crowdsourcing strategies used by the U.S. health facilities during crisis capacity of the COVID-19 pandemic. We examined donation requests made by hundreds of health facilities between spring and early summer of 2020. When little guidance was available from regulatory agencies, how did the facilities formulate their homemade facemask specifications? What were the logistical considerations for crowdsourcing homemade masks? Our findings and the framework may help refine crisis capacity guidelines, as preparation for future pandemics that disrupt supply chains and cause shortages in respiratory protection equipment for healthcare workers and the public.

## 3 | CROWDSOURCING

Crowdsourcing helps solve problems in different settings, such as health systems, by a large number of individuals (the crowd) with relevant competencies.<sup>15</sup> Harnessing the skills and resources of the crowd may help achieve outcomes faster and at lower cost and risk.<sup>16,17</sup> The crowd—organisation's customers or general public—offers solutions to a problem posted by a crowdsourcer that may work with the crowd directly or through intermediaries.<sup>17–19</sup>

We conceptualise health organisations' mask donation requests as emergent and informal crowdsourcing of physical products to solve PPE shortages. Our analysis of such requests is combined with existing knowledge on crowdsourcing to develop a framework for crowdsourcing homemade facemasks from the general public.

## 4 | METHOD

We content analysed homemade facemask donation requests by health facilities in the U.S. compiled in a publicly available database created in the early months of the COVID-19 pandemic to help U.S. hospitals manage severe shortages of PPE. Systemically developed and maintained by graduate students in a public health programme at a major U.S. university, the database offers a list of health organisations requesting homemade facemask donations: hospitals, nursing homes, assisted living facilities, first responders, homeless shelters, outreach programs,

free-standing emergency rooms, and medical clinics. The database lists facility names, addresses and phone numbers, quantity of masks needed, whether a specific mask pattern is requested, and delivery instructions. We downloaded the database document on 17 June 2020 when it listed 772 facilities in 47 U.S. States and the District of Columbia (<https://docs.google.com/document/d/12a5Y00Z9RpHZk9Zkzl4NOj9CbzhFfoKjPLFFC-21LU/edit>). The database was listed among the United States mutual-aid networks and promoted by the New York Times' coronavirus briefing newsletter on 25 March 2020 as a means of helping the local communities.

## 4.1 | Data analysis

We first examined the organisations requiring crowdsourced facemasks by facility type. Then, mask requests were analysed to reveal common mask patterns and types, sewing instructions, and the number of masks requested. We also analysed instructions for pre-delivery mask preparation and delivering masks to health facilities. Open coding strategy was used for the content analysis.<sup>20</sup> We analysed the manifest content, as recorded by the database organisers. Initial categories were derived from the first ten entries. The rest of the database was reviewed request-by-request, to document emerging codes, aggregate repeating codes, and note any 'other' findings. The codes were discussed by authors to clarify them in the context of all available information for the requesting organisations. Our objective was to offer a rich, context-grounded summary of mask requests and crowdsourcing strategies used during the early months of the COVID-19 pandemic by hundreds of U.S. health facilities that experienced PPE shortages. We draw conclusions on how health-related organisations fulfilled their PPE needs in the face of scarcity of science-based guidance on facemask materials and designs. Based on our findings, we propose a framework for crowdsourcing last resort homemade masks.

## 5 | FINDINGS

The database listed hospitals, medical or health centres, which collectively represented healthcare systems, small regional/local hospitals, and university-affiliated medical centres. When a hospital within the same health system was listed separately, it was counted as a separate entry. Other facilities (25 out of 772, 3%) were rehabilitation care and behavioural health centres, hearing services, and non-medical facilities such as retirement communities and community outreach programs.

### 5.1 | Mask pattern and type requests

Most facilities (480 out of 772, 62%) requested specific masks and provided information, hyperlinks to the patterns and sewing instructions on their own websites or external sources. External links included health organisations (e.g., CDC, Cancer Treatment Centres of America), newspapers (e.g., New York Times), retail stores (e.g., Joann), blogs, webpages, and YouTube tutorials.

Among facilities that provided their own mask pattern and instructions was Kaiser Permanente that offered a printable mask pattern with sewing instructions, an accompanying video tutorial, and details about the appropriate materials, washing and reusability needs. The Cleveland Clinic and Deaconess Health System also created dedicated webpages for mask-making.

In general, the requested mask types fell into two main categories: shaped masks and pleated mask. Table 1 illustrates the requested mask types and various mask specifications.

Shaped masks generally conform to the contours of the face, sitting closer to the mouth and cheeks, formed by stitching shaped pattern pieces, usually with a vertical seam along the centre, while the sides extend on the cheeks

TABLE 1 Summary of mask type and specification requests

Mask pattern requests	<ul style="list-style-type: none"> <li>▪ 38% of health facilities did not request specific patterns/mask types</li> <li>▪ 62% requested specific masks, providing pattern resources</li> </ul>
Types of masks requested	<ul style="list-style-type: none"> <li>▪ Shaped masks</li> <li>▪ Pleated masks</li> </ul>
Mask specifications requested	<ul style="list-style-type: none"> <li>▪ <b>Fasteners:</b> Elastic ear or head loops; fabric ties, bias tape, binding, t-shirt yarn, ribbon</li> <li>▪ <b>Features:</b> Pocket/opening for filters; flexible nose wire; clear vinyl window</li> <li>▪ <b>Sizing:</b> Adult and children's; multiple patterns or mask dimensions</li> <li>▪ <b>Materials:</b> <ul style="list-style-type: none"> <li>- Cotton or cotton blend predominantly requested</li> <li>- Woven or knit distinction was not clarified; weave type was rarely specified; tight weave/dense specified by some</li> <li>- Other materials: Polyester, nonwoven interfacing, flannel, towelling, T-shirt knit, denim, surgical sheets</li> <li>- Other specifications: Latex-free, no rubber, no metal, pre-washed fabrics, new fabrics, withstand laundering</li> <li>- Insertable filters: Coffee filters, unused HEPA vacuum cleaner filters</li> <li>- Different colours and prints, for example, solids, bold, fun prints, light colours for soil visibility</li> </ul> </li> <li>▪ <b>Mask layers:</b> Ranging from no specification to 1, 2, 3, 4 layers (e.g., 2 layers with interfacing in-between)</li> <li>▪ <b>Mask-making kits or supplies</b> provided by some hospitals</li> </ul>

towards ears. Developed by clinicians at UnityPoint Health, the Olson Mask is an example of a shaped mask that was referenced by several facilities, with occasional modifications.<sup>21</sup> A subcategory of shaped masks, a circular mask is intended to fit over N95 respirators to extend usability; it can also be worn alone. The sides of these masks do not extend on the cheeks.

The pleated mask is similar to the rectangular medical masks. Two or three pleats run horizontally along the mask and create a raised cup shape over the nose and mouth when worn. Pleated and shaped masks had either ear or head loops, or head ties made of various types of materials. While some indicated preference for ties, others requested elastic ear or head loops, as ties would get tangled in laundry. Some patterns specified by health facilities had a built-in opening for inserting filters. The Olsen Mask is an example of a fitted mask allowing filter insertion. Built-in wire to help the mask fit around the nose was another requested feature. In Northside Gwinnett-Duluth mask, a pipe-cleaner was stitched in the upper edge of the mask. A few facilities recommended using similar flexible wires but others cautioned against wires, which could be hazardous after laundering. Intermountain Healthcare, for instance, scanned donated masks with a metal detector for wires or pins before laundering and distributing them to employees and patients.

Cotton and cotton-blend fabrics were predominantly requested for masks. Although tight-weave cotton was specified by some, the distinction between woven or knit fabrics was rarely stated. Kaiser Permanente helped volunteers choose more effective fabrics, both woven and knit cotton, with high density and specific fabric weight. Cotton type specifications included single ply T-shirt material, dress shirt, sheets, batik, quilting fabric, poplin. Other materials included polyester, flannel, or nonwovens used as mask layers. OSF Healthcare requested cotton outer layer and polyester inner layer, mentioning that two layers of cotton t-shirts material could be used as well, or polyester could be replaced by a cotton layer. Other fabric specifications included using water repellent fabrics or sprays, prewashed fabrics, using surgical sheets to make single-use masks, and using only new fabrics instead of old garments or bedding.

A few facilities provided mask-making kits or supplies to be used by volunteers. Northside Gwinnett-Duluth, for example, provided surgical instrument wrap material to use in combination with other necessary materials to make 'multi-use version of a surgical mask' that 'can sustain cleanings as approved by the Northside infection prevention team' and 'have the same or better protective value' as single-use surgical masks. A small number of facilities only accepted masks that met specified requirements; however, many more facilities were also willing to accept masks that deviated from them.

Mask or pattern types were unspecified by 292 facilities (38%), of which less than 10% (62 of 292) gave other specifications, referring to mask wearers' demographics, mask materials, ties, etc., as shown in Table 1.

## 5.2 | Mask delivery to health facilities

Mask delivery methods varied, as facilities made efforts to minimise contact with mask contributors and reduce traffic. Indiana University Health Network, for instance, provided a form that asked to wait for specific pick up or delivery instructions; their supply chain operations team assessed each donation. Other methods included dropping masks off at designated locations, provision of drop boxes, pick up arrangements, and mailing to addresses provided (Table 2). Drop off locations included local fire stations, police departments, specific drop boxes or areas at hospitals or other locations in the community. With a drive-by drop off option, employees collected donated masks from the car.

The West Virginia Association of Local Health Departments implemented a collection programme for homemade masks and distributed them to health facilities in need. Avera Health also accepted facemask donations through its central distribution hub, in addition to pre-arranged pickup or delivery to its system hospitals in multiple states.

## 5.3 | Pre-delivery mask preparation

Although most health facilities did not provide such instructions, a few facilities specified how to prepare masks for donating: Put the masks in plastic bags or containers; bag each mask individually; bundle no more than a specific number of masks (Table 2). While one facility intended to launder crowdsourced masks, others requested washing the

TABLE 2 Requirements for mask pre-delivery preparation, delivery option, intended uses, and quantities

Pre-delivery preparation	<ul style="list-style-type: none"> <li>▪ Requests with no pre-delivery specifications were most common</li> <li>▪ Limited specifications generally related to washing and packaging:               <ul style="list-style-type: none"> <li>- Sewers should wash the masks before donating</li> <li>- Facilities will wash/sanitise or treat masks</li> <li>- Package in plastic bags/containers, individually or in bundles, before donating</li> </ul> </li> </ul>
Delivery options	<ul style="list-style-type: none"> <li>▪ Drop off (pre-arranged or open): Drive-by, drop box, specific locations (e.g., police, loading dock)</li> <li>▪ Arranged pick up by personnel</li> <li>▪ Mailing</li> </ul>
Intended uses	<ul style="list-style-type: none"> <li>▪ Healthcare workers, patients, visitors, nonclinical settings, distributing to community members, covering N95 respirators to extend use, single or multiple uses, children and adult, people with latex allergies</li> </ul>
Quantity requested	<ul style="list-style-type: none"> <li>▪ Most facilities requested as many masks as possible</li> <li>▪ Several noted specific numbers, ranging from 20 to hundreds</li> </ul>
Other product requested	<ul style="list-style-type: none"> <li>▪ Hospital gowns, surgical caps or hair covers, button headbands, mask headbands, 3D printed ear guards, beard covers, protective hoods, and face shields</li> </ul>

masks before donating. Lawrence General Hospital in Massachusetts asked to wash the masks with scent-free soap, dry with high heat, and individually bag each facemask. Some facilities requested to clearly mark the boxes with the content, quantity and contact information.

## 5.4 | Requested mask quantities and intended uses

Most facilities listed in the database intended to crowdsource as many masks as possible. Few smaller facilities requested specific number of masks based on employee numbers. Most facilities did not provide information on the intended number/length of uses for masks. When such information was given, it varied widely. Mask washability and durability for extended use was emphasised by some facilities. Others requested masks for single use only. Kaweah Delta Medical Centre in California indicated that the masks were for 'single use only in crisis mode when there are no hospital-grade masks available.'

The database did not include information specifically on intended mask uses. However, the analysis of mask requests revealed several intended uses: for health workers, for distribution to community organisations and individuals in need of masks, and to help conserve 'precious protective equipment,' and as covers for N95 respirators to help extend their usability (Table 2). Some facilities, like Cleveland Clinic, emphasised that donated masks were for 'reinforcing cough etiquette' and not intended to be used as PPE.

## 6 | DISCUSSION

The database analysis revealed a healthcare system in crisis—over 700 health organisations in nearly all US states in need of last resort means of respiratory protection. The database serves as a vivid illustration of poor pandemic preparedness of the national healthcare system, amid PPE shortages, inadequate stockpiles, and disrupted supply chains. At the same time, the database reveals creative problem solving on a nationwide scale, local experimentation, and a genuine concern for the wellbeing of frontline personnel, patients, and community members. Public Health graduate students acted as crowdsourcing intermediaries that collected information from facemask seekers and broadcasted them to local volunteers with sewing expertise.<sup>17,22</sup>

A review of the pre-COVID-19 literature on PPE and pandemic preparedness leaves no doubt that PPE shortages were predicted. A report by a National Academies special committee stated that 'although the time at which a pandemic might arrive is unknown, most public health officials hold the opinion that the world is overdue for such an event'<sup>23</sup>(p. 1). Anticipating supply chain disruptions, the committee recommended solutions to PPE shortages, such as dual sourcing of highest priority supplies, including N95 respirators. Nevertheless, half a year into the COVID-19 pandemic the American Nurses Association (ANA) reported that N95 respirator reuse was on the rise: two-thirds of 21,500 ANA members said in a survey that they were required to reuse N95s.<sup>24</sup> Reports of PPE reuse and rations continued 9 months into the pandemic.<sup>4</sup>

Given pandemic-level demand for respirators and facemasks,<sup>25,26</sup> they should be prioritised for use by frontline health workers and other essential employees, followed by high-risk groups. The general public needs science-based guidance on mask materials and designs so that crowdsourcing systems can be deployed on a short notice to produce non-medical grade equipment for respiratory protection. Similarly, health organisations need guidance on effective crowdsourcing strategies and practical management of these crowdsourced masks.

U.S. health organisations instituted various strategies for crowdsourcing facemasks, offering requirements for mask design and materials, pre-delivery preparation, delivery methods, and post-delivery handling. As evident in the diversity of specifications, health organisations had to improvise—some had detailed specifications, but most submitted general requests. The analysis of specifications revealed often opposing ideas related to mask types, fabrics, designs, and pre-donation preparation. Most organisations, however, did not seem to possess or refer to

science-based information on producing effective masks. Facilities directed volunteers to Internet sources linked to health organisations and much more frequently to non-scientific mask making sources, such as craft websites and newspaper articles.

Although cotton was the most requested fabric specification, few facilities detailed the types of fabrics and fibres to use for masks. Cotton fibres and yarns can be made into a wide range of fabrics with varied properties (e.g., weight, density, tensile strength, filtration capacity) used in many different applications. Sufficient knowledge exists on cotton and other fibres and fabrics to make science-informed decisions on homemade mask material selection, however, health facilities were not equipped to access this knowledge. For example, given viral spread mechanisms and available information on fabric properties and structure, fabrics with tighter weave and high thread count would be more protective than stretchy jersey knit.

Similarly, we see evidence that existing knowledge on materials and technologies used for medical masks and respirators was rarely applied to make informed material choices. For instance, medical masks and respirators are typically made of polypropylene nonwovens. The irregular and complex fiberweb pathways of nonwovens enhance their filtrating capacity.<sup>23</sup> Polypropylene can be charged to further increase filtration efficiency through electrostatic attraction, without adding additional weight or density to the material.<sup>27</sup> Spunbonded polypropylene can be found in many consumer products and is an option for crowdsourced masks.<sup>27</sup> Yet, polypropylene was not specified by health facilities. It could be due to material shortages, insufficient access to information, or both.

Varied specifications likely reflect local, last-minute improvisations in response to crisis surge capacity, as well as inability to close information gaps on how to source last resort PPE that maximum effectiveness. This study offers empirical evidence that even though there was a significant scientific knowledge base about cotton and other types of fibres and fabrics, many health facilities did not use it to formulate effective specifications for crowdsourced masks. There is an urgent need for readily available resources and guidelines that could be easily accessed and followed by health organisations during crisis capacity. Such guidelines should address mask production specifics, pre-delivery mask preparation (laundering, packaging), delivery instructions, and post-delivery donation management. These details were omitted in most requests we analysed but are needed for planning a system for crowdsourcing last resort PPE. Contactless methods of delivering facemask donations, centralised collection systems and other strategies documented here provide a starting point for planning future crowdsourcing systems.

## 7 | AN EMPIRICAL FRAMEWORK FOR CROWDSOURCING HOMEMADE FACEMASKS

A national pandemic preparedness plan should include guidelines for crowdsourcing homemade, non-medical grade facemasks, which provide source control respiratory protection and can be used as last resort PPE. Our findings pave the way to an empirically grounded framework for an intermediary-enabled community facemask crowdsourcing system. Following Afuah and Tucci,<sup>22</sup> such crowdsourcing is defined as a collaboration-based strategy, where an intermediary or, alternatively, the hospital itself collects specifications from a health facility and broadcasts them to volunteers. Next, volunteer mask makers self-select to implement science-based solutions and processes provided by the health organisation to create specified masks.

Hetmank<sup>16</sup> identified four components that are included in typical crowdsourcing systems and a range of functions that should be addressed within each component. These are (1) user management (register user, evaluate user, form user groups, enable coordination), (2) task management (design task, assign task), (3) contribution management (evaluate contribution, select contribution), and (4) workflow management (define workflow, manage workflow).<sup>16</sup> Considering typical crowdsourcing system functions, requirements for crowdsourcing physical products, and the insights gained through our analysis, we outline essential considerations for crowdsourcing homemade facemasks (Figure 1).



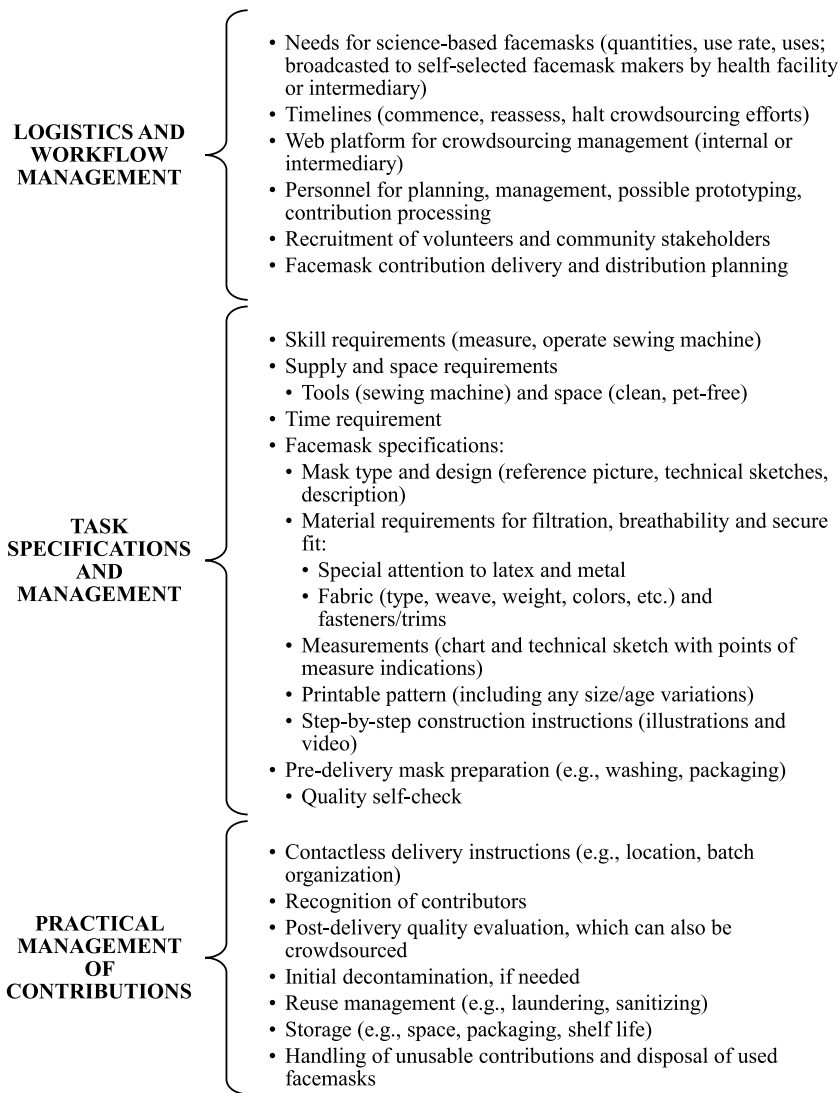


FIGURE 1 Empirical framework for facemask crowdsourcing

## 7.1 | Logistics and workflow management

In complex crowdsourcing systems, logistics and workflow management are of crucial importance for assuring high-quality contributions.<sup>16</sup> Figure 1 summarises the logistics and workflow management to achieve facemask crowdsourcing objectives. First, homemade facemask needs should be identified by a health organisation or an intermediary who will inform the crowd and offer science-based guidelines. Estimated quantity could be calculated based on intended uses, PPE supply conditions, and use rate consideration. These considerations could also be helpful in defining timelines, including when the efforts should start and end. A web platform for managing crowdsourcing can be a website internal to one health organisation or a centrally operated website, perhaps managed by the administration of a health system. An external government body such as CDC or, as in our study, a group of public health students could act as an intermediary, providing a platform for connecting multiple health facilities in need of masks with volunteers who can make them. Intermediaries typically manage the process, the crowd, and the technology.<sup>17</sup>

The Public Health students did not manage the crowd or the process, but they created and managed the database, connected with crowdsourcers, and communicated facemask task specifications to potential crowdsourcees (volunteer mask-makers). The web platform, internal, central, or external, should contain task specification and instructions to volunteers. It may also provide interaction space for volunteers, indicate contact information, allow for answering volunteer inquires, and offer social media handles and links to useful resources.

Identifying recruitment strategies and coordinating volunteer mask-makers is essential: How would the volunteers be reached and informed of the health facility's facemask needs? Posting information on the website, social media, local newspapers, and news channels are some options. Local sewing/quilting groups and other organisations would also be helpful for this purpose for local healthcare organisations. Members of these groups could form teams and start collaborative mask-making initiatives, maximising on collective skills and resources to support local communities. Zogaj et al.<sup>17</sup> state that in crowdsourcing systems, tasks are usually completed by individuals independently or by teams that form to solve a problem together. Local apparel manufacturing companies could also be an option as they are already set up for production of textile products. Because outbreak control measures would affect how crowdsourced masks are handled, the model also includes a contribution delivery function.

## 7.2 | Task specifications and management

The quality of contributions highly depends on the quality of task specifications.<sup>16,22</sup> The task is about what needs to be completed and how, which includes the skills needed to complete the task. For making homemade masks, the skills may include measuring and cutting fabric, operating a home-sewing machine, understanding basic pattern and sewing concepts, etc. Hetmank<sup>16</sup> argued for clearly defined tasks, whereas Afuah and Tucci<sup>22</sup> warned that well understood tasks help decrease interaction costs between crowdsourcers and volunteers.

Our framework includes a range of requirements, constraints, technical specifications for mask design, assembly, pre-delivery preparation, and quality control measures. Supply and space requirements could include a home sewing machine, basic sewing supplies, thread, etc., as well as pandemic-relevant specifications for the work area and conditions (e.g., clean/disinfected workspace, hand hygiene, no pets). Task specifications include the time requirement—the approximate length of time required for a person possessing the required skills to make one mask.

A significant part of task specification and management component of the crowdsourcing framework is the facemask specifications—material selection, technical details, and mask construction processes. These specifications define how the mask should be made and how the finished product should look and perform, based on relevant scientific knowledge about the virus spread and pandemic control, mask fit requirements, filtration efficiency and breathability standards of various materials, various fibre and fabric types, textile product construction techniques and technical aspects, and other relevant information. For example, for material specification, the type of fabrics should be clearly indicated for making masks, considering filtration capacity and breathability requirements. In addition, materials for fasteners and other components (e.g., flexible nose piece) should be specified.

Mask type and design features are part of the task specification, accomplished by using a reference image of a sample mask, technical sketches illustrating different design features, and textual descriptions. The type of the mask, its design elements and fit must be similarly informed by scientific understanding. For example, gaps created at the edges of the mask due to improper fit greatly reduce its filtration capacity.<sup>26</sup> Homemade masks may not be comparable to certified masks, but a sample mask created based on science-based specifications should be evaluated for filtration efficiency, breathability, fit and other aspects such as washability, before finalising its selection for crowdsourcing. Independent laboratories or university-affiliated researchers could conduct the evaluation. Ideally, CDC or other relevant organisations would provide science-based guidance and specifications for homemade masks, and other health organisations could refer to these resources.

Mask specifications include finished mask measurements. A measurement chart along with mask sketch with points of measure shown could be used for different mask sizes. It can be a printable mask pattern that shows mask

size variations or separate patterns for each size. Volunteers need step-by-step instructions for mask construction, including images of main steps and an instructional video. Pre-delivery mask preparation instructions are about washing the masks, packaging them individually or in batches, and labelling them prior to donating. The final component of task specification is a quality self-check by each volunteer. To help the healthcare facility avoid getting facemasks that are not useful, a structured checklist could be developed addressing main task requirements, from specified construction technics to mask packaging.

### 7.3 | Practical management of contributions

Contactless delivery options and initial handling procedures are important when crowdsourcing physical products within a pandemic context. Received masks are subject to a quality evaluation to ensure they meet acceptable standards.<sup>16</sup> Several randomly selected samples from each batch of facemasks received can be checked to address any shortcomings on the task specification Q&A section, social media platform, or website. Addressing issues early and publicly may increase the quality of future contributions. It may be necessary to establish more rigorous evaluation methods, based on the desired mask quality. Masks may need initial decontamination by washing or otherwise sanitising after they are received. Alternatively, volunteers can wash the masks before donating. Washing and sanitising masks is a consideration for reuse of the masks as well. Based on our analysis, some health organisations utilised homemade masks as single-use PPE. Others washed and reused them. For reusing the masks, sanitising, laundering, and possibly packaging processes should be established. Storage needs for new mask contributions as well as the reused ones should also be identified, including space for storing the masks, packaging needs, as well as shelf life. Facilities also need to identify strategies for handling unusable contributions (e.g., disposal, donating). Low-quality and insufficient contributions are considered some of the possible issues in crowdsourcing.<sup>17</sup> Disposal of used face-mask should also be planned within a crowdsourcing system. When the masks would be thrown away (e.g., after certain number of uses) and how are important considerations.

Our model includes recognition of contributors. We also recognise value capture opportunities—benefits that offset involvement costs. The most significant value capture is likely to happen at the community level when volunteers learn to make science-based facemasks and share their products and knowledge with other community members and organisations.

## 8 | CONCLUSIONS

We analysed facemask donation requests by U.S. health facilities as they faced PPE shortages due to the COVID-19 pandemic. Based on our findings and existing crowdsourcing knowledge, we proposed an empirical framework for homemade facemask crowdsourcing by health facilities consisting of (a) logistics and workflow management, (b) task specifications and management, and (c) practical management of contribution functional areas. It outlines evidence-based details on defining and managing workflows, tasks, and contributions, from specifications of what needs to be done, by whom, for whom, to defining a system for managing crowdsourced contributions with quality controls and instructions on preparing and safely delivering donations (Figure 1).

Our study highlights the importance of including alternative production of last resort PPE during crisis surge capacity into a comprehensive pandemic planning strategy. It is a response measure in addition to industrial mass production and stockpiling of PPE. Effective crowdsourcing systems help overcome lack of time, skills, and resources.<sup>17</sup> The crowdsourcing framework could find applications in the production of other healthcare items such as surgical gown or caps, which can also be in high demand and short supply during pandemics.

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## CONFLICT OF INTEREST

None declared for all authors.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available in a document titled "Hospitals Accepting Homemade Masks at Hospitals Accepting Homemade Masks." These data were derived from the following resources available in the public domain: a hospital list maintained by public health students. <https://docs.google.com/document/d/12a5YO0Z9RpHZk9ZkzI4NOj9CbzhFfoKjPLFFC-21LU/edit>

## ETHICS STATEMENT

Not applicable.

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