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## Breaking the chain: Governmental frugal innovation in Kerala to combat the COVID-19 pandemic

Soumodip Sarkar

CEPAGE-UE and Department of Management, University of Évora, Palácio do Vimioso (Gab. 224), Largo Marquês de Marialva, 8, 7000-809 Évora, Portugal  
Fellow (Associate), Asia Centre, Harvard University, 1730 Cambridge St, Cambridge, MA 02138, USA

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### ABSTRACT

As the COVID-19 pandemic causes unprecedented disruptions in citizens' lives and work, prompting a wide range of responses from governments across the globe. The southern Indian state of Kerala, India's COVID-19 "ground zero", stands out with a fatality rate at a fraction of other richer Indian states and countries. This has happened despite the state presenting strong vulnerabilities to COVID-19. Using the theoretical lens of frugal innovation, I analyse how the Kerala State Government (KSG) combated the spread of COVID-19. This research uncovers the mechanisms at play as KSG implemented and used frugal technologies as platforms that helped decision making and strategy to fight the pandemic. I find a rich interplay of frugal innovations promoted by the government, in partnership with research institutes and private sector actors, which are cheap and efficacious. The study defines and promotes the concept of government frugal innovation (GFI) and provides valuable insights and tools to help governments navigate and effectively respond to this crisis, encouraging the rest of the world to learn from Kerala's experience. My conceptual model characterizes GFI as involving collaborative aspects, and holds practical implications beyond the times of crises.

### 1. Introduction

On January 24, 2020, a 23-year-old passenger disembarked at Kochi airport in the southern Indian state of Kerala, and from there went by car to her hometown, a distance of about 85 kms. This passenger had just returned from Wuhan, China, where she studies medicine. A few days later, she and two other students who had also come from Wuhan, were declared as the first known Indian cases of the COVID-19 disease, caused by the severe acute respiratory syndrome 2 virus (SARS-CoV-2). First detected in Wuhan, China, in late 2019, and the subsequent exponential global spread of this virus strain to the CoV-2, "threatens to become one of the most difficult tests faced by humanity in modern history" (WEF, 2020). With a population of about 36 million people, Kerala became India's "ground zero" of a pandemic that has shaken the world, so far infected 67million, and killed over 1.5 million people worldwide (as of 8 December, 2020). Memories of prior epidemics in Kerala were still fresh, the most recent being the Nipah virus that struck the state in, 2018, killing 17 people.

On 11 March, 2020, the World Health Organization (WHO) declared the COVID-19 outbreak as a pandemic – the worldwide spread of a new disease. A couple of weeks later, on 24 March, 2020, the Indian Prime-

Minister announced a nationwide lockdown to combat the spread of the disease. By then Kerala had 107 reported cases of COVID-19, a fifth of India's total and the largest of any state. A few months on, the state's experience in managing the pandemic is being hailed as the "Kerala model", encouraging the rest of the world to learn from its experience (Faleiro, 2020). Despite an anticipated rise in COVID-19 cases both due to migrants returning from the Middle East, and the easing of lockdown restrictions by the Indian government, Kerala has managed to curb the Case Fatality Ratio or CFR, which reflects the ability of the government to limit the impact of the virus, to only 0.37%, which is one of the lowest in the world (Worldometers.info, 2020) and in India, where the CFR is 1.46% (COVID-19 India Org Data Operations Group, 2020), over the COVID-19 affected duration till date. Kerala's CFR remains one of the lowest in the world, while much richer states of Punjab suffered 3.5%, Maharashtra 2.6%, and Gujarat 2.1% (as of 8 December). The Economist (2020b) termed Kerala's handling as "Bargain abatement" with "stellar results" an allusion to successful containment involving very little expenditure. The low-cost pandemic combating techniques highlight the role of 'frugal innovations' developed and orchestrated by the Kerala State Government (KSG). Governments worldwide have deployed a range of technological tools to try to stay ahead and flatten the curve.

E-mail address: [ssarkar@uevora.pt](mailto:ssarkar@uevora.pt).

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Resource-constraints have been known to trigger cost-effective, good-quality solutions (Gibbert, Hoegl, & Valikangas, 2014; Lim & Fujimoto, 2019). Innovations emerging from these limited resource settings are often deemed frugal, sometimes involving adaptations and reengineering of pre-existing technologies (Sarkar & Pansera, 2017). While depending upon the perspectives given the many definitions (Bhatti et al., 2017), frugal innovations are generally understood to be low-cost and efficacious, new or adapted products (or services), mostly emerging from contexts of institutional voids and resource constraints, involving the creative use of existing resources. Cases of frugal innovations in healthcare include cataract surgery for about €25 by the Aravind Eye Hospital, General Electric's approximately €900 EKG machines, and Aurolab's high-quality, €4 intraocular lenses (Bhatti et al., 2017; Govindarajan & Trimble, 2012). Low costs do not necessarily mean low quality, for instance Aurolab's low-cost lenses are exported worldwide (Bhatti et al., 2017).

The speed and severity of the viral transmission have prompted many frugal innovative responses globally, especially from developing economies (Agarwal, Brem, & Dwivedi, 2020; Harris et al., 2020), including Kerala (Economist, 2020b). These innovations can be effective given the constraints faced by the governments (Harris et al., 2020), yet do not imply poor quality. The deployment of frugal innovations by the KSG motivates my study, prompting the following questions - what are the types and nature of frugal innovations deployed by the KSG to combat the spread of COVID-19? what are the mechanisms that underlie KSG's characteristic response through frugal innovations?

Mine is a qualitative approach, particularly recommended in crisis scenarios, with case and anecdotal data exemplifying why some organizations are "more successful in responding to (or even surviving) unexpected, abrupt and/or 'extreme' events" (Linnenluecke, 2017, p. 4). I employ data collected from multiple secondary sources to analyse KSG's implementation and use of frugal technologies, as one response to COVID-19. I uncover a wide range of cheap and efficacious innovations promoted by the government (state, local and government agencies), frequently involving partnerships with research institutes and private sector actors.

My study contributes to theory, practice and policy discourse (explored in more detail in the discussion section). I extend frugal innovation conversations beyond the realms of private sector engagement, to include the government as an agency in the development of technology solutions, adding both breadth and depth to the domain. My study also initiates theoretical conversations around the role of cooperation in the development of frugal innovations, which has only found sporadic mention. At a policy level, my study contributes by showing how cheap and adapted technologies can be efficacious in combating the pandemic in particular and emphasizing how frugal innovations can be a way to cope with reduced public spending in general. When it comes to healthcare, I also respond to the plea for richer countries to learn more from poorer ones (Crisp, 2010). In the context of the pandemic, KSG's frugal innovation strategies are an illustrative response to the appeal for the development of innovative and low-cost interventions (Harris et al., 2020). Overall, this study proposes greater consideration of government frugal innovations as a way of providing low-cost and efficacious solutions. While frugal innovation emerges as an important point in the agenda of developed economies, my study draws attention to a huge reservoir of potential frugal solutions, suggesting that these can be absorbed and adapted to more developed contexts (Radjou, Prabhu, & Ahuja, 2012).

This paper is structured as follows. In Section 2, I provide a brief overview of the frugal innovation literature and define government frugal innovation (GFI). Section 3 frames our empirical setting and explains the methodology. Section 4 presents the main findings, while in Section 5, I explain these findings, including discussing the theoretical and practical contributions. In the final section, I highlight some limitations of my research, and point out to potential avenues of future research.

## 2. Theoretical framing- Frugal innovation

Innovation is considered a critical source of competitive advantage (Dess & Picken, 2000; Tushman & O'Reilly, 1996), and the most important determinant of organizational performance (Mone, McKinley, & Barker III, 1998). Multifaceted and contextual, innovation has become an 'umbrella' construct, studied at multiple levels- product or process, organizational, or market; and at the regional or national level. A useful conceptualization of public sector innovation is "new or improved methods of promoting an organization or its services; new or improved methods of influencing the behaviour of and interactions with intermediate and end users (citizens, firms or other institutions); or the initial commercialization of public services, whenever they are sold to customers." (Scupola & Zanfei, 2016, p. 238).

The Western centrality of innovation studies has been brought into sharp focus with the rise of China and India, and the distinct ways innovations emerge in these economies. In resource scarce countries, shortage does not impede innovation, but can rather shape it. Stripping down resource needs to the minimum, the innovation process undertaken in the context of scarcity, has led researchers to conceptualize such innovations as being "frugal", drawn from the Latin word- *frugalis*. Frugal innovation essentially explicates the phenomenon as involving simplifications (Lim & Fujimoto, 2019), delivering fundamental needs with scant resources (Economist, 2010; Radjou et al., 2012.; Zeschky, Widenmayer, & Gassmann, 2011), and at lower costs (Zeschky, Winterhalter, & Gassmann, 2014). Frugal innovation perspectives sometimes invoke the notion of appropriate technologies in healthcare (Bianchi, Bianco, Ardanche, & Schenck, 2017), and a set of small-scale, labour-intensive technologies, easy to operate and maintain (Schumacher, 1973). In India, General Electric developed a handheld portable electrocardiogram (ECG) device for less than €900, not only much cheaper than similar devices elsewhere, but also adapted for the rugged and infrastructurally challenged settings of poorer countries<sup>1</sup>.

The rising interest on how poorer countries innovate, has also led to the forging of terminology such as 'frugal innovation' (Bound & Thornton, 2012), 'reverse innovation' (Govindarajan & Trimble, 2012), 'Jugaad innovation' (Radjou et al., 2012), 'BOP innovation' (Prahallad, 2012), 'Gandhian innovation' (Prahallad & Mashelkar, 2010), 'empathetic innovation' (Gupta, 2010), 'long tail and long tailoring' innovation (Anderson & Markides, 2007), 'below-the-radar innovation' (Kaplinsky, 2011), 'inclusive innovation' (George, McGahan, & Prabhu, 2012), and 'grassroots innovation' (Sarkar & Pansera, 2017). Despite the different ways of framing, a common theme within these approaches is that frugal innovation arises from contexts characterized by material, financial and skilled human resource scarcity, to produce goods or services which can get the 'job done' to satisfy the needs of less endowed consumers.

Among the early conceptualizations of frugal innovation is 'doing more with less for more (people)' Prahallad & Mashelkar (2010, p.132). While this gives a broad framing of the phenomenon, growing relevance of the phenomenon has led to a number of other definitions being proposed. These definitions have tended to rest principally on dimensions of affordability; functionality as being 'good-enough'; and as serving the needs of the poor (frequently those residing in the 'Bottom of the Pyramid, or BOP'). This trilogy of dimensions can be encountered in many definitions of frugal innovation (e.g., Agarwal, Grottke, Mishra, & Brem, 2016; Agnihotri, 2015; George et al., 2012).

Despite frugal innovation sometimes associated with low-cost improvisations implicating connotations of slapdash, extemporaneous *jugaad* approaches (Radjou et al., 2012), recent efforts have tried to move the conversation to a more refined understanding of what frugal innovation means. The Economist (2010) which helped popularize the concept a decade ago, had cautioned that "There is more to this than simply cutting costs to the bone.... Frugal innovation is not just about redesigning products; it involves rethinking entire production processes and business models". Similarly, Zeschky et al. (2014) argued that frugal

innovations were not simply “re-engineered solutions but originally developed products or services for very specific applications in resource-constrained environments” (p. 23).

As scholars begin to encounter practices of frugal innovation in developed economies (e.g. Kroll et al., 2015; Lim & Fujimoto, 2019; Weyrauch & Herstatt, 2017) the discussion in this domain has moved to an increased recognition that being frugal doesn't necessarily imply sacrificing on performance levels. Weyrauch and Herstatt (2017) in their study on the practice of frugal innovation in the German industry, found the prevalence of three main attributes: substantial cost reduction, concentration on core functionalities, and optimized performance level. Performance is considered optimized when it corresponds to the desired level, and not overshoots it, as in the case of conventional innovation. This greater emphasis on performance moves the debate of frugal solutions on being centred not only on low price, but also of high quality, ease of use, and robustness (e.g., Lim & Fujimoto, 2019; Rao, 2013; Weyrauch, 2018; Zeschky et al., 2014). This re-examination of frugal as geared towards performance underpins ‘function analysis’ which “focuses on what functions must be included in an object in order to fulfil the requirements placed on the object” (VDI, 2019, p. 3, cited from Winkler, Ulz, Knöbl, & Lercher, 2020). India serves as an ‘ideal laboratory’ for conceiving and introducing frugal innovation, and a ‘lead market’ for frugal innovations (Pisoni, Michelini, & Martignoni, 2018; Tiwari & Herstatt, 2012). This can even extend to cases involving complex designs, technologies or processes. India's cheap Tata Nano car, enhanced cost–performance frontiers by making design/architectural changes (Lim & Fujimoto, 2019). Arvind Eye care is an illustration of frugal innovation focused on processes, by introducing ‘assembly-line’ type approach to create a new model for cataract surgeries (Rangan & Thulasiraj, 2007). Frugal innovations in healthcare do not imply low quality but rather the provision of safe healthcare in the most effective manner, given the circumstances and constraints (Bhatti et al., 2017; Harris et al., 2020).

While frugal innovation is a useful lens to explain resource-constrained innovations, the literature has limited itself to explaining *low-cost product* innovations by the private sector, to serve the poor. This burgeoning literature suffers from many of the same failings as the much larger innovation literature, for instance ignoring the collaborative process of knowledge and resource exchanges. Moreover, extant literature overlooks the role that governments play in leading innovation processes to produce robust, of high-performance technological solutions, at low costs. I define governmental frugal innovation (GFI) as involving minimal resources to produce efficacious (or modify existing) goods or services at low costs developed by, in partnership with, or facilitated by the government, with the aim of improving social welfare. GFIs not only harbours the promise of low-cost innovations, it also involves more open platforms with the participation of other public sector or governmental units, along with firms, and could also involve citizens, and arises in resource scarce contexts.

### 3. Research methodology

#### 3.1. Situational context: The state of Kerala

Kerala is a narrow strip of land between the Arabian Sea and the Western Ghats, located in the southwest corner of India, home to 36 million inhabitants. Starting from the 1970s, Kerala has strongly pursued a social development strategy resting on health and education, often touted as the ‘Kerala Model of Development’ (Parayil, 1996; Véron, 2001). While lagging on indicators of industrial development, Kerala ranks highest in India on the Human Development Index, and life expectancy is 73.2 years (Census Data, 2011) and an infant-mortality rate of 10 per 1000 live births (National Institute for Transforming India, 2016). These are far above the country averages of 69 and 30 respectively (The World Bank, 2019), at par with those of developed economies.

While Kerala has a decentralized and well-developed health system, closer inspection reveals Kerala's striking vulnerabilities in the context of COVID-19. Kerala's population density is among the highest in the world, with 919 persons per km<sup>2</sup>, as compared to 417 for India as a whole or China's 123 (Véron, 2001). Over 60% of COVID-19 victims in India are asymptomatic<sup>3</sup>, with higher density populations catalysing viral spread (Rocklöv & Sjödin, 2020). Kerala's high density is therefore a challenge to promote social distancing and isolation measures. Moreover, at 13.5% of the population, Kerala also has the highest percentage of citizens over the age of 60, a demographic group at risk from the virus, much higher than the India average of 8.2%. Kerala's per capita income is €2400, a fraction of Belgium (€40,200), Germany (€41,400), or the UK (€36,500). Kerala has only 1.07 doctors and 2.97 hospital beds per 1000 people, much less than countries like Belgium and Germany with 6.19 and 8 beds per 1000 people, respectively.

Kerala's migrant population is another major challenge. Over 1.6 million Keralites<sup>4</sup> work abroad, mostly in the UAE, sending about 15 billion Euros<sup>5</sup> to the state, more than 10% of the country's total remittance. These transfers account for over 35% of the state's domestic product, the highest in the country. Over 100,000 of these overseas migrants returned to Kerala just before the Lockdown, or as part of the ‘Vande Bharat’ mission (bringing Indian expatriates back), 84,000 of whom were quarantined in the state. Thousands have been returning regularly since then, being out of work in their host countries, further enhancing the risk of contagion. Moreover, attracted by Kerala's higher wages, the state has a huge migrant population of 2.5 million<sup>6</sup>. Following the lockdown these migrant workers were left jobless, unable to go back to their home states. Social distancing and hygiene emerged consequently as big challenges from the agglomeration of these migrants.

Kerala has one of the highest rates of communicable diseases, often described as the diabetes capital of the country. A large number of people suffer from heart, respiratory and liver diseases. The state was also the most affected by previous epidemics such as the Nipah Virus Outbreak of, 2018 (WHO, 2018) and smallpox. Summer monsoon rains, which begin in June, usually trigger a spike in diseases like influenza, dengue and scrub typhus. Fever is a common symptom in many of these diseases. According to one doctor “This can complicate diagnosis. To make sure we do not end up facing a fresh wave of infections during the rains, we have to be very vigilant during the monsoon” (BBC, 2020).

Kerala is often touted as ‘God's own Country’. Over 600 km of Arabian Sea shoreline, palm-lined beaches, idyllic scenery and backwaters attract global tourists, and frequently features as one of the top travel destinations (featuring in National Geographic's 50 Places of a lifetime list). In 2019, the state attracted close to 20 million tourists, contributing to €5.36 billion<sup>7</sup>. These tourists are all potential carriers of the virus, as other countries have discovered.

Thus, despite having a strong healthcare baseline, Kerala's demographic, economic and social indicators paradoxically suggest a perfect storm with regards to the potential spread of the COVID-19. Kerala's high morbidity rate, an elderly population in a high-density state, its habitants are vulnerable to the ravages of COVID-19. Its global and national engagement via its large diaspora, migrant workers from other Indian states, a large tourist population- are all factors that pose a big risk to the health and safety of its people. Despite Kerala's vulnerability which suggests that it should probably be one of the badly affected state by COVID-19 in India, international media has hailed Kerala's performance as “The Kerala Miracle”.

#### 3.2. Data collection

This study took place during ongoing COVID-19 pandemic in India. Despite the impossibility of primary data collection, secondary informants provided a rich source of evidence. I sought data from live-news reporting, newspaper articles, media interviews, social media, and some institutional and start-up websites. This strategy of gathering



data from multiple informants and heterogenous sources lead to a richer and potentially more reliable results, permitting triangulating data points (Glaser & Strauss, 1967; Miles & Huberman, 1994). A total of 1400 pages of news articles were analysed, along with 56 h of TV coverage, and social media coverage. I also sought expert opinions from two well regarded researchers on innovation, one who studies technology trajectories and improvisation, and the other frugal innovations. For situational context perspectives, I spoke to two government officials, who discussed with me their initial reactions following the first cases of COVID-19 in Kerala, the technologies deployed, and partnerships formed.

### 3.3. Data analysis

My analysis was iterative, involving repeated comparisons of emerging data (Glaser & Strauss, 1967) till a coherent narrative emerged. The data was analysed using the NVivo 9 software, widely used for heterogeneous, qualitative datasets (Miles & Huberman, 1994). Following the recommendations of Gioia, Corley, and Hamilton (2013), the analysis progressed through three recognizable steps. First, I applied open coding (Miles & Huberman, 1994) to examine frugal innovations used to combat COVID-19, searching for words/terms most associated with the domain. The first-order concepts emerged from informant-centred codes that were based on common (and similar) statements (see Appendix A). The next step involved second-order themes where I investigated for relationships between and within the initial codes leading to the creation of second order themes. This step involved more abstract, and general coding of data, called axial coding (Locke, 2001; Strauss & Corbin, 1998), to determine themes while adhering to the primary data. These themes remained faithful to the underlying data but were more abstract and general. The themes were named (e.g. “informing”, “monitoring”, “testing”) based on my review of documents (e.g. from the WHO) on strategy descriptors to combat the pandemic. At the final stage of the analysis, I abstracted the second-order themes into higher-order dimensions, again iterating between the data and the emerging dimensions for constant comparison (Glaser & Strauss, 1967), identifying five dimensions. These aggregate dimensions reflected the

driving dynamics that characterized the frugal innovation processes. Fig. 1 provides an overview of the data structure. There were three coders involved in the data analysis processes, a Master’s and a PhD student, as well as a Professor, who independently assessed the emerging constructs, resulting in 97% agreement (for the first order concepts). As the research progressed, the emerging themes and the GFI overarching dynamic were constantly compared with extant literature on frugal innovation to seek both similar as well as conflicting frameworks. Tying emergent theory to extant literature enhanced the internal validity, generalizability, and theory building (Eisenhardt, 1989, p. 545).

## 4. Findings

In what follows, I juxtapose the data against theory to describe and discuss my findings on frugal innovation as the KSG’s response to the COVID-19 pandemic. The import of the threat posed by COVID-19 was interpreted early in January by Kerala’s health minister KK Shailaja, upon reading a news item of ‘a new SARS-like virus in Wuhan’. She noted “The virus had not gone even to other countries then, but I was sure it would come to Kerala. I knew we had Malayali (people from Kerala) medical students in Wuhan - some graduates had approached me for internships some years ago. They would bring the virus”<sup>8</sup>. By January 24, 2020, when the first student landed in Kerala, Shailaja had already put protocols in place recommended by the WHO. Kerala got to work a week ahead of other Indian states, checking incoming passengers by early March and closing the airports to international flights on the March 22, 2020.

Fig. 1 presents the first order codes, the five second order categories and the aggregate dimension of GFI.

### 4.1. Empowering

During public health emergencies such as the COVID-19 pandemic, an essential lifesaving action is empowerment through risk communication (WHO, 2020), whereby citizens are provided with the knowledge about the virus, towards responsibility to take informed decisions for their protection. During the breakout of SARS, there had been

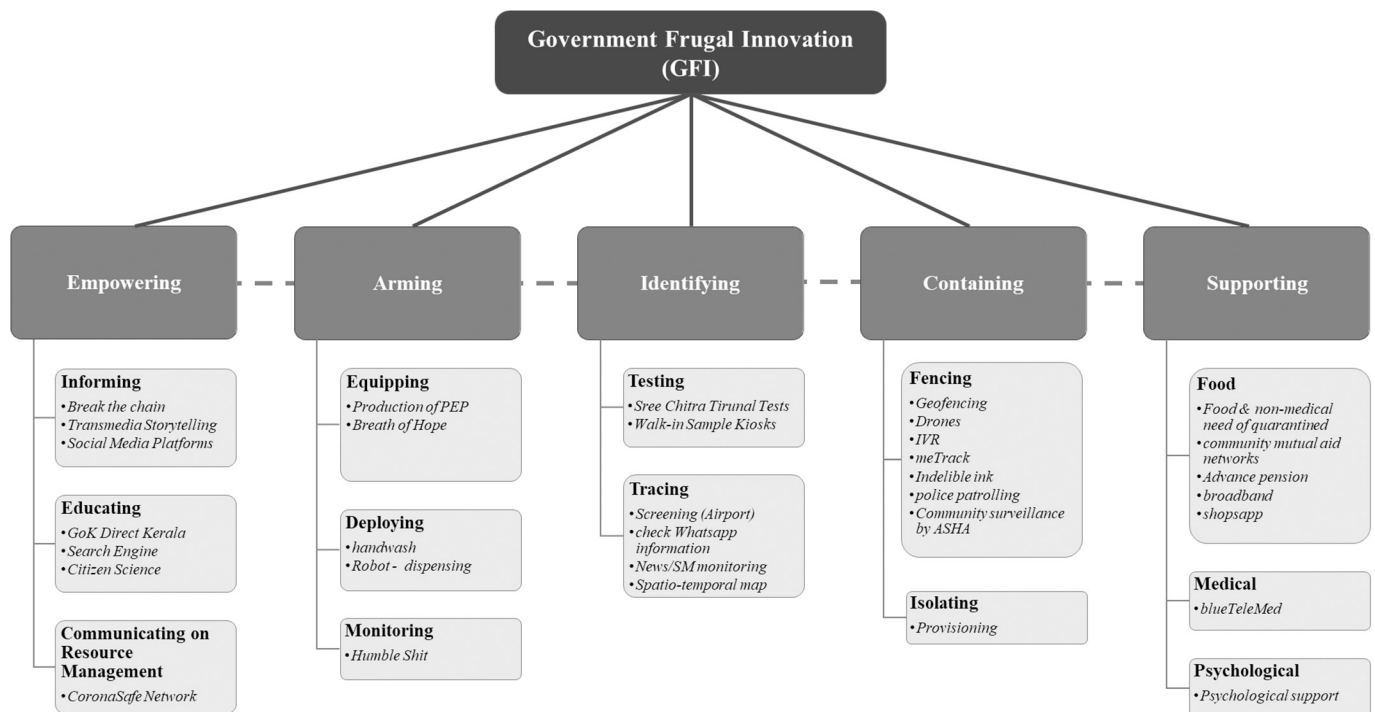


Fig. 1. First-order codes, second-order codes and the aggregate dimensions.

allegations of a cover-up by China (Washer, 2004), and in the case of COVID-19, there were also claims reported in the Western media of the Chinese authorities not revealing the full extent of the threat from the virus (New York Times, 2020). From the Nipah outbreak, Kerala had learned that transparency informs a more effective response. Mainstream media was co-opted as a partner in public health emergencies, a practice from the time of Nipah. Regular and accurate information was made available on the number of people under observation, numbers tested, positive cases, and deaths. My analysis revealed citizen-empowerment via informing, educating, and resource management, by adapting and contextualizing existing technologies.

**Informing** To disseminate health-related information, Kerala relied innovative and inexpensive mediums. A campaign “Break the Chain” was introduced by the KSG right before the lockdown in mid-March. Using the slogan SMS (using soap or sanitizer, using masks, and maintaining social distance), its principal aim was to inform on the importance of hygiene. The campaign later involved prominent personalities and reputed cartoonists who designed cartoons on SMS on public walls. ‘Break the Chain’ kiosks were installed at the entrance of residence complexes, major offices, and bus stops for maximum exposure. Setting up a kiosk was cheap and effective, installed in places where the contagion risk is high.

The KSG also employed multiple platforms, print, digital and social media – to systematically disseminate its COVID-19 prevention messages. Information regarding the pandemic and precautions to be taken, were published across all platforms, also in the migrants’ languages. It engaged in *transmedia storytelling*, essentially creating content that had potential to engage with citizens using disparate techniques to permeate their daily lives.

Endeavouring to better connect with the public and the youth, the KSG used *social media platforms* such as Facebook, twitter, TikTok and Instagram, to promote social distancing. Its reach can be understood from the Kerala Police’s Facebook follower count of over 1.4 million, one of the most followed police department pages across the world. Kerala police leveraged this follower base creatively. Measures such as policemen dancing and showing correct ways to wash hands, composing poems on social distancing in vernacular languages has been widely followed. The social media cell of Kerala police also produced a short clip promoting break-the-chain. They made use of VFX (visual effects) to portray containment by using sanitizers and protective gears, which were catchy, and aptly delivering the message.

In tracking movements of confirmed cases, a geo-tagged map was prepared, and circulated using mainstream media, to inform on risk assessment. The media also shared the experiences of those people who lived through quarantine, self-isolation and even completed treatment, recording their experience, thereby creating a rich source of content for people to reflect upon.

**Educating** Kerala leveraged learnings from the past to battle COVID-19. For instance, in the 1990s, when Kerala was threatened by HIV, the state used the media to ensure that sensationalism was avoided. From the Nipah outbreak in, 2018, the KSG quickly realized that it was equally important to educate and answer citizen queries and counter the spread of rumours during the epidemic- infodemic. The WHO director highlighted “we’re not just fighting an epidemic (pandemic); we’re fighting an infodemic” (Lancet, 2020, p. 537).

During epidemics, misleading rumours and conspiracy theories are common, and in the case of COVID-19, some authors noted that “A striking particularity of this crisis is the coincidence of virology and virality: not only did the virus itself spread very rapidly, but so did the information—and misinformation—about the outbreak and thus the panic that it created among the public” (Depoux et al., 2020). The KSG made significant attempts to prevent the spread of infodemic following the COVID-19 outbreak. One such measure was the multilingual mobile application (app), *GoK Direct Kerala*, powered by a start-up named Qkopy. This app acts as a one-stop source educating citizens regarding the developments of the virus. Although similar to a nationwide app

called *Arogya Setu*, GoK is more exhaustive and dynamic. Users are informed through a daily bulletin (in English and Malayalam) about the details of those under surveillance and home isolation, samples sent for testing, the results of these tests, updates on confirmed cases etc. GoK also provides information and updates for travellers, details about quarantine protocol, and health and safety tips for visitors to the state. GoK has proven handy in preventing a district from becoming a hotspot as the information of cases are also made available by districts. This gives authorities as well as citizens an opportunity to control the further spread of cases with the use of real time data.

*The authentic information regarding COVID-19 and the virus outbreak can be obtained through this app. Within a day of the launch of this service, the State Government was able to disseminate authentic updates and instructions to over 2 lakh people instantly.* (Qkopy in a statement shared with News<sup>10</sup>).

To empower medical researchers, the Indian Institute of Information Technology and Management in Kerala launched a new *search engine*, *vilokana.in*, a dedicated tool to assist scientists, doctors and researchers on the latest research about COVID-19. While there are many search engines, and even websites like Reddit helping researchers, COVID-19 has a Kerala context, featuring a lot of Indian-specific virus research and findings. Other functionalities like detecting fake information, access to a quick summary of articles provide additional functionality.

A *digital dashboard* [Covid19kerala.info](https://www.covid19kerala.info), is a citizens’ initiative using publicly available and crowd-verified data on COVID-19 outbreak in Kerala gleaned from government bulletins. This data is then utilized to provide real-time analysis and daily updates of COVID-19 cases in Kerala. The initiative was born at a knowledge intermediary, the Government College, Kasaragod, and created by data modelling experts. The dashboard was inspired by a Japanese crowd-sourced platform [Covid19 japan.com](https://www.covid19japan.com), but with many adaptations. According to the creator of the Japanese dashboard:

*The team in Kerala took our code, changed it to their needs and made it better. Then they pushed us to adapt those improvements as well* (Shane Reustle, as reported in News)<sup>11</sup>.

Kerala relied heavily on inexpensive technology for an efficacious response to COVID-19, tweaking what already existed. With the aim of giving policy makers a dashboard of more than 20 web applications, a team of developers, data analysts, software experts, paramedics, doctors and KSG officials were brought together, to create *Corona safe network*. In order to ensure transparency, an issue that the nationwide initiative *Arogya Setu* faced, the state decided to make the project open source. The application has facilities resource availability, by monitoring hospitals beds, ventilator facilities, ambulances, blood banks etc.

**Communicating on Resource Management** Kerala’s open-source strategy is centered around two components — *Corona Literacy Mission* (spreading awareness on the way the virus spreads, and precautions to be taken), and the *Corona Care Centres* (temporary facility created to augment the existing healthcare infrastructure). According to Usha Titus, principal secretary of higher education in the state and one of the main officers liaising with the technology team:

*This is what you can call a practo-initiative with government support. This is actually a civil society response, but the civil society consists of people in the IT business (...) Practo is short for online practise of doctors. (...) What is being prepared are a set of frameworks in case there is a surge of patients. The plan is to have not just information for the people, but to set up corona-care facilities for frontline of healthcare, templates that lay down the resources that are required for us, manpower requirements, and then for the quarantine centres also several departments have come out with protocols<sup>12</sup>.*

#### 4.2. Arming

Following the global rush to acquire ‘personal protective equipment’ (PPE) provoking scarcity and pushing up prices (Economist, 2020a), the KSG came up with innovative solutions. Arming citizens implied provisioning them with appropriate protective tools to combat the pandemic, involving three pathways equipping, deploying and monitoring.

**Equipping** The KSG issued directives on March 24th to engage tailoring units of prisons to produce masks. The Chief Minister tweeted saying, “It has commenced (producing) on a war footing”<sup>13</sup>. The state had also made early efforts to make sanitizers available at affordable prices for its citizens. Utilizing a WHO-approved formula, Kerala State Drugs and Pharmaceuticals (KSDP) initiated production to make 100,000 of sanitizers available within ten days at affordable prices.

The Kerala Start-up Mission (KSUM), a government-supported entrepreneurship development agency, also stepped in to connect engineering talent and start-ups prompted by the KSG, to ensure the swift development of required technology. The “*Breath of Hope*” initiative was an interdisciplinary team composed of IT Professionals, doctors, and biomedical engineers to develop innovative medical devices like the half-ventilator, and face shield. The KSUM also facilitated the development of many medical items like masks and respiratory items using its Fablabs.

**Deploying** The use of a unique water-based sanitizer by a Chemtech company, Aqoza Technologies is yet another such example. The company’s Managing Director, Razin Rahman noted, “During the Nipah outbreak, there was a need for *mass disinfectant* which had the potential to sanitize airports”<sup>10</sup>. Instead of using alcohol-based disinfectants, this product uses a hypochlorous acid-based solution, which the company claims can disinfect Coronavirus. Aqoza Technologies has provided its disinfectants to airlines, IT Parks, and commercial buildings. According to the CEO when dissolved in water, this solution acts as a more powerful sanitizer than alcohol-based ones<sup>10</sup>. Alcohol-based disinfectants are toxic whereas water-based products are safe for children as well. While it sells directly to citizens, Aqoza was able to scale-up its production due to absolute support from KSG (including from local governments), and state civic bodies and agencies such as the police and armed forces.

To dispense sanitizers and masks, robots were deployed in the city of Kochi. Asimov Robotics, a Kerala start-up used *Karmi-Bots*, to dispense hand sanitizers at entrances of office buildings and public places, and also for thermal imaging. These robots remain connected via distributed sensor network and use AI (Artificial Intelligence). Another team of innovators developed a low-cost automated hand-sanitizer machine that contained a larger volume of sanitizer liquid to cater to the large population. To account for power shortages and the absence of charging points, there is also a battery-operated option.

**Monitoring** Lack of toilets often meant that despite the lockdown, people often stepped out to find access to public toilets. Kerala-based start-up, *Humble Shit* developed a toilet monitoring system, that measures cleanliness of a toilet based on 24 different parameters. According to its founder, Samir Singh, public toilets are a source of diseases, and to combat this, the platform collects various data points such as the number of people who have used the washroom, time spent, or the number of people inside a toilet. *Humble Shit*’s data helps the authorities to manage the cleaning of toilets appropriately, using resources more effectively<sup>10</sup>. The *Humble Shit* initiative is facilitated by the KSG, with strong cooperation between the two, and the start-up’s numbers are helping the authorities to manage the cleaning and monitoring of toilets appropriately.

#### 4.3. Identifying

Identifying involved rapid case detection to ensure timely treatment and isolation crucial in pandemic control, and detecting cases involving

testing and tracing.

**Testing** Testing is our ‘window’ onto the pandemic according to the WHO, with rapid collection and testing a priority. Given its resource scarcity in Kerala, frugal testing measures were used.

A frugal test kit dubbed as ‘Chitra N-Gen LAMP-N’ was developed by an autonomous state institution, the Sree Chitra Tirunal Institute for Medical Sciences and Technology (SCTIMST), with the support of the state’s disaster management body. Following guidelines of the US Center for Disease Control (CDC), the test takes less than two hours to confirm COVID-19’s presence. It detects the N-Gen of the coronavirus using RT-LAMP (Reverse Transcriptase Loop-Mediated Amplification), a one-step technique, that utilizes an isothermal setup to create copies of the virus (The Hindu, 2020). It can distinguish two regions of the gene, ensuring testing success even if one region of the gene undergoes mutation during its current spread. The kit cuts testing costs by 80%, ranging from 11€ (Rs. 1000) to 60€ (Rs. 5000) and is 100% confirmatory by reducing false negatives<sup>14</sup>. In a country where there is scarcity of certified testing laboratories, another advantage is that the tests do not require Bio Safety Level (BSL) 2 or 3 laboratories, which are specifically designed to handle experiments with microbes that are related to human diseases or microbes that are exotic and can cause serious human damage through inhalation respectively (Trapotsis, 2020) and can be carried out in even district hospitals. The reduced need for BSL 2 or 3 labs, directly translates into a reduced demand for PPE kits, expensive equipment, sanitization facilities and equipment and personnel. The original technology had been developed for detecting tuberculosis bacteria in sputum, and with the onset of COVID-19, the method was adapted for the detection of this SARS virus strain. Confirming the ease of use of this frugal innovation, the institute’s director Asha Kishore claimed that “The machines required for our test are not complicated and can be kept in district hospitals. The expertise required is simpler and this can be deployed anywhere”<sup>14</sup>.

With regards to the actual collection of sample specimens, drawing inspiration from South Korea, Kerala installed low-cost portable booths for collection all over the state. Little more than a phone booth, these *Walk-in Sample Kiosks* or WISKS have a glass front, with fixed extended gloves attached, through which a healthcare worker from inside the cubicle collects samples. By inserting a hand in the rubber gloves, swab and blood samples are collected, and after each, the rubber gloves and the chair are disinfected, reducing both time and costs. The fully contactless collection process takes around five minutes, the entire kiosks costing approximately €170–230, maintaining all social distancing norms<sup>15</sup>. They are also portable and can be mounted on a vehicle thus gaining enormous mobility. Kerala’s chief minister had said after the launch of kiosks that Kerala’s Test Positivity Rate (TPR) (the number of positives for every 100 tests) was 1.7%, while the country’s TPR was 5 (Onmanorma, 2020). A low percent positive rate indicates low transmission of Coronavirus among communities, and such an indicator helps governments and policy makers to make informed decisions on the level of restrictions to be implemented, and it is recommended that the TPR should remain less than 5% (WHO, 2020). As of July 2020, countries South Korea and Australia had TPR below 1% whereas countries like Mexico, Nigeria and few US states like Florida and Nevada had TPR higher than 15% (Dowdy & D’souza, 2020).

Additionally, using minimal resources, Kerala implemented a random testing strategy to detect the virus with stratified sampling. A priority list in which tests were undertaken was prepared, for instance with 15% taken from primary contacts of confirmed cases. As noted by one health official: “One of the major expenses in detecting and treating COVID-19 is procuring PPE kits. During the sample collection, the health workers have to wear PPE kits which cannot be reused. A PPE kit is very expensive and in case a high number of COVID-19 cases are detected, there will be a shortage of PPE kits in the state. The major benefit of WISK is that health workers do not need to wear PPE kits.”<sup>21</sup>

**Tracing** While my study revealed a number of approaches to enact defence against COVID-19, *contact tracing* emerged as one fundamental

strategy. A stringent screening system was put in place in all of Kerala's four international airports, with a detailed history of all passengers maintained and shared with multiple agencies. The process began for passengers who had come three months prior to when screening actually began, and they were traced and tested. While maintaining privacy, their travel history was also posted to alert people from those regions to come forward for testing and taking precautions.

An initial suspect was first interviewed in detail, recording who the person met and where he went. All who had come in contact with a suspected positive case were painstakingly traced via interviews, mobile phone tower locations and a Google maps timeline. A contact-tracing team, including many volunteers, used this information to construct a *Spatio-temporal map* (a geographical flow-chart), then published in the local media, serving as an alert for the local population. In the case of one family that tested positive in the Pathanamthitta district, which became India's first hotspot, the local administration traced 1254 contacts of this family in four days, quarantining all<sup>8</sup>. The teams had to visit all the places that the family had been to, collecting CCTV footage, checking records of hotels, houses and a private hospital. This became a model for Kerala's other districts as well as for other parts of India. The team responsible for contact tracing went through hours of CCTV footage of travel locations of people tested positive of COVID-19. "We traced 1,254 contacts of this family in four days, and quarantined all of them," said PB Nooh, an administrator of Pathanamthitta, which became India's first hotspot<sup>9</sup>.

This combination of easily available low-technology, complemented by more intensive methods of poring over data and physical sleuthing, formed an essential pillar of Kerala's COVID-19 response.

In the case of India's patient zero, the medical student arriving from Wuhan, a task force recreated the student's entire journey. It identified all who had come in contact with her, and as noted by Kavya Karanakaran, the doctor responsible for the tracing:

*China returnees were under surveillance from the third week of January. The majority of them were studying medicine and we didn't have to impress upon them the importance of quarantining. The challenge was pinpointing the contacts. Mapping out the journey itself was not difficult with regard to travel history. The rest depends on the memory of the patient. But we have alternatives for this (...). We got contacts from students of other years and tracked their batchmates. In some cases, they did not have Indian (phone) numbers... We contacted them through social media, tried to establish their location and asked them to quarantine themselves<sup>16</sup>.*

Another illustration of the frugal tracing technology is the use of both print and television in each district, which not only identified infodemics, but noted the needs of those in quarantine, as well as keeping tabs on pneumonia deaths. As noted by a primary health worker:

*We see reports that people under quarantine have a water shortage or that food kits are not reaching them or that they are being harassed. We also learn about people who were cured and collect positive stories which helps boost the team. A crucial aspect is going through the obituary page and tracing pneumonia deaths, which cannot be dismissed in the current scenario<sup>16</sup>.*

#### 4.4. Containing

Containing strategies of countries meant quickly closing their borders, and carefully monitoring anyone coming in, and isolating the infected. These strategies have been most successful in slowing infections (NYT, 2020a). Analysis of KSG data on the frugal innovations with regards to containment, led to two emergent second order constructs- fencing and isolating.

**Fencing** Reflecting on Kerala's prior experience with the Nipah virus, the state's former health secretary noted, "You can't imagine the

terror we went through at that time, and fear is a very good trainer"<sup>17</sup>. This experience enabled Kerala's preparedness in containing COVID-19. Kerala began checking passengers a week ahead of other states and closed its airport along with the other states on 22nd March. The state had closed schools on 10th March, banning socio-cultural gatherings. Kerala also advanced with a "*Fencing model*", whereby everyone within a 3 km radius (focal area) and a buffer area (5 km) of a positive case, was screened for symptoms.

Kerala police's cyber cell (Cyberdome), developed a *geofencing* surveillance platform to track the movement of high-risk people, those under quarantine, and those whom officials considered might break the protocol. The state police also used information technologies (IT) to track people who violated the 21-day lockdown and used modern gadgets to prevent people from leaving their homes. These included measures ranging from utilization of drones and a geofence-based home quarantine app to a telemedicine platform.

The Kerala Police deployed high-performance quadcopters — *drones* with four rotors — on lockdown watch. Named 'Project Eagle Eye', the police also invited private players to build a network of 350 drones which could scan every corner of the state. The small drones had been fitted with sirens and flashing lights to make announcements.

As the number of people in quarantine increased, making phone calls to ensure protocols were being followed, became increasingly difficult. To automate part of the process, a Kochi-based technology start-up, Billion Lives through a contract with the state health department, found an alternative to making thousands of manual calls, by adapting an *Interactive Voice Response* (IVR) System. With pre-recorded questions, automated calls through IVR were placed to those under quarantine. The IVR data from such calls were processed through analytical tools. This was reflected on a dashboard where the symptoms of every single quarantined person were plotted. By viewing the dashboard in real-time, the doctors were able to assess the medical parameters of those quarantined. According to the manager of the COVID control cell, Dr. Sharath Chandra Bose: "Even when we deputed 10 to 20 people to make phone calls to those under quarantine, we couldn't reach enough people. On a regular day, with about 10 lines, we could call only about 600 people. That means, if we had to make a repeat call to a person, we could do so only after 10 days, ... The IVR system helps us in identifying the symptomatic among the quarantined, isolate and test them as soon as possible..."<sup>18</sup>

In another containment initiative, a Keralite entrepreneur based in Japan developed an app *meTrack*, to monitor effective quarantining. According to him "Our existing solution was to monitor the time spent by people inside facilities such as hospitals and factories or by guests in front of a pavilion during an event, to analyse their interest". They had added a few more components to it and developed *meTrack*<sup>19</sup>. This app allows healthcare officials in Kerala to track and quarantined cases, as well as provides an online site for the health administrators with dashboards to monitor all quarantine activities in real time. For quarantining, 27,000 institutions were identified where up to one million people can be accommodated. Schools, colleges, and tourist houseboats were converted into isolation wards. To isolate the COVID-19 patients, wards in District hospitals were identified. The four-week home quarantine for suspected cases was to be administered by village councils, whereas the confirmed cases were transferred to the nearest healthcare facilities.

#### 4.5. Supporting

**Supporting** In contrast to other parts of India, and in many other resource scarce contexts worldwide, Kerala's strategy to control the pandemic also involved a set of supporting measures, aimed towards the provisioning of necessities. While the overarching aim of supporting strategies was to provide for the basic needs of the population, it was also driven by concern that people do not break social distancing norms, especially those in quarantine. An evidence of how official thinking on



support can be gleaned from the following statement by a doctor of a primary health centre:

*We were prepared for asymptomatic ... even before we had any such cases. If we identify a cluster of comments (in social media), it means there is a need. Now, we go through all the comments. It need not be about the health department. Even if it is regarding the civil supplies department or excise, we hand over the data to the authorities<sup>20</sup>.*

My analysis uncovered three main mechanisms of support- food, medical, and psychological.

**Food** There was daily monitoring of non-medical essential needs of those in quarantine and the information was relayed to the village councils- the gram panchayat. By the following day, the requirements of households were then supplied. In the third week of March, KSG's chief-minister launched a *community kitchen* initiative in every gram panchayat, so that all who needed would be fed. The community provides free food in the entire state, with kitchens in every village and municipality. This is in striking contrast to the experience of the poor in other parts of India, especially migrant workers who were left without jobs, and without means or ways to return to their homes when a nationwide lockdown was declared across the country.

The large number of Kerala's diaspora, mostly working as laborers in the UAE were housed in empty buildings during a mandatory quarantine on their return. While schools remained shut, meals were still delivered to children at their houses, and information was received and disseminated via local government helplines. Community mutual aid networks were created even at village levels to monitor the needs of people as well as to ensure that quarantines were maintained.

One initiative of the Kerala Police was to launch *shopsapp*, a mobile app for essential commodities. *Shopsapp* was developed by Kerala Police in cooperation with a start-up called Invent Labs Innovations. The app informed citizens about shops that were open in the neighbourhood, and from where they could order essential supplies.

**Medical** The Kerala police teamed up with the state chapter of Indian Medical Association (IMA) and a firm BlueEHR, to make *doctors' consultations* available online through blue Telemed, a telemedicine app. Through the app, people could consult doctors via video calls. While serving the medical queries of the population, it also reduced travel need, and at the same time engaged doctors who were otherwise at home without regular practice following lockdown. While in the first phase the doctors who signed up were general medical practitioners, services of specialists were soon added. The app also featured the issue of e-prescriptions which could be used at the nearest pharmacy store to get medicine. If hospital visit were recommended, the app also permitted the doctor to issue an e-pass that could be shown to police if the person was stopped on the way to the hospital.

The state police also launched an online platform for those who needed to make emergency trips to apply for vehicle passes via a web portal, [www.pass.bsaf.kerala.gov.in](http://www.pass.bsaf.kerala.gov.in). Earlier motorists had to carry a self-declaration form with details of the trip or go to the local police station to obtain the vehicle pass. Via the portal, motorists could enter their travel details, and the local police would verify their applications for approval. As noted by the head of the state police cyber unit, "The advantage of the system is that the applications will get processed more quickly as people can save time visiting the office of the district police chief."<sup>20</sup>

**Psychological** Attention was paid to the psychosocial needs of those isolated and quarantined. This was a lesson that the state had learnt from the Nipah outbreak where families underwent a great deal of stress. *Telephone counselling* and support were provided by psychologists and psychiatric social workers to those in quarantine. Besides, telecom operators were required to increase bandwidth to enable people to work from home, and state libraries also provided books to the quarantined. All these measures not only provided support to the population, but also minimized the need to break social distancing and promoted isolation.

## 5. Discussion

Kerala stands out not only in India, but internationally as an exemplar (Economist, 2020c), and held as a lesson to be learnt by others (MIT Tech Review, 2020). My findings suggest that behind the supposed miracle is the enactment of a set of government-promoted measures, whose collective action and interaction, aided in the pandemic combat. Low-cost, and efficacious technological solutions formed the corpus of frugal innovations initiated by the KSG, complementing each other, their systemic interactions contributing to Kerala's resistance to COVID-19.

The KSG relied on innovative and inexpensive mediums, employing multiple platforms, print, digital and social media – to systematically disseminate precautionary measures. For instance, a mobile application was used to act as a one-stop source; a search engine to empower medical researchers; a crowd-sourced platform to provide real-time analysis and daily updates of COVID-19 cases; and others. Acute scarcity of PPEs prompted the KSG to come up with innovative solutions to fashion protective gear and involved collaborating with start-ups to produce mass disinfectants and toilet monitoring systems. In order to identify suspected cases, KSG promoted the provision of cheap test kits, facilitated collection, installed low-cost portable walk-in booths, engaged in intensive contact tracing by combining easily available technology. These were complemented with intensive methods of data analysis and physical investigation. Geofencing software tracked quarantined people along with drone deployment. Support measures were taken to provision not only food, but also medical necessities, including the creation of telemedicine apps for medical consultations. These measures were prompted not only for the physical and mental wellbeing of the population, but also to minimize the need to break social distancing rules. Food and essentials were regularly delivered with the help of decentralized local institutions like panchayats and municipalities, and by volunteers.

Kerala's use of technology, including IT and social media, implied very low costs, tweaking what already existed. Since this involved adapting extant technologies, KSG focused on making these solutions more reliant and relevant to fight the virus. The original technology for the water-based hand sanitizers had been used for detecting tuberculosis bacteria, which adapted this technique. Similarly, while other apps existed, for instance the central government promoted Aarogya Setu, concerns of privacy and lack of transparency made the citizens apprehensive of using such apps. However, the apps promoted by KSG were transparent, with their source code made openly available to the public. Kerala's GFIs involved open platforms with the participation of intermediaries, to do 'more with less'. Table 1 below provides a brief characterization of some of the frugal innovations that emerged from my findings, and the involvement of developmental partnerships.

Technologies in general, and IT in particular have been deployed to foster new horizontal opportunities, and bypasses traditional bureaucratic structures for alternative delivery arrangements (Allen, Juillet, Paquet, & Roy, 2001). Their use acquired a greater urgency given the importance that time plays in limiting the pandemic. Social media has been an important tool during crisis situations (Saroj & Pal, 2020). Being decentralized, distributed, and networked, with vast number of users at multiple- points of information, production and consumption (Boyd & Ellison, 2007), social media tools are being extensively used globally following the pandemic (see NYT, 2020b). The social media cell of Kerala Police routinely added humorous content, providing a type of infotainment. The messages used in the social media were played out with other strategies such as Break the Chain and SMS.

My findings underscore how GFI is enacted, involving the government, its agencies as well as private sector partners. I distil and wrap the empirical insights in the form of a conceptual model of GFI in Fig. 2 below.

Fig. 2 conceptualizes how government involvement and partnerships are forged, whose action and interaction lead to frugal innovations. The

**Table 1**  
Examples of KSG's frugal innovations.

Innovation	Description	Frugality	Partnerships
'Break the Chain' kiosks	Informing citizens about the importance of public and personal hygiene, and enabling washing	Inexpensive information campaign; Adapting existing kiosks for provisioning handwashing;	Local municipalities; cartoonists, sportspersons and other public figures
Transmedia storytelling	Kerala policemen dancing to popular songs, for example to demonstrate the correct way to wash hands Kerala police utilizing VFX to depict the Corona virus; drafting poems on the need to fight together	Minimal costs, targeted at poor people as well as for the young	Local police
Using social media platforms such as Facebook, TikTok, Instagram, Twitter, WhatsApp; VFX technologies	To widen the reach and effectively convey the messages on precautionary measures; combat infodemics	Little or no cost message dissemination; Leveraging existing platforms	Social media platforms
Multilingual application (app) GoK	Disseminating information; combat infodemics; quarantine protocols	Free service; created by large talent pool of cheap coders	Start-up (Qkopy)
Vilokana.in – A search engine	AI based search engine, aimed at promoting research on COVID and also promoting research in the country; filters out articles and papers based on fake information;	Free service; created by large talent pool of cheap coders	The Indian Institute of Information and Management, Kerala (IIITM-K) Technology
<a href="#">Covid19kerala.info</a>	Citizens' initiative of a multi-source open dataset of metadata from the COVID-19	Adapting existing dashboard from Japan	Technology volunteers
<i>CoronaSafe network</i>	Open source public utility developed with an aim to provide a single stop location for citizens to track the COVID -19 status; Provides access to ambulance, medicine network and a lot more.	Integrated of 17 apps to dispense correct information to citizens;	Kerala state disaster mgmt. Authority and a multi-disciplinary team of researchers, developers, health-staff, and developers
Local sanitizer production by KSDP	Reduced the cost of sanitizers by 85–90% making sanitization more affordable.	Lowered costs by local production. More	Kerala Medical Services Corporation
Rapid testing kits developed by STIMST	Brings down the testing time to 10 min and is affordable.	The testing kit is more accurate, cheaper and faster than any of the previous existing testing kits	Developed by (STIMST) as collaborative government initiative

**Table 1 (continued)**

Innovation	Description	Frugality	Partnerships
Walk-in Sample Kiosk (WISK)	Walk-in sample testing, which are quick, contactless and inexpensive	Low-cost portable booths for collection all over the state; minimal operating costs	
Spatio-temporal maps	Collects information through interviews, mobile phone tower locations and a Google maps timeline to track case suspects	Uses existing technology complemented with labour intensive methods	
IVR System for real time monitoring	Helps to keep check on the health condition of people under quarantine.	Helps in effective monitoring while minimizing contact. Automated calls saved precious human labour hours	Start-up Billion Lives.
Geofencing – Using technologies such as Global Positioning System (GPS), RFID tags, Wi-Fi or a person's mobile phone to track their location.	It monitors high risk contacts (ones with close association with positive Covid cases and who can potentially break protocol)	Leverages technology for effective monitoring, saving man hours and reducing cost incurred.	Kerala police Cyber dome. Mobile service providers for GPS and tower locations
'Project Eagle Eye', Network of 350 drones	The drones monitored and advocated quarantine; Fitted with sirens and flashlights and are equipped with speakers for announcements.	Reduced monitoring expenses;	Partnership with private firms
ShopsApp, a mobile app for providing essential commodities	Customers can order essentials from nearby shops using this app for home delivery to ensure food security.	Free service; talent pool of low-cost coders involved	Kerala Police Cyber dome. Partnership with start-up Invent Labs Innovation
blueTeleMed	Telemedicine mobile app that facilitates free video doctor consultation; e-prescriptions provided as well as transport pass.	Reduces workload on hospitals and health worker ensures affordable accessibility of medical expertise.	Indian Medical Association.

KSDP - Kerala State Drugs and Pharmaceuticals; KSUM – Kerala Start-up Mission; ICMR - Indian Council of Medical Research; STIMST- Sree Chitra Tirunal Institute for Medical Sciences and Technology; NIV - National institute of virology.

resulting framework embedded within a resource scarcity setting, illustrates how this dynamic is motivated by the resolution of societal problems. GFI is motivated by three fundamental tenets – inclusivity and improvement in access to primary needs, solutions concentrating on core-functionalities while using minimal resources, and to the extent possible utilizing existing resources leading to significant cost reductions, along the lines of what had been suggested in recent literature (e.g. [Weyrauch & Herstatt, 2017](#)).

Within the ecosystem of government and its public sector undertakings, there are other actors such as research institutions, start-ups, private firms and citizens. Within this ecosystem, the government plays

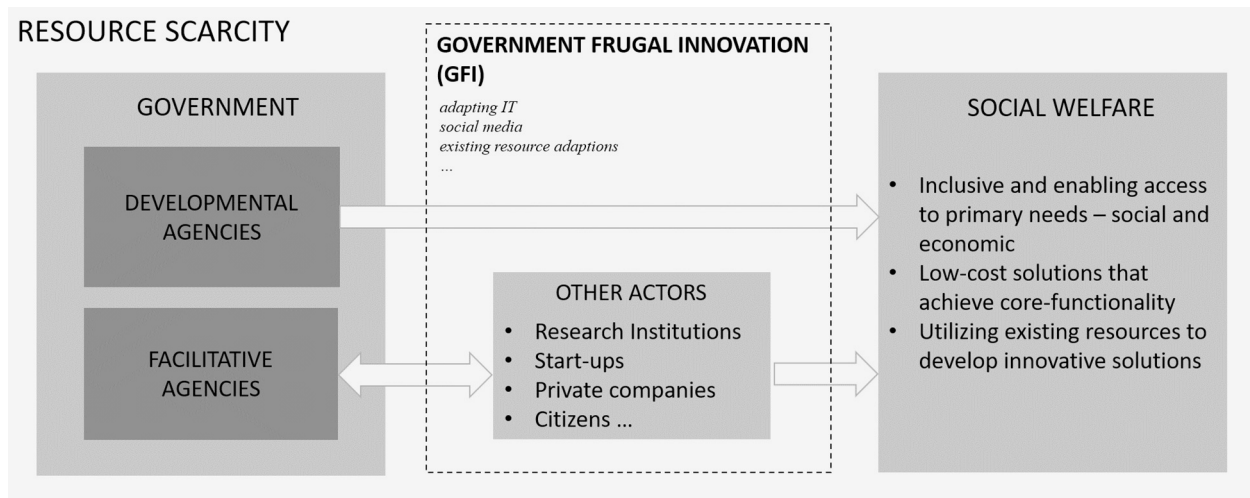


Fig. 2. Conceptual Model of Governmental Frugal Innovation (GFI).

the agency role, where it is both the developer, as well as the facilitator of frugal innovations by knowledge intermediaries and start-ups. Through the development role, the government directly engages with the society through innovations which can include adapting IT, mobilizing social media, establishing infrastructure and equipment and through the facilitator role, the government indirectly engages with the society by promoting frugal innovations through changes in public policy, as evidenced in KSG's response to the COVID-19 pandemic. The facilitator role emerges as a critical capability for the government to act within this network to resolve social problems faced by its citizens.

My study articulates a specific definition of GFI, locating this idea within the frugal innovation literature, with the government playing an active role in the development and promotion of new goods and services. My proposed definition of GFI fits with societal problems derived from contexts and needs that differ from the ones that arise out of a crisis like the COVID-19 pandemic. For example, in Kenya, Safaricom (35% government owned) in collaboration with Vodafone Group LLC launched M-PESA service, a mobile-based money transfer service in 2007 that did not require a bank account for money transfer, which ultimately improved livelihoods of over 194,000 households (Suri & Jack, 2016). Doing so, the Kenyan government, here through its Central Bank, played an active role in the facilitation of a new service that utilized existing infrastructure with only minimal development costs through innovation in public policies. Not only did the Kenyan government facilitate innovations, it also established a culture and attitude that the governments of the developed nations can adapt (Prabhu & Radjou, 2010). My definition of GFI encapsulates such innovations that are driven by the goals of inclusive and better social welfare, in which governments play a facilitative as well as a developmental role.

GFI is not an end state but rather an enabling condition that delivers efficacious solutions at low costs. GFI is also not a homogeneous work, and I find that the time frame in which these interactions work, is condensed due to the urgent need for a quick and efficacious response to a crisis, as that prompted by the COVID-19 pandemic. GFI resonates with the concept of lean government (Janssen & Estevez, 2013), of doing 'more with less', both concepts aiming to work "efficiently with knowledge" to turn it faster into "value" (Tiware & Herstatt, 2014; Sehested & Sonnenberg, 2011). However, lean objectives might differ considerably, as unlike frugal, the outcome of a lean innovation does not necessarily imply a low-cost product. As noted by Tiware and Herstatt (2012), "it takes much more than efficient management of the innovation process (i.e. lean) to come up with a successful disruptive, game changing innovation" (p. 249). Frugal innovation arises from resource constraints and aims specifically to develop cheap and high value products and services which requires a much more creative and

innovative process (Tiware & Herstatt, 2014).

**Theoretical Implications** At the theoretical level, I extend the literature of frugal innovation to include the government as the agency. Extant conversations in this domain have remained in the realms of private sector engagement, ignoring innovations developed or promoted by the government. My study therefore contributes and adds breadth to the frugal innovation literature, which has witnessed rising scholarly interest phenomenon. My theoretical framing also add depth to the domain, whose literature as noted by Prabhu (2017) has been overwhelmingly empirical, where "frugal innovation is a descriptive notion" (p. 5). Secondly, the COVID-19 pandemic has highlighted the importance of a government's capacity and capabilities to handle emergencies, and the protection of public health. This requires that governments have dynamic capabilities (Mazzucato & Kattel, 2020), including coming up with innovative responses. However, when it comes to the role of government in promoting innovations, where "the literature implicitly holds that inventive capabilities were largely private and the government played little role in targeting and organizing innovation" (Thomson, 2014, p. 2). My study therefore contributes to a strand of public sector literature that emphasizes the governments' role in promoting innovation (Mazzucato, 2011). My study articulates a specific definition of GFI, locating this idea within the frugal innovation literature, with the government playing an active role in the development and promotion of new goods and services. My proposed definition of GFI, and the conceptual model that I build, conceives the idea of GFI arising out of resource scarcity, and involves the development (and facilitation) of new public goods and services, using minimal resources at low costs. Third, my study also initiates theoretical conversations around the role of cooperation in the development of frugal innovations, which has found only sporadic mention (e.g. Angot & Plé, 2015; Dahan, Doh, Oetzel, & Yaziji, 2010; Sharmelly & Ray, 2018). Yet much of frugal innovation involves important collaborative aspects, which also includes the government and public bodies. General Electric for instance partnered with medical research institutes, state governments, and NGOs to provide affordable and accessible healthcare solutions in India and Bangladesh. Similarly, Xerox fashioned collaborative partnerships with the Indian Institute of Science, and Indian Institute of Technology to provide affordable solutions for rural businesses in India (Radjou et al., 2012). Finally, my findings point out to the role of IT in frugal innovations, especially when the government acts through the developmental role, thereby addressing the concern of some authors (e.g. Howell, van Beers, & Doorn, 2018), who noted that "While IT plays a role in frugal innovation, literature discussing IT and frugal innovation is minimal" (p. 229). KSG's frugal innovations frequently involves the interplay of information technology, government, and citizens.

**Practical Implications** There are also at least a couple of practical implications uncovered by my findings. First, following the COVID-19 crisis, it has become imperative to develop ingenious, effective and timely solutions to tackle the spread of the virus, where the government plays a fundamental role. KSG's frugal innovations holds promise for other states around the world, on how to combat COVID-19 at low costs, and also offers more durable lessons of innovations that can serve citizens at normal times. GFI by the KSG can be an inspiration to other governments and echoes a call by the WHO which has appealed for the development of innovative and low-cost interventions (WHO, 2020). With governments in developed regions continually pushed to be innovative (Gil-Garcia, Helbig, & Ojo, 2014), constrained fiscal situations of governments emphasize how frugal innovations are a way to cope with reduced public spending (Singh, Gambhir, Sotiropoulos, & Duckworth, 2012). In this longer-term perspective, my study reveals how cheap and adapted technologies can be efficacious. Particularly when it comes to healthcare, I provide compelling empirical evidences and suggestions of 'what richer countries can learn from poorer ones' (Crisp, 2010). Second, my study highlights the cooperative aspect of working across sectoral boundaries to achieve common goals. Successful cooperation implies compliance with government interests, and complementarity of parties in terms of resources and expertise. The COVID-19 pandemic ensured the overriding goal of public health, and private sector expertise was tapped upon to fight the pandemic. While such cooperative actions tend to be temporary, an important policy implication is the need to create a framework for collaboration, such that there exist mechanisms for enabling, preserving and enhancing cooperation towards the achievement of societal goals. This therefore echoes a call of "concerted decision making among the stakeholders" (Gray, 1989, p.15) for successful partnerships.

In sum, my study proposes greater consideration of GFI as a way of providing low-cost and efficacious solutions, and as a complement to society's innovation repertoire. My research provides valuable theoretical and practical insights, putting the spotlight on the government as a protagonist of frugal innovations, a domain hitherto appearing largely as an empirical descriptor (Prabhu, 2017). With practicing frugal innovation emerging as an important point in the agenda of developed economies (Shepherd et al., 2020), my findings draw attention to a huge reservoir of frugal solutions, suggesting that these can be absorbed and adapted to more developed contexts (Radjou et al., 2012; Ramachandran et al., 2012).

## 6. Limitations and future research directions

This study has a few limitations, calling for some caution to be exercised in generalizing my findings. **First**, my data was derived from media coverage, most notably newspaper and TV analysis, and I was unable to get a citizen perspective on the effectiveness of frugal innovation strategies to limit the transmission. **Second**, the efficacy of many epidemic combat strategies depend on other factors that interacted with frugal innovation strategies for their success. For instance, with over 96% literacy rate, the highest in India and among the highest worldwide, it therefore has a higher absorptive capacity of innovation, and that citizens understand the need for control measures crucial in the COVID-19 combat strategy. Moreover, Kerala has a strong community and community-level resilience (Singh et al., 2012), and how these complements or even replaces technological responses to handling the pandemic, may have played an important role in limiting COVID-19 spread. Third, my research doesn't cover other factors that have contributed to Kerala's COVID-19 defence strategy. While frugal innovations by KSG formed the centrepiece of my study, it is important to recognize that there are likely other perspectives and drivers, including institutional factors, which have also helped the state combat the crisis. Finally, with many GFIs facilitated by KSG through intermediaries, such cooperation may be more revealing given the COVID-19 crisis, and a

much greater challenge in more normal circumstances. Value creation between public and private sector organizations are different (Pedersen, 2020), creating such partnerships in the technology domain poses the challenge of collaboration. Forging partnerships requires shared purposes and agendas (Allen et al., 2001). While the threat to the health and welfare of Kerala's citizens following COVID-19 provided such a shared purpose, collaborations under normal circumstances should not be taken as a given, and mechanisms need to be drawn for their sustainability.

While these above noted limitations in turn each provide opportunities for further research, interested scholars can additionally explore other fruitful avenues. For instance, in the COVID-19 context, it would be interesting to investigate how other countries have handled the crisis, doing a comparative analysis with regards to control mechanisms, technologies employed, expenditures and the outcomes. Such analysis could also be used to study within the federal union of India, for its 28 states and 8 union territories, also taking into account institutional factors. Another COVID-19 inspired future research stream could be to contrast and juxtapose Kerala's GFI experience with that of China and Western nations. Despite both China and the advanced economies possessing significant technological resources, following political and institutional constraints, their deployment has been significantly different in either context (Kummitha, 2020). With far fewer resources, Kerala's experience on the other hand, suggest a "third way" to fight the pandemic, i.e., the use of frugal technologies deployed by the government. I therefore strongly encourage scholars to pursue this line of thought, which also holds strong policy implications.

At a theoretical level, my GFI definition provides a trajectory for research on this phenomenon, and I suggest further steps towards fostering theory building around this concept. Application of my definition to normal times shows promise, and future research can explore the generalizability of the definition as well as the contextual factors that are necessary to build and sustain such innovations. Particularly, the directions of interest are the necessary conditions that enable frugal innovation in a more resource endowed setting and the motivations underlying GFI. While a few governments have been able to build and sustain the culture of innovating frugally, research needs to explore this in detail and understand how governments can embed the values and attitudes facilitating frugal innovations over the long-term. Finally, as mentioned earlier in my discussion, frugal innovations share similarities with lean innovations. I therefore suggest research that can explore a conceptual framework which can bring out the commonalities, differences and implications of these and other related concepts. These suggested lines of future enquiry are in my opinion, productive lines of enquiry for scholars who wish to pursue, what I consider to be, an important area of management and public policy thought.

## Credit author contribution statement

**Soumodip Sarkar:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Writing - original draft, Writing - review & editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Derivation of first-order, second-order codes and the aggregate dimensions

Aggregate dimensions (third order)	Second-order themes	First-order codes - data exemplars
Empowering	Informing	Awareness campaign – “Break the Chain” <sup>23</sup> Preparation for the new normal <sup>22</sup> Prevent the spread of fake news <sup>22</sup> Clear communication channels <sup>22</sup> Wearing masks mandatory, a fine of Rs 5000- Dr. Amar Fettle <sup>24</sup>
	Educating	Sends COVID-19 updates and travel information via phone notifications, and via SMS <sup>10</sup> Messages are delivered both in English and in Malayalam, the local language <sup>25</sup> Saji Gopinath, CEO, Kerala Startup Mission and Director of IIITM-K, said, “AI tools can help extract contextual insights from research articles.” <sup>26</sup> Authentic information regarding COVID-19 <sup>27</sup> Disseminate authentic updates and instructions <sup>27</sup> Corona virus awareness videos made by the Kerala police <sup>28</sup>
	Communicating on Resource Management	A tracking system to record and analyse suspects and contacts <sup>29</sup> Keeps track of data about the available hospital beds and quarantine facilities in the district <sup>29</sup> Detailed food delivery services and ambulance network <sup>29</sup>
Arming	Equipping	District control rooms set up to procure PPE such as masks and gloves <sup>30</sup> Procurement of PPEs, masks and essential medicines were expedited <sup>31</sup> District hospitals were instructed to earmark isolation wards for Covid-19 patients <sup>31</sup> A Health Information System for population health management and disease surveillance <sup>31</sup>
	Deploying	Asimov Robotics deployed robots at entrances to office buildings to dispense hand sanitizer <sup>25</sup> Masks and hand sanitizers became too costly. Local production boosted especially by Kudumbashree teams <sup>39</sup>
	Monitoring	Collects data points such as the number of people who have used the washroom, total time spent by these people <sup>25</sup> Help the toilet managing authorities to clean the toilets appropriately <sup>25</sup> Daily monitoring of the contacts over the phone also through a neighbourhood watch <sup>32</sup> Village councils enforced and monitor mass quarantine with the consent of the people. - B Ekbal <sup>33</sup> Calls made twice a day from the district control room, as well as once in the evening from the local primary health centre <sup>32</sup> Health inspections prevented mass outbreaks among migrant workers <sup>34</sup>
Identifying	Testing	Using centrally procured real-time polymerase chain reaction (PCR) testing kits <sup>22</sup> Spearheaded the use of rapid testing kits and walk-in clinics. First state to procure rapid test kits from the Pune-based Mylab <sup>34</sup> Institute director Asha Kishore: “The test will be India’s confirmatory diagnostic test for N gene of SARS-CoV-2 using RT-LAMP technique”. This technology is much faster than RT-PCR <sup>14</sup>
	Tracing	Telephone call records, surveillance camera footage and phone location data to track the contact <sup>35</sup> GPS tracking of quarantine locations <sup>32</sup> Employing dedicated neighbourhood watch staff <sup>32</sup> Geo-mapping tools to plot the addresses of those under observation in homes <sup>32</sup>
Containing	Fencing	A questionnaire by ASHA Workers filled with 20 questions used to keep a check on violations of home quarantine <sup>32</sup> Screening at the airport was tightened <sup>36</sup> “We realized a storm was coming. So, we began erecting our defenses,” Shahina Saleem, the president of the 23-member local village council <sup>33</sup> Software tracks the people’s movements in quarantine using Geofencing <sup>28</sup> Drones to track the public’s movement <sup>28</sup>
	Isolating	Kerala’s residents were housed in empty buildings during their mandatory quarantine <sup>37</sup> Locations Identified to Isolate 1 Million incoming Kerala Residents <sup>24</sup> Local Kerala authorities partnered with tour companies <sup>34</sup> Requisition boats to provide a safe and secluded place for those infected to recover <sup>34</sup> Temporary quarantine shelters were established to accommodate tourists and other nonresidents <sup>36</sup> Sent into a compulsory 28-days home quarantine ensured by the village councils <sup>31</sup>
Supporting	Food	Convinced ISP to boost network capacity to support those working from home <sup>34</sup> “With the help of community volunteers and panchayat, we were able to meet their non-medical needs” Abey Sushan, District Programme Manager with National Health Mission, Pathanamthitta <sup>38</sup> Panchayat officials supply non-medical needs to the households <sup>31</sup> Kerala government announced a \$2.6 billion coronavirus relief package <sup>34</sup> Delivering food to schoolchildren reliant on free lunches <sup>34</sup> Setting up community kitchens to feed the public <sup>34</sup> The local village council opened a community kitchen. Free lunches provided for more than 1200 people <sup>33</sup>
	Medical	Automated calls through IVR would be placed to those under quarantine, with a set of pre-recorded questions <sup>32</sup> Local health officers are making sure that villagers on medication get their pills on time <sup>33</sup> “Very useful for police officers as basic consultation with a doctor can be done very quickly,” – Manoj Abraham, Additional Director General of Police and Head of Kerala Police Cyberdome <sup>28</sup> Local health officers are making sure that villagers on medication get their pills on time <sup>33</sup>
	Psychological	Every quarantined member will have a designated field staff <sup>31</sup> Calls made for psychological support <sup>31</sup> Counsellors made more than 340,000 telephone calls to personnel working in affected areas to counsel them on how to handle stress <sup>33</sup>

## Appendix B. Cited sources

Cite Num	Referenced Source	Title description	Accessed in:
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31	<i>The Telegraph</i> (April 24, 2020)	African nations are precariously positioned to fight Covid-19. What can they learn from Kerala?	<a href="https://www.telegraph.co.uk/global-health/science-and-disease/african-nations-precariously-positioned-fight-covid-19-can-learn/">https://www.telegraph.co.uk/global-health/science-and-disease/african-nations-precariously-positioned-fight-covid-19-can-learn/</a>
32	<i>The Indian Express</i> (Updated: March 13, 2020)	Covid-19: How a Kerala district brought nearly 900 people within surveillance net	<a href="https://indianexpress.com/article/india/kerala/covid-10-coronavirus-kerala-pathanamthitta-district-surveillance-precuations-6311041/">https://indianexpress.com/article/india/kerala/covid-10-coronavirus-kerala-pathanamthitta-district-surveillance-precuations-6311041/</a>
33	<i>BBC</i> (April 16, 2020)	Coronavirus: How India's Kerala state flattened the curve	<a href="https://www.bbc.com/news/world-asia-india-52283748">https://www.bbc.com/news/world-asia-india-52283748</a>
34	<i>The Diplomat</i> (May 09, 2020)		

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Cite Num	Referenced Source	Title description	Accessed in:
35	CNBC (March 26, 2020)	How a South Indian state flattened its coronavirus curve Use of surveillance to fight coronavirus raises concerns about government power after pandemic ends	<a href="https://thediplomat.com/2020/05/how-a-south-indian-state-flattened-its-coronavirus-curve/">https://thediplomat.com/2020/05/how-a-south-indian-state-flattened-its-coronavirus-curve/</a> <a href="https://www.cnbcm.com/2020/03/27/coronavirus-surveillance-used-by-governments-to-fight-pandemic-privacy-concerns.html">https://www.cnbcm.com/2020/03/27/coronavirus-surveillance-used-by-governments-to-fight-pandemic-privacy-concerns.html</a>
36	Washington Post	Aggressive testing, contact tracing, cooked meals: How the Indian state of Kerala flattened its coronavirus curve	<a href="https://www.washingtonpost.com/world/aggressive-testing-contact-tracing-cooked-meals-how-the-indian-state-of-kerala-flattened-its-coronavirus-curve/2020/04/10/3352e470-783e-11ea-a311-adb1344719a9_story.html">https://www.washingtonpost.com/world/aggressive-testing-contact-tracing-cooked-meals-how-the-indian-state-of-kerala-flattened-its-coronavirus-curve/2020/04/10/3352e470-783e-11ea-a311-adb1344719a9_story.html</a>
37	The Economist (May 9, 2020)	Vietnam and the Indian state of Kerala curbed Covid-19 on the cheap	<a href="https://www.economist.com/asia/2020/05/09/vietnam-and-the-indian-state-of-kerala-curbed-covid-19-on-the-cheap">https://www.economist.com/asia/2020/05/09/vietnam-and-the-indian-state-of-kerala-curbed-covid-19-on-the-cheap</a>
38	The Quint (Updated: April 14, 2020)	How Kerala's Pathanamthitta District fought Covid-19 and won	<a href="https://www.thequint.com/coronavirus/kerala-pathanamthitta-hotspot-coronavirus-model-handling-covid-19-hospitals-trace">https://www.thequint.com/coronavirus/kerala-pathanamthitta-hotspot-coronavirus-model-handling-covid-19-hospitals-trace</a>
39	Ideas for India (May 2, 2020)	Kerala's management of Covid-19: Key learnings	<a href="https://www.ideasforindia.in/topics/governance/kerala-s-management-of-covid-19-key-learnings.html">https://www.ideasforindia.in/topics/governance/kerala-s-management-of-covid-19-key-learnings.html</a>

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**Soumodip Sarkar** is a Full Professor at the Department of Management, University of Évora, Portugal, and researcher at CEFAGE-UE. He is currently also an Associate (Non-resident Fellow) of the Asia Center at Harvard University. He is also the Vice-Rector of the University of Évora, as well as the Executive President of the Science Park of the region (PACT).

His current research interests include frugal innovation, entrepreneurship and resource constrained innovation. His recent research has been published in high impact journals such as: *Scientometrics*, *Journal of Business Venturing*, *Journal of Small Business Management*, *European Management Journal*, *Entrepreneurship & Regional Development*, *Technology Forecasting and Social Change*, *Journal of Business Research*, *Service Business*, *Sustainability*, *Journal of Cleaner Production*, *Journal of Knowledge Economy*, *European Journal of Innovation Management*, *Service Industries Journal*, *Trends in Food Science and Technology*, *Regional Science and Urban Economics*, *Energy Journal* among others. He has published four books on entrepreneurship and innovation, and his most recent book, *EntreSutra* was recently published by Bloomsbury. He has been a coordinator as well as team member of sixteen international (EU funded) as well as regional projects, and currently involved in nine different projects.

Prof Sarkar has given a large number of international keynote speeches, and is a highly sought after speaker on the relevance of entrepreneurship and innovation in society. He has been featured in national and international media, including the Economist and BBC.