POOLED TESTING STRATEGY DURING COVID-19

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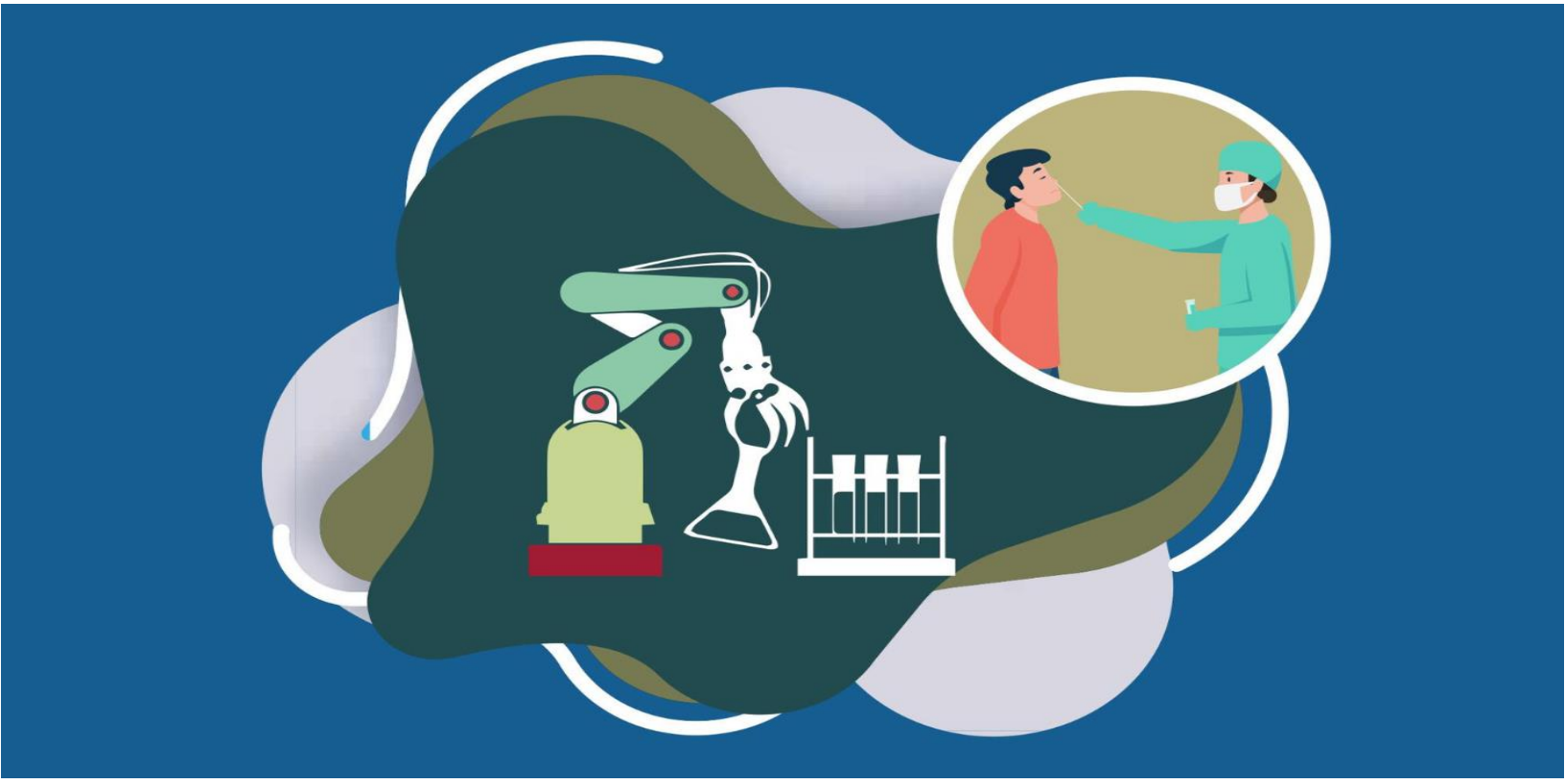

The study team comprised Sarang Deo as the Principal Investigator, Ashish Sachdeva as the Co-Principal Investigator, and Nikhil Chandak as the Analyst.

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1. Background

Since its initial clinical observations in Wuhan, China in December 2019, most nations in the world struggled to contain the SARS-CoV-2 virus. In India, there were significant resurgences of the disease after the initial outbreak and lockdown in March 2020. India was one of the world's worst-hit nations in terms of COVID-19 spread with around 33 million confirmed cases and 445,000 fatalities as on 3 September 2020. Yet, the country was testing less than 0.1% of its population at that time. [(1)]

Testing played a major role in managing pandemics like COVID-19. India too very quickly ramped up its testing capabilities and aligned its digital technology expertise, calibrating its response and preparedness to the evolving nature of the pandemic. The testing rate was enhanced significantly with the introduction of rapid antigen detection tests besides molecular tests, which remained the mainstay of diagnosis. Strengthening testing capacity also entailed stepping up capacity, data monitoring, skilled human resources and supply chain constraints. In line with these efforts, pooled testing as a strategy had seen excellent results globally and was introduced in Indian laboratories to increase the number of tests and to identify infections in the communities at a time when the COVID-19 pandemic was raging and individual testing was, both time-consuming and relatively more expensive. Pooling means combining samples from multiple individuals in a "batch" or pooled sample, which then undergoes diagnostic testing. Instead of directly sending the original samples, a pooled sample is prepared and sent for testing. In case the pooled sample turns out to be positive, all the samples are tested individually. If the pooled sample turns out to be negative, then all the individual samples are considered negative. Pooled testing helps to conserve testing reagents, reduces the cost of testing substantially, facilitates surveillance and screening in large populations with a low prevalence of the infection, and enhances the throughput by increasing the number of specimens tested per testing cycle and reduces the turnaround time of reporting the test results. There are several disadvantages of pooled testing as well, pooling may result in low sensitivity especially when more samples are pooled for testing, while testing reagents are conserved during pooling, other consumables such as swabs, collection vials, PPE kits, etc., may not be conserved, if the pooled sample turns out positive, then all the individual samples need to be tested. This may increase the turnaround time for testing if there is a surge in infections since there are more chances of detecting positives.

Our team conducted an analytical analysis to estimate the benefits of pooled testing. We study pooled testing for COVID-19 (both global and Indian experience), the benefits of pooled testing, and also talk about alternate pooled testing strategies.

2. Standard Pooling

2.1 What is pooling?

Pooling means combining samples from multiple individuals in a “batch” or pooled sample, which then undergoes diagnostic testing. Instead of directly sending the original samples, a pooled sample is prepared (generally, by taking a fraction of each sample) and sent for testing. In case the pooled sample turns out to be positive, all the samples are tested individually, which is known as de-convolution. If the pooled sample turns out to be negative, then all the individual samples are considered negative. This method of pooled testing was first proposed by Robert Dorfman in 1943. [(2)] It was used in the screening

of HIV/AIDSin the initial days to preserve the testing reagents, which were hard to come by. Pooled testing proved tobe a highly cost-effective strategy and has also been used historically to detect blood donors' infections. [3]For screening infectious diseases, pooled testing is most effective when the prevalence of a particular pathogen is low. We describe below its advantages and limitations.

Advantages

- Helps to conserve testing reagents.
- Reduces the cost of testing substantially.
- Facilitates surveillance and screening in large populations with a low prevalence of infection.
- Enhances the throughput by increasing the number of specimens tested per testing cycle and reducesthe turnaround time of reporting the test results.

Disadvantages

- Pooling may result in low sensitivity especially when more samples are pooled for testing, it will lead to dilution, thereby decreasing the sensitivity of the test.
- While testing reagents are conserved during pooling, other consumables such as swabs, collection vials, PPE kits, etc., may not be conserved.
- If the pooled sample turns out positive, then all the individual samples need to be tested. This may increase the turnaround time for testing if there is a surge in infections since there are more chances of detecting positives.

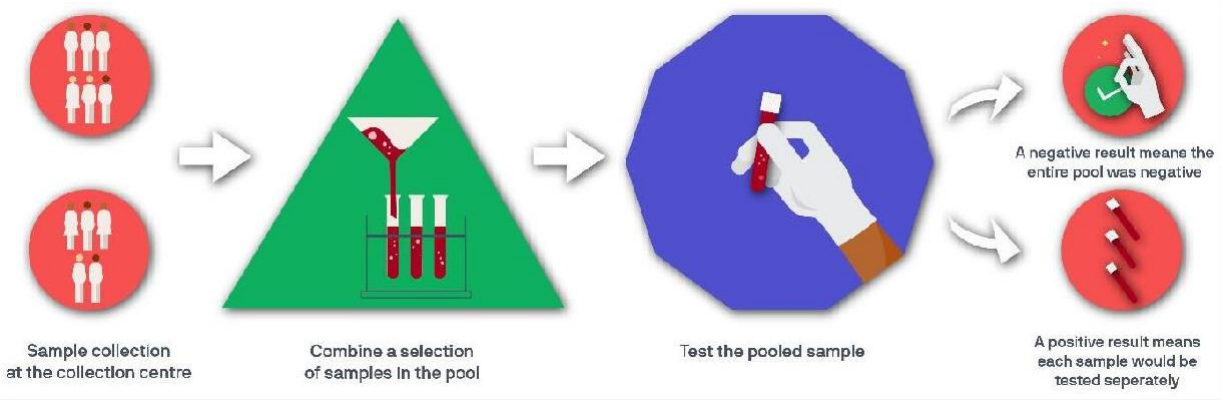
Looking at the above pros and cons, one can conclude that doing pooled sampling will be ideal:

- When the prevalence of infection is low
- For facilitating large-scale surveillance of susceptible populations
- When done at the collection centres, rather than within the laboratories
- By using automated specimen aliquoting, thereby reducing human errors and ensuring the follow-up of individual samples in the pool
- With the use of minimum consumables

It has been found that the use of pooled testing hinges on two essential criteria;

- The prevalence of infection in the population/community
- The pool size, i.e., the number of samples that get pooled together in a single pool

Figure E-1: Dorfman's Algorithm for pooled testing of samples



2.2 Pooled testing for COVID-19

As described earlier, pooled testing as a strategy is not new. Therefore, when the pandemic struck in early 2020, countries fell back to this time-tested method to increase the testing volume, decrease turnaround time and preserve cost. Wuhan, which is widely accepted as the epicentre of the pandemic, used pooled testing on a mass scale to identify susceptible cases. [4] It tested 6.5 million people in just 19 days using this method. Wuhan's experience with pool testing showed its credibility and use in surveillance. Germany used pooled testing as a strategy to increase the number of tests and identify infections in the communities. It could stem the tide of the pandemic relatively better than many of its European neighbours because of pooled testing. [5]

Considering its value, many countries have employed pooled testing as an integral part of their testing strategy. Below is a table elaborating on a few countries' experiences with pooled testing.

Table E-1: Global experience in using pooled testing for COVID-19

Country/Region	Experience with pooled testing
United States of America	CDC has released guidelines for the use of pooled testing. Laboratories certified under the Clinical Laboratory Improvement Amendments (CLIA) can use a specimen pooling strategy. [6] The CDC recommends that laboratories should determine prevalence based ona rolling average of the positivity rate of their SARS-CoV-2 testing over the previous 7–10 days.
United Kingdom	The UK has recommended the use of pooled testing for universities. The universities of Cambridge and Nottingham are doing pooled testing to keep the campuses open. [7] The universities are encouraging students to self-administer these tests.
South Korea	South Korea used pooled testing to screen high-risk population groups such as residents in nursing homes. [8] The testing was implemented based on the guidelines of the Korea Centers for Disease Control and the Korean Society for Laboratory Medicine.
Rwanda	Researchers from Rwanda developed an algorithm to detect COVID-19-positive samples from a pool of 99 swabs. [9] This algorithm is inspired by the geometry of a hypercube and helps identify a large number of people with a low viral load. It is estimated to be 20times cheaper than normal COVID-19 testing. It is currently used to screen air travellers in Rwanda and is also used in South Africa to test rugby players.
Ghana	Ghana started using pooled testing right from the early stages of the pandemic as it was facing a shortage of testing facilities. [10] The country also found using pooled testing more prudent as the prevalence of infection in the country was very low. The nodal laboratory at Noguchi Memorial Institute for Medical Research (NMIMR) started with a pool size of five and gradually increased it to ten.
Israel	Researchers at the Ben-Gurion University of the Negev (BGU) have developed a novel algorithm for pooled testing called the Pooling Based Efficient SARS CoV-2 testing or P-BEST*)*. This is a single-step group testing approach for a large number of samples by distributing the samples across multiple pools. Researchers found that if the rate of COVID-19 positivity in a given population is below 1.3%, the P-BEST method offers both an eight-fold improvement in testing efficiency and an eight-fold reduction in test costs over individual testing.

By analysing the experiences of different countries as mentioned in the above table, it can be concluded that:

- Pooled testing can be done if the prevalence of COVID-19 infection is low in a particular community. This can be determined by looking at the rolling average of the positivity rate for 7-10 days.
- Pooled testing can be done to look for infections in a homogenous community such as school/college students or high-risk categories such as old-age residents.
- Pooled testing is a cost-saving strategy which can be employed in resource constraint situations.
- Pooled testing is an effective strategy for mass screening and surveillance.
- There are various strategies for pooled testing which can be adopted based on the need and circumstances.

It is now generally accepted in the scientific community that the increase in the prevalence of infections would lead to a decrease in the pool size. [11]. Studies conducted in Israel and Germany have shown that up to 32 or even 64 samples can be pooled together to get adequate results. [12] Even a pool of five samples increases testing efficiency and a substantial cost reduction. [13] A study conducted in Nebraska, United States has determined the relationship between prevalence and optimal pool size. [14]

Below is a table summarising the optimal pool size (the size of a pool leading to the maximum reduction in expected tests) for varying positivity rates. Further, a graph is shown displaying the change in optimal efficiency with varying pool sizes for positivity rates 1%, 2%, 3%, and 5%. Here, optimal efficiency is the ratio of individual tests, which is the same as the number of samples, to the expected number of tests for a given pool size. All the calculations hereafter are done under the assumption that samples are independent and identically distributed across pools.

Figure E-2: Variation in optimal efficiency with pool size

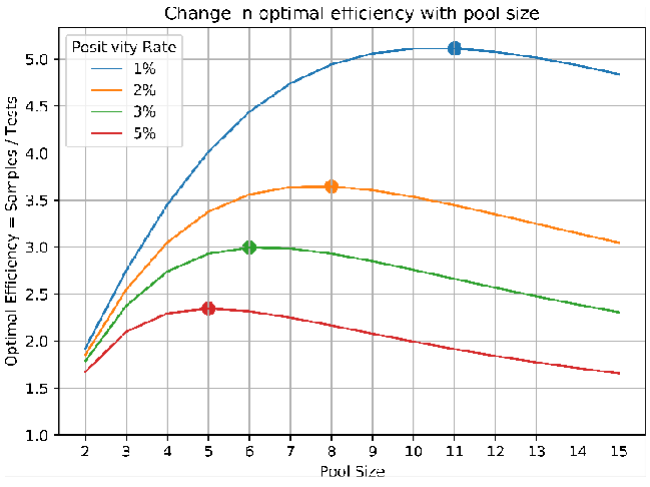


Table E-2: Comparison of optimal pool size and positivity rate

Positivity Rate (%)	Optimal Specimen Pool Size
1	11
2	8
3	6
5	5
7	4
10	4
15	3

2.3 COVID-19 pooled testing in India

Understanding the importance of pooled testing, the ICMR released an advisory with a set of criteria for pooled testing in India. [15] The following are the recommendations laid out by ICMR in its advisory:

- Use pooled testing only in areas where the positivity rate of COVID-19 testing is <2%.
- In areas with a positivity rate between 2–5%, pooling may be considered only in community surveys or surveillance among asymptomatic individuals. Symptomatic patients, known contacts of confirmed cases, and healthcare workers in direct contact with confirmed cases should be excluded.
- Pooling is not recommended in areas with a positivity rate >2%.
- The preferable number of pooled samples is five.
- Based on the ICMR advisory, several states issued guidelines for pooled testing and devised their own strategy based on the local conditions. A few examples of such state-specific strategies are explained below.

Punjab

Punjab was one of the first states in the country to conduct pooled testing trials in Govt. Medical College, Amritsar, and Govt. Medical College, Patiala on 15 April 2020. The state follows the ICMR guidelines but has tweaked them based on its needs. [15] Sample collection is being done at hospitals, flu corners, isolation hospitals, as well as in hotspots and large outbreak areas. In addition, in selected areas such as slums and migrant clusters, house-to-house visits are also conducted, and samples are taken at a field station. These samples are then transported to the nearest Viral Research Diagnostic Lab (VRDL) for processing. Based on the assessments conducted by PATH, the following strategies for pooled testing were observed:

- **Strategy 1:** (positivity <2%): All samples collected at collection centres are segregated and packed in separate boxes based on the patient categories of ICMR. The RT-PCR laboratory receives the samples along with the line list mentioning the categories for each patient/sample. The staff prepares a pool of five samples as per the line list received from the collection centres.

- **Strategy 2:** (positivity >2%): Pools are prepared using three samples in each pool irrespective of the patient category.

Kerala

Kerala released its advisory on pooled testing in the month of May 2020. [16] As per the advisory, the District Surveillance Officer (DSO) will be in charge of implementing and collecting samples for pooled testing. Persons who are eligible for pooled testing are as follows:

- Samples of persons selected under the sentinel surveillance.
- Samples taken from persons who have come to the state from outside.

The advisory mentions that individual samples are to be collected in a modified 0.5 ml Viral Transport Media (VTM) and pooled at the RT PCR laboratory. Further, it explicitly states that samples should not be pooled at the collection centres.

Karnataka

The state adopted a pooled sampling strategy late into the pandemic in October 2020, when the test positivity rate (TPR) fell considerably. [17] It mentions that pooling of samples is permitted only in *talukas* where the test positivity rate is below 5%. In Bengaluru, pooled testing is permitted only in those zones where the TPR is below 5%. The total number of RT-PCR tests assigned to each state remains. It mentions that for arriving at the TPR, a rolling average of the last seven days should be taken. Deputy Commissioners/Special Commissioner of Bruhat Bengaluru Mahanagara Palike (BBMP) should notify *talukas*/zones for pooled testing every Monday based on last week's positivity report. It is instructed in the advisory to pool five samples at once, and further action has to be taken based on ICMR guidelines.

Tamil Nadu

In Tamil Nadu, pooled testing is carried out in areas with a TPR of <2%. Like Kerala, Tamil Nadu also does pooled testing for the screening of international and domestic travellers coming to the state. The rationale behind this is that the TPR in this category of individuals is found to be close to 1.5%.

To summarise, the states have adopted the ICMR guidelines by and large while making some minor changes based on the local conditions. The maximum pool size set by the states stands at five for a positivity rate below 5%. The states are currently following the standard Dorfman pooling strategy, with sample collection done at the collection centres and the process of pooling being carried out in the testing laboratory. Kerala explicitly forbids pooling at the collection points, though no further explanation is given in the advisory.

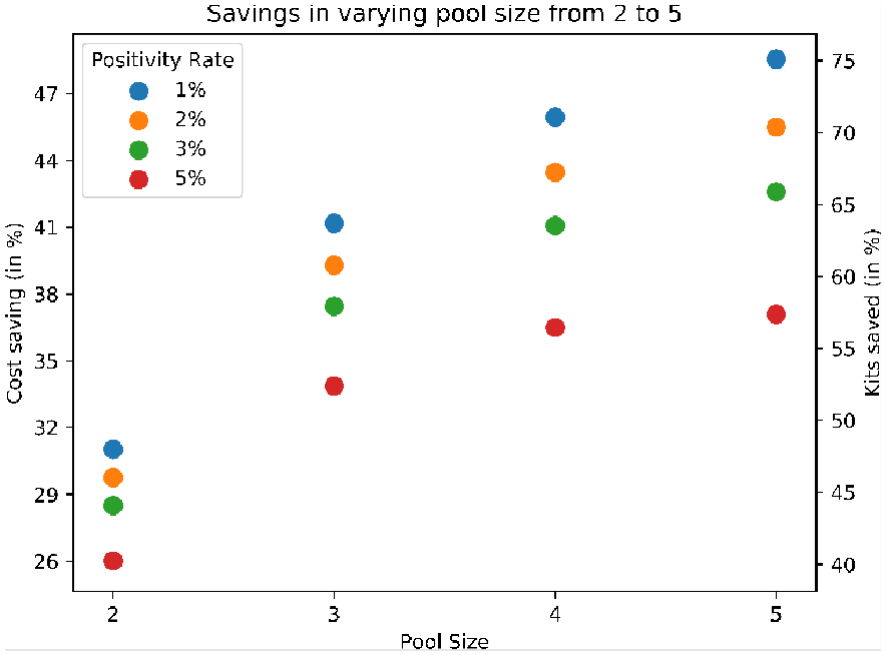
2.4 Cost reduction

Pooled testing leads to a reduction in the number of testing kits in comparison to individual testing, so testing reagents and their cost will be preserved. While the reduction in the number of 'kits' through pooled testing can be shown directly, the savings in cost is slightly more involved. Previous studies have estimated that the average public RT-PCR cost of testing one sample is Rs 643. This can be divided as follows:

- **Collection & Transportation cost:** Rs148 which is the operational cost of collecting a sample on the field and transporting it to the lab.
- **Testing cost**: Rs 495 which accounts for the in-lab cost which can be further divided as:
  - ***Cost of Reagents***: Rs 415 which is the cost incurred due to the use of RT-PCR kit and RNA extraction for testing.
  - ***Others***: Rs 80 which is the cost of consumables related to the processing of a sample in the lab but not directly consumed in testing like pipettes, swabs, PPE kit, etc.

Thus, by pooled testing, we use fewer kits and save on the cost of testing reagents. As the government has recommended pool size to be not more than five, a scatter plot has been created below *Figure E-3* to demonstrate the number of expected testing kits and the cost which can be saved through pooled testing fordifferent pool sizes (from 2 to 5), under different positivity rates (1%, 2%, 3%, 5%).

Figure E-3: Cost and kits saved for varying pool sizes under different positivity rates



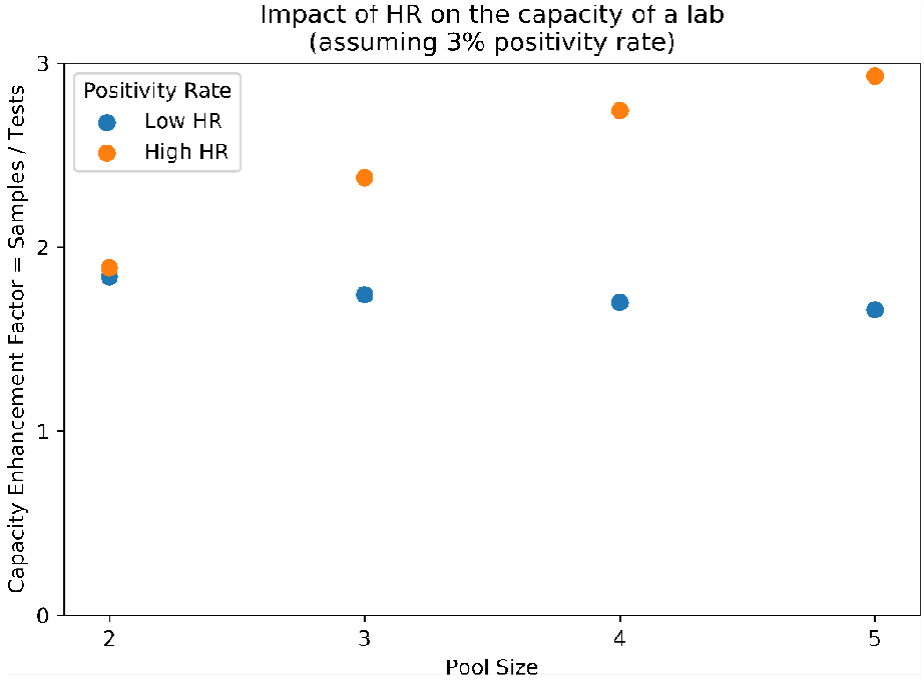
Hence, we see that with pools of size 3 – 5, 34% – 49% of the cost can be saved on *average* when the positivity rate varies from 1% – 5%.

2.5 Increased throughput

As the number of expected tests via pooled testing is less compared to individual testing, a lab can test more samples under the same capacity leading to a rise in its throughput. The process flow from a sample's arrival to the sample's result was studied during field visits to analyse this enhancement in capacity. Different activities throughout the process of testing samples were modelled like sorting, preparation, RNA extraction, and time taken by RT-PCR machine. Various combinations of the different resources (machines and HR) were considered to observe the difference in a lab's capacity and identify the bottleneck resource (resource providing the lowest output).

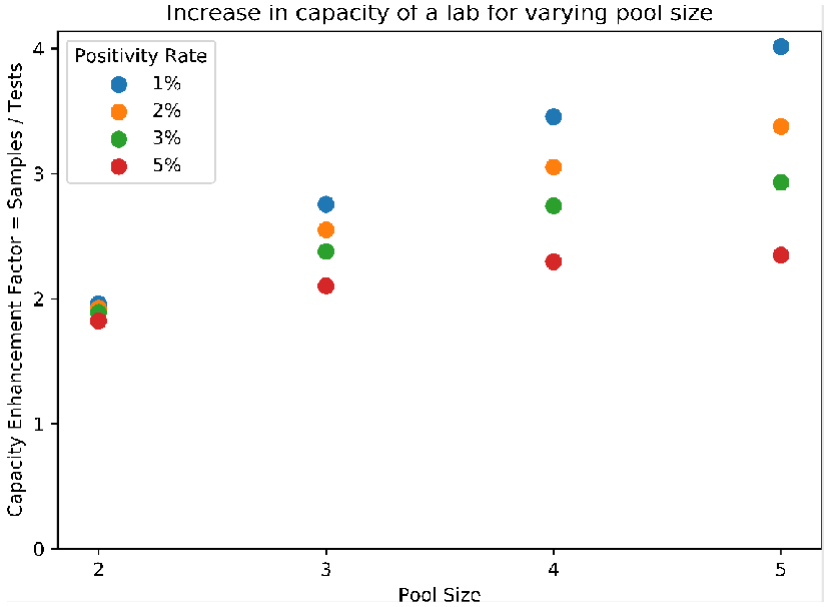
It was observed that the increase in capacity depends upon the number of different HRs present in a lab. Further, the increase in the lab's capacity may not be linear with pool size, i.e., 5-pool may not increase the capacity five times. The lab analyst informed that although pooled testing reduces the machine's per-sample processing time, it increases the processing time of activities, such as sorting and sample preparation. The impact of HR on the capacity of a lab is shown in *Figure E-4*, assuming samples have a 3% positivity rate.

Figure E-4: Effect of HR on the capacity of a lab



An increase in throughput is shown by pooled testing assuming enough HR are available. The capacity enhancement factor is the ratio of the number of samples that can be processed to the number of tests done by a lab. The figure below shows the factor by which pooling enhances a lab's capacity.

Figure E-5: Increase in throughput by pooled testing for different pool sizes and positivity rates



Pools from size 3 – 5 are observed and a lab's capacity can be increased at least two times and as high as four times when the positivity rate varies from 1% – 5%, assuming enough HR are available.

2.6 Discussion

The utility of pooled testing is seen as a means to test a significantly larger population with no additional resources compared to individual testing. Pooled testing is being adopted increasingly as it not only saves cost but also increases the throughput of a lab significantly. Pooling size has been restricted to five in ICMR guidelines, but it has been shown in numerous global experiments that pools up to size 32 are feasible. [12]

It is also shown that optimal pool size depends on positivity rate, so dynamic pool size can also be employed to minimise the expected number of tests. While larger pool sizes will be immensely beneficial (for example, in screening asymptomatic individuals predicted to have a low positivity rate), they should be employed in practice only after a careful review of the admissible loss in sensitivity. Further, a decentralized mode of calculating the rolling average of positivity rates, as done in Karnataka, can help plan for pooling in a better fashion and subsequently reduce the load on laboratories.

The Dorfman Pooling strategy, which has been discussed thus far, is also known as sample/media pooling and is commonly practised in India and worldwide. In this method, individual samples are collected at collection centres and then sent to laboratories for pooling. This section proposes a different technique for pooling aimed at addressing the limitations of sample pooling. The two key disadvantages of the currently practised pooling method are:

- It does not help in any significant reduction of workload at the laboratories since the same laboratories have to not only test samples but also create pools of them.
- It might lead to a substantial dilution of viral RNA present in any of the samples, thereby affecting the analytical sensitivity of RT PCR assay.

Swab pooling, on the other hand, helps to overcome these challenges as it is done at the collection centre

or in the field, thereby reducing the chances for laboratory manipulation and lessening the workload of the laboratories. It also minimises the chance of dilution of viral RNA. [20] The details of Swab Pooling are below.

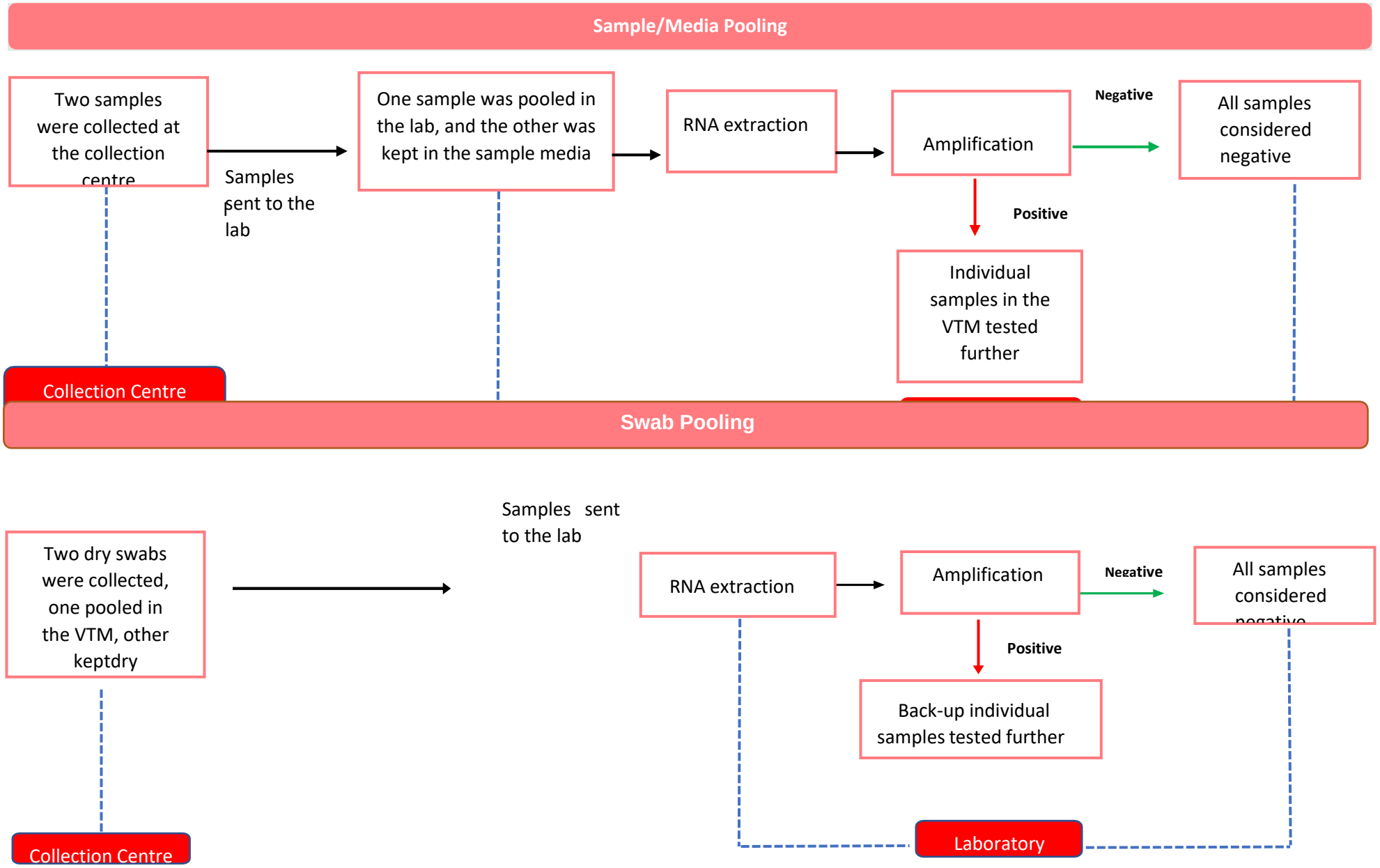
3. Alternate Pooling Strategies

3.1 Swab pooling

The process for Swab pooling follows:

1. The first step is to collect two dry swabs from the same individual. One swab is mixed into the pooled VTM tube, while the other swab acts as a backup and is kept dry (without VTM) throughout transportation.
2. If the pooled tube turns out to be positive, then this backup swab is used for individual testing. At the collection centre, the VTM tube is opened only when the swab is ready to be concentrated and immediately closed after and put back into a refrigerated area.
3. The last four digits of the individual's SRF ID are added to the white space of the VTM tube. Generally, for an individual sample, name, sex, SRF ID, and more details have to be noted down on itstube, but for this pooling scheme, identities of multiple samples must be accommodated on the sametube, so the last four digits are used since they are sufficient for unique identification.
4. The number of samples mixed into the VTM tube depends on the allowable pooling threshold. Both the individual dry swabs and pooled tubes are sent to the same lab after which the normal pool testing procedure follows. Below is an illustrative flowchart to summarise the process:

Figure** Error! No text of specified style in document.**-1: Comparison between Sample and Swab Pooling



3.2 Review of swab pooling

No dilution of samples	The swab collected from an individual is entirely mixed into a VTM tube for pooling instead of a fraction of it being used. Hence, the the pooled tube is more concentrated than usual.
Reduced workload in the lab	As the pooling of samples is done in the collection centre itself, the workload of technicians is reduced significantly.
Reduced TAT	The lab agents don't need to spend time sorting the samples depending on the source or positivity rate and don't haveto prepare pools. This contributes to a significant reduction in TAT
Cost savings	In sample pooling, all the swabs are sent in VTM whereas in this method, only the pooled tube is prepared and sent in VTM while other swabs are kept dry.
Extra training	Technicians at the collection site have to be cautious in handling swabs to minimise the chances of cross-contamination. While they do have basic training in how to handle VTM tubes, extra training should be given to minimise errors.
Quality control	As the technicians on-site may not be skilled at pooling, it is desirable but not necessary to have a lab HR present at the collection site for supervision.

3.3 Swab pooling in the laboratory

While the above strategy seems quite promising to address the drawbacks of standard pooling techniques, the overhead costs of training technicians on-site can be quite high, and there is also a chance of cross-contamination of samples when they are pooled on-site. Cross-contamination is highly undesirable as not only will the viral media of the samples in the pooled tube get affected, but it may also leadto false positives, drastically increasing the number of tests required to identify the positive cases correctly.

The study team proposed a simple method to overcome this challenge. As earlier, two dry swabs were collected from an individual at the collection site. However, these were not pooled at all at the collection sites, so both swabs were sent to the lab. At the lab, pools were prepared like earlier at collection sites. Here, an entire swab was mixed to prepare the pool instead of a fraction of it being used earlier since there was now another backup swab. Thus, there was no dilution of the samples in the pooled tube, and

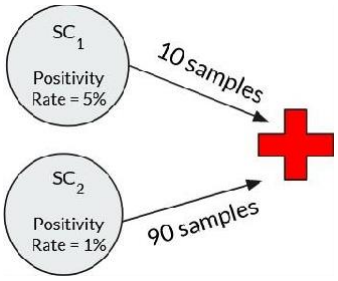
cross-contamination was minimised due to the proficiency of the lab technicians in handling tubes and preparing pools.

This method can be used if there is a possibility of cross-contamination in swab pooling. Through this scheme, there is less dilution when compared to the typical pooling strategy. However, the workload remains the same. Any of these two strategies described below can be employed above as per the recommendation from the state officials.

3.3.1 Mixed and separate pooling of independent groups

A lab receives groups of samples from varying collection sites constituting overall a heterogeneous population comprising of healthcare workers, symptomatic and high-risk persons, asymptomatic individuals, and more. Due to variation in positivity rates in the group of samples received from each collection site, a question arises as to whether to mix samples across groups and then pool all of them togetheror to separately pool them in their groups. The same is addressed below in various scenarios under the assumption that the samples are independent of each other in each group. The illustration below depicts this scenario.

Figure E-7: Illustrative scenario for Mixed and Separate Pooling



Consider two different collection sites SC1 and SC2. Suppose SC1 sends 10 samples with a positivity rate of 5% to a lab, while SC2 sends 90 samples with a 1% positivity rate to the same lab. If separate pools are created for SC1 and SC2, the expected number of total tests is 4.26 + 22.41 = 26.67. Whereas, if the samples are mixed randomly, the average positivity of a sample will be the weighted average of positivity rates of SC1 and SC2. Here, the average positivity rate after mixing randomly is 1.4%. With this weighted positivity rate, the expected number of tests that need to be performed after mixing is 26.8.

Thus, in this example, numerically, pooling separately is beneficial than pooling after mixing though the difference between the two came out to be very small. To investigate the difference between these two methods further, the study team analysed three different scenarios and plotted the difference between the expected tests of the two methods in each while observing which method might be better.

For varying positivity rates and the number of samples for two sample collection sites, 3D mesh plots were created to see the difference between the expected number of tests by mixed pooling and the expected number of tests by separate pooling. In Plot 1, the number of samples coming from SC_1 is takento be 50 while that from SC_2 is taken to be 450, and the positivity rate is varied from 0.1% to 10% for both.In Plot 2, the positivity rate at SC_1 is taken to be 1% while at SC_2 it is taken to be 5%, and the number of samplesis varied from 10 to 1000. In Plot 3, SC_1 is kept fixed with a positivity rate of 3% with the number of samples

being 500 while both the positivity rate and the number of samples at SC_2 are varied from 1% to 10% and 10 to 1000 respectively.

Figure E-8, E-9, E-10: Comparison of separate and mixed pooling

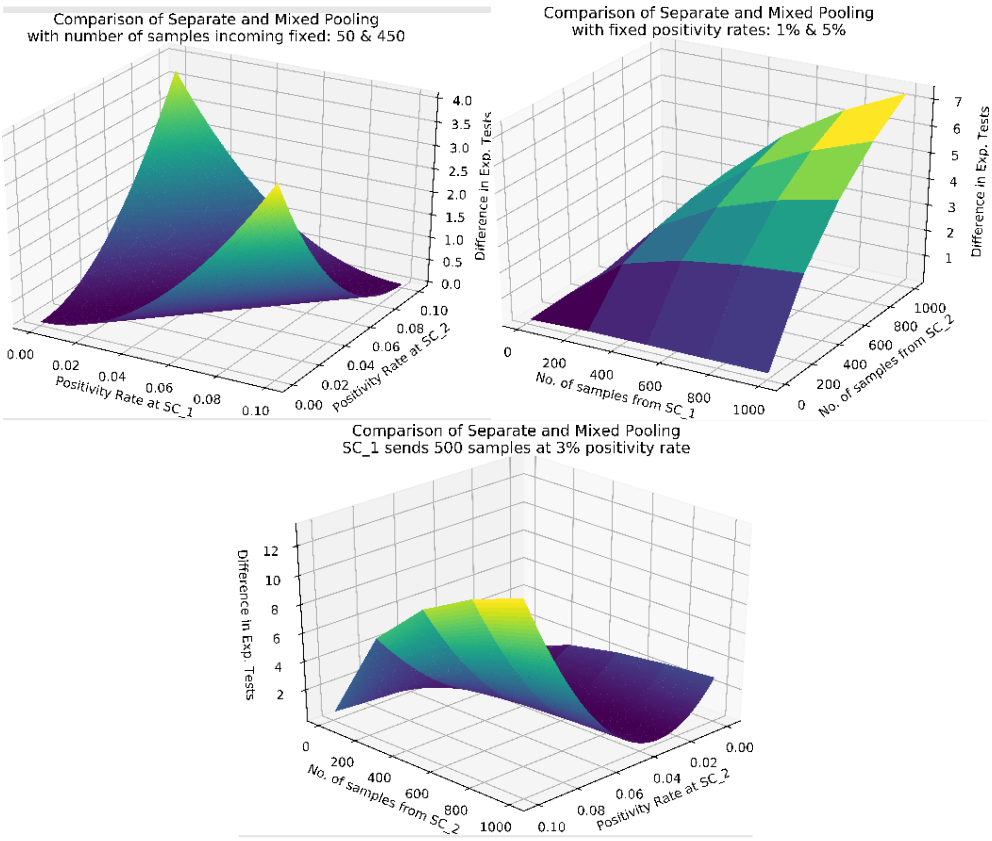


Figure E-8 shows the difference in the expected number of tests when the positivity rate at both the collection sites is varied keeping the number of incoming samples from them fixed. *Figure E-8* shows the difference in the expected number of tests when the number of incoming samples from both the collection sites is varied keeping the positivity rate at each of them fixed. *Figure E-8* shows the difference in the expected number of tests when one sample collection site is fixed with a positivity rate of 3% and 500 samples while both the parameters of the other sample collection site (positivity, number of samples) are varied.

Interestingly, in all of these mesh plots, the difference remains positive irrespective of the variation in the parameters. Thus, the expected number of tests by pooling after mixing randomly is better than separate pooling but only marginally. As the difference in the expected number of tests between the two methods is insignificant, we recommend that labs pool by mixing samples randomly as time will not be wastedin sorting the samples by their source.

So far, samples have been considered to be independent of each other at their respective collection sites, but this is hardly true. Samples are often collected in batches from specific groups of people like neighbours or residents of a housing society, office colleagues, students, factory workers, etc. This leads to samples being correlated to one another, and thus, each sample cannot be treated independently of others.

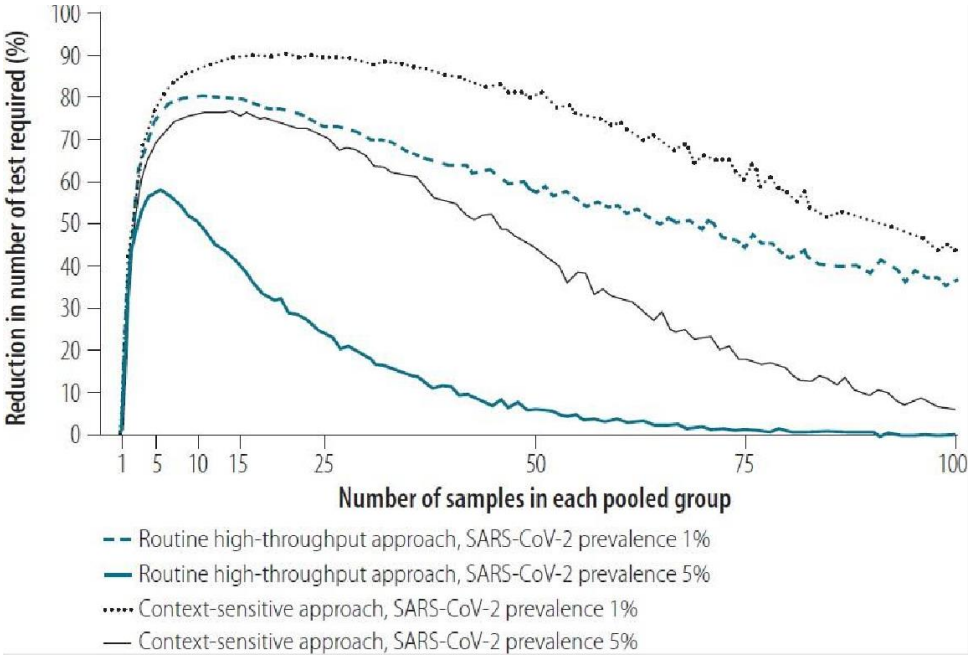
3.4 Pooling of correlated groups

Previous studies have referred to such groups as 'homogenous' and found that pooling samples of homogenous groups is better than the standard Dorfman Pooling strategy. [21] Here, the methodology and benefits of pooling homogenous groups are detailed.

This approach to pooling is a context-specific technique wherein teams carrying out contact tracing can designate homogenous groups in the field for subsequent pooled analysis. Here, first groups of similar people of defined size are formed, and swabs of all group members undergo pooled testing via RT-PCR. In the second step, all members of any group who tested positive are investigated individually. The second step requires a lower number of tests than the Dorfman Pooling strategy, thus bringing down testing costs. This method of testing can be used as part of surveillance to quickly and cost-effectively establish the severity of an outbreak in an area or amongst a group of people. It is also beneficial in establishing a within-group prevalence. [21]

Further, previous studies have shown that 58–89% fewer tests would be required for a pooled group size of 3 to 25 samples in a population of 150 000 with an infection prevalence of 1% or 5% when compared to individual testing. [22] The below figure shows that this context-sensitive approach offers higher savings in comparison to the normal pooling strategy (referred to as the 'routine-high throughput strategy' in the plot below).

Figure E-11: Reduction in the number of tests required with pooled sample analysis by strategy



3.5 Discussion

There are several methods of pooling apart from the normal and often followed sample pooling process. These methods were found to be cost-effective and relatively more efficient. There was also enough scientific research and practice that substantiated their benefits. Policy-makers can adopt any of these strategies based on the need and the context:

- Swab pooling at the collection centre/on-site pooling can be adopted after providing basic training to the field sample collectors on how to do pooling at the site and how to avoid contamination. This method will also reduce lead time in getting results from the pooled samples.
- If there are concerns for containment or there is an absence of training for the collection staff, then there is the choice of going for swab pooling at the laboratories.
- Pooling of homogenous or context-specific pooling can be used for surveillance or identification of disease outbreaks among specific groups.

Also, if swab pooling is employed on-site, it may further benefit by pooling homogenous groups. The fact that the population naturally comes in batches of homogenous groups like a family with symptoms coming to deposit samples for testing or screening a large cohort of school children will inherently lead to a context-sensitive approach; hence, yielding a significant reduction in expected tests on top of the other benefits of on-site swab pooling like no dilution of samples and reduced workload for lab agents.

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