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# A FRAMEWORK FOR PERFORMANCE EVALUATION AND MONITORING OF PUBLIC HEALTH PROGRAM USING COMPOSITE PERFORMANCE INDEX

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***Abstract:*** *A public health program (PHP) taken up by the government of a country refers to all organized measures to prevent disease and promote health among the population, by providing different planned cares/services to the people. Usually, the target population for different PHP are different. The basic requirement for success of a PHP is to ensure that all the planned cares/services are reached to each member of the target population. Therefore, the important performance measures for a PHP are the implementation status of all the planned cares/services under the PHP. However, management and monitoring of a PHP become quite difficult by interpreting separately the information contained in a large number of performance measures. Therefore, usually a metric, called composite performance index (CPI), is evaluated to understand the overall performance of a PHP. However, due a scaling operation involved in the CPI computation procedure, the CPI value does not reveal the true overall implementation status of a PHP and consequently, it is effective for management of a PHP. This paper presents a new approach for CPI computation, in which scaling/normalization of the performance variables is not required and therefore, it can be used for monitoring the true overall implementation status of a PHP in a region. A systematic approach for monitoring a PHP using the CPI values is proposed and applied for monitoring the maternal and child healthcare (MCH) program. The results are found effective towards continuous improvement of implementation status.*

***Keywords:*** *Composite performance index, Maternal and child healthcare, Monitoring implementation status, Performance measures, Public health program*

## 1. Introduction

Public health program (PHP) refers to all organized measures to prevent disease, promote health, and prolong life among the population as a whole. Today, the government of each country takes up several PHPs, through a broad range of people and organizations and agencies, with the aim to promote and protect the health of the nation and its communities. The common PHPs undertaken in different countries are disease prevention and health promotion in children, adolescents and pregnant women. Public programs of every stripe and size across the nation require appropriate performance measurements (indicators) for creating and carrying out activities to being accountable

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for achieving results – meeting goals, effecting change, and improving the quality of their services (Lichiello and Turnock, 1999). For the purpose of management and monitoring of a PHP, usually different performance measures (indicator variables) are defined taking into account different activities under the PHP. However, it is truly very difficult to make a meaningful decision by examining the values of the several indicator variables individually.

The composite index is a good measure/metric which can present the 'big picture' of a PHP and is easier to interpret than trying to compare many separate indicators. Thus, most commonly composite index is used for comparing relative status of implementation of a PHP in different regions. Several authors (Saisana and Tarantola, 2002; Salzman, 2004; Sharpe, 2004; Jacobs et al., 2006; Smith, 2009) have studied various methodological issues, and highlighted usefulness as well as pros and cons of composite index. The computation of composite index usually require some transformation of the original data.

The current article is in connection to our involvement in assessing the quality of field data on maternal and child healthcare (MCH) program being captured in the web portal of a province of India. The field data on different cares/services provided by the health departments in different regions of the province is uploaded daily in the web-based data capturing portal to facilitate routine assessment of the implementation status of the said PHP and its management. At the end of every month, the values of the performance variables are computed based on these captured field data for each region as well as for the whole province. To facilitate easy comparison of implementation status of the PHP in different regions, the values of the performance variables in each region are further converted to composite performance index (CPI). Conventionally, the arithmetic mean (AM) of the scaled values of the performance variables is considered as the CPI. We were interested to develop a management and monitoring scheme for the MCH program using these CPI values as the monitoring statistic. However, we observe that although these CPI values are useful for comparing the relative overall performance of different regions at a given time period, but not useful for developing a monitoring scheme. This is because of distortion of the true picture about the overall implementation status in different regions due to the scaling operation.

This paper presents a new method for computation of CPI, developed in the context of the MCH program in a province of India. In this method, the computed CPI values of different regions (sub administrative areas) represent the true overall implementation status with respect to various planned activities under the program. Therefore, it can be used for developing an effective monitoring system as well as it can be used to compare the relative overall performances of different regions.

This paper is organized in the following sections. Literature review is presented in Section 2. In Section 3, the current method of computation of CPI for the MCH program is described first and then, the demerits of this computation method are illustrated using hypothetical examples. Section 4 describes the developed method for computation of CPI in the context of the MCH program. Section 5 generalizes the developed method for CPI computation so that it can be easily applied to any PHP. A scheme for management and monitoring of a PHP using the CPI values is presented in Section 6. Section 7 illustrates the application and effectiveness of the proposed procedure using the field data of the MCH program. Section 8 concludes the paper.

## 2. Literature review

Macfarlane (2005) presented the main factors that influence the implementation of disease prevention and health promotion programmes in children and adolescents. Segall (2003) highlighted that improvement in the working and living conditions of health workers is a precondition for the effective delivery of public health services. Green and Collins (2003) discuss about the nature of tensions that public health managers face and suggest ways forward in relation to these problems. Frieden (2014) identified six necessary components for effective public health program implementation. Milat et al. (2015) have provided a narrative review of models and success factors for scaling up public health interventions. The focus of public health project is different from that of usual engineering and software development project, and therefore, Santos et al. (2014) emphasize on research towards the development of a specific model of success factors for public health project. Ahmed et al. (2016) presented a case study of application of the business-oriented SWOT analysis to the design and implementation of the program that successfully targeted lowering maternal mortality.

Lichiello and Turnock (1999) emphasized that all the PHPs require appropriate performance measurements (indicators) for creating and carrying out activities to being accountable for achieving results – meeting goals, effecting change, and improving the quality of the services. Several articles (Derose et al., 2002; Smith, 1990; Yuen and Ng, 2012) discuss about the definition, characteristics and measurement of a good performance indicator for a PHP. Many authors (Koshel, 1997; Papanicolas et al., 2008; Roper and Mays, 2000) address the methodological issues related to collection and assessment of performance indicators. Some other articles (Loeb, 2004; Love et al., 2008; Mays et al., 1998) attempt to identify the performance indicators that are critical for organizational assessment and improvement. Suen et al. (1997) and Loeb (2004) has analysed the current state of performance measurement in healthcare.

Importance of performance monitoring is highlighted by several authors (Dever, 1997; Jackson et al., 1998; Frieden, 2014). Tremain et al. (2007) have presented a variety of approaches for conducting evaluations of performance improvement. Pur et al. (2010) have proposed a hierarchical resource allocation modelling approach for primary health-care network monitoring. According to Jocobs et al. (2006) measuring performance using indicators is only one part of quality improvement strategies which also includes identifying important quality issues, analysing the information obtained, planning a response, and taking action to improve quality. Jackson et al. (1998) mentioned that the true value associated with performance measurement will only be realized when the key stakeholders are making data driven decisions. However, in reality, often data driven decisions cannot be taken because of a) absence of an appropriate technique for summarizing the information contained in a large number of performance variables, and b) absence of a systematic procedure for monitoring the performance of a PHP.

It is truly very difficult to make a meaningful decision by examining the values of the several individual indicator variables. The composite index is a good measure/metric which can present the 'big picture' of a PHP and is easier to interpret than trying to compare many separate indicators. Thus, most commonly composite index is used for comparing relative status of implementation of a PHP in different regions. Saisana and Tarantola (2002) and Sharpe (2004) have presented the current methodologies and practices for composite indicator development. Appleby and Mulligan (2000) and Jencks et al. (2003) have used budget-pie method, balance scorecard method and average ranking method respectively. Various methodological issues for development of composite indicator have been addressed by many authors (Smith, 1990; Salzman, 2004; Jacobs et al., 2006; Smith et al., 2008).

These approaches either transform the actual values of individual measures into ranks or scale the actual values of individual measures into certain intervals at some stages of the computation. As a result, true picture about the overall performance or implementation status is distorted, although these indices remain very useful for comparing the relative overall performances of different regions. However, since the true picture about the overall performance is distorted, no effective management and monitoring scheme for a PHP can be developed based on these composite indices. Therefore, there is a need to develop an appropriate methodology for computation of CPI so that it can be used not only for comparing relative overall performance of different regions, but also for establishing an effective management and monitoring scheme.

## 3. The current method of computation of CPI for the MCH program and its demerits

Among the various stages of women's lives, the child-bearing period represents a period of elevated risk, and the care provided is critical for both the woman's and her child's health and survival. The major causes of maternal deaths are known to be haemorrhage, toxaemia, anaemia, obstructed labour, puerperal sepsis etc. On the other hand, the leading causes of infant deaths are known to be birth defects, low birth weight, maternal complications, neonatal infections etc. Inappropriate practices such as delayed initiation of breastfeeding, delayed clothing and early bathing, not seeking care when newborns are sick increase the risk of newborn deaths. Most of these deaths are preventable with good ante natal, delivery, post natal and new born cares. The country launched the MCH program to provide the necessary ante natal cares (ANC), delivery cares (DC), post natal cares (PNC) and new born care (NBC) to pregnant women and the new born children. Several performance variables/indicators are defined for the MCH program to assess whether the intended results are being achieved. Here only a few important performance measures (variables), which are evaluated regularly, are considered and listed in Table 1.

**Table 1.** Performance variables for the MCH program

| Sr. No. | Performance variables (in proportion) | Abbreviation | Desired value |
|---|---|---|---|
| 1 | First trimester registration to total ANC registration | $P1_{ANC}$ | Higher-the-better |
| 2 | Pregnant women received 3 ANC check up to total ANC registration | $P2_{ANC}$ | Higher-the-better |
| 3 | Pregnant women received TT2 or Booster to total ANC registration | $P3_{ANC}$ | Higher-the-better |
| 4 | JSY registration to total ANC registration | $P4_{ANC}$ | Higher-the-better |
| 5 | Deliveries conducted at public institutions to total reported deliveries | $P1_{DC}$ | Higher-the-better |
| 6 | Caesarean-section delivery at public institution to total public institutional delivery | $P2_{DC}$ | Lower-the-better |
| 7 | Women received post partum check-up within 48 hrs. of delivery to total reported deliveries at public facilities | $P1_{PNC}$ | Higher-the-better |
| 8 | Women received post partum check up between 48 hrs. and 14 days of delivery to total reported deliveries at public facilities | $P1_{PNC}$ | Higher-the-better |

**Table 1.** Performance variables for the MCH program (continued)

| Sr. No. | Performance variables (in proportion) | Abbreviation | Desired value |
|---|---|---|---|
| 9 | Newborns weighed at birth to total live births | $P1_{NBC}$ | Higher-the-better |
| 10 | Newborns breast fed within 1 hour to live birth | $P2_{NBC}$ | Higher-the-better |
| 11 | Newborns having weight less than 2.5 kg. to total newborns weighed at birth | $P3_{NBC}$ | Lower-the-better |

### 3.1. The current method of computation of CPI

Suppose, the country consists of *m* distinct regions and the entire MCH program has *n* performance measures (variables). Then, $X_{ij}$ ($i$ = 1, 2,..., $n$; $j$ = 1, 2, ..., $m$) represents the value of the $i^{th}$ performance variable in the $j^{th}$ region. The value of $X_{ij}$ is expressed as proportion and, for some performance variables, higher values are desirable, whereas for others, lower values are desirable. Presently, the CPI is computed using the following steps:

***Step 1***: Normalize or scale the observed values of the performance variables in different regions into (0, 1) interval in such a way that the higher scaled value is desirable for all the performance variables. The following two equations are used for data transformation:

$$X_{ij}^{s} = \frac{X_{ij} - Min(X_{ij})}{Max(X_{ij}) - Min(X_{ij})}, \text{if higher value is desirable for } X_{ij} \quad (1)$$

$$X_{ij}^{s} = \frac{Max(X_{ij}) - X_{ij}}{Max(X_{ij}) - Min(X_{ij})}, \text{if lower value is desirable for } X_{ij} \quad (2)$$

where $X_{ij}^{s}$ is the scaled value of the performance variable $X_{ij}$; $Max(X_{ij})$ and $Min(X_{ij})$ are the minimum and maximum of $(X_{i1}, X_{i2}, X_{i3}, ..., X_{im})$ respectively, for the $i^{\text{th}}$ performance variable across regions.

***Step 2***: Compute the CPI of the entire public health program for $j^{\text{th}}$ region ($j$ =1,2,3,..., $m$) as:

$$CPI_{PHP}^{j} = \frac{\sum_{i=1}^{n} X_{ij}^{s}}{n} \quad (3)$$

### 3.2. Demerits of the current method

The goal of a PHP is to bring all the people of the country under the purview of the health program, i.e. to ensure that the benefits of the program are reached to all. This goal can be achieved by continuously improving the implementation status, usually measured as percentage (%) of people covered, in all the regions. Since the administrative units in different regions are different, the implementation status may vary widely in different regions. So another important requirement towards achieving the goal is to try for bringing uniformity of performance among different regions.

The problem with the current method for computation of CPI value is that the computed CPI value of a region does not represent the true overall implementation status of various planned activities under the program in the region. This happens due to scaling or normalization operation being carried out in step 1 of the current method. The reasons for this deficiency are explained below with the help of a hypothetical situation.

Consider that the marks obtained by five students in four subjects of a mid-semester and final semester examinations are tabulated in columns 2-5 of Tables 2 and 3 respectively. In each subject, the target marks was 100. The CPI values computed using the current method and the average scores for these five students in the two examinations are shown in Tables 2 and 3 respectively.

**Table 2**. Actual marks in mid-semester examination, and computed CPI and average marks

| Roll No. | Actual marks | | | | Scaled value | | | | CPI | Avg. marks |
|---|---|---|---|---|---|---|---|---|---|---|
| | Eng. | Math. | Geog. | Hist. | Eng. | Math. | Geog. | Hist. | | |
| 1 | 65 | 92 | 76 | 39 | 0.76 | 1.00 | 0.32 | 0.32 | 0.60 | 68.00 |
| 2 | 51 | 61 | 71 | 30 | 0.10 | 0.00 | 0.05 | 0.00 | **0.04** | 53.25 |
| 3 | 70 | 90 | 88 | 56 | 1.00 | 0.94 | 0.95 | 0.93 | **0.95** | 76.00 |
| 4 | 68 | 82 | 89 | 58 | 0.90 | 0.68 | 1.00 | 1.00 | 0.90 | 74.25 |
| 5 | 49 | 69 | 70 | 35 | 0.00 | 0.26 | 0.00 | 0.18 | 0.11 | 55.75 |
| Min. | 49 | 61 | 70 | 30 | | | | | | |
| Max. | 70 | 92 | 89 | 58 | | | | | | |

**Table 3**. Actual marks in final-semestral examination, and computed CPI and average marks

| Roll No. | Actual marks | | | | Scaled value | | | | CPI | Avg. marks |
|---|---|---|---|---|---|---|---|---|---|---|
| | Eng. | Math. | Geog. | Hist. | Eng. | Math. | Geog. | Hist. | | |
| 1 | 25 | 24 | 16 | 21 | 0.71 | 0.17 | 0.80 | 0.60 | 0.57 | 21.50 |
| 2 | 26 | 26 | 15 | 19 | 0.86 | 0.50 | 0.60 | 0.20 | 0.54 | 21.50 |
| 3 | 21 | 27 | 13 | 22 | 0.14 | 0.67 | 0.20 | 0.80 | 0.45 | 20.75 |
| 4 | 27 | 29 | 17 | 23 | 1.00 | 1.00 | 1.00 | 1.00 | **1.00** | 24.00 |
| 5 | 20 | 23 | 12 | 18 | 0.00 | 0.00 | 0.00 | 0.00 | **0.00** | 18.25 |
| Min | 20 | 23 | 12 | 18 | | | | | | |
| Max | 27 | 29 | 17 | 23 | | | | | | |

Note that the minimum and maximum possible values of CPI are 0 and 1 respectively, and the same for the average marks are 0 and 100 respectively. It appears from the CPI values in Table 2 that Roll no. 2 has performed very poor in the mid-semester (whereas, his/her average marks is 53.25), and Roll no. 3 has performed very good in the mid-semester (whereas, in reality, his/her actual average marks is 76 only). On the other hand, the CPI values in Table 3 give an impression that Roll no. 4 has performed extremely well whereas Roll no. 5 has performed extremely poor in the final semester. However, both the students have performed very poor since their average marks are below 25.

Similarly, the demerit of the current method is that if a region achieves the highest value in each of the performance measures among all the regions (even though all the highest values themselves are observed to be very poor for all the performance measures), its overall performance will be extremely good, and if a region achieves the lowest value in each of the performance measures among all the regions (even though all the lowest values are observed to be very high for all the performance measures), its overall performance will be extremely poor. Since the computed CPI value in a region is not the true representative of the actual implementation status in the region, no scheme for monitoring the health program can be developed based on this CPI value.

Another important weakness of the current method is that the computed CPI value is considerably insensitive to the changes in one or more individual performance measures. This happens due to usage of AM for converting different performance measures into a single composite value.

Usually, under a PHP, a large number of activities are planned and therefore, a large number of performance variables are defined for assessing the implementation status of the program. So the effect of changes in the performance measures is not sensitive enough, if the AM of a large number of performance variables is computed.

## 4. Proposed method of computation of CPI for the MCH program

Three basic requirements for developing a measure of overall performance based on the several performance measurements are: a) Values of all the performance measurements must be unit less or of the same unit, b) The minimum and maximum values of all the performance measurements should be the same, and c) Desired values for all the performance measurements must be unidirectional.

It may be noted that all the values of the performance measures shown in Table 1 are expressed in proportions, which implies that there is no need for data transformation to satisfy the first two basic needs. This is because proportions are unit less and the possible minimum and maximum values for them are 0 and 1 respectively. On the other hand, a lower-the-better type performance variable can easily be converted to a higher-the-better type performance variable and vice versa. So the third basic need can also be satisfied easily. It is, therefore, feasible to compute the CPI value without carrying out any normalization or scaling operation of the observed performance measures.

On the other hand, ideally, any change in the value of a performance variable should be adequately reflected in the measured value of the overall performance. It is well known that the geometric mean (GM) of individual values is more sensitive to the changes in the one or more individual values than the AM. So, a better choice for converting different performance measures into a single value may be to use the GM instead of AM. But, in that case, if the value of a performance variable is zero (or very poor), the overall performance will appear to be zero (or very poor), which may be unacceptable. It is, therefore, planned to make a trade-off between these requirements by using a combination of GM and AM for converting different performance measures into a single value.

All the cares/services offered under the MCH program can be divided into four subgroups, e.g. ANC, DC, PNC and NBC. Under each subgroup of cares/services there are several performance variables. It is decided first to assess the CPI of each subgroup of cares/services ($CPI_{sub}$) as the GM of the relevant performance variables and then, to assess the CPI of the entire MCH program ($CPI_{MCH}$) as the AM of the $CPI_{sub}$ values. The CPI of the entire MCH program is, therefore, estimated as the average of geometric means (AGM). Mathematically,

$$CPI_{MCH} = (CPI_{ANC} + CPI_{DC} + CPI_{PNC} + CPI_{NBC})/4, \; 0 \le CPI_{MCH} \le 1$$

where,

$$CPI_{ANC} = \sqrt[4]{(P1_{ANC}) \times (P2_{ANC}) \times (P3_{ANC}) \times (P4_{ANC})}, \; 0 \le CPI_{ANC} \le 1$$

$$CPI_{DC} = \sqrt[2]{(P1_{DC}) \times (1 - P2_{DC})}, \; 0 \le CPI_{DC} \le 1$$

$$CPI_{PNC} = \sqrt[2]{(P1_{PNC}) \times (P2_{PNC})}, \; 0 \le CPI_{PNC} \le 1$$

$$CPI_{NBC} = \sqrt[3]{(P1_{NBC}) \times (P2_{NBC}) \times (1 - P3_{NBC})}, \; 0 \le CPI_{NBC} \le 1$$

It may be noted that in the process of computation of the CPI values, all the lower-the-better type performance variables e.g. $P2_{DC}$ and $P3_{NBC}$ are transformed into higher-the-better type performance variables so that all the performance variables are of higher-the-better type. Therefore, higher values of $CPI_{ANC}$, $CPI_{DC}$, $CPI_{PNC}$, $CPI_{NBC}$ and $CPI_{MCH}$ will be desirable.

## 5. Generalisation of the proposed AGM method for computation of CPI

For fulfilling the objectives of a PHP, usually, it becomes necessary to offer several types of cares/services to the people, which can be categorized into different subgroups, and the number of cares/services under different subgroups may be different. For the purpose of generalization of the proposed AGM method, let a PHP offers $g$ subgroups of cares/services and the number of performance variables in $k^{th}$ subgroup of cares/services is $n_k$ ($k$ = 1, 2,..., $g$) and $\sum_{k=1}^{g} n_k = n$, where $n$ is the total number of performance variables for the PHP. Suppose, the PHP is launched in an area (e.g. country or state) which consists of $m$ regions. Then, the value of the $i^{th}$ performance variable ($i$ = 1, 2, ..., $n_k$) within $k^{th}$ subgroup of cares/services in the $j^{th}$ region ( $j$ = 1, 2, ..., $m$) can be denoted as $p_{i(k)j}$, and the $CPI_{PHP}$ in different regions can be obtained using the following steps:

***Step 1***: Express the values of all the performance variables in proportions.

***Step 2***: Transform the $i^{th}$ performance variable within $k^{th}$ subgroup of cares/services in $j^{th}$ region, $p_{i(k)j}$ into new variables (called as the monitoring variables), $q_{i(k)j}$ as follows:

$q_{i(k)j} = p_{i(k)j}$, if $p_{i(k)j}$ is higher-the-better type (4)

$q_{i(k)j} = 1 - p_{i(k)j}$, if $p_{i(k)j}$ is lower-the-better type (5)

***Step 3:*** Compute the CPI value for $k^{th}$ subgroup of cares/services in $j^{th}$ region $(CPI_{sub}^{kj})$ as follows:

$$CPI_{sub}^{kj} = \sqrt[n_k]{q_{1(k)j} \times q_{2(k)j} \times q_{3(k)j} \times ... \times q_{n_k(k)j}} = \sqrt[n_k]{\prod_{i=1}^{n_k} q_{i(k)j}} \tag{6}$$

where, $q_{i(k)j}$ is the $i^{th}$ monitoring variable within $k^{th}$ subgroup of cares/services in $j^{th}$ region.

***Step 4:*** Compute the CPI of the entire PHP in $j^{th}$ region ($CPI_{PHP}^{j}$) using the following equation:

$$CPI_{PHP}^{j} = \frac{CPI_{sub}^{1j} + CPI_{sub}^{2j} + CPI_{sub}^{3j} + ... + CPI_{sub}^{gj}}{g} = \frac{\sum_{k=1}^{g} CPI_{sub}^{kj}}{g} \tag{7}$$

The values of $CPI_{sub}^{kj}$ and $CPI_{PHP}^{j}$ (for all $k$ and $j$) will lie between 0 and 1, and higher values for these indices indicate better performance.

## 6. Developing management and monitoring scheme

In a PHP, the value of a performance variable (i.e. proportion of success) in a region is measured based on enumeration of the total number of successes in the entire population in the region. The CPI value for $k^{th}$ subgroup of cares/services in $j^{th}$ region ($CPI_{sub}^{kj}$) is the GM of $n_k$ number of enumerative measures of proportions, and CPI value for the entire PHP in $j^{th}$ region ($CPI_{PHP}^{j}$) is the AM of the CPI values of all the subgroups in the $j^{th}$ region. Since, the rate of successes with respect to different types of cares/services are usually not the same in different regions, the values of the performance variables (measured in proportions) are different in different regions. Thus, the CPI values for $k^{th}$ subgroup of cares/services ($CPI_{sub}^{k}$) as well as CPI values of the entire PHP ($CPI_{PHP}$) varies across the regions within a geographical area.

The ultimate goal of a PHP is to attain a value of one with respect to all the performance variables in all the regions of a geographical area. The health managers of the PHP are expected to put efforts continuously to achieve this goal. Therefore, it is expected that values of the individual performance variables as well as $CPI_{sub}^{kj}$ and $CPI_{PHP}^{j}$ values increase over time in all the regions. The main point of concern to the health managers is to detect the regions lacking implementation of the planned activities within the entire geographical area based on a single metric instead of several individual performance indicators. Since $CPI_{PHP}^{j}$ value in $j^{th}$ region is a function of the values of individual performance variables, this statistic can be utilized effectively for identifying the poorly performing regions. The main issue to the health managers, therefore, becomes identification of the abnormally low $CPI_{PHP}^{j}$ ($j$=1,2,…,$m$) values (i.e. determination of the critical lower value for $CPI_{PHP}^{j}$), which could be done easily if the statistical distribution of $CPI_{PHP}^{j}$ values over all the regions could be well defined, i.e. shape and parameters of the distribution could be established theoretically. Our extensive review of statistical literature reveals that no work is attempted yet to derive the distribution of a complex statistic like $CPI_{PHP}^{j}$, which is AM of GMs of a few groups of measures of proportions. In such a situation, any one of the following two approaches may be adopted for determination of the critical lower value (CLV) for $CPI_{PHP}^{j}$: (a) simulate the distribution of $CPI_{PHP}^{j}$ and then select $p^{th}$ percentile point as the CLV, or (b) use the frequency distribution of $CPI_{PHP}^{j}$ values observed in the past and then select $p^{th}$ percentile point as the CLV. However, simulation studies might not always reflect the real scenario of public health. On the other hand, for obtaining frequency distribution, sufficiently large number of values of $CPI_{PHP}^{j}$ must be available and thus, implementation of the monitoring system may be delayed. But this problem can be overcome by reducing the interval of data compilation. For example, if the field data is compiled fortnightly instead of monthly, available number of values of $CPI_{PHP}^{j}$ over the same period of time will be doubled. Therefore, it is proposed to use the frequency distribution for determination of the CLV of $CPI_{PHP}^{j}$. Determination of CLV for the CPI of the subgroups of cares/services will facilitate identification of the subareas of cares/services lacking proper implementation. Therefore, it is suggested to determine the CLV values of all $CPI_{sub}^{k}$ ($k$ = 1,2,..,$g$) using this approach.

The purpose of monitoring the PHP process differs from a manufacturing process in many aspects. For example, the manager of a manufacturing process puts continuous effort to ensure that a nominal value is maintained and the purpose of monitoring a manufacturing process is to detect occurrences of abnormally low or high values with respect to a desired nominal value and the prevailing natural variation. For this, control chart is a very useful statistical technique where customarily $\mu - 3\sigma$ and $\mu + 3\sigma$ (where $\mu$ and $\sigma$ are the mean and standard deviation of the performance characteristic) are considered as the upper control limit (UCL) and lower control limit (LCL) of a control chart for monitoring manufacturing processes (Montgomery, 2001). In terms of percentile points, $p = 0.00135$ and $p = 0.99865$ are taken as the LCL and UCL respectively of these control charts. However, the managers of the PHP put continuous efforts to achieve the maximum value and the purpose of monitoring the PHP is to detect occurrences of abnormally low values only with respect to the prevailing natural variation. Therefore, in this situation, a value of $p = 0.00135$ will be too small for determination of CLV of $CPI_{PHP}^{j}$ under the assumption that there will be continuous improvement. So it is decided to consider $p = 0.05$, which corresponds to $\mu - 2\sigma$ lower limit assuming Normal distribution for determination of CLV of $CPI_{PHP}^{j}$.

Dot plot of $CPI_{PHP}^{j}$ values of all the regions in a chart, with CLV line placed on it, can reveal pictorially the fluctuation of $CPI_{PHP}^{j}$ values among different regions as well as unnaturally poorly performing regions. Therefore, it is suggested to mark dot plot of $CPI_{PHP}^{j}$ values of all the regions in the chart with CLV line placed, every time when data are compiled and $CPI_{PHP}^{j}$ values are computed. The health managers should identify the responsible subareas of cares/services for the regions with abnormal $CPI_{PHP}^{j}$ values and put extra efforts in these regions to improve the implementation status. As $CPI_{PHP}^{j}$ values are expected to increase continuously, CLV cannot be static. After every considerable period of time, CLV of $CPI_{PHP}^{j}$ is to be determined afresh based on the frequency distribution of the most recent past observations. As a rule of thumb, it is suggested to determine CLV of $CPI_{PHP}^{j}$ afresh if no $CPI_{PHP}^{j}$ value falls below CLV threshold in two consecutive previous time points.

### 6.1. The proposed monitoring scheme

The proposed monitoring scheme for a PHP can be described in the following four steps.

*Step 1: Determination of the basic parameters of the PHP*

(i) Identify the $m$ regions (which are essentially administrative subareas) through which a PHP is implemented in the entire geographical area like a country or a state.

(ii) Define and list down the total $n$ performance indicators for the PHP. Divide these appropriately into $g$ subgroups such that $\sum_{k=1}^{g} n_k = n$, where $n_k$ is the number of performance variables under the $k^{th}$ subgroup.

(iii) Determine the most appropriate time interval (week, fortnight, month etc.) for compilation of field data.

*Step 2: Determination of the critical lower value (CLV) of the monitoring statistic ( $CPI_{PHP}^{j}$ )*

Collect the past data and compute the CPI values for $k^{th}$ subgroup of cares/services in $j^{th}$ region, $CPI_{sub}^{kj}(k = 1,2,...,g;\ j = 1,2,...,m)$ and CPI values of entire PHP ( $CPI_{PHP}^{j}$ ) using equations (6) and (7) respectively. Obtain the frequency distribution of the computed $CPI_{PHP}^{j}$ values and select 0.05th percentile point of the frequency distribution as the CLV of $CPI_{PHP}^{j}$. For obtaining the frequency distribution, number of $CPI_{PHP}^{j}$ values should be more than 50.

Similarly, CLV of each subgroup of cares/services may be obtained, which will be useful for identification of the subareas of cares/services that are responsible for abnormal $CPI_{PHP}^{j}$ values.

*Step 3: Obtaining dot plot of the current & future values of the monitoring statistic ( $CPI_{PHP}^{j}$ )*

Considering time point in the horizontal scale plot the current $CPI_{PHP}^{j}$ values of all the regions against different time points and place the horizontal line indicating CLV as the threshold of the monitoring statistic $CPI_{PHP}^{j}$ on the chart. Plot the future $CPI_{PHP}^{j}$ values obtained in the successive periods in the same chart but modify the CLV line if no $CPI_{PHP}^{j}$ value falls below CLV line in two consecutive previous time points.

Dot plots of CPI values of each subgroup, $CPI_{sub}^{kj}(k = 1,2,...,g)$ with appropriate CLV line may also be obtained separately which will facilitate diagnostic of the problematic subareas of cares/services.

*Step 4: Interpretation of the dot plot*

If any point falls below the CLV line in the dot plot of $CPI_{PHP}^{j}$ values, consider it as abnormal or unusual observation. Then, examine all the dot plots of $CPI_{sub}^{kj}(k = 1,2,...,g)$ values for identification of the problematic subareas of cares/services. Investigate for the root cause analysis for the regions performing abnormally and initiate appropriate actions.

If no $CPI_{PHP}^{j}$ value falls below CLV line in two consecutive previous time points, consider that the overall performance of the PHP has improved substantially and the current CLV line is no longer appropriate for monitoring of future performance. Then, take into consideration recent 50-100 observed values of $CPI_{PHP}^{j}$ and determine new CLV of $CPI_{PHP}^{j}$ values using step 2.

## 7. Illustrations

To illustrate the application and effectiveness of the proposed monitoring scheme, the field data of the MCH program of the selected province are taken into consideration for the period January’16 to March’17. The MCH program is implemented in the province through 19 administrative subareas, called districts, i.e. $m$ = 19. The most important 11 performance measures (variables) which are evaluated regularly for the MCH program are listed in

Table 1. The same 11 performance variables are considered as the total number of performance variables for the MCH program, i.e. $n$ = 11, which are divided into 4 subgroups of cares/services, i.e. $g$ = 4. These subgroups are ANC, DC, PNC and NBC respectively. Out of total 11 performance variables, four, two, two and three performance variables are related to ANC, DC, PNC and NBC respectively, i.e. $n_1 = 4$, $n_2 = 2$, $n_3 = 2$, $n_4 = 3$ and $n_1 + n_2 + n_3 + n_4 = 11$. For the MCH program field data are compiled on a monthly basis, i.e. time interval for data compilation is equal to 1 month.

The $CPI^{j}_{PHP}$ values in the first three months (January to March) were computed using equation (7) and then, frequency distribution (shown in Figure 1) of these values were obtained using SPSS software. The 05th percentile point of this frequency distribution is found to be 0.61 and therefore, the CLV of the monitoring statistic ($CPI^{j}_{MCH}$) is determined as 0.61. Similarly, CLVs of $CPI^{ANC}_{sub}$, $CPI^{DC}_{sub}$, $CPI^{PNC}_{sub}$ and $CPI^{NBC}_{sub}$ are determined as 0.42, 0.64, 0.40 and 0.66 respectively.

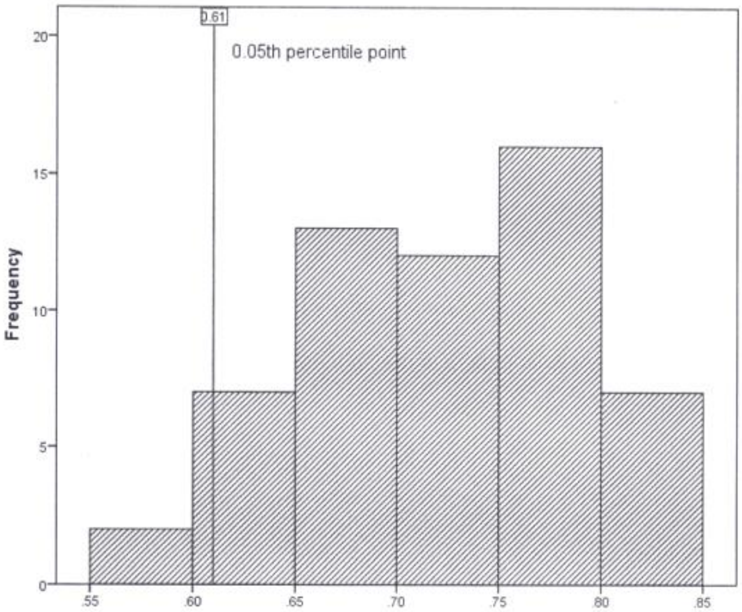


**Figure 1.** Frequency distribution of $CPI^{j}_{MCH}$ values in the first three months

The dot plots of the observed $CPI^{j}_{MCH}$ values from the month of April (denoted by the number 4) to March (denoted by the number 15) are shown in Figure 2. The horizontal straight lines in this chart are the CLV line at different time periods.

It is observed from Figure 2 that in the Month of April, $CPI^{j}_{MCH}$ values of two regions fell below the CLV line. The two regions were identified as regions 3 and 14.

With the aim to identify the responsible subgroups of cares/services for these abnormally low values, dot plots of the CPI values of all the four subgroups of cares/services were obtained (shown in Figure 3). The horizontal straight lines in these charts are the CLV lines.

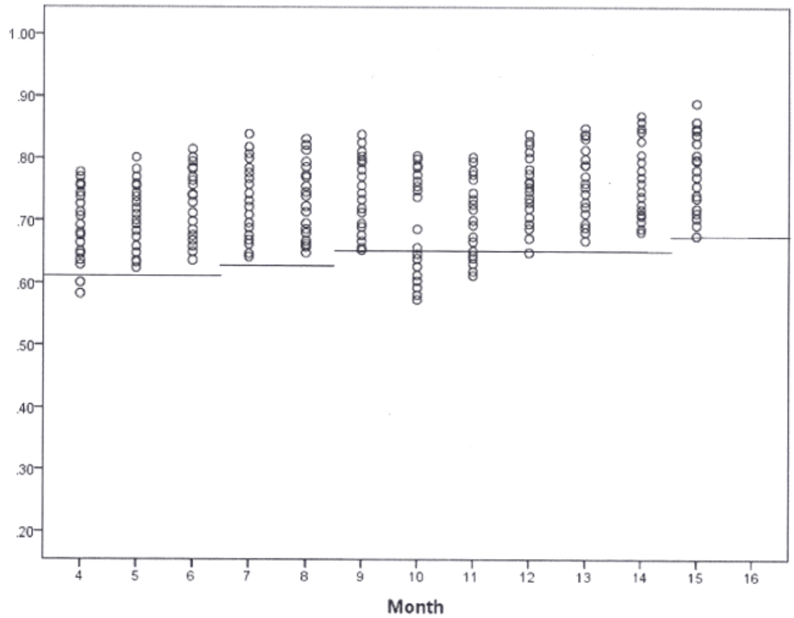


**Figure 2.** Dot plot of $CPI_{MCH}^{j}$ values from April to March

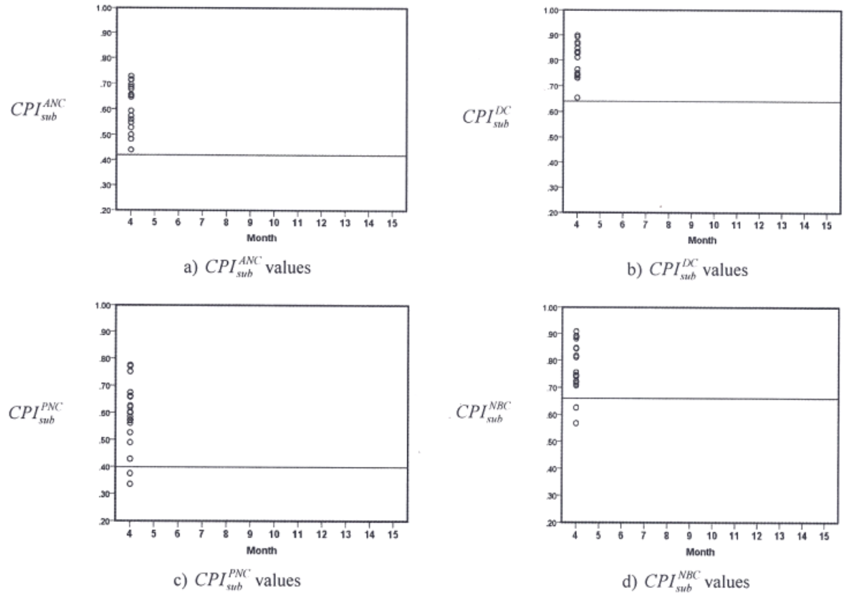


**Figure 3.** Dot plots of CPI values of different subgroups of cares/services in April

The dot plots in Figures 3a – 3d, reveal that the root causes for low $CPI_{MCH}$ values in these regions were due to the poor implementation status with respect to PNC and NBC cares/services. Investigations were carried out and then some special initiatives were taken for these regions, which resulted noticeable improvement in the overall performance of the MCH program. As can be seen from Figure 2, no $CPI_{MCH}^{j}$ value fell below the CLV line in the month of May and June. So it was considered that the CLV line determined at the end of March is no longer appropriate and therefore, based on the observed $CPI_{MCH}^{j}$ values during April-June, a new CLV was determined as 0.63. No $CPI_{MCH}^{j}$ value fell below this CLV line in July and August again. Therefore, more appropriate CLV for the future months were determined again based on the observed $CPI_{MCH}^{j}$ values during June-August and it was found to be 0.65. It was observed surprisingly that $CPI_{MCH}^{j}$ values of several regions fell below the new CLV line in October (denoted by 10) although the $CPI_{MCH}^{j}$ values for a large number of regions were substantially high. There were two distinct groups of regions with respect to $CPI_{MCH}^{j}$ values. Dot plots of the CPI values of the four subgroups of cares/services (shown in Figure 4) exhibit the same pattern.

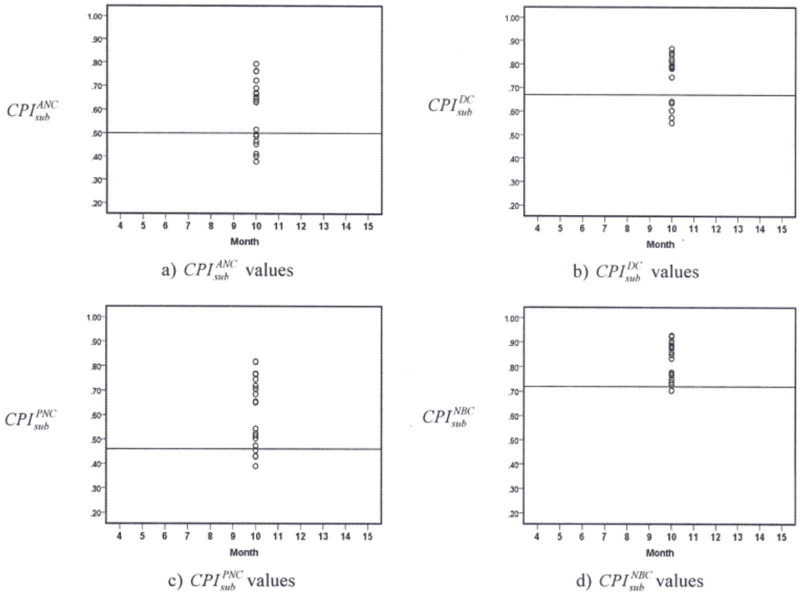


**Figure 4.** Dot plots of CPI values of different subgroups of cares/services in October

It was revealed from root cause analysis that several areas were flooded during this period and most of those poor performing regions belong to these flood affected areas where the MCH program could not be worked out properly. Based on these findings, the health managers took some actions in the form of deployment of additional health workers, incentive scheme etc. and decided to give special attention to these flood affected regions. As a result, the $CPI_{MCH}$ values started improving again from the next month onwards. It can be observed from Figure 2 that no $CPI_{MCH}^{j}$ value fell below the CLV line in the months of January'17 and February'17. Therefore, more appropriate CLV for the future months were determined again based on the observed $CPI_{MCH}^{j}$ values during December16-February’17 and it was found to be 0.68.

## 8. Conclusions

A public health program (PHP) usually have a large number of performance measures. Management and monitoring of a PHP by examining separately so many performance measures are quite difficult and also ineffective. For understanding the ‘big picture’ of a PHP and its management, usually several performance measures of the PHP is converted to a number, known as composite performance index (CPI). Traditionally, the CPI is widely used in healthcare program as a tool for conveying summary performance information and signalling policy priorities. In this paper, a new two-stage procedure (called AGM method) for computation of CPI is proposed. The CPI value obtained by the proposed AGM method offers the following three advantages: 1) it represents the true overall performance of a region, 2) it is more sensitive to the changes in one or more individual performance measures and 3) it can be used as a monitoring statistic for routine management and monitoring of a PHP. The MCH program in a province of India is monitored using the proposed monitoring scheme. The results show that it is very effective towards continuous improvement of implementation status of a PHP. One of the limitation of this research is that the critical lower values (CLV) of $CPI_{SUB}$ and $CPI_{PHP}$, which are required for establishing the management and monitoring scheme, are to be determined empirically. The CLV values can be determined easily if the statistical distribution of $CPI_{SUB}$ and $CPI_{PHP}$ are known. Further studies are, therefore, required for derivations of the statistical distributions of the statistics $CPI_{SUB}$ and $CPI_{PHP}$ which would facilitate developing better monitoring schemes using statistical principles.

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