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FEATURE ARTICLE

Economic Impact Studies of Pressure and Vacuum Metrology at CSIR-NPL, India

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Abstract: Measurement standards and metrological activities provide scientific and metrological infrastructure in the country. The Pressure and Vacuum Metrology (PVM) activity has a major role in national and international metrological research and development. The PVM group is successfully providing national calibration and measurement services and fulfilling its national duty as per the mandate of CSIR-National Physical Laboratory (CSIR-NPL). Since last 35 years, no significant efforts were made to assess socio-economic impact of the services provided. Such impact studies are carried out by several National Metrology Institutes, but in India it is still an unexplored area so far. This motivated us to carry out the impact assessment, and present paper is an attempt made in this direction. Systematic studies of the contribution of PVM, established at CSIR-NPL, on national industrial growth and economy, are carried out by assessment of impact. The aim of the present paper is to present the summary of the results thus obtained which is based on the investment made over the years and the estimated benefits to the users. The studies are based on some industrial survey, personal interviews and interactions with stakeholders and sampling of services provided over the years. An overall social rate of return, an indicator of system efficiency, is found to be 180% which is quite high as compared to the present rate of return (8%). This indicates that the PVM activity is quite efficient, and future investment in the activity is safe and would provide excellent returns. The studies are very useful for broader understanding of the economic benefits of PVM and to improve understanding of the decision and policy makers about the relevance, continuation and further investment in PVM activity. This present case study may be explored and applied for other metrological fields also.

Keywords: Economic impact; Pressure and vacuum; Net present value; Benefit-to-cost ratio; Social rate of return; Industrial survey

1. Introduction

The National Metrology Institute of India (CSIR-NPL), being a public funded institution, has huge societal responsibilities to fulfill its mandate for the country. As per its charter, it is providing national standards of measurements to country through continuous research and development in metrology as evident in most recent publications [1–10]. In Indian industrial and scientific development, the role of Pressure and Vacuum Metrology (PVM), established at CSIR-NPL is significant and irreplaceable in the advancement of field and its related technologies [11]. No doubt, PVM group is successfully fulfilling its national duties, providing national calibration and measurement services since last 35 years. In order to prove the facts, it is essential to quantify the social achievements by performing the *economic impact analysis*. Impact analysis is not just only a tool for the assessment of performance of any public institution but it also provides guidelines for managerial decisions for future plan of the institute. This has motivated us to undertake the task to perform the impact analysis of PVM activity of CSIR-NPL.

2. Methodology

Performing the economic impact analysis is a very challenging assignment, especially for the hardcore scientists

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and engineers always engaged in scientific research and developments. It is a challenge in determining all the factors contributing and playing role in profit–loss assessment in the societal structure wherever PVM activity of CSIR-NPL is directly or indirectly contributing/involved.

All the stakeholders and beneficiaries of PVM were classified into 3 tiers.

(i) Tier 1 includes all the industries which are directly dependent on calibration and measurement facilities of the PVM. Such users obtain the calibrations for their master instruments like dead weight testers, pressure transducers pressure dial gauges, etc.
(ii) Tier 2 beneficiaries are the industries which use the services of tier 1 users in order to get traceability of their instruments. For example, automobile industry which uses the pressure transducers developed and calibrated by some other company to develop a finely tuned car; and.
(iii) Tier 3 beneficiaries are basically the end-users which use the product and services developed by tier 1 and tier 2 industries for example barometer developed by the tier 1 industry, car developed by tier 2 industry, which have taken calibration service of PVM group directly or indirectly.

In any pressure-related product development, the benefit of the PVM is engraved into 3 different stages of the economic activity which are research and development (R&D), production and commercialization [12]. In order to assess the economic impact of the group, we have to evaluate all the benefits from different tiers of the beneficiary. These beneficiaries industries are also indirectly involved in the activities for the societal cause which further strengthen the impact on the society [13].

The economic assessment performed on the division is *retrospective* in nature. We have utilized the past investments and outputs of the PVM group over the time. The past record not just only provides the performance of the group but also the insight into the future for managerial decisions regarding the Institute.

In order to evaluate the impact in all 3 tiers, a *counterfactual method* is adopted [14]. In this method, specific questions were asked like what extra cost industries or users will bear in the absence of services provided by PVM group? This extra cost is the benefit enjoyed by all the tiers because of the services of the PVM and it clearly shows the economic impact of the PVM. Therefore, this extra cost is estimated using the survey from the industry which is a resource-based time-dependent task [15]. The tier 1 industry survey was conducted from the telephonic interviews or the survey feedback form. In the tier 2 industries, it was difficult to evaluate the benefits as these industries are not directly involved with the PVM activity except the traceability through tier 1. The most difficult part was to quantify the benefits in the tier 3 as it is basically determined from the quality of products and services the tier 3 user has attained because of quality of services from tier 1 and tier 2 [16].

Apart from these situations, when we moved from tier 1 to tier 3, the number of population for survey increases exponentially. This is the reason why the time and resources for the survey also increases. Keeping in mind all the factors mentioned above, we have estimated benefits only from the tier 1 of the beneficiaries. As mentioned above, such assessment of tier 1 would not provide the actual economic impact of the PVM activity but it certainly provides the most pessimistic assessment which can be utilized to judge the performance of the PVM activity. The output from the survey are the number of the calibrations performed by the industries on each calibration obtained from PVM group, the annual earning on this basis and frequency of the calibration for an instrument. This survey outputs along with output from the NPL data record files of PVM group (shown in Fig. 1) are used in the impact study.

In an economic assessment of the public funded institute, generally, 3 parameters are used to represent the performance of the system:

(i) *Net Present Value* (NPV)
(ii) *Benefit-to-Cost Ratio* (BCR); and
(iii) *Internal Rate of Return* (IRR) or S*ocial Rate of Return* (SRR) in case of public funded institute

2.1. Net Present Value

In the retrospective analysis of the economy, we consider a large lapse of time over the years. During these years, the actual value of the money keeps on decreasing. That is why the investment or the profit in the initial years will have different value in the present year. In order to accommodate this inflation over the years, present value of the benefit is calculated using a fixed interest rate known as government rate of interest (rate of safe return). These adjusted benefits for each year are added to obtain the total profit for current year known as net present value (NPV). Hence, we can write as [17];

$$\mathrm{NPV} = \sum_{i=1}^{T} \mathrm{NB}_i/(1+r)^i \tag{1}$$

Here, NB_i is the net benefit for the ith year, T is the number of years over which assessment is performed and r is the government rate of return.

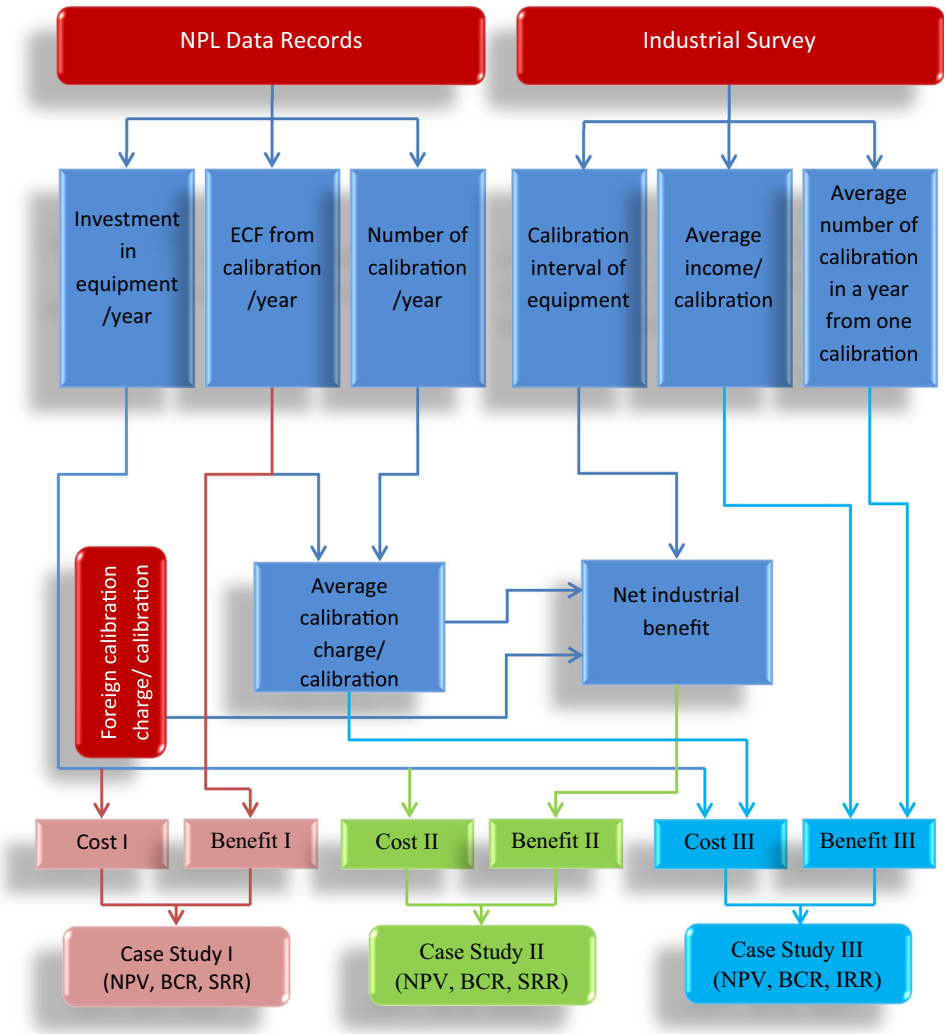

Fig. 1 Flowchart of economic analysis

2.2. Benefit-to- Cost Ratio

The performance parameter NPV just only represents the present worth of the institute but is not helpful in performance comparison with other institutes. It is because different institutes or projects will have different scale of investment or cost. Hence, their benefits' scale will also be different. In order to overcome this, we have taken the ratio of the benefit to the cost adjusted for the current year [17]. So, benefit to cost ratio (BCR) is given by;

$$\mathrm{BCR} = \frac{\sum_{i=1}^{T} B_i/(1+r)^i}{\sum_{i=1}^{T} C_i/(1+r)^i} \tag{2}$$

Here, B_i and C_i are the benefit and cost, respectively.

2.3. Internal Rate of Return

This performance parameter represents the growth rate of the project or institute. This is evaluated by finding out the rate of return for which the NPV is zero. The more the internal rate of return (IRR), more will be its sustainability in the environment of high inflation rate. That is why it is also the measure of efficiency of the institute and is computed as follows [17];

$$\mathrm{NPV} = 0 = \sum_{i=1}^{T} \mathrm{NB}_i/(1+\mathrm{IRR})^i \tag{3}$$

3. Method Used

In this paper, we present three types of the study of economic impact from the year 1998 to year 2017 and further 3-year projections up to year 2020. This long period of study of more than 20 years is taken as the effect of the benefits of government institute/division/section like PVM group of CSIR-NPL takes long time to reach different tiers of the society. In these studies, data from the survey and NPL record files are utilized to calculate the different

economic impact parameters (NPV, BCR and SRR). During these studies, although, we have taken some assumptions, but these assumptions are such that the impact factors will always be calculated for most pessimistic case. Hence, this way we can obtain the least possible performance values of the system (PVM group). First of all, the fixed cost and initial investment before the year 1998 is taken as zero because such cost and investments will be utilized for the long period (in years) and also the case study is from 1998 to 2020; therefore, its effect will be insignificant.

Now, from Eqs. (1), (2) and (3), it is observed that we need two important input variables to calculate assessments parameters (NPV, BCR and SRR). These input variables are cost (C_i) (investment) and benefit (B_i), which will vary depending on the system. In our three studies, we will explain how these cost and benefit are evaluated for the assumed systems. Another important input variable is government rate of return (r) which is taken as 8% wherever it is required. As the record of the extra cash flow (ECF) generated from the year 1998 to 2011 is not available, we have calculated these from using the least recorded ECF (again pessimistic case) with an annual decrease @ 8% from year 2011 to 1998. Also the data for the year 2018–2020 are forecasted using drift method.

It is important to note that since the currency (Indian Rupee in the present case) of same amount for different year will be different, so special precaution is taken to convert it to the same equivalent value by using the government rate of return. For example, the value of Rs. 2000/- in the year 1998 will be different in subsequent years. Therefore, in these studies, wherever the mathematical operation (addition, average, etc.) on the currency value of different years are performed, first all the values are converted to equivalent of a reference year (in most of cases, year 1998) by using r as 8% and is referred as the constant currency value of the reference year. Three studies along with adopted method are described as follows;

3.1. Study I (Impact Analysis Taking CSIR-NPL PVM Group as a System)

As mentioned in the previous section, for the study of impact analysis of government institute on the society, we have to consider the different benefits along the different tiers, but this study is devoid of this concept. In this impact analysis, we have taken only CSIR-NPL PVM group investment (on equipment purchase) as cost (C_i) and extra cash flow (ECF) as benefits (B_i) (red lines in Fig. 1). Using these two input variables (cost and benefit) in Eqs. (1), (2) and (3) using r as 8%, the three assessment parameters are evaluated. Study I can be considered as the simple analysis of profit and loss for the division without considering the societal benefits, i.e., the benefits along the tier 1 or tier 2. This study can prove that the NPL pressure standard group is self-sustainable or not?

3.2. Study II (Impact Analysis Considering the Effect of PVM Group up to Tier 1 Only)

In this study, we have taken the CSIR-NPL PVM group and tier 1 beneficiaries as a system. This study is considered more realistic economic impact effect as compared to Study I, because of the inclusion of the benefits to tier 1 beneficiaries, but the question is how to calculate the benefits of tier 1 beneficiaries?

This is done by using the counterfactual approach, i.e., the question like what extra cost tier 1 beneficiaries will have to bear in the absence of services provided by PVM group? This extra cost is the benefit enjoyed by the tier 1 because of the services of the PVM group. Next is to evaluate this extra cost. This extra cost will include an extra calibration charge for getting services from abroad from an equivalent NMI having similar compatible services, transportation cost to foreign country, cost due to inclusion of administration, different time zone, etc. In this study, the extra calibration charges of foreign country a only taken as the benefits to beneficiaries of tier 1. For evaluating this extra calibration charges, first the average calibration charge for single calibration by PVM group is calculated. This is obtained by using the NPL record data. From the record data, we have the total ECF from calibration over the years and the number of calibration reports for each year which represents the number of calibration performed in a year. From these two data, we have obtained the calibration charge for a single calibration for the different years by dividing the total ECF by number of calibration performed. These different year's calibration charges are averaged out to obtain the single calibration charge of PVM group. The lowest calibration charge per calibration of foreign NMI (NIST-USA) is used. The difference between the Indian NMI PVM group calibration charge and foreign calibration charge will provide the extra cost, which represents the benefits of tier 1, per calibration. When this benefit is multiplied by the number of industrial calibrations per year (obtained from NPL record data file), it will give the total benefits per year of the tier 1 beneficiaries. Since the survey report represents that the industry frequency of calibration is of 2 year, the mentioned benefit also occurs in every 2 years. Hence, the total benefit (B_i) from the year 1998–2020 is obtained by adding the every 2 year benefits. On the other hand, cost (C_i) is the investment in the PVM group which is same as the previous study. Using these cost and benefits, NPV, BCR and SRR are calculated (green lines shown in Fig. 1).

3.3. Study III (Economic Study for the Industries Only)

In the previous study, the economic impact of PVM group up to tier 1 is considered, but its actual impact is deeper, up to tier 2 and tier 3. As stated earlier, assessing the impact for tier 2 and tier 3 is difficult, costly and time-consuming, so we have carried out our evaluation of impact study up to the tier 2 indirectly. The tier 1 industries are providing calibration services to more industries or calibrating their products in order to serve the tier 2 beneficiaries. However, these tier 1 industries have obtained calibration certificates from PVM group, so this way the impact of PVM group is indirectly reached tier 2 beneficiaries through the calibration traceability chain. The more is the benefit to the tier 1 industry, more tier 2 industries have been addressed, and consequently the PVM group impact has reached more beneficiaries. With this view, in this third study, tier 1 industries are considered as a system in order to evaluate the impact on the tier 2 beneficiaries.

Cost (C_i) for the industries is estimated as the sum of the equipment maintenance cost (taken as 50% of the maintenance cost occurred in the PVM group) and equipment calibration charges. From the survey reports, we have the total number of calibration performed by industries for each calibration obtained from PVM group and the annual income from the calibration. These two data provide the total benefits (B_i) for this study. Using these costs and benefits, NPV, BCR and internal rate of return (IRR) are obtained (light blue line as shown in Fig. 1).

4. Results and Discussions

First let discuss the survey for the study and its output. The studies are based on some industrial survey, personal interviews and interactions with stakeholders and sampling of services provided over the years. Specific survey form was designed for this purpose. Admittedly, the sampling survey was not large but adequate to make some assessment. We normally provide services to approximately 127 customers per year. A sample survey of 60 customers was considered adequate. Out of the 60, we have received 35 survey forms, 19 were interviewed telephonically and 6 through personal interactions while their visit to CSIR-NPL. Out of the 35 survey forms received, 5 have returned forms with some missing information. Therefore, only 30 forms were considered for the estimation. Time taken during the survey is 1 year (2017–2018). It was carefully taken into the considerations that all type of customers, small and large, NABL accredited and non-accredited, govt. and private, are included to make a wider representations. It is also mentioned that almost 50% of the customers are our regular clients and rest are newly added. As mentioned earlier, the survey is performed on the sample of the 60 industries. In these industries, the distribution based on the NABL accreditation and type (government or private) of the industries are shown in Fig. 2.

From Fig. 2, it is evident that more than 50% of the industries are maintaining the quality system as ISO/IEC 17025:2005 including private sectors (60% of the total sample). This represents that the industries are leaning more toward the quality product development while going extra miles at the expense of some instant profit.

The other outputs obtained from the survey are the number of the calibration performed by the industries on each calibration obtained from PVM group, the annual earning on this basis and frequency of the calibration for an instrument. The pictorial representation of such data is depicted in Fig. 3. These 3 outputs of the survey report are utilized with the outputs from the PVM group' record data file to obtain the economic impact for the different cases mentioned above. As mentioned earlier, we have performed the economic assessment for the years from 1998 to 2017 with three projected years. We have used the retrospective method for the year up to 2017 and its projection (drift method) for the remaining years. All monetary values

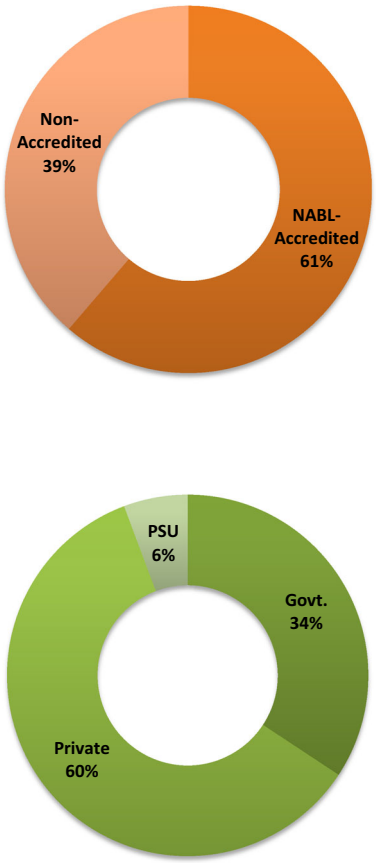

Fig. 2 Pie chart showing the NABL accreditation and industry type

are evaluated in terms of constant 1998 year Indian rupees value. The PVM group investments on instruments and incomes (benefits) from the services provided are shown in Table 1.

The cumulative net profit present value during 1998–2020 is shown in Fig. 4. The breakeven point defined as change from negative zone to positive zone provides the clear picture when investments from loss come to profit. When the net present value is evaluated @ 8% interest, the first breakeven point is observed during 2007 and sustained during 2008. However, due to further investments thereafter, the net profit value again comes to the negative zone. The second break-even point appears during year 2019 (Fig. 4). It clearly reveals that we can expect and forecast profits for the coming years.

As stated earlier, we performed 3 economic assessments. In first assessment, only sole investment and profits of PVM are involved (Table 1). In second impact study, we have taken into account the benefits up to the tier 1 industries in order to evaluate the more realistic impact assessment. Therefore, the benefits due to PVM activities to clients industries are included for each year. These

Table 1 Investment and income details of PVM during 1998–2020

Sl. no.	Year	Cost (Rs. in lakhs)	Benefit (Rs. in lakhs)
1	1998	45.00	16.20
2	1999	60.00	17.50
3	2000	0.00	18.90
4	2001	68.00	20.41
5	2002	0.00	22.04
6	2003	0.00	23.80
7	2004	0.00	25.71
8	2005	0.00	27.76
9	2006	0.00	29.99
10	2007	0.00	32.38
11	2008	23.00	34.97
12	2009	84.00	37.77
13	2010	110.00	40.79
14	2011	0.00	44.06
15	2012	176.62	44.20
16	2013	0.00	53.00
17	2014	0.00	61.60
18	2015	210.00	61.00
19	2016	0.00	78.20
20	2017	0.00	82.20
21	2018 (Projected)	0.00	89.80
22	2019 (Projected)	0.00	97.40
23	2020 (Projected)	0.00	105.00

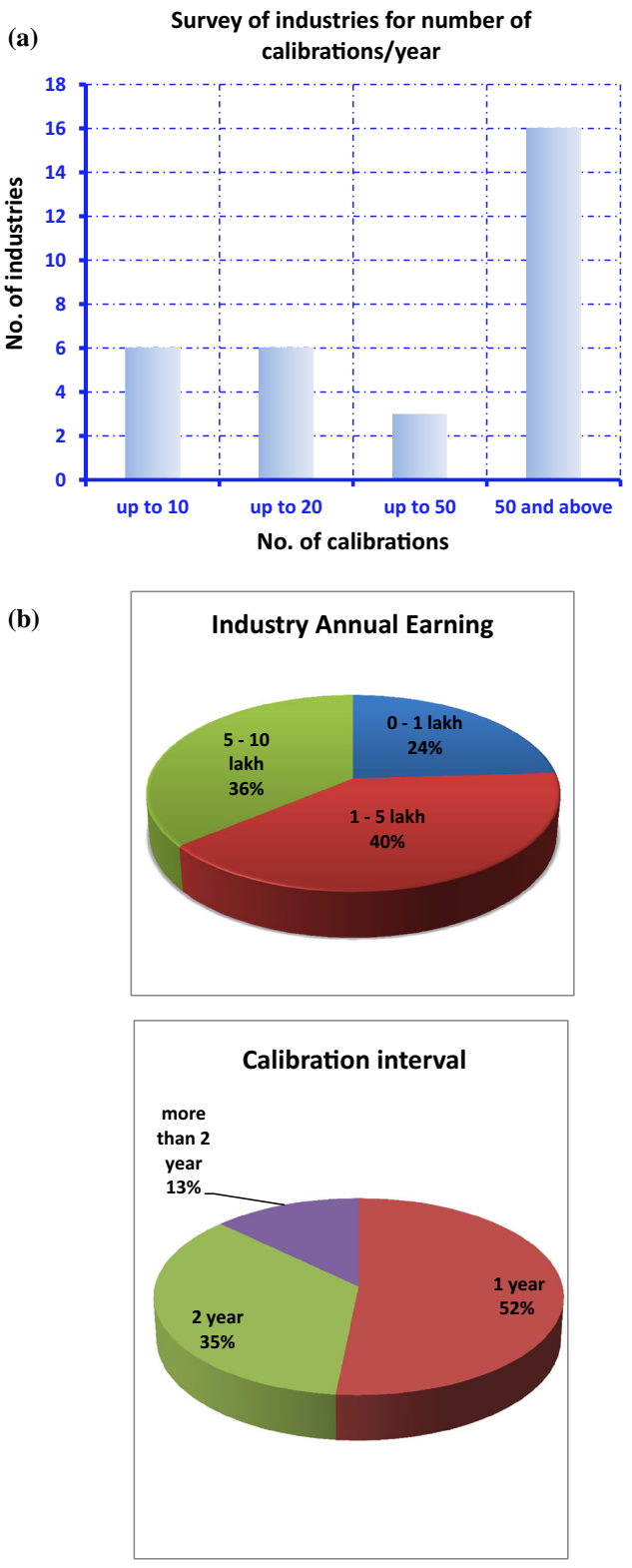

Fig. 3 **a** Bar chart showing the survey report: It represents the number of calibrations performed yearly from the each calibration obtained from PVM group. **b** Bar chart for annual income and frequency of calibration

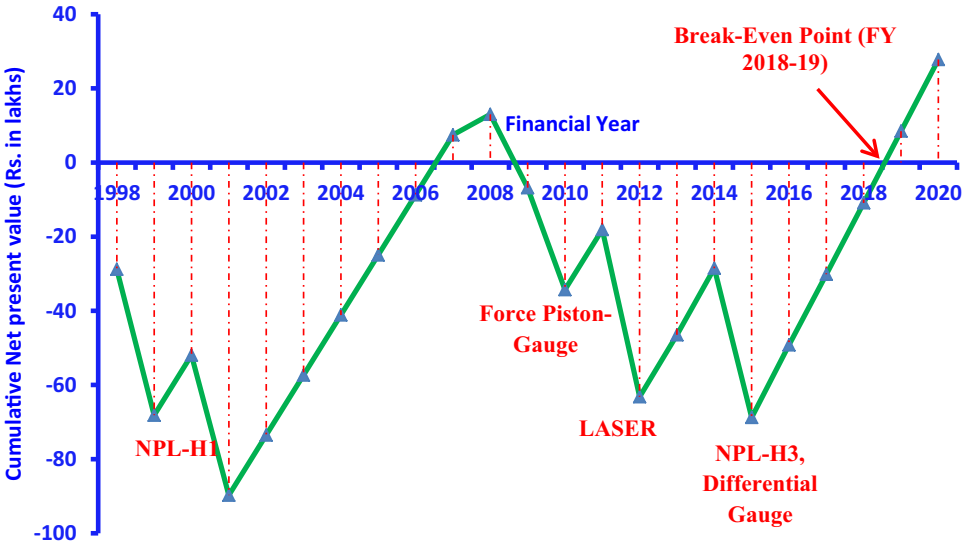

Fig. 4 Cumulative net profit present value for the period from 1998 to 2020. The major investments made in standards in PVM activity are marked in red

benefits are the extra calibration cost, transportation cost, administrative processing cost and risk factors, etc., if such calibrations services would have been performed in other NMIs abroad. These costs are incorporated in industry annual income in order to obtain the pessimistic economic assessment and to avoid the over estimation of the economic impact. Such annual assessment of number of calibrations performed by these industries in-house after taking traceability from PVM group from the survey report of 30 industries is shown in Fig. 3a.

The final report is shown in Table 2 and Fig. 5. For this second study, the cumulative net profit present value during 1998–2020 is shown in Fig. 6. In first tier beneficiaries, the benefits are much more as compared to investment which causes a rising trend of cumulative net profit. Also the investment and benefit are forecasted almost same for each year that is why this graph is showing almost linear trend.

In order to describe the benefits in financial terms, the total investment of Rs. 777.0 lakh made in the PVM over the years has already earned Rs. 1065.0 lakh directly from the services provided and paid back the investment made and is in profit mode, and this trend of profit will continue. Further, the industries who obtained our services (tier 1) have earned estimated profit of Rs. 524.64 lakh. Subsequently, the benefit of tier 2 is estimated to be more than Rs. 2000.74 lakh keeping apart the tier 3 benefits which are huge and beyond our estimations being indirect benefits. A table for comparison of the economic impact of different NMIs for different sectors is shown (Table 3), including the NMI India's PVM group. Even if the sectors are different, a conclusive idea about the rough estimate impact for economic analysis can be drawn.

There are some other direct benefits from the PVM activities which are not included in the impact assessment. These include more than 100 research papers published in peer-reviewed SCI journals; papers presented/published in national and international conferences/seminars/symposia/workshops/books/monographs; master and Ph.D.

Table 2 Economic impact assessment results for each case

Performance parameters	Lower bound (pessimistic) estimation
Economic assessment for the division only	
Net present value (constant 1998 Rs.)	27.78 (in lakhs)
Benefit-to-cost ratio (constant 1998 Rs.)	0.08
Social rate of return	10.8%
Economic assessment up to first tier beneficiaries	
Net present value (constant 1998 Rs.)	524.65 (in lakhs)
Benefit-to-cost ratio (constant 1998 Rs.)	2.45
Social rate of return	180%
Economic assessment of Industries only	
Net present value (constant 1998 Rs.)	2000.74 (in lakhs)
Benefit-to-cost ratio (constant 1998 Rs.)	23.90
Internal rate of return	980%

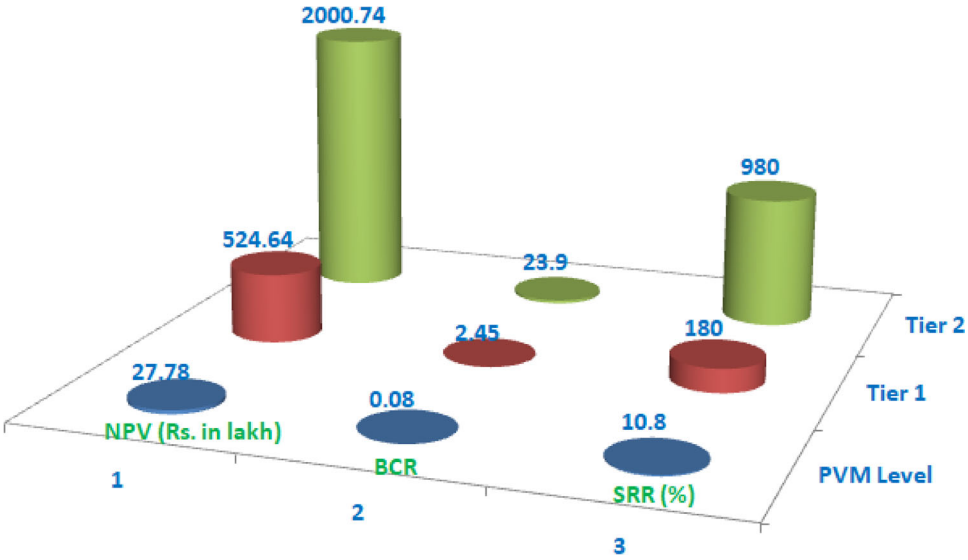

Fig. 5 A bar chart showing the final results of economic impact assessment parameters

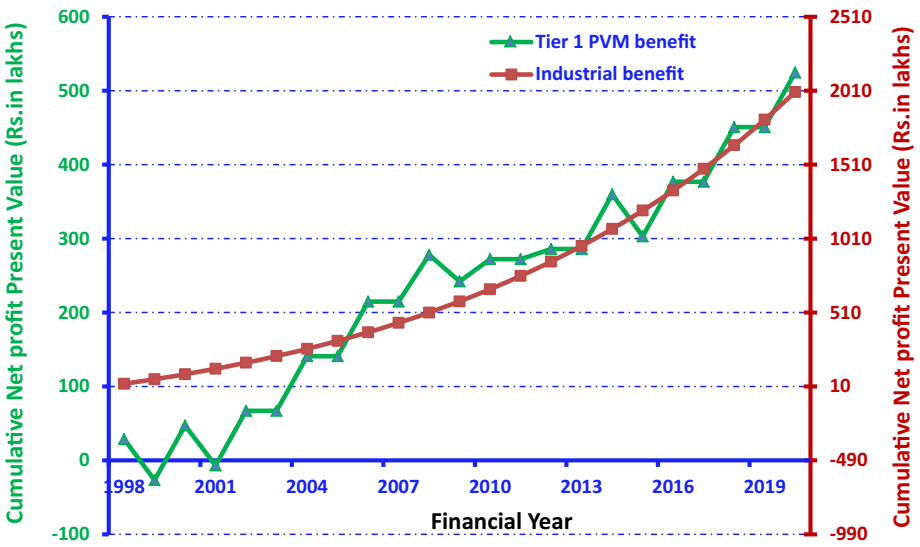

Fig. 6 Cumulative net profit present value for the period from 1998 to 2020 for first tier of beneficiaries

Table 3 Comparison of impact analysis of different NMIs

NMI with sectors	NPV	BCR	SRR
NIST, USA (Photonics: power and energy calibration, 2000–2002) [17]	$48 M	3–11	43–136%
NIST, USA (Josephson volt standard, 2000–2002) [17]	$42 M	5	877%
NPL, UK (DATABUILD, 2012) [15]	£320 M	4.5	–
NPL, India (PVM group activity)	Rs. 524 lakh	2.45	180%

dissertations completed; trained manpower through various training courses organized; global visibility of CSIR-NPL by publishing Calibration and Measurement Capabilities (CMCs) in Key Comparison Data Base (KCDB) of BIPM; successful participation in several key comparison exercises and publication of their results in KCDB, etc. However, it is not possible to make impact assessment of these benefits, but their visibility is certainly enormous and cannot be neglected.

5. Conclusions

As per economic assessment, the net present value is positive which represents that investments made in PVM

projects are quite beneficial. All the performance parameters show positive results even if the assessment is up to PVM level only. If all the benefits of next tiers of beneficiaries are included, the SRR is found to increase manifold. The net present values obtained is Rs. 27.78 lakh, Rs. 524.65 lakh and Rs. 2000.74 lakh for PVM level, tier 1 and tier 2, respectively, which is a very positive output, and it reflects the system is in profit mode at all the levels. Also, benefit-to-cost ratio has increased substantially from 0.08 (PVM level) to 2.45 (tier 1) and then 23.9 (tier 2).

In economic terms, an institution/Division/Section is considered efficient if its SRR is more than the govt. rate of return. In the present case, the SRR achieved is 10.8% at the level of PVM group itself which indicates PVM is in profit mode and efficient. Further, SRR increased to 180% and 980% in case of tier 1 and tier 2 beneficiaries which is indicator of huge social impact of facilities created by PVM and services provided to industries. Therefore, the PVM activity has great potential and is also showing satisfactory economic impact even in the most liberal case. The future investment in the activity is possible and would yield great dividends. The studies carried out in the present research would be an eye opener for the people normally criticizing the efficiency of the govt. institution. Admittedly, the study is carried out for a section of the institution, but the same way it can be extended to other sections and as a whole for the institution.

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