Abstract—Performance evaluation is an important measure of the total quality management which can be used to assess the performance of an individual or an organization with respect to set goals and targets. The metrics/parameters used for evaluating the performance and the way in which these are measured using appropriate tools and techniques play a major role in the evaluation process. This is even more challenging in the case of R & D organizations where the outcome/output may not be tangible/measurable and varies from one to another, depending on the nature, vision, charter and character of the Laboratory. A typical scenario with regard to the Council of Scientific and Industrial Research (CSIR), India, one of the premier Research Organizations in the country with 37 constituent laboratories across the country and strength of about 5000 scientists has been chosen in this paper as it truly represents the character of public funded R & D institution. Each laboratory has its own unique identity, character and area of research. This paper aims to identify all the essential parameters, factors and dimensions related to R & D performance analysis and arrive a framework that can help in objectively assessing or evaluating the performance of each laboratory.

Keywords—Knowledge generation, Knowledge transfer, Knowledge management, Performance evaluation, Mapping strategies, R & D organizations

I. INTRODUCTION

CSIR, India and its constituent laboratories are involved in world class research with corporate social responsibility. Many industries, institutes of national importance and premier private organizations approach CSIR for their problem solution measures in the form of Contract Research, Consultancy and Specialized testing services. The technologies developed at CSIR are being used by various industries in the country.

Two parameters, character and competence broadly define an organization. The “character” of CSIR is that of a collection of thirty-seven heterogeneous laboratories engaged in different areas of science, engineering and technology, each with its own vision, mission, activities and stakeholder focus. CSIR acts as a binding adhesive in bringing together all the laboratories. In effect, it is a loosely bound federal structure, with high degree of functional autonomy at the laboratory level in defining the vision, mission and activities of the laboratory.

The performance of any organization can be assessed through its stakeholders. The stakeholders being the scientists and other supporting staff, its clientele and any other indirect beneficiaries. Thus stakeholder satisfaction/participation may be one of the many parameters that form part of the performance evaluation.

Any R & D Activity will have three main dimensions – (i) the R & D input which is the front-end for innovation and this input is the resources available with each of the laboratories in terms of its expert manpower, facilities/sophisticated equipment etc. The next dimension is the process where the actual knowledge portfolios described in section II come into play and finally is the output/outcome based on which the evaluation takes place which has been discussed in section III.

Fig. I depicts the above three dimensions of an R & D activity. This evaluation can be objective only of if all the influencing parameters have been identified exhaustively and these parameters are effectively evaluated based on the outcomes whether these are long term or short-term and are tangible or intangible.

Fig.1 A Typical R & D Activity

CSIR is continuously introspecting and ever evolving organization with a cherished desire to make large national and international impact through its contributions to society, economy and environment. It is one of the most transparent organizations within the National Innovation System. With a view to improve its effectiveness and efficacy, the organization has periodically subjected itself to peer reviews. This organization is ever committed to enhanced contribution to the nation[1]. It has been in the front-end of research and is constantly engaging in innovative and state-of the art research. The type of research and the areas of research engaged in are beyond the scope of this paper. One is advised to visit the CSIR website (http://csir.res.in) to get an idea of the innovations and the R & D in which the CSIR laboratories are involved.
II. LITERATURE SURVEY

The challenges and problems concerning the evaluation and measurement of R&D have been observed by many researchers in a large number of earlier studies. Gold [2] identified some of the key problems in evaluating R & D performance. Brown and Gobeli [3] have presented the top ten R & D productivity indicators on the basis of classification to measurements of resources, project planning and management, outcomes, outputs etc. Werner and Souder [4] presented an example of an integrated metric that combines several objective and subjective metrics including the effectiveness index, timeless index, future potential index, etc. Baglieri et al [5] have suggested the measurement of R & D performance through intangible assets based on value created through R & D. Ojanen and Tuominen [6] have presented a simplified approach of selecting and developing performance evaluation methods for measuring the overall effectiveness of R & D with respect to the Telecom Sector. Chiesa et al [7] had conducted an exploratory study on R & D performance measurement practices based in a survey of Italian R & D intensive firms.

III. IDENTIFICATION OF PARAMETERS

The second dimension of R & D activity is the process of research which is the focus of this study as the parameters that are critical to each of the laboratories depending on their individual nature and character are identified here.

As stated earlier, the mandate of each laboratory is different. The contribution to public, private, strategic and societal goods from each laboratory are in varying proportions and thus, there is no uniformity to come out with a common generalized approach. It is therefore difficult to quantify the output /outcome of research and compare one laboratory with the other on the same platform.

The four goods namely, public, private, societal and strategic are defined as below:

Public: Basic research as reflected by publications, development of standards, databases, etc., and the policy support to government could be classified under public goods as they meet the criteria of non-rivalry and non-excludability. Publications can be quantified based on the citation index of each paper and the quality can be assessed through the impact factor though citation index and impact factor are debatable.

Private: Industrial training programmes, consultancy services, certification and testing services, and sponsored research are considered as private goods as beneficiary preferences is reflected in their willingness to pay for these services. Intellectual property, particularly patents, technologies, products, processes and copyrights are in the private domain, but public funds have been used both at their generation (project) stage and at the patenting stage.

Social / Societal: Social/Societal good element is evident in activities, which generate livelihood opportunities to people located in far-off regions or to poor as in development of technologies, which use traditional knowledge, and use of local resources endowments. Examples include natural hazard/disaster mitigation, environmental benefits from development use of technologies such as for coal-washing, mine safety, eco-friendly products and processes, pollution prevention and abatement.

Strategic: Strategic goods are those that are visible in the activities directly related to achieving self-reliance and services that meet the national/indigenous needs including national security for which no solution is available and enables creating technological options and ‘resource centres’, ‘spin-offs’, etc.

The one unifying factor for all these Laboratories are that they serve as knowledge resources/repositories which generate knowledge, transfer knowledge or engage themselves in knowledge management and are recognized for the knowledge they possess/create.

Also, the character of any laboratory can be determined by its charter and by its proportional commitment to various goods such as, public goods, private goods, societal goods and strategic goods. For example, a laboratory conducting high-end research will have sufficient contributions and achievements in public goods that are characterized by high impact factor journal publications and highly cited papers, etc than other goods while another laboratory can thrive on its problem solving capabilities and is involved in many consultancy projects thereby generating external cash flow.

It is therefore obvious that the number of publications in high impact factor journal or number of citations alone cannot be the deciding factor for performance evaluation of a laboratory, but an objective evaluation has to be done through a more holistic approach. In this paper, it is attempted to identify the critical parameters depicting/showcasing the performance of the laboratory, analyze these performance parameters and map them into four different knowledge portfolios. In accordance to this mapping, suitable algorithms can be formulated to measure the performance parameters. The algorithm for this computation is beyond the scope of this paper, however the factors that play a vital role in formulating the algorithm have been identified in this paper.

One of the most challenging aspects is the selection of a suitable set of appropriate measures for the right subjects of measurement. Further, there is also the problem of determining the right norms with which to make comparisons.

Table I is a summary of parameters [8] identified by each individual laboratory that they feel are critical to their performance. It is to be noted that not all the parameters are critical to all the labs. The new Information and Communications Technology initiatives being adopted by CSIR will enable easy capture of these performance parameters.

The description of the knowledge portfolios and the parameters that are mapped into these portfolios is described below. Once the parameters are identified, each of these are mapped to any one or multiple combinations of the four knowledge portfolios depending on the attributes associated with the parameters.

A probable mapping of the performance parameters of the four knowledge portfolios identified is enumerated below.

$K_G$: Knowledge Generation through Publications, Products, Technologies, Contract Research, R & D (Sponsored & Grant-in-Aid Projects) etc.

$(G_1, G_2, ... G_n)$

$K_T$: Knowledge Transfer through Seminars, Workshop, Capability Building, guidance to Research Scholars,
PG Students and other HRD activities etc. \((T_1, T_2, \ldots T_n)\)

\(K_R\) - Knowledge Recognition through Awards, Rewards, contribution to Forums /Boards /Committees at the National and International level \((R_1, R_2, \ldots R_n)\)

\(K_M\) - Knowledge Management through Patents, Copyrights, application of Knowledge, Resource Generation etc. \((M_1, M_2, \ldots M_n)\)

Each of these knowledge portfolios are given suitable weightages based on the character of the lab and also depending on the performance in the previous years.

**TABLE-I**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
<th>Knowledge Portfolio</th>
<th>Goods catering to</th>
</tr>
</thead>
<tbody>
<tr>
<td>(G_i)</td>
<td>Paper publication in Journal/Conference, National/ International /Refereed Journals (Impact Factor, SCI for Journals, etc.)</td>
<td>Knowledge Generation</td>
<td>Public</td>
</tr>
<tr>
<td></td>
<td>Chapter/Editing of Books/Publishing of Books/Monographs/ Special Publications/ Technical Reports, Brochures, etc</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resource generation (ECF) through externally funded projects such as consultancy, contract R&amp;D, testing and IPR licensing, Technical Services and the nature of the Projects handled - Mission Critical, Industry, Strategic,Societal</td>
<td>Knowledge Transfer</td>
<td>Public/ Private/ Societal/ Strategic</td>
</tr>
<tr>
<td></td>
<td>Technical Events organized such as conferences, seminars, workshops and capacity building programmes, Student guidance, Human Research Development, extramural R &amp; D etc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(R_i)</td>
<td>Socially relevant S&amp;T contributions through drafting of codes/codal provisions, manuals, handbooks, chapters, R&amp;D reports etc</td>
<td>Knowledge Recognition</td>
<td>Societal</td>
</tr>
<tr>
<td></td>
<td>Participation in policy decisions, international projects, inter-institutional MoU/collaborations/visits, Framing of new standards, policies, procedures/ Awards, recognitions of scientists etc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(M_i)</td>
<td>Development /Management of Facilities, Management of Intellectual Property through patents, Copyrights etc</td>
<td>Knowledge Management</td>
<td></td>
</tr>
</tbody>
</table>

The above parameters are not exhaustive. The criticality of the parameters and significance of each can vary from laboratory to laboratory depending on the nature and character of the laboratory and also its mandate/charter.

Fig.2 depicts the process of performance assessment beginning from the research inputs, parameter identification and grouping into knowledge portfolios and then subjective evaluation through quantification and arriving at the laboratory score.

**IV. PERFORMANCE MEASUREMENT**

The actual computation of the weightages is beyond the scope of this paper, however the following need to be factored in while computing the weightages.

- The mandate of the Laboratory
- The character/nature of the Laboratory
- The age of the laboratory which will influence
  - The resources available in the laboratory in terms of manpower, facilities etc
  - Both tangible and intangible benefits accrued by the Laboratory
- The impact of the research on different goods viz – public, private, societal and strategic etc.

Depending on the above factors each Knowledge portfolio is assigned a weightage. The parameters that are mapped to the respective portfolios assume values depending on the outcomes/outputs.

Table II illustrates a mosaic of the four Knowledge portfolios of three laboratories with different characteristics. Laboratory A is involved in high end research, Laboratory B is in mainly involved in providing services and Laboratory C is primarily focused on research for business development.

While the quantitative numbers play a major role in arriving at the weights such as number of publications, number of products etc, the qualitative factors such as the quality of publications (in terms of impact factor, citation index etc) must be also be factored. The utilization of resources in terms of manpower, infrastructural facilities and other assets must also be a deciding factor for these weightages. Another main factor for computing the weightages is the impact of the contributions of the
Laboratory either for the public/private/societal/strategic sector. The character of the Laboratory must be kept in mind at all times while fixing the weightages. The weightages can generally range from 15% to 45%.

The following could be the probable weightages of the knowledge portfolios for the three laboratories:

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>KG</th>
<th>KT</th>
<th>KR</th>
<th>KM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory A</td>
<td>60</td>
<td>20</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Laboratory B</td>
<td>15</td>
<td>40</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Laboratory C</td>
<td>30</td>
<td>50</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

The corresponding Laboratory Score \( S_l \) due to different knowledge portfolios can be computed as follows:

\[
S_G = W_G \sum_{i=1}^{n} G_i \\
S_T = W_T \sum_{i=1}^{n} T_i \\
S_R = W_R \sum_{i=1}^{n} R_i \\
S_M = W_M \sum_{i=1}^{n} M_i
\]

where

\[
W_G=KG/100, \ W_T=KT/100, \ W_R=KR/100, \ W_M=KM/100
\]

The proposed (overall) laboratory score, \( S_l \) can be computed as \( S_l = S_G + S_T + S_R + S_M \).

The computation of the \( G_i, T_i, R_i \), and \( P_i \) is not within the scope of this paper.

Each laboratory critically assesses its current state in terms of its stakeholder focus. This is necessary to ensure continuing stakeholder satisfaction as well as relevance. The laboratories must also ensure that investment of resources (human, capital and financial) is aligned to the desired focus.

As is expected from any organization, the Return on Investment (ROI) can be a determining factor to assess the performance. Since in R & D projects/programs, ROI cannot be always tangible and immediate, it is necessary that a factor is assigned to each of these parameters depending on the resource investment – the primary resources being, man, material (equipment, infrastructure etc.) and time.

Depending on the inputs of identified critical parameters of performance of the laboratory provided, a weight is arrived at for each of the parameter. Since it is not possible to directly arrive at the individual weights based on the current performance, the weights are calculated with respect to the year previous to the year under consideration and depending on the inputs for the year under consideration, the weights can be assigned to the parameters.

The total of the above weightages is computed and the laboratory score is arrived at on a scale of 10.

Table III depicts the computation of the scores of Laboratories A, B and C depending on the weightages assigned to the four Knowledge Portfolios represented vide Table II

<table>
<thead>
<tr>
<th>Knowledge Portfolios</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S_G )</td>
<td>0.60*( G_A )</td>
<td>0.15*( G_B )</td>
<td>0.30*( G_C )</td>
</tr>
<tr>
<td>( S_T )</td>
<td>0.20*( T_A )</td>
<td>0.40*( T_B )</td>
<td>0.50*( T_C )</td>
</tr>
<tr>
<td>( S_R )</td>
<td>0.10*( R_A )</td>
<td>0.20*( R_B )</td>
<td>0.10*( R_C )</td>
</tr>
<tr>
<td>( S_M )</td>
<td>0.10*( M_A )</td>
<td>0.25*( M_B )</td>
<td>0.10*( M_C )</td>
</tr>
</tbody>
</table>

Thus, the score for each of the Laboratories A, B and C would be

\[
S_A = 0.60*G_A + 0.20*T_A + 0.10*R_A + 0.10*M_A \\
S_B = 0.15*G_B + 0.40*T_B + 0.20*R_B + 0.25*M_B \\
S_C = 0.30*G_C + 0.50*T_C + 0.10*R_C + 0.10*M_C
\]

V. CONCLUSIONS
This paper aims at identifying the various parameters that can help in the evaluation of the performance of a laboratory based on its character and contributions to the four goods. The purpose of grouping into the four knowledge portfolios and computation of weightages is to bring into light the underlying fact that the performance of a laboratory should not be evaluated just by tangible outcome/outputs but to also quantify and subjectively evaluate the intangible benefits of research so that laboratories are evaluated in a more holistic manner for their performance and facilitate planning strategies for future.

ACKNOWLEDGMENT
This paper is being published with the kind permission of the Director, CSIR-SERC.

REFERENCES