Research Policy Framework Document

Aiming for Excellence: Pathways to Institutional Advancement through Research

Foreword

All India Council for Technical Education (AICTE) is a statutory body established by an Act of Parliament (Act 52 of 1987) under Ministry of Human Resource Development, Govt. of India. AICTE as per its mission to be a true facilitator and an objective regulator has initiated several initiatives with focus on planned and coordinated development of technical education in the country.

AICTE has always encouraged academic excellence in academic institutions. AICTE has a vision to improve the standards of technical education and to provide competent technical manpower for the nation. In this endeavor AICTE signed a Memorandum of Understanding with Clarivate Analytics on 25th April, 2017.

Clarivate Analytics is one of the world's largest providers of intellectual property and scientific information, decision support tools, and services. Clarivate Analytics is well-known for brands that include Web of Science, EndNote, Derwent Innovation, Derwent World Patents Index, Cortellis, and Converis among others. The AICTE-Clarivate Analytics collaboration aims to drive research as an integral component of academic excellence.

Clarivate Analytics with AICTE has developed this research policy framework document **"Aiming for Excellence: Pathways to Institutional Advancement through Research'** to help AICTE approved academic Institutions to increase awareness of research and develop a strong research program. AICTE encourages that this policy document may be adopted by the AICTE approved institutions as it would enable institutions to develop short term and long term research program plans, put in place infrastructure to enable research, and establish governance mechanisms to promote and strengthen research.

I congratulate Clarivate Analytics for preparing this research policy framework document.

Prof. Anil D. Sahasrabudhe
Chairman, AICTE

Aiming for Excellence: Pathways to Institutional Advancement through Research

Foreword

The quest for new knowledge and the application of knowledge to important societal needs should be part of the life of every institution of higher education. Research, therefore, is essential and not merely an activity supplementary to teaching.

Research experiences enrich an institution in many ways. First, teachers who engage in research can integrate their experience in the classroom: instead of rote learning an instructor can challenge students to grapple with fundamental questions and problems as researchers do. In such an environment, students report more interest in their coursework and more confidence in their teachers. Second, instilling a research culture improves the institutional environment for all, not only students, and signals high aspirations and a seriousness of purpose of the institution. Third, research requires infrastructure, including modern facilities, equipment, and supplies, so establishing research activities means improving the physical condition of an institution. Doing this requires funding but once established a vibrant program of research can attract support from government, industry, and private sources, a fourth benefit. Fifth, research builds and burnishes the reputation of an institution, attracting superior students and faculty. Not only are faculty drawn to such an institution but they are more likely to remain, which is important because retention of talented instructors and researchers contributes to sustaining excellence.

Sixth, a research program opens up possibilities for collaboration, locally, regionally, and globally. These connections raise the profile of an institution and create opportunities for advancement of many kinds, including associations with industrial firms that are nowadays an increasingly important partner in higher education initiatives. These are only a few of the benefits of establishing, maintaining, and extending a program of research at an institution of higher education.

This document describes steps along the road to a robust research program within an institution. It focuses on key considerations, including the necessity of careful, evidence-based planning, both short- and long-term; building human capital, resources and funding, and fashioning collaborations, institution to institution, people to people, and across sectors; ensuring governance mechanisms to track and promote the institution's research program, including both qualitative and quantitative assessment; and, establishing an enduring system of continuous improvement, with feedback channels across all departments and dimensions of the institution.

It is a privilege for Clarivate Analytics to consult with the All India Council of Technical Education to achieve its mission of regulating and improving the technical education system of India.

David A. Pendlebury,
Bibliometric Expert,
Clarivate Analytics

Contents

1.   The Mission of an Educational Institution

"What is the mission of an educational institution such as a university?" From Abraham Flexner to José Ortega y Gasset to Clark Kerr and others, there have been many ideas and descriptions. All would agree, however, on the important pedagogical role of the institution.

Yet history reveals more.

Educational institutions have been one of the most civilizing forces on the planet for more than 1,000 years. They both collect and create a body of knowledge and then pass that accumulated learning through generations. In doing so they shape lives, one by one, and through the instrument of educated and skilled people facilitate discovery, inventions, and contribute to a more rational and richer society. The effect is an ever widening circle of experience and influence that expands outward and eventually touches everything.

Every institution, whether large or small, teaching- or research-focused, new or old, is a significant node in the network of an ever more interconnected world.

The hallmark of our age, pessimists might say, is cynicism. But those familiar with and sensitive to the past know that educational institutions provide a proven pathway to a better future. To be associated with such an institution – as a student, teacher, researcher, administrator, or graduate – is to participate in and contribute to this continuum of transformative good for the world. Therefore, labor and talents will not be wasted if spent to improve our educational institutions, which form a pillar of society and civilization.

2.   A Multidimensional Framework for Achieving Excellence

For an institution to improve and then excel, attention should be directed across many of its dimensions and activities: teaching, research, human capital, infrastructure, funding, and administration, to name a few.

Best practices captured in academic research include the following as key attributes of educational institutions operating at the highest level:
- A high concentration of talent, both faculty and students
- Abundant resources to foster a rich learning environment and support advanced research
- Governance procedures that value foresight, strategic vision, and the flexibility to make changes without excessive reliance on bureaucracy.

These are characteristics of a 'world class university' but are desirable aspirations for any institution seeking to develop and advance.

This document focuses on how research activities can contribute to the overall quality of an institution and enhance its stature. It describes how to fashion, support, and sustain a culture of research, even if such a culture has not existed or has not been emphasized previously.

Moreover, there is good evidence that research supports and improves teaching, helping to build excellence in this dimension as well. Therefore, perceiving that an institution is teaching-only or vocationally oriented and not in need of a research component is incorrect. A research program can have salutary effects on faculty, on the nature of their teaching, and on their students, undergraduate and postgraduate. A mentality of 'teaching-only' inhibits opportunities for institutional growth and improvement.

Evidence is accumulating that students do benefit in significant ways from having researchers as instructors, if the institution balances resources spent and rewards assigned between research and teaching. This positive view, which has been consistently detected in recent studies, sees the benefits of 'research-led teaching.' In this approach, the experience of the researcher is integrated into teaching. Instead of offering cookbook experiments, faculty members present students with fundamental research problems, perhaps ones in which they are engaged that have not yet been solved. In such a classroom, students report more interest in their coursework and more confidence in their teachers. They may even more often consider careers in the field of instruction than those who do not experience this type of teaching.

Incorporating research at every stage of a degree program is a must to ensure developing a research culture and growth of institutions.

Thus, research can be directly incorporated into teaching, making use of the instructor's own research to benefit student learning and outcomes. At the undergraduate level, research is most easily integrated into the curriculum. The various ways that research might be integrated into classroom based teaching include:

- Creating exercises that help students to develop research skills (i.e., literature reviews, critically reading articles, publishing to a publicly accessible site)
- Encouraging students to use research tools such as software, research equipment etc.
- Involving undergraduate students in research seminars, visits of guest speakers and in symposia.
- Providing hands-on laboratory training to students and encouraging them to do original research (internships, projects etc.). Independent laboratory exercises or special projects will help promote research creativity if students are encouraged to explore the problem from multiple angles
- Educating students on evidence based research and on how to draw inferences and make empirical observations.
- While designing lessons, lectures and activities, highlight recent research that is relevant to course material.

Use texts or readings that focus on the "how" (strength of particular approaches) and the "why" (societal or other relevance) when addressing problems

- Emphasizing how to critically read and interpret scientific texts and encouraging students to formulate hypotheses. Introduce students to a sequence of articles that reports a single line of research from one laboratory. Students will receive each article in sections (Introduction, Results and Methods, and Discussion), and will be asked to work through the data as if they had generated it themselves. This would allow the students to see if the experiments they proposed are those selected by the authors, both helping them understand the role of creativity in scientific progress and creating a "lab meeting" atmosphere in the class.
- Teaching students to develop an experimental plan and implement the same in a laboratory setting.
- Encouraging students to work in groups to address novel scientific questions aimed at generating and testing new hypotheses. This will foster a spirit of collaboration and team work.
- Finally, all students should be required to report their findings in a journal style manuscript outlining research methodology, results, and inferences.

The above approaches will lead to an increase in critical thinking ability, experimental design ability, and self-rated abilities such as navigating the literature, thinking like a scientist, and understanding research in context. Thus, incorporating research into classroom-based teaching ultimately leads to a) stimulation of student interest, b) creating a classroom environment of lifelong learning for both student and teacher, and, finally, c) striving to achieve optimum outcomes for the society.

These are generalizations, certainly. Specific environments count, including availability of required resources, as well as the capability and motivation of the researcher-teacher. The argument advanced here is that research activity within the institution has many benefits, including its potential to improve the quality of instruction.

Taking a cue from the above points, this paper follows a three-part framework to guide institutions in driving research excellence:

- Developing and executing a robust research program that includes long term planning, building human capital, deploying requisite resources, sourcing funding and leveraging the right collaborations (Section 3)
- Establishing governance mechanisms to track and promote research (Section 4)
- Ensuring continuous improvement and sustainability (Section 5)

3.   Developing and Executing a Robust Research Plan

An institution seeking to grow its research activities should proceed step by step. Good intentions and an ambition to succeed are not enough. Success requires planning. An institution intending to build a robust research program will need to develop a long-term research plan with short-term and long-term objectives. The following activities are key in building such a plan:

- Assessing and reviewing research activity
- Defining and refining research focus
- Developing a talent recruiting, recognition, and retention plan
- Driving collaboration to improve and extend research impact
- Deploying infrastructure and resources
- Developing a comprehensive funding plan

3.1   Assessing and Reviewing Research Activity

Assessing an institution requires both qualitative and quantitative information. Often, qualitative information is small-scale and bottom-up, such as the opinions of the faculty in a particular department on the sufficiency of resources for their activities. Quantitative data is frequently global and top-down. Questions drawing on quantitative information are many, such as 'What is the proportion of extramural funding received from industry compared to government support?' or 'How many of our faculty members are Ph.D.s from top-ranked universities?'

There is neither 'king' nor 'queen' valuing qualitative and quantitative data. A strong kingdom – or institution – needs both. They inform one another, revealing specific dimensions of activity and performance that when seen from a single source might be missed. In the evaluation of research, peer review was paramount for many years, especially during the second half of the 20th century. And it still is. But nowadays bibliometric or informetric data, including publication and citation indicators, have usefully supplemented personal judgment and have at times added more fairness to the traditional subjective system of reviewing research and researchers. Similarly, the patents and industry projects are some of the other objective criteria for highlighting research output.

To begin, qualitative and quantitative information on the research activity of an institution should be collected. This includes opinions and perhaps surveys of faculty and those who support the research activities of the institution. Outside reviewers are typical in any institutional assessment, so researchers and research administrators from other institutions should be called upon. The review may also include organizations and agencies that have funded research at the institution and, importantly, they should be asked why the institution was successful in receiving their support.

Then there are quantitative data of many types related to inputs and outputs of the research system.

Inputs include human capital – faculty, students, and staffing – their numbers and their distribution in different departments. Funding for research is another input. An analysis of research funding details its level and patterns over time. Other important information includes which areas of research have been supported and which faculty members have received the grants. The identity of the funders is noteworthy, too. As government funding has become constrained around the world, there is specific interest in increasing industry, foundation, and private support for research within the institution.

In terms of outputs, there are many types to consider, both formal and informal products of research. The following table summarizes these, divided by their area of potential impact – scientific-scholarly, educational, economic or technological, and social or cultural:

Impact	Publication	Non-publication
Scientific-scholarly	Scientific journal paper; book chapter; scholarly monograph; conference paper; editorial; review	Research dataset; software, tool, instrument; video of experiment; registered intellectual property rights
Educational	Teaching course book; syllabus; text- or handbook	Online course; students completed; degrees attained (e.g., doctorates)
Economic or technological	Patent; commissioned research report	Product; process; device; design; image; spin off; registered industrial rights; revenues from commercialization of intellectual property; industry projects
Social or cultural	Professional guidelines; policy documents; newspaper article; press story; encyclopaedia article; popular book or article	Interviews; events; performances; exhibits; scientific advisory work; Communication in social media, e.g., blogs, tweets

SOURCE: Henk Moed, Advanced Evaluative Informetrics, 2017

In addition to conducting a standalone assessment of the research performance of an institution, it is also important to benchmark the performance of the institution with the peer and top institutions in the country and around the world. Alternatively, the standalone performance could be compared against the benchmark on an average for the institutions in the country.

Traditionally, books, papers, and patents, as well as citations to them, have counted most in gauging institutional and individual research performance. But today there is a strong movement globally to record and value other types of research output, such as research that has societal impact.

- Developing a robust research program requires careful, evidence-based assessment and planning
- A summary of an institution's current research activities requires both qualitative and quantitative data, including inputs, outputs, and outcomes
- External reviewers, as well as internal reviewers, are important to the objective assessment of an institution's research program

3.2   Defining and Refining Research Focus

Having gathered and analyzed qualitative and quantitative data on an institution's current research activities, other factors should be considered.

For example, what is the historic character of the institution? What types of research has it emphasized and why? Often there are geographic, economic, or social and cultural explanations. One should ask: Are these hereditary endowments still productive or relevant for the institution? Can the institution build on its history or should it consider new areas of research focus? Do the new areas under consideration conform to the mission of the institution?

The answers to these questions are complex, laden with values and judgments, and are unique to each institution. And there are always constraints in fashioning a potential research strategy, such as the talents of current faculty and available resources. These and many other considerations will certainly inform decision-making.

A research advisory board should be constituted to support the decision making for every research discipline that is critical to the institution. The board should include alumni of the institution as they have a good understanding of the institutional context/strengths/weakness as well as being up-to-date on the state-of-art technology in academia or industry in which they are currently working. The research advisory board will therefore be able to make apt recommendations for defining and refining the research focus of the institution.

Identifying a short list of research areas for focus is key to ensure efficient use of talent, resources, and funding. The recommendations from the research advisory board can be supplemented with insights derived from research analytics outlined below to identify the research areas:

- Analyzing research landscape
- Conducting SWOT Analysis of past research in the institution
- Studying Research Frontiers to refine research focus
- Consulting with thought leaders to confirm research focus

3.2.1   Analyzing research landscape

Study of the research landscape is very beneficial to understand the trends in global or regional research areas. Analysis of the research landscape can take a wide variety of shapes and forms depending on the objectives. Research landscapes can be leveraged most effectively in defining and refining one or more areas of research focus, keeping in view the following considerations:

- Institutions should ensure that the research focus of the institution is contemporary and relevant. This can be achieved by analyzing the global and national research landscape to understand the top and rapidly growing areas of research thereby making informed choices and keeping pace with and/or staying ahead of the other research institutions. Other areas to watch are those with declining research output to make necessary exclusions.
- Institutions should also ensure that they leverage the research landscape to identify research gaps and white spaces so that they can focus on novel research thereby deploying their efforts and resources effectively.
- Both the scientific literature and patent data should be leveraged to ensure that the research focus is informed by basic research as well as applied research and innovation data.
- Institutions can also use a survey of the landscape to identify the most productive and impactful research institutions and funders in a given research area. However, these are more relevant in defining the collaboration and funding plan and are covered in section 3.4 and 3.6 respectively.

3.2.2   Conducting SWOT Analysis of Past Research in the Institution

One technique for assessing an institution's current research position is a SWOT analysis. The acronym stands for Strength, Weakness, Opportunity, and Threat. Data that describe research performance of an institution are arrayed in quadrants, using two measures.

In the analysis below, an institution's research performance is charted in two dimensions: percentage share of paper output in a particular broad field and citation impact (citations per paper) of the institution's papers relative to world

average citation impact in a field. It is evident that Physics (PHYS) research is a strong research area for this institution: there is a large output of papers that have above average influence. For Materials Science (MAT), on the other hand, there is large production of papers but their impact is below expectations. That conveys a threat for the institution: evidently many resources are devoted to this activity ineffectively. Fields displayed in the lower left quadrant are areas of weakness, exhibiting both low production and low impact. But fields located in the upper left quadrant offer potential for investment and expansion. For example, Neuroscience (NEU) papers have achieved high impact but production has been low. This represents an opportunity for an institution's research program. Of course, behind papers are people, so this type of an analysis reflects research talent as well as historic performance.

SOURCE: Clarivate Analytics, InCites

A SWOT analysis of an institution's research takes an internal and retrospective view. Another approach would look outward and prospectively. Instead of what was or is, it considers what could be.

3.2.3   Studying Research Fronts to Refine Research Focus

Research fronts and science mapping are a source for observing the current research activity in an area and could be helpful in establishing a research program in a promising new area, if it is within the realm of research important to an institution and perhaps also one in which there is already some activity.

The research fronts appearing in Essential Science Indicators are built around highly cited papers, specifically papers that for their field and age rank in the top 1% by citations. An institution that is attempting to establish a research program may not have many or any of these papers to its credit. However, the papers that cite the core of the research front, which may themselves not be highly cited or may be new, can be harvested for papers from an institution that is beginning to expand its research activity. That is important evidence of research activity.

Each year Clarivate Analytics, in partnership with the Chinese Academy of Sciences, surveys the entire scientific and social science literature as represented in publications indexed in the Web of Science. The most-cited papers over the past five to seven years are identified in each field. These influential papers are then analyzed for patterns of co-citation, meaning how often papers were cited in pairs. This is a technique that reveals association and similarity between papers, as indicated by the cited references the experts (authors) append to their papers. When multiple highly cited papers are co-cited together, clusters of closely related papers form that represent the specialty structure of science. The clusters are typically small in terms of publications and number of authors. They deal with problems and issues at the forefront of research and that is why they are called research fronts. After the research fronts are identified, they can be mapped in two or three dimensions to show their relationships, connections, and distances from one another. Visualization and mapping science has itself become an important research front over the last decade. It offers much to assist those responsible for setting research strategies at the national and institutional level. It also benefits funders in their choices of which projects and investigators to fund.

Below is a representation of the top ten research fronts in chemistry and materials science according to the average age of the co-cited papers forming the front. If the average age is recent, that indicates an area of study in which the foundational literature is new or turning over rapidly. The circles displayed show the volume of citations to papers in the research front each year. Clearly 'High-efficiency perovskite solar cells' is a hot area of activity in chemistry and materials science.
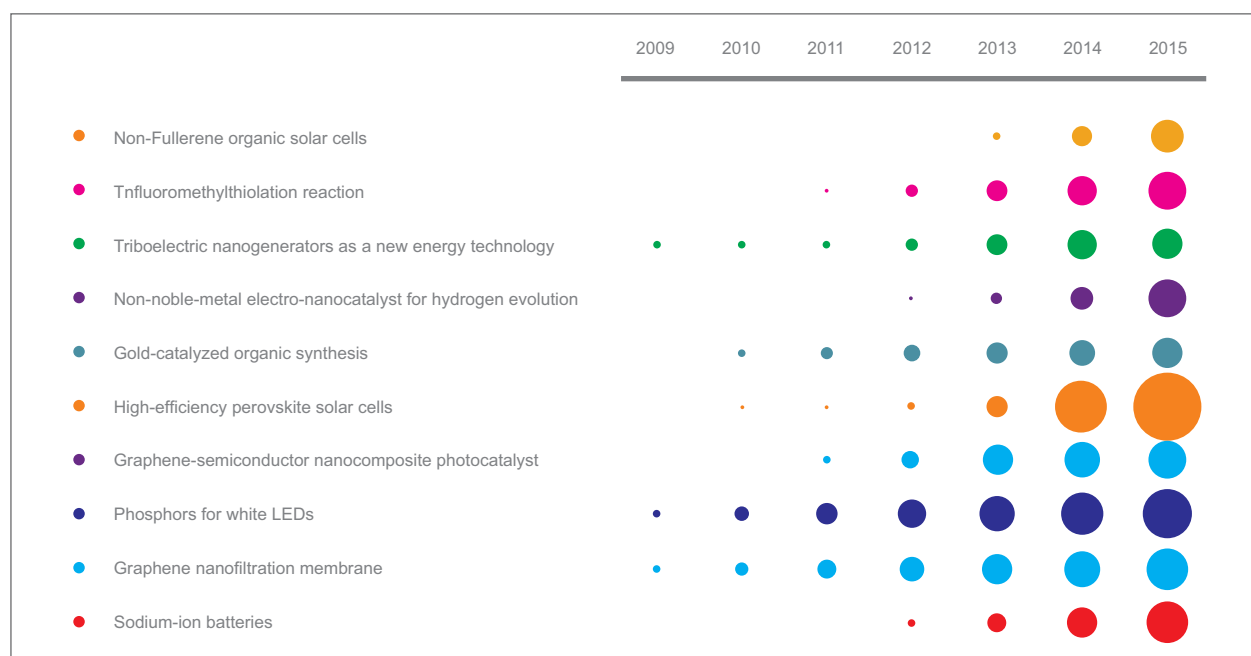
SOURCE: Clarivate Analytics and Chinese Academy of Sciences, Research Fronts 2016

The objective analysis of what is happening in research and of which areas are attracting attention can provide a stimulus to ideas about new research directions for a nation or an institution. It is not a matter of chasing fads, but of knowing the dynamics of the contemporary research landscape from a global perspective and making choices that match with a nation or institution's interests and resources.

3.2.4 Consulting Thought Leaders to Confirm Research Focus

A systematic analysis of the data to understand the research landscape, a SWOT analysis, and detection of emerging research will bring out several evidence-based insights in defining and refining an institution's research focus. However, inputs from thought leaders will be instrumental in bringing in practical aspects arising from experience and expertise.

Thought leaders are typically an excellent consulting source for shaping the chosen research focus areas as well as overall research program planning, given their hands-on experience. Some of the approaches and steps that institutions can leverage to identify, profile, and partner with the thought leaders for consulting are as follows.

- Identify top researchers and thought leaders in a given area based on publishing, patenting, and clinical trials information.

- Further profile the identified individuals by analyzing related activity on professional and technical social media platforms
- Partner with the shortlisted individuals to seek their inputs on the research focus both in the short term and longer terms
- Further leverage thought leaders by tapping into their networks for widening the institute's research and commercialization/industry collaborations

In summary, any research plan will have short-term and long-term goals. For example, a short-term goal may be simply participation in research that is both important to the institution and is plainly growing, as known through community opinion and analysis of the literature. A long-term goal may be to build up a core of researchers in this area to establish a footprint for the institution as a leader in the field.

- Formulating an institution's research strategy should consider its mission, institutional history, faculty talents, and resources
- Analysis of past performance using qualitative and quantitative data, including bibliometrics, will help reveal research strengths and weaknesses, as well as opportunities
- Choices always depend on human judgment, albeit aided by information
- The road to research success is long, perhaps 10 years or more, so short and long-term goals should specified

3.3   Developing a Talent Recruitment, Retention and Recognition Plan

When assessing an institution's research program, seeking out opportunities, and imagining possible strategies, there is arguably no other more important focus than its present human capital. The recognition, retention, and recruitment of talented and passionate researchers are key elements for sustainable development of excellence in research within the institution.

The 1999 Nobel laureate in chemistry, the late Professor Ahmed H. Zewail of Caltech, was often quizzed on the ingredients for a successful research program, both at the national and institutional level.

"The answer lies in accepting a triad of essentials," he said. "First, and most important, are the people involved. Giving proper priority to providing thorough and inspiring education in science, technology, mathematics and engineering is essential. Research and development needs to attract the best young minds. Large buildings and massive funds will not produce much without the right people. Second, an atmosphere of intellectual exchange is of paramount importance for ideas to crystallize. To distract faculty members with the writing of extensive and numerous proposals or to turn them into managers is the beginning of the end. The modern enterprise of science has become so bloated and complex that the traditional models of funding must be re-examined. How do we focus resources on the best science and what is the level of funding needed to serve society best? Third, without resources little can be achieved, no matter how creative the mind. Obviously, investment in science is needed to build instruments and to hire competent staff. Countries and institutions that provide the requisite infrastructure and the funding for ideas will be the homes of discoveries. But such support should follow the vision of creative researchers, not be built merely to lure money or to force people into fashionable research areas such as nanotechnology."

Thus, Zewail's first thought was the people involved in research, and while he spoke of attracting the best students he would readily agree that an institution also needs to nurture, retain, and seek out the 'best minds.'

Taking stock of the faculty and their talents should be pursued qualitatively and quantitatively. Methods and best practices for evaluating research outputs will be described in the next section, which focuses on assessing and monitoring research progress.

With respect to recruitment, however, a few approaches may be mentioned here. Informal channels of personal association and communication will bring the name of a promising young researcher to the attention of an institution. But this may be supplemented by systematically analyzing authorship of recent highly cited papers in a research area of interest to the institution. Authors of papers in relevant research fronts may be a more precise approach. And looking to indicators of a qualitative nature is also useful, such as monitoring the awardees of prizes recognizing early career achievement. These examples focus on younger researchers but using citations and awards to recognize accomplished mid-career scientists and scholars is equally profitable. Both of these quantitative and qualitative indicators reflect, after all, community or peer esteem.

Talent is the backbone of the right growth path for any given institution; it is even more critical in context of the emerging institutions with nascent research programs. The following two pronged approach is recommended:

- As a short term approach to solve the issue of mediocrity and lack of creativity at institutions, it is important to provide flexibility to Institutions to hire from industry and from the globally available talent pool. Recruiting internationally trained scientists and/or industry trained scientists as faculty members will add immense value to the research programs in an institution. This would also need policy intervention to provide for additional funds for these resources. In addition, re-hiring retired professors to retain experience is another approach that can be considered.
- As a long term approach to nurture talent it is important to train and up-skill the current talent pool and train them, at the top Institutions in India and across the globe, to ensure adequate exposure thereby building a future supply of a stronger talent pool.

Since research talent is rare, and even rarer when combined with excellent teaching skills, finding and keeping the best faculty should be of paramount concern for an institution. Creation of industry endowed positions, increasing the age of retirement and deployment of faculty members on short sabbaticals to industry are few approaches that could be considered to attract and retain faculty talent.

Researchers are typically self-motivated, value autonomy, thrive in environments of mutuality and collegiality, and respond well to flat, decentralized institutional organization and procedures in contrast to vertical, command-and-control management styles.

Rewards appreciated by researchers often have to do more with respect and recognition than with money, however, pay that is below standard grade is certainly corrosive to morale and undermines retention strategies.

Following are the various measures that can be deployed to incentivize research:

- Financial rewards for quality publications
- Financial rewards for innovations as measured by patents
- Promotion evaluation to include research output as measured by quality publications, patents, and technology transfers to industry
- Providing additional funding and resources to high performing researchers
- Royalty sharing with faculty and researchers for commercial activities and invention technology transfers

In deploying these measures, institutions should be cognizant of some of the pitfalls. Enormous cash awards for research performance may have negative unintended consequences, since they tend to change the research culture and lead to goal displacement. If a faculty member has teaching responsibilities, a balance must be struck between time for research and time for teaching and for student advisement.

And the students should not be forgotten, for they too are part of the human capital of an institution. They also may play an important role, whether as undergraduates or postgraduates, in supporting and carrying out the research conducted at the institution.

- Recognition, retention, and recruitment of talented and passionate researchers is of paramount concern
- Researchers are most likely to achieve their best performance in an open, collegial, and decentralized environment
- Providing time for research is essential and must be balanced with teaching duties
- Rewards are important but are often more about recognition than money, although pay must be fair
- Students can provide an institution with human capital for its research program, and researchers require this important support to carry out their work

## 3.4   Driving Collaboration to Improve and Extend Research Impact

Researchers also highly value opportunities for collaboration, internally and externally. Globalization has introduced more and more collaboration of all types into research activity, which Jonathan Adams of Digital Science has called "the fourth age of research," coming after individual, institutional, national pursuits. "Institutions that do not form international collaborations risk progressive disenfranchisement, and countries that do not nurture their talent will lose out entirely," he says.

"Incentives must be put in place to enable universities to participate in international networks. For example, tangible projects involving participation could be given explicit recognition and credit in systems for assessing research quality…. Insight into the evolving research of the emerging economies will be limited without active engagement and collaboration. Relying simply on what is published in journal articles has long been recognized as a poor mode of knowledge transfer."

Developing collaborations, building a network of research partners – locally, nationally, and abroad – both creates a stimulating environment for faculty and also opens up new opportunities for an institution by raising its visibility and stature. But any collaboration plan should match the core teaching and research interests of an institution with those of other institutions and individuals.

Collaborators certainly arise in the natural formation of contacts researchers build themselves through shared interests with colleagues. But research collaborators may also be pursued through careful analysis of co-authorship, of citation networks (such as in an analysis of those cited by institution's researchers in their papers as well as those who cite them), and of funding acknowledgements recorded in the scientific and academic literature.

The graphic below illustrates an analysis of co-author collaboration at the level of institutions for two universities: the University of Copenhagen and Seoul National University. The data are derived from the Web of Science and represent papers in pharmacology from the two institutions published during 2011-2015.
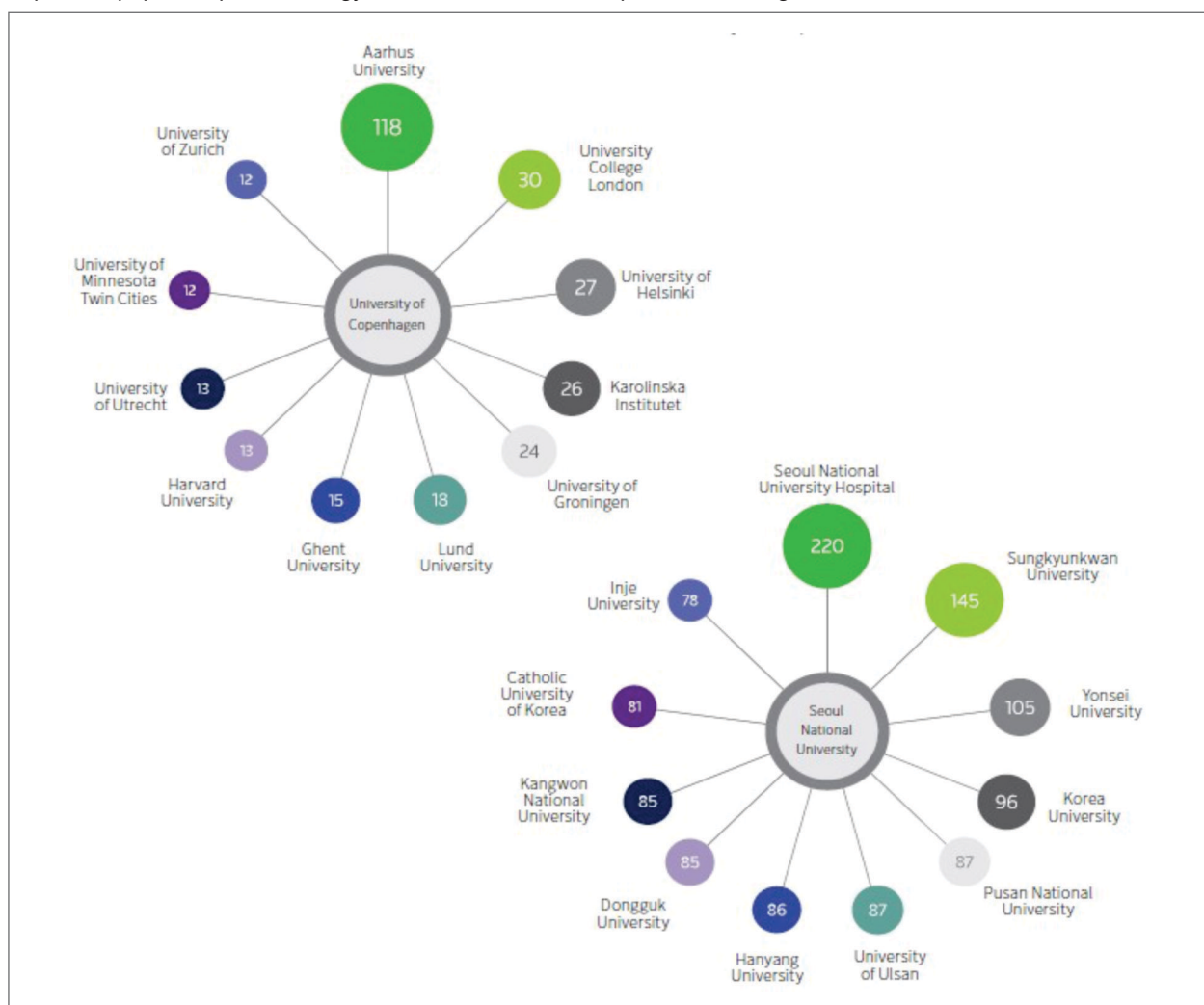
Both universities produced approximately the same number of papers in this area during this recent five-year period: 1,553 for Seoul National University and 1,452 for the University of Copenhagen. All the collaborations listed for Seoul National University are domestic whereas those for the University of Copenhagen are mostly international and not only European. In fact, the percentages of papers with international collaboration for the two universities are 18.4% and 47.3%, respectively. The papers from the Korean university were cited 16% below the world average in this field but those from the Danish university scored 38% above the world average.

Institution-to-institution collaboration plans require a wider view to match more shared interests and attributes than would be done in seeking individual research collaborators. As mentioned, industrial collaboration and funding has become a priority for many universities whose governmental funding has slowed or actually decreased.

Finally, researchers benefit greatly from the opportunity to attend conferences and deliver presentations about their research. Not only does this promote the researcher and the research of the institution, but it also gives attendees who may be seeking collaborators an opportunity to suggest partnerships.

- Collaboration, including international collaboration, is an essential feature of research performed at the world level
- Individual and institutional collaborations should match with the research plan and program of the institution
- Systematic analysis of the scientific and academic literature can suggest potential research partners and identify those with greatest research impact who could contribute to improving research quality at the institution
- Resources are required to enable researchers to attend conferences, which increases the visibility of the research, the researcher, and the institution and helps establish research collaborations

3.5 Deploying Infrastructure and Resources

An institution aiming to raise its research profile must focus on improving its infrastructure, equipment, information resources, and support staff – all are necessary components for conducting successful research. And all require funding.

A deficient physical infrastructure is certainly a detriment to conducting research at a world standard and above. It also dampens interest in the institution among potential professors and researchers as well as students. Infrastructure is more than the physical plant, the bricks and mortar. It also includes equipment and supplies necessary for performing research, as well as knowledge of how to use the equipment and maintain it.

Information resources are essential. Having smooth and easy access to the professional literature ensures an institution's researchers are up-to-date and know what others are doing. Unnecessary duplication of research is one frequently overlooked benefit of a careful literature search.

Often early researchers ignore the need for thorough literatures review and discovery process. It is very critical that the researchers and scientists are empowered with all the relevant tools for progressing on the research in an effective and efficient manner along the entire research cycle. For example

- Research and Discovery stage – Access to relevant scientific literature in the form of high-impact journals and scientific citation databases so that these could be leveraged for scientific literature review, for developing and progressing the research hypotheses, and for assessing the state of art in subject areas of research interest. The novelty and impact of research can be increased by leveraging quality abstracting and indexing databases.
- Authoring and Publishing Stage – Access to authoring and publishing tools such as reference management, plagiarism checking, tools to shortlist journals and submit manuscripts

Furthermore the leaders of the institution should ensure they have the tools to conduct a thorough analysis of their research output and benchmark it against peer institutions and world output in general.

If infrastructure, equipment, and information resources are the engine of research, it is funding that fuels and powers up the engine.

Without adequate infrastructure, resources, and funding, a research program cannot be established let alone pursued and expanded.

3.6 Developing a Comprehensive Funding Plan

Finding funding is labor intensive, extremely competitive, and robs time from doing research. Institutions typically look to the following sources for funding research:

- Government ministries and departments: MHRD, DST, CSIR, DBT, BIRAC, MoES, SERB, etc.
- Other universities with larger research programs
- Multi-lateral global funding organizations such as Asian Development Bank, UNDP, World Bank, Wellcome Trust, etc.
- Commercialization of Intellectual Property
- Industry collaborations and consulting projects
- Alumni network

An institution can help researchers by establishing an Office of Research Support that facilitates applying for grants and guides researchers to potential funding sources.

At times, funds for institution research must come from internal sources. This is sometimes referred to as core support. Such seed money represents self-investment and is essential for new researchers trying new things.

To build a sustainable funding ecosystem it is critical for the institution to patent, publish, and prosper through their research. Once the intellectual property is created, it could further be commercialized, working closely with the industry.

Just as an Office of Research Support assists researchers in obtaining funds, an Office of Industrial Relations and an Office of Technology Transfer can play an important part in, respectively, forming relations with industry and performing contract research, and in patenting and commercializing inventions, as well as in licensing to obtain royalty streams.

In India there is a growing interest in obtaining private support from well-to-do patrons who express support for research and from alumni of an institution who are charitably inclined. Personal appeals have long been a fundraising method at U.S. universities. This activity has crossed the Atlantic to take root in the United Kingdom. It will eventually reach other nations as government, industry, and foundation funding is unlikely to keep pace with all the good research that should be performed.

While many government funding sources may be well known, systematic analysis of the research literature can reveal unknown funders. One example of this type looks at funding acknowledgments recorded on research papers. Since 2008, Clarivate Analytics has included this information when indexing publications.

To start, a researcher or staff member would search for a set of papers in a field or on a specific topic. The search could also proceed by collecting papers of peers working on similar research problems. After a group of relevant reports is assembled, the papers can be summarized by funding acknowledgments. The results often turn up public and private sources of funding that will be unfamiliar to the researcher but are sources of potential support.

For example, a search of the Web of Science for papers on remediation of soil and water, with an address of an author affiliated with an Indian institution, and published from 2010-2017, retrieved 1,037 items. Naturally, many of these papers acknowledge funding from Indian sources: CSIR, DST, UGC, and others. But other and foreign funders appear, too, including agencies and universities in China, South Korea, the Czech Republic, Australia, the United Kingdom, Saudi Arabia, and South Africa, as well as the European Commission.

Field: Funding Agencies	Record Count
NATIONAL NATURAL SCIENCE FOUNDATION OF CHINA	7
EUROPEAN COMMISSION	4
KOREAN GOVERNMENT MEST	4
NATIONAL RESEARCH FOUNDATION OF KOREA NRF	4
KING ABDULLAH UNIVERSITY OF SCIENCE AND TECHNOLOGY KAUST	3
MINISTRY OF EDUCATION YOUTH AND SPORTS OF THE CZECH REPUBLIC	3
AUSTRALIAN GOVERNMENT	2
AUSTRALIAN INDIA STRATEGIC RESEARCH FUND	2
BRITISH COUNCIL	2
CHINESE ACADEMY OF SCIENCES FELLOWSHIPS FOR YOUNG INTERNATIONAL SCIENTISTS	2
CHINESE GOVERNMENT HEAVY METALS POLLUTION CONTROL SPECIAL FUND	2
COOPERATIVE RESEARCH CENTRE FOR CONTAMINATION ASSESSMENT AND REMEDIATION OF THE ENVIRONMENT CRC CARE	2
CRC CARE	2
CSIR NEW DELHI	2
DEANSHIP OF SCIENTIFIC RESEARCH AT KING SAUD UNIVERSITY	2
EPSRC	2
FACULTY OF SCIENCE UNIVERSITY OF JOHANNESBURG SOUTH AFRICA	2
GOVERNMENT OF AUSTRALIA DEPARTMENT OF EDUCATION EMPLOYMENT AND WORKPLACE RELATIONS	2
INTERNATIONAL SCIENCE AND TECHNOLOGY COOPERATION PROGRAM OF CHINA	2
KING SAUD UNIVERSITY	2
KING SAUD UNIVERSITY DEANSHIP OF SCIENTIFIC RESEARCH COLLEGE OF SCIENCE RESEARCH CENTER	2
KOREA MINISTRY OF ENVIRONMENT	2

SOURCE: Clarivate Analytics Web of Science

In the example above, one funder is the Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (or CRC CARE), which is part of the CRC program of the Australian government. CRC supports industry-led collaborations between industry, researchers, and the community.

Not only does this type of analysis lead to new funding sources, it also points to potential individual and institutional collaborators.

- Systematic analysis of the scientific and academic literature can reveal new sources of funding (as well as new individual and institutional collaborators)
- Offices of Research Support, of Industrial Relations, and of Technology Transfer can greatly assist researchers in gaining support for themselves and for their institution
- Private funding is a new potential source for research support

4. Governance Mechanisms to Track and Promote Research

To ensure that the institution's research plan is being carried out and is effective, governance mechanisms are needed to track research outputs and outcomes.

As stated, an institution, for many reasons, will have particular purposes and goals, and its research plans will be different from others. What one institution values highly in the research realm, another will give a low priority.

As shown previously, there are many types of research outputs to consider. For example, one institution may see research that contributes to solving local or regional problems as important, even if the work is not published in an international journal. Another will give special attention to research that underpins teaching and whose product is an online course. Still others will value traditional research activities contributing to knowledge creation and the publication of papers in journals which influence the scholarly community, as evidenced by the citation record in the literature.

Therefore it is important that an institution carefully separates its policy choices and its evaluative framework from the measures it uses to gauge performance and success. Henk Moed, Visiting Professor of Sapienza University of Rome and the foremost authority on the use of citation data in research evaluation makes this point explicitly in his book Applied Evaluative Informetrics. He warns against the danger of having available measures become by default what an institution values, aims for, and rewards.

It is only after the policy decisions of an institution have been set that appropriate measures and indicators will be chosen to track those activities. Of course, there is no one set of such measures or indicators. Whatever the policy and evaluative framework, Moed calls for clear communication and transparency so that faculty will know how they are being assessed and can contest or clarify decisions made on the basis of the measures and indicators employed.

As mentioned, there is a trend in research evaluation to take into account a wider variety of research outputs and outcomes than in the past. An argument has been made in the last few years that new measures are required to capture research impact beyond the walls of academia. Social media data, it has been suggested, are a rich source of new measures, called altmetrics, and that they capture some of this impact, such as in blogs, tweets, recommendations, etc. The societal impact of research represents a key current concern of governments and funders around the world. Also, peer review activity, data sharing, and software creation are research activities that many say should be recognized and formally rewarded.

While these activities, one may agree, have equal or perhaps greater value in some situations as do tradition research outputs such as papers and patents, there is little history and experience of potential measures to record these. There is no standard or best practice in this realm. Altmetric indicators, in particular, are in a very early stage of investigation and experimentation.

What is better known and understood are bibliometric indicators of research activity and performance, which have been studied and applied for more than 50 years.

For this reason, the remainder of this document will focus on publication and citation data, their uses and possible abuses, and best practices and applications for research performance assessment and for monitoring and tracking developments and trends in research.

- In tracking and evaluating research performance, universities will value research output and impact differently

- It is important not to confuse or conflate policy choices about research directions and goals with indicators of performance: the former determine the latter

- A wider range of research outputs are increasingly valued but there is little agreement on standard measures to capture non-traditional products and impact of these research-related activities

4.1   Bibliometric and Other Indicators for research evaluation

Commonly used measures of research output and impact include:

Basic Research Productivity And Impact	• # Publications • # Publications on Web of Science •# H-Index	• # Citations •# Citation per document •% of Documents cited	•Impact Relative to Country •Impact Relative to Area •Impact Relative to World
Scientific Excellence	•Category Normalized Citation Impact	•%Paper published in top quartile •% Documents in Top1% or Top 10%	• Hot Papers • Highly Cited Papers
Scientific Collaborations	• # National Collaborations	•# Industry Collaborations •Consulting Revenue	• # International Collaborations
Intellectual Property	• # Patents published •# Patents grant success rate •# Copyrights	•Geographical coverage •Industry influence	• Commercialization
Other Output	• # Drugs •# Medical Devices •# Biomarkers	• # Clinical Trials	

(These are certainly not all bibliometric indicators for assessing research performance but they represent the main types. A fuller list may be found in Clarivate Analytics InCites database.)

Common use is not necessarily best practice. To begin, the journal impact factor should not be used to evaluate a paper published in the journal. The journal impact factor is a short-term measure of average performance for a journal, not for a paper. Citations to individual papers in any journal will exhibit a sharply skewed distribution. Since the journal impact factor calculation is a mean score, most items with fall below the mean. In any case, one can simply look up the actual number of citations to a paper and not rely on proxies such as the impact factor. For very recently published papers that have not had time to attract citations, the journal impact factor may suggest something about the quality of paper with respect to the peer review standards of the journal, which are generally more stringent the higher the impact factor score.

The practice of comparing papers from different fields according to their impact factor is not valid: different fields exhibit different rates of citation and papers of different years will have had more or less time to be cited.

The practice of adding up the journal impact factors of the papers by an individual to create a composite performance score for that individual is to be condemned as worst practice. Such a system of evaluation reveals that theassessors do not know what they are doing.

If evaluating a paper, citations to the paper should always be obtained. If evaluating a journal, the journal impact factor is fit for purpose.

The h-index has become a much used measure of an individual's performance since it was introduced in 2005. Simply stated, an individual's h index is the number of papers he or she has written that have been cited h times. This measure combines both output and impact as a composite score. But an h-index score is highly influenced by the field of the investigator (different fields have different rates of citation), the number of papers the researcher has produced, and the time they have had to attract citations. This measure, therefore, favors senior researchers who publish in high-citing fields, such as molecular biology or neuroscience.

An important criticism of the h-index – and for that matter any single measure – is that it cannot capture the multidimensional nature or range of research performance, of an individual or of an institution. Instead, bibliometric best practice is to use multiple measures that reflect different facets of research performance.

The indicators listed above are valid measures for use in evaluation of individuals, institutions, and nations. Publications represent units of output. One may wish to count papers in different ways, depending on indications of contribution to a paper and not mere participation. In some fields, the position of the author name conveys the extent of contribution or responsibility. A fractional counting of publication output may be required, especially on papers with many authors. Number of citations represents gross influence. Robert K. Merton, the sociologist of science, likened citations to "repayments of intellectual debts" and "pellets of peer recognition." But, as mentioned, total citations will be determined not only by influence but also by the age of the publications and the field they represent. The golden rule is to compare like with like, meaning papers of the same field or on a similar topic and of the same publication years. Citations per paper, or weighted impact, is likewise subject to field and age differences. That is why relative citation impact (citations per paper), also called normalized, is important. This transformation of raw scores allows for cross-field and cross-time comparisons since it provides a scaling to allow like-for-like comparisons. Another name of this measure, which is used in Clarivate Analytics InCites, is Category Normalized Citation Impact, or CNCI.

It was mentioned that citation data are highly skewed. Roughly, they exhibit an 80:20, or Pareto-type, distribution, where 20% of the items capture 80% of the citations. There are usually many papers in any collection that are uncited. Because citations per paper and normalized citations per paper measures are calculated using means, the few highly cited papers will move the mean upward. Using a mean to characterize items in a skewed distribution is often criticized: if one seeks a measure of central tendency, the criticism is valid, however if the intent is comparisons of different entities, the use is usually valid since the underlying data of the entities is similarly skewed, at least in large collections.

Another method of characterizing citation performance of a paper or collections of papers uses percentiles or percentile rank indicators. The rank of a paper within a distribution is transformed to a percentile on a 1 to 100 scale. This allows a paper (or in the case of mean or median percentiles, a collection) to be specified and compared with others more exactly.

Finally, because highly cited papers are infrequent but important, another valuable measure is the number or percentage of output that ranks at the top of any citation distribution, say the top 1% or the top 10%. Bibliometricians have reached an informal consensus that top 10% papers strongly suggest excellent performance.

- Single measures of research output and impact are to be avoided since research activities and outcomes are inherently multidimensional: use multiple indicators
- Performance measures must be normalized for field and year of publication to ensure fair comparisons of research performance
- Highly cited papers, outliers in statistical terms, are in fact some of the most valued outputs of research activity and should receive special attention

4.2   Institution Rankings and Benchmarking Performance

The past 15 years have witnessed the proliferation and growing influence of institution rankings. Some are based on reputational surveys only, but the majority of the popularly quoted ones also integrate bibliometric indicators. The CWTS Leiden ranking uses only bibliometric indicators. The pioneer global ranking of universities known as the Shanghai ranking (formally, the Academic Ranking of World Universities, or ARWU), uses a combination of bibliometric indicators, awards, and other data. The well-known Times Higher Education (THE) and QS rankings combine reputation scores from surveys with bibliometric data.

Clearly, these rankings have a use, namely, in promoting the institutions that are highly ranked. Across these rankings, the same 1,000 or so universities generally appear and there is little substantive variation among the top ranked (Harvard, Oxford, Stanford, etc.), for which one doesn't need a ranking to recognize research excellence. As one moves down the rankings, there is great variability in the placement of institutions.

The main criticisms of these institution rankings are: 1.) their use of a composite score to obtain a rank that collapses or crashes the multidimensional aspects of a institution's nature, activities, and performance, 2.) a lack of meaning in what the ranking of an institution conveys , 3.) the selection of indicators and the weightings given to them are based on preferences alone, because there is no universal definition of research performance, let alone of 'best universities', and 4.) that the rankings give an impression of precision that they do not have. In summary, one ranking scheme is so different from another that no consensus can be obtained from all.

A better aim is to examine institutional performance in separate dimensions using different indicators. More transparency and better access to the underlying data in each ranking, so that it may be analyzed by end-users, would improve the utility of institution rankings.

Best practice in benchmarking entails finding universities that are similar in their organization and mission and obtaining a range of publication and normalized citation indicators for each, and then to carefully analyze and compare the performance of each across different dimensions. As one comparison is made, a question will arise that requires another indicator to reveal a different dimension, and so on. An analyst must repeatedly interrogate the data to obtain useful information about performance and success.

It cannot be stated often enough that bibliometric indicators of research performance are meant to supplement and not substitute for peer review. For institutional research assessment, their value lies in the top-down summary that these indicators provide. But they should be combined with other types of data and interpreted carefully by knowledgeable reviewers.

- Popular institutional rankings have little meaning without understanding their different methodologies and having access to the underlying data
- Benchmarking should use multiple measures of research performance and focus on comparisons of similar institutions
- The numbers do not speak for themselves: bibliometric indicators provide useful top-down summaries of an institution's research activities according to a variety of measures but require human interpretation to make a judgment about research performance

4.3   Monitoring the Structure and Dynamics of the Research Landscape

One important way to ensure that the research activities of the institution are progressing is to examine its activities within the overall research landscape to ensure its research is sufficiently active, relevant, and useful.

Research fronts and science mapping were mentioned earlier in this document in the context of assessing an institution's current and potential research activity (See section 3.2 - Defining and Refining Research Focus).

Using the literature and its citations to define and reveal the organic structure of research at the level of specialty areas is generally pursued as an exercise apart from research performance analysis, but it should not be thought separate or irrelevant to fashioning a research plan and gauging an institution's research performance.

There are many ways to make science maps, to show the socio-cognitive relationships among papers, people, journals, and institutions. The publication and citation data can be clustered using text analysis or citation linkages or a hybrid of both. In Clarivate Analytics Essential Science Indicators, co-citation analysis is employed and every two months some 8,000 research fronts are presented, some new, some growing from earlier fronts, some merging, and others dying. Representations of these dynamics give much insight on the contemporary landscape of research, including where there is much activity and even where new areas are beginning to emerge.

In fact, participation in the formation of a research front constitutes an indicator itself, quite apart from citation impact measures. Research participation, after all, is a prerequisite to having research impact. Participation across research fronts of interest can be monitored and measured, so this could be an important indicator of progress in research activity for an institution. It also conforms to Moed's interest in indicators of performant status.

- Research fronts and science mapping can not only reveal areas of specialty research in which an institution is active but can also suggest areas of growth and possible promise for an institution
- While an institution attempting to establish a robust research program may have no or few 'core papers' among the defined research fronts, the papers citing the core papers can be searched for those from a particular institution
- Participation is a prerequisite of performance, so monitoring and quantifying such participation can provide useful information on the research progress of a institution

4.4   Tracking and Monitoring all Research Activity in the Institution

Governance of an institution's research activity and performance requires many things, some of which are described above. But an information system is essential. This should include a variety of statistical data on the institution's condition and activities, including research, should provide analytical tools, make accessible reports and reviews, and be easy to use (or else it won't be used).

In terms of research activity, the standard for an institution is a so-called Current Research Information System, or CRIS, that makes available a range of data that may be used by faculty and research administrators within the institution as well as by those outside the institution, such as funders, industrial partners, and even the public. Not only does this help inform the institution's community of the research activities being conducted, but it also makes these activities known beyond the institution's community.

A CRIS contains information on the institution's research staff, their publications, grants they have received, partnerships they have formed for commercialization, patents applied for and granted, and much other information.

Such an information system contributes to making an institution more efficient and effective. It is a key part of ensuring continuous improvement and sustainability of a research program.

- A standard requirement for an institution research program is a Current Research Information System (CRIS)
- The institution's information system should support institutional development and foster best practices that lead to excellence

5.   Continuous Improvement and Sustainability

An emphasis on human development is another essential. In the 21st century people – researchers and research support staff – require constant continuing education. This can be facilitated by the institution through hosting workshops and seminars designed to promote best practices in research, publication, managing workflow, finding funding, human and resource management, as well as in teaching.

The goal is an institution that improves through experience and continual learning, supported by an information system that provides feedback on many different activities of the institution to correct mistakes and inefficiencies. In doing so, such a system aids in developing excellence in all spheres of an institution's activity.

A well-structured training program is critical to ensuring continuous improvement in institution

- Conducting effective research to power discovery
- Authoring influential publications
- Avoiding and discouraging plagiarism
- Writing effective funding applications
- Using bibliometric and other indicators to evaluate research performance
- Using technology to monitor research

Lastly, but, importantly, the leadership of an institution should communicate, continuously and very clearly, its purpose and priorities so that faculty and staff know and collectively work toward the institution's stated mission for research. If research is a priority then the administration should provide participatory leadership to match the way that researchers themselves function. Researchers typically do not take kindly to orders but are open and responsive to collaboration on projects of common interest, such as the quality and advancement of research activities within the institution.

- Good governance requires information on activities and progress, which should be open and available to the institution's community and beyond
- To manage and inspire researchers, the administration of an institution should provide participatory leadership, partnering with researchers to help them achieve their goals in the way researchers understand and behave

6.   Concluding Remarks

In conclusion, here are 10 key points presented in this policy document:

- Research is an important – even essential – component of an institution's mission: knowledge creation and dissemination are key
- Developing a robust research program requires careful planning including evidence-based assessment
- An institution's research plan must consider its institutional ancestry, resources, talents and capacities of current staff, and its realistic, practical opportunities
- Research talent is a first-order concern, so recognition, retention, and recruitment of well-trained, creative, and passionate scientists and scholars should be a priority
- Researchers require time, not only for their work but for their development: an institution's expectations of research performance should be balanced in a reasonable way with teaching duties
- Opportunities for collaboration are desired and in fact necessary for an institution's researchers
- "…without resources little can be achieved…" Systematic analysis can lead to new sources of research funding
- Governance requires monitoring and evaluation, but policy should determine measures of performance and not the reverse
- Bibliometric indicators, when used properly according to best practice, can usefully supplement peer review of the institution's research program and of individual researchers
- Universities seeking to establish a research program should consider using indicators in special and new ways, such as determining performant conditions and providing support to deserving researchers who have not yet made their mark

This document is intended to encourage institutions to consider how to build up or improve research activity at their institution. It does not offer "one-size fits all" prescriptions or advice. Each institution is different and each may take from the foregoing what best applies to its situation. It is hoped, however, that principles of best practice recorded here will be noted and applied. The AICTE intends to provide incentives in the form of awards and research funding to those institutions that work on these principles to improve their research.

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