An investigation into behaviours in and performances of a R&D operating unit

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The desire to improve the quality of life has driven research and development (R&D), and as a result technology. However, it has been noted that global R&D problems are, still, not well structured, and there are no unique solutions for the challenges of global innovation. The factors and interdependencies that influence the management of R&D remain complex. One of the key, central challenges of the complexity is the management of knowledge and human resources. The interplay of these issues must be considered carefully in the strategic decisions of R&D organisations that aim to be world-class. The South African Council for Scientific and Industrial Research (CSIR) is such an organisation, which is mandated to undertake and apply directed research and innovation in science and technology to improve the quality of life of people on the African continent. R&D, as well as R&D outcomes as integral parts of the research and innovation value chain, is the focus of the CSIR. The careful management of the knowledge value chain, from inputs to outputs, including the required internal processes, to achieve targeted and broader R&D impacts is accentuated in the environment in which the CSIR's innovation activities occur. As part of internal processes, a monitoring and evaluation system of R&D inputs and outputs has been established to derive measures of performance and quality of the CSIR's science and technology; much emphasis is placed on measurements that focus on human resources, knowledge stocks, and finances. The complexity of measuring, and managing, behavioural changes has been highlighted in literature as an area that requires further investigation to define clear, comprehensive performance measures for R&D organisations. This investigation subsequently set out to determine to which extent: the criteria of the internal individual performance measurement system correlate to the true work breakdown of researchers; the day-to-day operations measurement and management systems correlate with the true work breakdown of the researchers, and the criteria of the individual performance assessment system; and the day-to-day operations measurement and management systems correlate with the key performance indicators (KPIs) of an operating unit in the organisation. The investigation suggests that there is a shortcoming in terms of how the performances of CSIR operating units, and especially the human capital component of the units, are measured, and how the overall performances of the R&D units in the organisation are measured; the current process-oriented measures do not seem to instil individual researcher behaviour that compliments the outcome goals of the R&D operating units. Based on the findings of the investigation, it is explored how the behaviours of researchers may best be influenced to enhance the overall organisational performance. Practical recommendations are made accordingly to improve the innovation environment within the operating units of the CSIR.

1. Introduction

The desire to improve the quality of life has driven research and development (R&D), and as a result technology; this drive has especially intensified over the past five decades. However, von Zedtwitz et al. (2004) note that global R&D problems are, still, not well structured, and there are no unique solutions for the challenges of global innovation. The factors and interdependencies that influence the management of R&D remain complex. One of the key, central challenges of the complexity is the management of knowledge and human resources. Ideas, created by individuals, are the core of innovation (von Zedtwitz et al., 2004), and R&D organisations need to acquire and maintain knowledge-generation, knowledge-uptake and knowledge-transfer skills (Lavis et al., 2003). These skills inherently imply that the principles of a learning organisation (Garvin, 2004) must manifest in R&D organisations (Brent and Pretorius, 2008). The interplay of these issues must be considered carefully in the strategic decisions of R&D organisations that aim to be world-class.

1.1 R&D in the CSIR

The profile and overview of the South African Council for Scientific and Industrial Research (CSIR) as a R&D organisation has been provided before (Brent and Pretorius, 2008). Fig. 1 highlights the requirement to establish a monitoring and evaluation system of R&D inputs and outputs to derive measures of performance and quality of CSIR's science and technology (CSIR Policy Group, 2004); much emphasis is placed on measurements that focus on human resources, knowledge stocks, and finances. In terms of the latter, Walwyn and Scholes (2006) have reported adverse consequences associated with the CSIR's previous R&D financing models. For example (CSIR Review, 2003):

"*While the CSIR and its different business units have shown considerable and laudable initiatives that have led to progress in regard to increasing external revenue, the Panel was of the view that external revenue has sometimes been pursued as an end in itself. This has entailed activities that have been de-linked from the CSIR's science base and indeed, at times, activities have been undertaken at the expense of the science and technology base*".

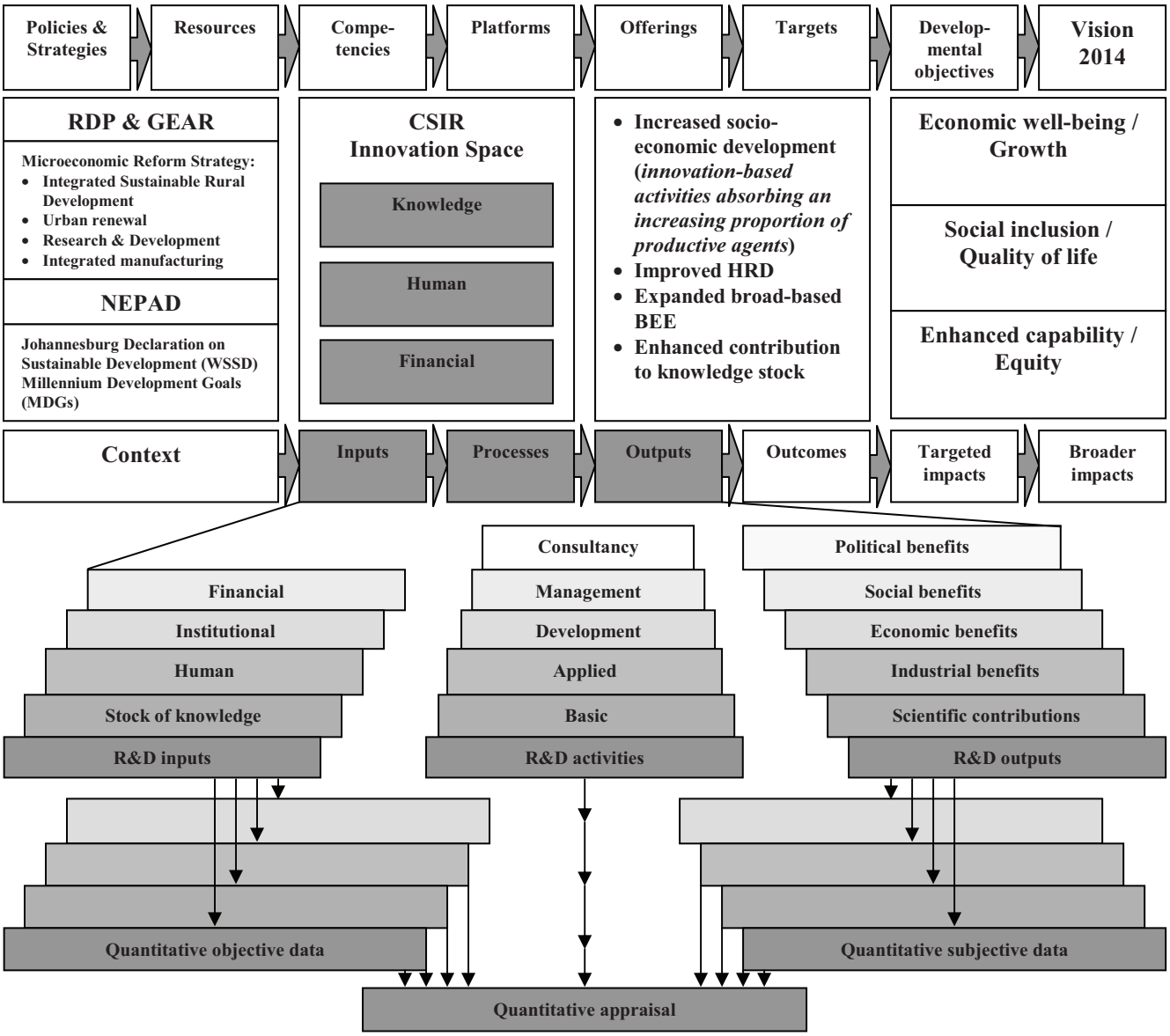

Figure 1. CSIR's innovative environment and knowledge value chain.

The subsequent reconfiguration of the CSIR (2008a) in 2005 aimed at strengthening the science and technology base, and improving the research output of the organisation; some of the changes have centred on the internal culture, in order to address the key performance indicators (KPIs) by which the CSIR's operating units are managed (Walwyn and Scholes, 2006):

- Stakeholders and customers;
- Finance and investment;
- Organisational;
- Learning and growth; and
- Organisational demographics.

However, a review of the CSIR 'Beyond 60' (B60) reconfiguration progress in October 2008 revealed inefficiencies that still remain in the organisation. The review was in the form of a symposium and work group sessions attended by one hundred participating senior staff members, representing a broad cross section of researchers in all operating units, including R&D managers.

A particular concern was the consensus reached that the B60 organisational structure has, in fact, increased administrative burdens, due to the extent of the involvement in administrative tasks and the necessity of follow-up to ensure the adequate completion of delegated tasks (CSIR, 2008b):

"*When considering the cost reductions of the B60 interventions, there appears to be no recognition that many researchers feel that their activities regarding procurement / finance/ HR / facility management have increased dramatically due to the complexity of the current systems and the lack of proactivity/ accountability of centralised service providers. The real costs should be recalculated to factor in researcher time and loss of productivity*".

In summary, indications are that the B60 reconfiguration has not resulted in behavioural changes that align individual researchers with the KPIs by which the operating units of the CSIR are measured (and managed). The complexity of measuring, and managing, behavioural changes has been highlighted (Brent and Pretorius, 2008) as an area that requires further investigation to define clear, comprehensive performance measures for R&D organisations.

1.2 Objectives of the paper

The preliminary, internal investigation suggested that there may be a shortcoming in terms of how the performances of operations, and especially the human capital component of the operations, are measured, and how the overall performances of the R&D operating units of the CSIR are measured; the current process-oriented measures do not seem to instil individual researcher behaviour that compliments the outcome goals of the organisation and its operating units.

The associated research questions, within the context of the CSIR operating units (see Fig. 1), are as follows:

- Do the criteria of the internal individual performance measurement system correlate to the true work breakdown of researchers?
- Does the day-to-day operations measurement and management system correlate with the true work breakdown of the researchers, and the criteria of the individual performance assessment system?
- Does the day-to-day operations measurement and management system correlate with the key performance indicators (KPIs) of the organisations?

By answering these research questions, the objective of this paper is to determine to what extent the individual performance measurement system, for researchers, compliments the key performance indicators of the CSIR. Then it can be established how the behaviours of researchers may best be influenced to enhance the overall organisational performance.

2. Conceptual framework for the investigation

Brent (2009) provides a detailed literature analysis of measurement and management systems in R&D organisations. The analysis highlights the complexity of influencing behaviours at individual, group, and operating unit or organisation levels in order to meet the research goals or outcomes of operating units or organisations. Behavioural change must occur through organisational learning across the organisational levels, and Crossan et al. (1999) suggest different social and psychological processes are necessary to link these levels. The Strategic Learning Assessment Map (SLAM) framework of Bontis et al. (2002) further emphasises a linkage between learning stocks and flows at and between the organisational levels, and business performance, although how these processes may manifest in practice is not clarified. The intellectual capital model of Leitner and Warden (2004) suggests that organisational processes should, ultimately, manage the linkages in a results-oriented manner; these results should reflect not only the learning performance, but also the financial and research output performance of an operating unit or organisation. Such a model corresponds well with the CSIR model of managing its innovation environment and knowledge value chain in terms of R&D inputs, and associated processes, and R&D outputs (see Fig. 1). In terms of R&D inputs and processes much emphasis is placed on financial, human, stock of knowledge, and other institutional measures. R&D outputs are measured primarily by scientific contributions, but also other, and often non-tangible, benefits to society in general. Kim and Oh (2002) specifically investigated the performance measurement of the human element in R&D organisations. They conclude that management processes should focus on measuring all the day-to-day activities that are required of individuals on research career pathways, as well as the productivity of researchers in terms of generating profit for the organisation; then the behaviours of individuals, and groups, can be measured more effectively.

All these aspects are observed, to some extent, in the international best practices of operational and performance measures (Brent, 2009). However, it is concluded that the specific linkage of the operational

practices, that relate to individual behaviours, and the R&D outputs of an organisation, has yet to be investigated; this is paramount if the CSIR is to achieve its mission and vision. Grupp (2000) hints towards a possible functional interplay between the knowledge (human) stock and the financial (and other) performances of a R&D organisation. Bessette (2003) suggests a method to measure the economic impact of R&D. An adaptation of the method (see Fig. 2) was deemed useful to investigate the before-mentioned linkage by:

- Identifying researcher day-to-day activities: The priorities and actions of individuals provide insight into the activities that constitute the job description of a researcher.
- Identifying researcher performance measures: The project attributable hours and the dissemination of knowledge are the primarily performance measures of researchers that relate to operational and R&D performances of the CSIR operating units.
- Identifying operational performance measures: The productivity of individuals and groups of researchers, also in terms of percentage of time worked on contract R&D projects, constitutes the primary (ongoing) measure of the financial performance of the CSIR operating units.
- Identifying R&D output measures: The publication equivalence of researchers, in the CSIR operating units, as recorded by the CSIR Technical Output Database (ToDB) is the determining measure of the R&D performance of the units.
- Determining if behaviours dictate appropriate operational performances and R&D outputs.

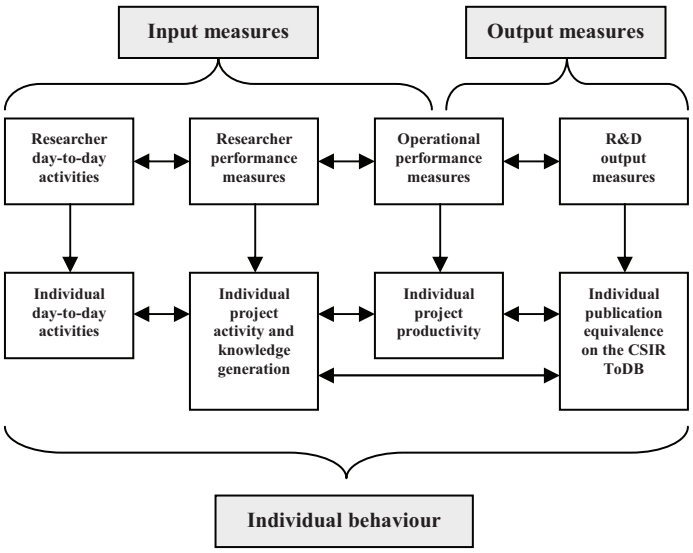

Figure 2. Individual measures to investigate the linkage between behaviours and performances (Brent, 2009).

3. Research methodology

A combination of research methods has been suggested in literature (Myers, 1997), because any chosen research method will have inherent flaws and the choice of method will always limit the conclusions that can be drawn (Sandura and Williams, 2000). For this reason it is essential to obtain corroborating evidence by using a variety of methods, referred to as triangulation (Myers, 1997; Sandura and Williams, 2000). To address the research objectives the research design subsequently combined the focus group (qualitative) and correlational (quantitative) analyses methods to one of the operating units of the CSIR as a case study (see Fig. 3). Thereby the research methods that are typically applied by the social, engineering and natural sciences, were merged with those that are utilised by the management sciences, as a research design more appropriate to the R&D management field.

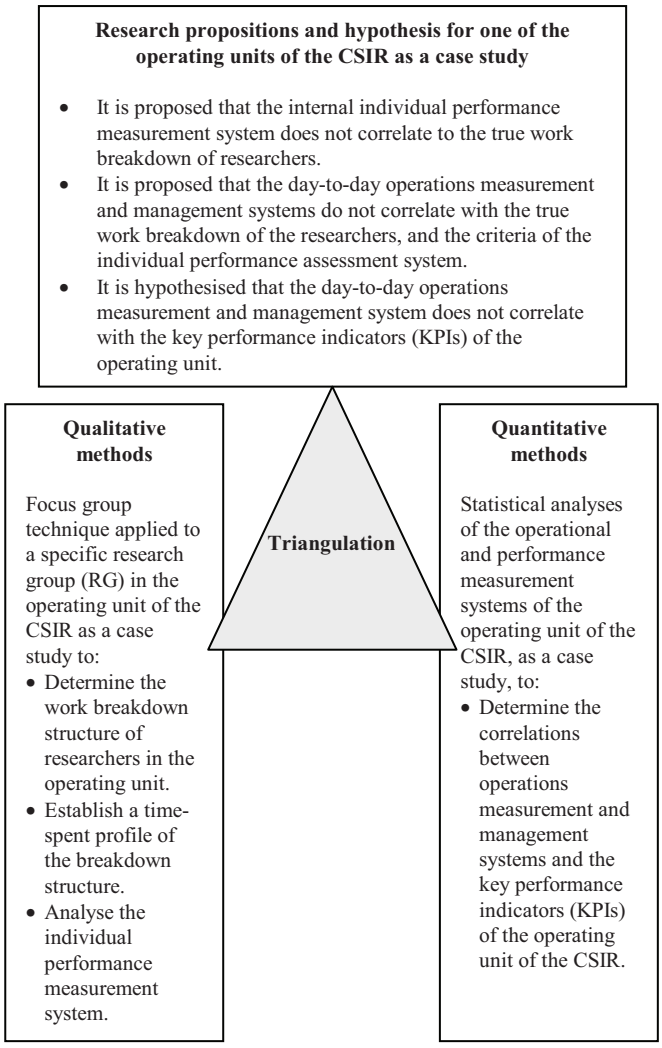

Figure 3. Research design framework for the investigation.

The strengths and weaknesses of the chosen research tools must be considered as these may have implications in terms of the analyses of the research outcomes.

3.1 Case study methods

In the management sciences, research often examines a small number of cases in depth rather than attempting to summarise numerical information (Monaghan, 2003). In these research efforts it is typically difficult to have generalised outcomes. To this end the reliability and validity of case-type approaches have been criticised, but Flyvbjerg (2006) argues against such criticisms and states reasons for choosing a case study approach as a research method:

- Case studies can be used, in certain situations, to develop general propositions and theories on the basis of specific case studies.
- Case studies, if utilised correctly, are not biased towards verification, and do not confirm the researcher's preconceived notions.
- Practical knowledge generated by case studies is of equal or even greater value than theoretical knowledge.

Eisenhardt (1989) further argues that the case study process can be described as highly iterative and strongly linked to data. The resultant theory from case study research is generally novel, testable, and empirically valid.

3.2 Qualitative methods

Focus groups have been used successfully in many areas of research; Barry et al. (2008) provide an overview of the various applications of this method. By definition, focus groups are organised discussions or interviews, with a selected small group of individuals (Blackburn, 2000; Gibbs, 1997), discussing a specific, predefined and limited topic under the guidance of a facilitator or moderator (Blackburn, 2000; Robinson, 1999). A focus group is also a collective activity, where several perspectives on the given topic can be obtained, and where the data is produced by interaction (Gibbs, 1997); the focus group is populated by individuals with specific experience in the topic of interest, which is explored during the focus group. The focus group has the following purposes (Robinson, 1999):

- Basic research where it contributes to fundamental theory and knowledge;
- Applied research to determine programme effectiveness;
- Formative evaluation for programme improvement; and
- Action research for problem solving.

In this investigation, the focus group technique was used for applied research with the goal of determining the effectiveness of researcher performance evaluation in one of the operating units of the CSIR

The benefits for the focus group participants include the opportunity to be involved in decision making, the fact that they feel valued as experts, and the chance to work in collaboration with their peers and the researcher (Barry et al., 2008; Gibbs, 1997). Interaction in focus groups is crucial as it allows participants to ask questions as required, and to reconsider their responses (Gibbs, 1997).

The advantages of the focus group method include (Barry et al., 2008):

- It is an effective method of collecting qualitative data as common ground can be covered rapidly and inputs can be obtained from several people at the same time (Hutt, 1979; Ouimet, 2004).
- During discussions, the synergistic group effort produces a snowballing of ideas which provokes new ideas (Gibbs, 1997; Blackburn, 2000).
- Data of great range, depth, specificity and personal context is generated (Blackburn, 2000).
- In the process, the researcher is in the minority and the participants interact with their peers (Blackburn, 2000).

The disadvantages include (Barry et al., 2008):

- Not all respondents are comfortable with working in a group environment and may find giving opinions in the bigger group intimidating (Gibbs, 1997; Ouimet, 2004).
- The outcome can be influenced by the group effect in that the opinion of one person dominates, that some are reluctant to speak and that an opportunity is not given for all participants to air their views (Blackburn, 2000).
- The researcher has less control over the data than in, for example, a survey due to the open-ended nature of the questions (Gibbs, 1997).

These disadvantages may be mitigated by ensuring that the moderator has sufficient skills, reliable data collection, and the use of rigorous analytical methods (Blackburn, 2000).

3.3 Quantitative methods

Quantitative methods are often depicted as the traditional scientific approach to research with an emphasis on a "systematic and methodological process that places considerable value on rationality, objectivity, prediction and control" (Walker, 2005). The process involves the collection of numerical data that, in turn, can be subjected to statistical analysis. Parahoo (1997) and Huitt (2001) identify three levels of quantitative research:

- Descriptive research provides an account of the characteristics of individuals, groups or situations; the researcher attempts to describe, in numbers, what is actually occurring.
- Correlational research examines the links (or relationships) between variables without introducing an intervention; the purpose of this type of study is often to predict the level of one variable by knowing the level of a second variable.
- Experimental research provides the framework for establishing a relationship between cause and effect; the purpose of this type of study is to determine if there is a causal relationship between two variables (independent and dependent) in an experimental group, by observing changes in the dependent variable in the experimental group as opposed to an equivalent and constant control group.

For this investigation the correlational research approach was utilised to establish the links between operations measurement and management systems, and the key performance indicators (KPIs), of one of the operating units of the CSIR. In this approach it is crucial to observe the extent to which a statistical correlation between characteristics of a sample is discovered (Williams, 2007), depending to some degree of how well those characteristics have been calculated (Leedy and Ormrod, 2001). Therefore, validity and reliability are important components that affect observed correlations; statistical tests are necessary to establish patterns for two variables (Creswell, 2002).

Major strengths of this approach have been identified in

that (Williams, 2007):

- The approach is well suited to study the breadth of a phenomenon; and
- Predictive relationships can be established.

However, the major weakness is that the investigation cannot produce in-depth descriptions, or causality.

3.4 Research methodology for this investigation

The overall research methodology that was applied in the investigation is summarised in Fig. 4.

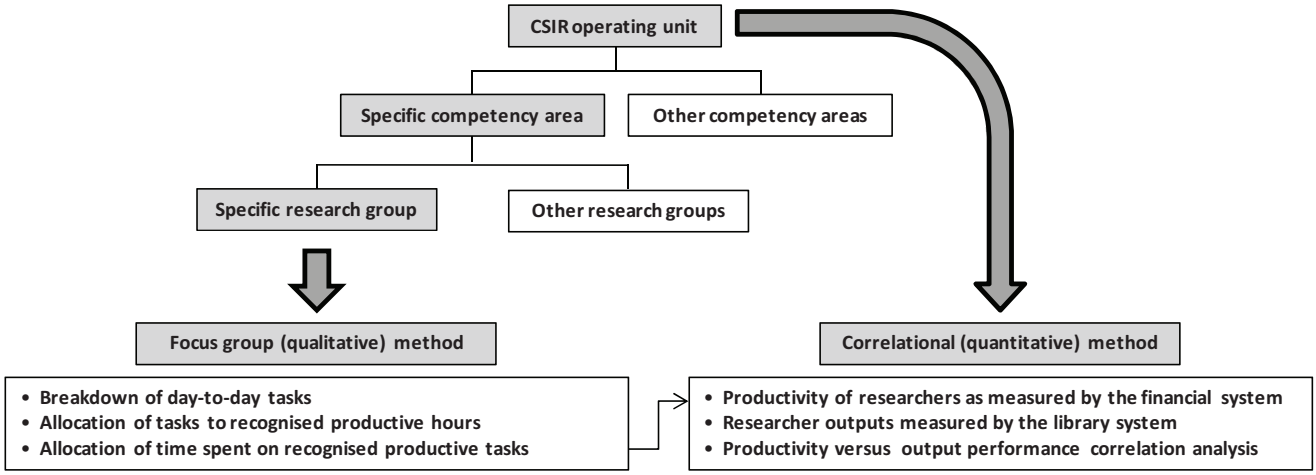

Figure 4. Applied research methodology of the investigation.

A specific research group (RG), which is situated in a competency area (CA) of the CSIR operating unit, was used for the focus group component of the investigation. The profile of the RG is such that it represents nearly all the researcher grade levels in the CSIR:

- Candidate researchers – researchers who would be required to work under supervision;
- Researchers – competent professionals who work independently within a given field;
- Senior researchers – seasoned professionals with a track record in research and development, who are able to guide others and lead projects;
- Principal researchers – specialists whose sustained track record has led to widespread recognition within their field, and who are able to lead research and development programmes (groups of related projects), often integrating approaches across fields; and
- Chief researchers – principal researchers whose sustained track record in research and development has led to international recognition.

As yet the RG does not have a top-end level researcher, i.e. of a chief grade status, but very few chief researchers, less than 20% of the total researcher compliment, are spread across the CSIR. As at the end of September 2008, the RG comprised of one principal researcher, two senior researchers, and three researchers.

The main stages of the focus group process, as described by Blackburn (2000), were followed. A monthly RG meeting, in the middle of the financial year, i.e. at the end of September 2008, was used as an opportunity to provide the researchers with an overview of what was being investigated; it was emphasised that the focus group activity did not form part of the normal performance appraisal process of the operating unit and that the results would be used anonymously. The research group leader (RGL) then facilitated a discussion to explore:

- The typical day-to-day tasks that the researchers engage in;
- Which tasks are normally recognised as productive hours in the organisation; and
- How much time is spent on the different tasks.

Once all the issues were clarified and there was a collective understanding of what was required from each individual, the RG meeting was closed and the researchers were allowed one week to respond to the RGL with their individual breakdown of the (typical) time spent on different tasks in a normal working month; the middle of the financial year is considered the best 'normal' case, since researchers are not over-burned with administrative tasks that are associated with the end and beginning of a financial year. For the purposes of analysis and reporting, the spreads of the times allocated were utilised in the investigation. As is indicated in Fig. 3, the Key Results Assessment (KRA) performance measurement process for the individual researchers were also utilised for the investigation. Table 1 provides the KRA process outcomes for the principal researcher, as in September 2008.

Table 1. CSIR overall Key Results Area (KRA) assessment process.

Key Results Area (KRA)	Performance (A)[a]	Weighting		Score (A×B)[a]
		Range	Actual (B)[a]	
Project activity	*3*	Candidates = 30 Others = 20-25	*20*	*60*
Project / resource management	*3.5*	Candidates = 20 Others = 12-20	*12*	*42*
Knowledge generation and dissemination	*3*	Candidates = 30 Others = 12-20	*14*	*42*
R&D impact	*3*	Candidates = 0 Others = 12-20	*12*	*36*
Human capital development	*3.5*	Candidates = 20 Others = 12-20	*13*	*45.5*
Attracting funding	*4*	Candidates = 0 Others = 12-20	*13*	*52*
Research leadership	*2.5*	Candidates = 0 Others = 10-20	*16*	*40*
			Total (out of 500)	***292***

a Values in italics are provided as an example of a singe principal researcher's KRA; the overall performance evaluation of the researcher indicates a slightly better performance than is expected of a principal researcher.

The entire operating unit was used for the correlational analyses component of the study (see Fig. 4). The compliment of the operating unit totalled one hundred and seventy six researchers as at the end of September 2008. More than twenty of these are at the candidate researcher level; since these are junior researcher their performance assessment is less stringent in terms of overall productivity and R&D outputs. A large number of individuals, especially on the candidate and researcher levels, are also employed on a contract basis, and are not captured on the operational performance management system of the operating unit. These individuals were subsequently not included in the final analyses. The final sample comprised of one hundred and eleven researchers with the profile summarised in Table 2.

Table 2. Sample profile for the correlational analyses.

Level	Researcher grading	Number
1	Researcher	50
2	Senior researcher	46
3	Principal researcher	13
4	Chief researcher	2
Total		**111**

The operational management system of the operating unit and the CSIR Technical Outputs Database (ToDB), which is administered by the library services of the organisation , were interrogate at the end of September 2008 for each of the individual researchers. The productivity and publication equivalence performances of the different levels were then rated, as per the KRA assessment process guideline of the organisation (Brent, 2009). Table 3 summarises the assigned ratings.

Table 3. Assigned ratings of the researchers' performances.

Productivity[a]		
Researcher level	**Acceptable**	**Not acceptable**
1	≥ 75%	< 75%
2	≥ 70%	< 70%
3	≥ 65%	< 65%
4	≥ 55%	< 55%
Publication equivalence[b]		
Researcher level	**Acceptable**	**Not acceptable**
1	> 0	0
2	> 3	≤ 3
3	> 6	≤ 6
4	> 9	≤ 9

a Productivity is measured as the percentage of time spent on funded R&D contracts, as at the end of September 2008.

b Publication equivalence are the number of article credits allocated to the CSIR for the three years up to the end of September 2008.

Page and Meyer (2006: 173) highlight that the chi-squared test of association is an appropriate statistical method that can be applied to a random sample of values for two (ordinal) discrete variables in order to test the significance of relationships between these variables. The chi-square test was subsequently applied on the ratings in Table 3 to determine the correlation between:

- The levels of researchers and their productivity;
- The levels of researchers and their publication outputs; and
- The overall productivity and publication outputs of the researchers.

4. Results

The results of the investigation are discussed along the lines of the two propositions and hypothesis put forward (see Fig. 3).

4.1 Proposition: The internal individual performance measurement system does not correlate to the true work breakdown of researchers

The focus group method, as applied to the specific research group (RG) of the CSIR operating unit, identified:

- The typical day-to-day tasks that the researchers engage in;
- Which tasks are normally recognised as productive hours in the organisation; and
- How much time is spent on the different tasks.

As is shown in Table 4, the researchers were requested to provide minimum and maximum estimates of the time spent on tasks that were identified in the focus group discussion, with the additional requirement that the medians of each researcher should add up to 100%. The trends in the profiles are what one would expect for the different researcher levels. For example:

- Principal (and chief) researcher levels tend to spend less time on managing and conducting research, compared to the other levels, but more time on disseminating the knowledge of multiple projects for which they are expected to provide guidance. The actual management of R&D projects, including knowledge dissemination, is usually the responsibility of senior researcher levels, although in one case a researcher did experience a heavy burden in this regard, whilst the researcher levels are expected to do the actual R&D work.
- General administration tasks are heavier for senior and upper researcher levels, and senior and lower researcher levels have the responsibility of 'R&D readiness' in terms of laboratory maintenance, quality assurance, etc.
- Communication requirements vary across the researcher levels, although one would expect this burden to fall with senior and upper staff; the one researcher is perceived to be an outlier in this regard.
- In the senior levels more attention is given to keeping abreast in the field (during office hours), although this aspect also depends on the postgraduate studies that researchers are engaged in.
- Knowledge dissemination, supervision and mentoring, academic-type activities, engaging with scientific communities, and developing research ideas and

proposals are all primarily associated with senior and upper research levels.

- Personal activities (in office hours) tend to decrease towards upper researcher levels, but this may (probably) be attributed to increasing responsibilities and pressures.

Table 4. Identified productive and non-productive tasks, and time spent, for individual researchers.

	Task	%	Researchers					
			1[a]	2[a]	3[a]	4[b]	5[b]	6[c]
Productive time / tasks	Project-specific admin/management, including meetings	Min	2	3	10	5	5	2
		Med	**3.5**	**4.5**	**15**	**7.5**	**7.5**	**4**
		Max	5	6	20	10	10	6
	Project-specific activities, i.e. doing the required technical work	Min	47	60	20	20	10	10
		Med	**57.5**	**67.5**	**40**	**30**	**20**	**15**
		Max	68	75	60	40	30	20
	External publications (project-time), i.e. reports and journal papers	Min			1	5	2	5
		Med			**3**	**7.5**	**5**	**7.5**
		Max			5	10	8	10
	Conference/seminar presentations (project-time), including paper preparation	Min			1	1	1	2
		Med			**3**	**3**	**2**	**4**
		Max			5	5	3	6
Non-productive time / tasks	General office admin, including meetings, S&T claims, etc.	Min	5	3	2	5	5	5
		Med	**6**	**4.5**	**5**	**7.5**	**10**	**7.5**
		Max	7	6	8	10	15	10
	Lab maintenance, equipment optimisation, internal quality assurance, i.e. R&D readiness	Min	2	10		1		1
		Med	**4.5**	**12.5**		**3**		**1.5**
		Max	7	15		5		2
	E-mails and other communication, e.g. expert advise to the public	Min	15	4	5	5	10	8
		Med	**17.5**	**5**	**12.5**	**12.5**	**15**	**14**
		Max	20	6	20	20	20	20
	Keeping up with the field, i.e. reading, etc.	Min	2	1	1	2	5	1
		Med	**4.5**	**2**	**3**	**4**	**10**	**3**
		Max	7	3	5	6	15	5
	External publications (non-project-time), i.e. reports and journal papers	Min			1	1	10	10
		Med			**3**	**3**	**15**	**15**
		Max			5	5	20	20
	Conference/seminar presentations (non-project-time), including paper preparation	Min			1	1	1	2
		Med			**3**	**3**	**2**	**4**
		Max			5	5	3	6
	Supervision and mentoring of students and junior staff	Min			1	2	1	2
		Med			**3**	**4**	**3**	**4**
		Max			5	6	5	6
	Academia participation, i.e. lecturing and external examination	Min				1		2
		Med				**3**		**4**
		Max				5		6
	Scientific community involvement, e.g. committees, reviewing, etc., and networking for research initiatives	Min			1	2	2	5
		Med			**3**	**4**	**3.5**	**7.5**
		Max			5	6	5	10
	Developing research ideas, expressions of interest, and generating proposals	Min	2	1	2	4	2	5
		Med	**3**	**1.5**	**3.5**	**6**	**5**	**7.5**
		Max	4	2	5	8	8	10
	Personal time, i.e. domestic responsibilities, leave, etc.	Min	2	1	1	1	1	1
		Med	**3.5**	**2.5**	**3**	**2**	**2**	**1.5**
		Max	5	4	5	3	3	2
	Total	**Med**	**100**	**100**	**100**	**100**	**100**	**100**

a Researcher level
b Senior researcher level
c Principal researcher level

The tasks that are, from the organisation's (financial) perspective, assigned to productive and non-productive time are also shown in Table 4. As another productivity measure, and given the key R&D output measures of the CSIR operating unit, the knowledge dissemination tasks were also grouped together, i.e. external publications, and conference and seminar presentations and papers, that are derived from both project and non-project attributable time. Thereby, the day-to-day productivity breakdown of the researchers could be compared to the individual performance measures (see Table 5); the actual Key Results Assessment (KRA) process for each individual researcher was utilised, and specifically the weights assigned to the project activity and project / resource management criteria, and the knowledge generation and dissemination and impact criteria of the KRA process.

Table .5 Day-to-day task breakdown versus individual performance measures and operations measures.

	Productivity / performance measures	%	Researchers					
			1[a]	2[a]	3[a]	4[b]	5[b]	6[c]
Project productivity	Productive tasks – financial perspective (from Table 3)	Min	49	63	32	31	18	19
		Med	**61**	**72**	**61**	**48**	**34.5**	**30.5**
		Max	73	81	90	65	51	42
	Project activity and project / resource management (from actual KRAs of researchers)	Min	32	32	32	32	32	32
		Act	**40**	**40**	**40**	**32**	**32**	**32**
		Max	45	45	45	45	45	45
	Financial productivity (from the operating unit's financial management system)	**Act**	**56**	**61**	**69**	**57**	**37**	**52**
Knowledge productivity	Productive tasks – knowledge dissemination (from Table 3)	Min	0	0	4	8	14	19
		Med	**0**	**0**	**12**	**16.5**	**24**	**30.5**
		Max	0	0	20	25	34	42
	Knowledge generation / dissemination and R&D impact (from actual KRAs of researchers)	Min	24	24	24	24	24	24
		Act	**24**	**24**	**24**	**32**	**32**	**32**
		Max	40	40	40	40	40	40

a Researcher level
b Senior researcher level
c Principal researcher level

A comparison of the day-to-day task breakdown of the different researchers, and the associated project-financial and knowledge-dissemination criteria of the individual KRA performance measurement system, shows a definite divergence at the lower researcher levels; only at the principal researcher level, and for one of the senior researchers, are there similarities between the median of the day-to-day productive tasks and the actual weights assigned to the associated criteria of the KRA performance measurement system. For the senior to lower researcher levels much more emphasis is placed, by individuals, on project productivity, i.e. from a financial perspective, than knowledge dissemination productivity, to the extent that individuals do meet the expectations of the KRA performance measurement system on project activity and project / resource management, and place too little weight, by far, on the knowledge generation / dissemination and R&D impact criteria. Therefore, to a large extent, and especially for the senior to lower researcher levels, the first proposition of the investigation is deemed to be true.

4.2 Proposition: The day-to-day operations measurement and management systems do not correlate with the true work breakdown of the researchers, and the criteria of the individual performance assessment system

The day-to-day operational performances of the CSIR operating unit are primarily managed through a financial system. For the six researchers that formed part of the focus group, the productivity of each researcher was subsequently extracted from the financial system (see Table 5).

For the lower researcher levels there would seem to be a tendency for the operational performance system to record lower productivity levels than the researchers themselves allocate to project-attributable tasks. For the senior and higher researcher levels the opposite is true. From discussions with the researchers in the focus group the following behaviours may explain these phenomena:

- Junior researchers are often concerned that they will run out of projects in any given financial year; therefore they tend to under-book hours on the financial system.
- Senior and higher researchers are required to manage finances closely and are able to distribute time over multiple projects; often they tend to allocate non-project activities to projects as the finances dictate, since, in an organisation such as the CSIR, profits on projects are not awarded.

To correlate the operational performances measures with the individual performance Key Results Assessment (KRA) process is more problematic. The productivity measure of the financial system is not, in any way, a reflection of the weights assigned to the project-related criteria of the KRA process (see Table 5). Rather, it measures the performance of a researcher on one criterion only, i.e. that of 'project activity'. If one considers the KRA rating system of this criterion (Brent, 2009) then none of the researchers in the research group meet the performance expectations for the criterion (see Table 6). Similarly, the R&D output measures that form part of operational management, as described by Brent (2009), relate only to one criterion of the KRA process, i.e. 'knowledge generation and dissemination'. At the time of conducting the investigation, the publication equivalence (PE) for each of the researchers for the specific financial year, was drawn from the Technical Output Database (ToDB) of the CSIR and compared to the KRA requirements of each researcher (see Table 6).

Table 6. Key operational measures in relation to individual KRA process performances.

	Operational / individual performance measures	Unit	Researchers					
			1[a]	2[a]	3[a]	4[b]	5[b]	6[c]
Financial measures	Performance (from the financial system)	%	61	72	61	48	34.5	30.5
	Expected performance (from KRAs)	%	40	40	40	32	32	32
R&D output measures	Performance (from the ToDB system)	PE#	0	0	1	2	4	6
	Expected performance (from the KRAs)	PE#	1	1	1	1	1	3

a Researcher level
b Senior researcher level
c Principal researcher level

Table 6 shows that the junior researchers struggle to meet the R&D outputs performance expectations of the KRA process. In contrast senior and higher level researchers by far exceed expectations. Discussions with the researchers in the focus group revealed that lower level researchers rarely drive the knowledge generation and dissemination criterion themselves, but depend on the lead from higher level researchers. For junior researchers the time spent on knowledge generation and dissemination is almost entirely dependent on whether project deliverables dictate such activities (see Table 4). Also, the ToDB operations management system is not engaged on a regular basis. Individuals may access the ToDB when KRAs are assessed, biannually, and the management structure of the operating unit utilises the ToDB on an annual basis to report of the R&D performance of the unit, and competency areas.

Irrespective of the individual performances in terms of the two specific KRA criteria, it is clear that the operations measurement and management systems only account for two of the five KRA criteria (see Table 1), and do not consider the weight distribution of the criteria to reflect the overall individual performances of researchers. The second proposition of the investigation is therefore also argued to be correct.

4.3 Hypothesis: The day-to-day operations measurement and management system does not correlate with the key performance indicators (KPIs) of the operating unit

To test the overall hypothesis, the correlation method described in sections 3.3 and 3.4 was utilised. Given, from the focus group outcomes, that the individual performances, as they relate to operational performances, seemed to be influenced by the level of researcher, the analyses were extended to include the following (see Table 7):

- The correlation of researcher level and project-financial productivity (T1):
  - H_0: There is no relationship between the level of researcher and the acceptable productivity of the researcher.
  - H_1: There is a relationship between the level of researcher and the acceptable productivity of the researcher.
- The correlation of researcher level and publication equivalence (T2):
  - H_0: There is no relationship between the level of researcher and the acceptable publication equivalence of the researcher.
  - H_1: There is a relationship between the level of researcher and the acceptable publication equivalence of the researcher.
- The correlation of project-financial productivity and publication equivalence (T3):
  - H_0: There is no relationship between the productivity of the operating unit researchers and the publication equivalence of the researchers.
  - H_1: There is a relationship between the productivity of the operating unit researchers and the publication equivalence of the researchers.

Correlation test 1

Table 7 shows that the first correlation test did not reveal a significant result; for this sample the null-hypothesis can not be rejected and there seems to be no

correlation in the operating unit between the researcher levels and the acceptable productivity of the researchers. For the upper researcher levels, i.e. principal and chief, the researchers are distributed evenly between acceptable and not-acceptable productivity. For the senior and lower level researchers those that have unacceptable productivity, as recorded by the financial system, are nearly double those that are acceptable. This outcome is a contradiction to the first proposition (see section 4.1), where it was indicated that the senior and lower level researchers place more emphasis on project productivity.

Table 7. Chi-squared test of association for the different hypotheses.

Test	Researcher Level[a]	Acceptable Productivity[b]	Not-acceptable Productivity[b]	Count	Outcome
T1	1	18	32	**50**	Can not reject H_0: There is no relationship between the level of researcher and the acceptable productivity of the researcher
	2	16	30	**46**	
	3	6	7	**13**	
	4	2	0	**2**	
	Count	**42**	**69**	**111**	
		$\chi^2 = 3.92 < 7.82$ (from χ^2 distribution table for a 5% probability level) Degree of Freedom = 3 Probability = 0.271			
Test	**Researcher Level[a]**	**Acceptable PE[c]**	**Not-acceptable PE[c]**	**Count**	**Outcome**
T2	1	33	17	**50**	Can reject H_0: There is a relationship between the level of researcher and the acceptable publication equivalence of the researcher
	2	19	27	**46**	
	3	9	4	**13**	
	4	2	0	**2**	
	Count	**63**	**48**	**111**	
		$\chi^2 = 8.56 > 7.82$ (from χ^2 distribution table for a 5% probability level) Degree of Freedom = 3 Probability = 0.036			
Test	**Productivity[b]**	**Acceptable PE[c]**	**Not-acceptable PE[c]**	**Count**	**Outcome**
T3	**Acceptable**	28	14	**42**	Can not reject H_0: There is no relationship between the productivity of the researchers and the publication equivalence of the researchers
	Not-accep.	35	34	**69**	
	Count	**63**	**48**	**111**	
		$\chi^2 = 2.7 < 3.84$ (from χ^2 distribution table for a 5% probability level) Degree of Freedom = 3 Probability = 0.097			

a 1 = Researcher; 2 = Senior Researcher; 3 = Principal Researcher; 4 = Chief Researcher.

b Productivity is measured as the percentage of time spent of funded R&D contracts, as at the end of September 2008, and rated according to Table 3.

c Publication equivalence are the number of article credits allocated to the CSIR for the three years up to the end of September 2008, and rated according to Table 3.

Correlation test 2

The second correlation test did reveal a significant result; with a probability of 5% the null-hypothesis can be rejected and it can be deduced that there is a significant correlation, overall, between the levels of researchers, in the CSIR operating unit, and the acceptable publication equivalence of the researchers. Table 7 indicates that for the upper researcher level, as can be expected from the outcomes of the two propositions (sections 4.1 and 4.2), three times more researchers are performing at an acceptable level compared to those that are deemed unacceptable as per the performance assessment process. For the lower researcher level nearly twice as many researchers have an acceptable performance ranking compared to those that have not. However, performances at the senior researcher level are, overall, unacceptable. This outcome highlights a potential problem for researchers to transcend from the lower to upper researcher level in terms of focusing on R&D outputs.

Correlation test 3

The third correlation test reveals that there is no significant correlation between the productivity of the operating unit researchers, in general, and the publication equivalence of the researchers. Those researchers that are deemed unproductive, as per the financial system, have roughly equal acceptable and not-acceptable R&D outputs. However, of those that are measured to be productive, twice as many have acceptable R&D outputs compared to those that unacceptable publication outputs. If this outcome is examined on the hand of the first two correlation tests, then it is realised that the lower and upper researcher levels tend to meet both the productivity and R&D output criteria:

- Fifteen of the twenty-eight researchers that meet the two criteria are at the researcher level, which constitutes 30% of the researchers at this level.
- Seven are principal or chief researchers, i.e. 50% of the researchers at this level.
- The six senior researchers that meet both criteria account for 13% of the researchers at this level.

Still, overall, 25% of the researchers in the CSIR operating unit are both financially and R&D output productive and 31% are not productive for either of the two measurement criteria. This means that nearly half of the unit's researchers show a discrepancy between what is measured operationally, on a day-to-day basis, and how the unit is measured in terms of R&D outputs as one of the key KPIs of the operating unit.

5. Conclusions and recommendations

The investigation has shown that there is indeed a shortcoming in terms of how the performances of operations, and especially the human capital component of the operations, are measured, and how the overall performances of the CSIR operating units are measured. It is then concluded that the current process-oriented measures do not instil individual researcher behaviour that compliments the outcome goals of the organisation and its operating units. From these observations it may be established how the behaviours of researchers could be influenced to enhance the overall organisational performance.

5.1 Day-to-day activities and the individual performance measurement system

One of the main outcomes of the investigation is that the researchers, especially the senior and lower level researchers, place too much emphasis on projects, i.e. getting the job done, and too little on knowledge dissemination. The behaviours of researchers at these levels are such that they will not put in the additional

effort to publish; two discussions points with researchers during the investigation emphasise this behavioural aspect:

- "*How can I write an article if I don't have a project to book my time on?*" It is often inconceivable for researchers that they can use non-productive time to explore new research areas, i.e. write position papers, or utilise results from projects to write papers that would benefit their research careers and the profiles of their respective research groups and the operating unit as a whole. To spend personal time on the activity of scientific writing also seems out of the question. The prospect of advancing on the research career ladder does not seem to be enough of an incentive.
- "*How can we write articles if it is not perceived [by the client] to be important?*" As is typically experienced in the practice of project management, 'scope creep' occurs in projects as the expectations of clients change; while publication activities might have been included in the original project plan, 'scope creep' often result in the reduction of financial resources, for time on publication activities. Even for R&D projects that are funded through the CSIR parliamentary grant there has been a clear shift from 'academic publications' to 'technology demonstrators', i.e. practical R&D outcomes; in some instances this has created confusion amongst researchers as to how the priorities of the organisation reflect in their own research career assessment process.

What is also clear from these discussions with researchers is that the individual performance measurement system is simply seen as an additional burden: "*...it is an unfortunate necessity, the usefulness of which is only to determine whether one is eligible in the next bonus round or for a pay-raise due to a shift to a higher pay-band on the research career ladder*". The performance measurement system does not influence the prioritisation of day-to-day activities by any means. It is also not perceived to relate directly to day-to-day operational measures and management practices, wherein the incentives for behavioural change may be found.

5.2 Day-to-day operational measures and management practices

Another major outcome of the investigation is that researchers, especially at the lower research career levels, but sometimes also at the senior level, rarely, if ever, engage with the knowledge dissemination operational measures. Only recently has a formal process been introduced to capture publications, and individual researchers are encouraged to use the system as part of the formal individual performance appraisal process. However, there still remains a general resistance to engage with the new capturing system.

The tendency for all levels of researchers, including the management structure of the operating units, is rather to remain focused on the financial aspects of the day-to-day operations. How this focus manifests in the day-to-day activities, as well as the individual performance appraisal process, is clear from comments from management staff during the investigation:

- "*If you do not meet the expectation of the first [productivity] criterion of the KRA assessment process, then you most probably do not perform at an acceptable level for the other KRA criteria*". The responsive behaviours from researchers are as can be expected: "*....if the Dashboard does not show you to be [financially] productive, then it is pointless to attempt to address the other issues*".
- "*We [the researchers] can not expect bonuses in the next financial year, since we [the operating unit] are underperforming this financial year*". A responsive comment from the researchers is also as can be expected: "*....if I am performing at an acceptable level, but the RG [Research Group], CA [Competency Area], or operating unit are not, then I will be disqualified for any incentives there are in the system*". An additional comment that is unexpected and sheds some light as to influencing behavioural change: "*....I will not work harder for a little bit more money anyway*".

The consequence of the constant focus on finances is that nearly all efforts are directed at this operational measure. It is often the case that researchers are encouraged to 'drop everything and attend to the finances'; it is not uncommon that a monthly meeting will start with a comment along the lines of: "*we'll see if we get to the other agenda points as we need to spend time on the finances*". The words of Goldratt (1994) ring true: "*Tell me how you measure me, and I will tell you how I will behave*".

5.3 Day-to-day operations management and the KPIs of the operating unit

The KPIs of the CSIR operating units are derived from information that is extracted from operational measurement and management system. However, the financial focus, as per the previous discussion, means that not all the KPIs are addressed with equal weighting on a day-to-day basis. Specifically, the investigation showed that financial performance does not imply R&D output performance. Attention must be given to measures that address all the performances that are required within and of the operating units.

5.4 Deriving measures to induce appropriate behaviours

In order to pursue its R&D strategy, the management of the CSIR operating units need to induce behaviours across the researcher levels that will deliver on the strategy. R&D output growth is often far more challenging for senior management than the financial side of the equation; the consequence is that considerable effort is placed on controlling costs and that behaviours become aligned with financial aspects rather than real R&D aspects. Following on the work of Goldratt (1994), measures are indeed a good approach to induce behaviours, but the measures need to address both financial and R&D output aspects

effectively. There are two factors that determine the magnitude of the impact a measure has on behaviour (Brent, 2009):

- Feedback – the response an individual experiences in relation to the performance against the measure; and
- Objectiveness – how well an individual can relate to the measure.

5.5 Improving measures in the CSIR operating units to induce appropriate behaviour

By considering the two measurement factors it is concluded that the financial performance measures have a high influence in the CSIR operating unit. The productivity measure is objective; researcher receive feedback in reasonably short times, with respect to (project) management practices, the bi-annual KRA assessment process, and the annual bonus pay-out; it is communicated on-line through the Dashboard tool for all peers to see in a transparent manner; and the cause and effect link is perceived to be clear.

In contrast the R&D output performance measures are low in influence. The publication equivalency measure that is used is objective, but does not meet all, if any, of the aspects associated with the feedback factor. It is then the aspects of the feedback factor of the publication equivalency measure that needs to be addressed, and the following are suggested:

- Speed of measurement feedback: The current capturing system, i.e. the ToDB of the CSIR, needs to be linked to the financial measurement system, i.e. the Dashboard, for prompt reporting and access to all staff members.
- Exposure of the measure: As per the financial measures, the Dashboard needs to be customised to reflect publication equivalence information per researcher alongside the normal productivity measure.
- Directness of communication: The publication equivalence aspect of the Dashboard needs to be updated at least monthly, and the management circulars, that primarily report on financial and human resource profiles at research group and competency area levels, also need to include publication output data.
- Cause and effect link: Good performance must be clearly linked to advantages for the individual. For example, opportunities to participate (and present papers) at international conferences are deemed, especially at lower researcher level, to be a high incentive; associate policies need to be implemented.

An additional element is that of 'manage by example'; the management should lead the way in terms of R&D outputs, which is, often, not the case in the CSIR operating units.

Finally, in terms of the need for further research, van Wilgen et al. (2008) highlight that R&D outputs need to be broadened beyond publications to technology demonstrators, which is defined as:

- The output of a R&D project, which has demonstrated that a particular technology may be operationally exploited to enhance capability, manufacture a product or deliver a service in a previously unknown manner; but
- Excluding demonstrators that were not intended to be transferred out of CSIR, e.g. research tools, or where the CSIR parliamentary grant contributed less than 20% of the total investment for the R&D project.

The need to measure technology demonstrators more effectively is pertinent if the true R&D output performances of researchers are to be understood. However, problems have been identified with technology demonstrators as indicators, especially in that the definition is still not clear, which confuses researchers. For example, experimental development makes up 50% of CSIR activities, and researchers question how this type of research relates to the definition. Also, the low level of technology readiness of demonstrators submitted by operating units for intellectual property and commercialisation purposes is an issue; 'technology readiness' assessment has now been introduced. Apart, from the lack of a clear definition, the reductions of value of co-funded demonstrators, and the exclusion of externally-funded demonstrators, also confine performance tracking. All these issues warrant further investigation.

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