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Research Article

Innovation Quality Management in Agricultural R & D Organizations- Mapping Innovation Quality and Performance

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ABSTRACT

Agricultural research in India is increasingly aligned to the market forces in response to the emerging challenges from the globalization and rapidly changing consumer preference. In this changed scenario innovation quality management (IQM) assumes greater importance. IQM is perceived as an amalgamation of quality management initiatives at R&D organization level and the performance of innovation in its intended use. The methodology for measuring innovation quality magnitudes and performance index of innovations in Indian Agricultural R&D organizations is proposed in this paper. Ninety-five variables describing quality magnitudes are grouped into 11 major dimensions comprising of 95 sub dimensions. Using confirmatory factor analysis on the responses of 613 scientific personnel of (ICAR), 39 sub dimensions pertaining to 11 dimensions were retained. The conceptual framework for Innovation Quality Magnitude was tested using hierarchical regression analysis. The weightage of 11 dimensions in the innovation quality index is computed using subjective and objective weights. The performance index of innovation is computed considering three elements i.e. – reach, significance and potency. These two indexes were integrated into matrix to describe overall innovation quality and performance scenario in public sector R&D organizations that facilitates development of strategic planning for improving innovation quality and sustainable performance. The proposed matrix can be used for dynamic mapping the relationship between innovation quality and innovation performance. The scope of this methodology can be extended to disciplines other than agriculture.

Keywords: Innovations, Quality Management, Performance Index, Innovation Quality Management, Agricultural R&D organizations.

1. Introduction

Innovation is irrefutably the most significant strategic and operational lever on hand for creating sustainable competitive advantage, in R&D of any sector be it be agriculture, industry or medicine. There is growing consensuses that innovations are critical inputs for long-term sustainability of an organization. Recent studies advocate that there is a wide gap between what organizations had targeted for and what output they are reaping from their innovation investments (Birchall et al., 2004).

Responding to the challenges from globalization, external market forces and economic liberalization, Agricultural R&D organizations need to address critical issues of poverty reduction, diminishing production and long term sustainability of livelihood security. This necessitates R& D organizations to perceive and respond to the emerging market driven developments through development and promotion of appropriate innovations. This realization has changed the orientation of these R&D organizations, shifting from a technology / production model to development and dissemination of consumer focused innovations. This significant transformation in the traditional viewpoint has resulted in greater emphasis on Innovation Quality Management (IQM). Conventional approaches to R&D quality management focus on tangible inputs and assets. Intangible assets are not adequately accounted in the process even though they contribute to about 80 percent of organizational value (Bartholomew, 1999 and Ana M. Aizcorbe et al., 2009). This, in turn, leaves modest impact and limited application in the area of innovation management. Moreover, it is often argued that the emphasis on research quality in terms of intangible assets also inhibits innovation (Tidd et al., 1997 and Prajogo and Sohal, 2001). Such debate brings the issues of innovation performance measurement and its quality management to the central stage of sustainable development.

References pertaining to concepts, definitions and methodologies of innovations management and quality management, as two different streams of subjects are abundant in the literature.(Tidd et al., 1997, Reed et al., 2000, Gow James,2005 and Kostas, 2010,). By carrying out these two concepts of Quality and Innovation management separately cannot guarantee the optimal performance. This leads to the attention of considering both concepts simultaneously which may result in higher accountability and will also guarantee the optimal performance. It is argued that though quality management is important in present R&D environment, it alone cannot result in sustainable development without integration and amalgamation with innovations (Choi et al, 2001). Quality management in general refers to the coordination of activities for quality assurance and control of processes, products, services as well as innovations to achieve continuous improvement and consistent quality (Pindur & Pam, 1993).

It starts with the “present” and makes analytical projections towards the “future” i.e., assessing the current status, extrapolate and plan quality towards the uncertain future. Innovation management is defined as the discipline to manage organizational processes for the enhancement of innovations in the system. It starts with retropolation of future visions, changes and necessities to the present. The objective is to grab maximum opportunities available for the continuous improvement and sustainable growth of the organization or the system. The resultant amalgamation of these two concepts is referred to as Innovation Quality Management (Figure-1). The figure represents the scenario for innovation quality management highlighting the area where innovation management and quality management can be unified in to innovation quality management for better sustainability. The success of innovation quality management depends on the information and past data available on the subject related to quality management and innovations to large extent within the organizations (Rana et al. 2010).

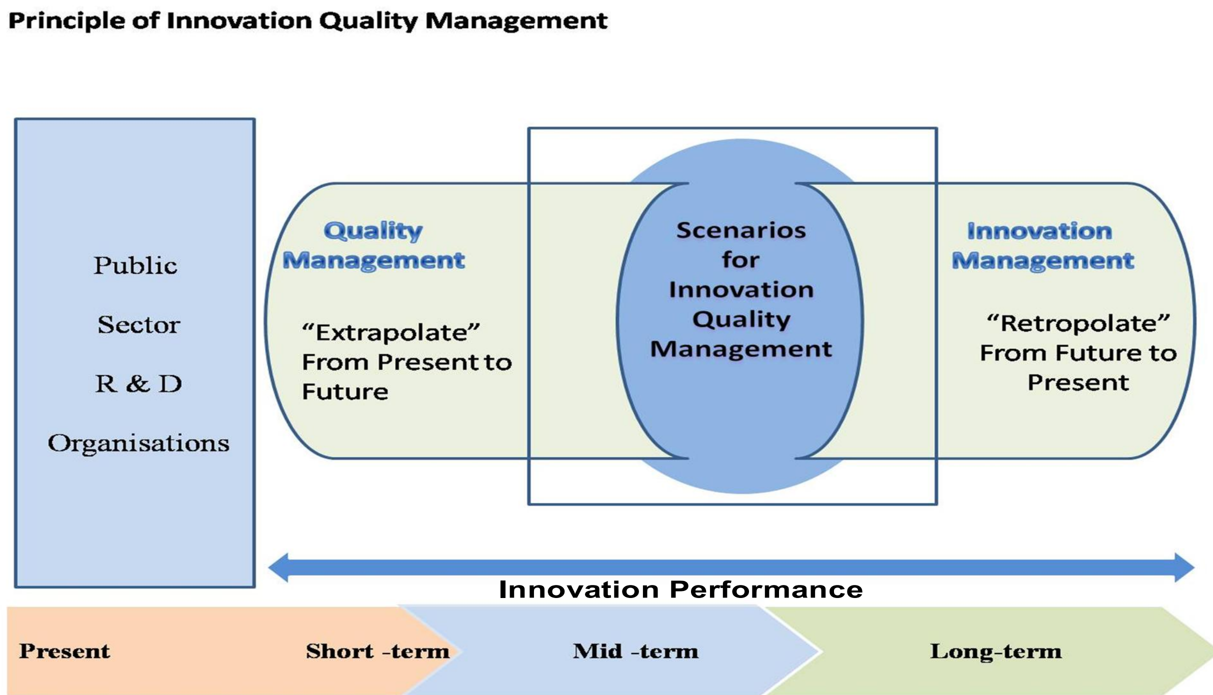

Figure 1: Innovation Quality Management.

The present studies typically focus on technological dimensions of innovation taking in to consideration only inputs, process and output (Ana M. Aizcorbe et al., 2009). The other aspects are not given due importance. The quality Management of innovations also depend on a wide variety of factors on organizational issues related to the organizational structure and culture and personnel or its dynamism, complexity or diversity (Fernando and Arturo, 2009; Fuentes-Fuentes et al., 2004; Jabnoun & Sedrani, 2005; Taylor & Wright, 2003).

This paper proposes general optimization model to simultaneously and optimally determine innovation quality and performance of Innovations with the objective of recognizing the importance of both technological and non technological dimensions for innovation quality management. It explores empirical as well as normative perspectives, to gain better insights into common and shared parameters for evaluation and accountability of innovation quality in agricultural R&D organizations. The construction of these indicators into model constitutes the main contribution of this study that will serve as a reference to measure performance excellence in the realization, advance and enhancement of innovation Quality management in agricultural R&D organizations. A series of investigations were conducted to develop the innovation Quality Management (IQM) model in the form of matrix.

2. Material and Methods

For assessment of innovations, the accent of a conceptual framework has to be pooled with the expansion of realistic measures and interactions with anticipated outcomes. The literature review of the Agricultural R&D organizations signifies that innovations in these organizations are related to modernization, knowledge management, nurturing creativity, enhancing public value and sustainability of the system. The key focus here is on the identification of the dimensions having direct insinuation in building realistic and measurable construct for mapping innovation quality management and its performance. The study was carried out in three stages. In the first stage the, construct 'innovation quality magnitude' was conceptualized by reviewing the literature on innovation quality and innovation performance in the second stage. The empirical indexes were developed to measure these constructs and in the third stage the two constructs of innovation quality and innovation performance were amalgamated to empirically analyze innovation quality management in the form of an assessment matrix.

2.1 Operational definitions of key constructs:

2.1.1 Innovation Quality Magnitude: The quality magnitude of innovations exerts a strong influence on the potential impacts associated with innovation performance due to the different characteristics associated with these innovations. In this study, Innovation Quality Magnitude is measure/degree of quality associated to particular innovations.

2.1.2 Innovation performance index: It is the measure of innovation efficiency and effectiveness to resulting in sustainable development and growth. It measures the impact of innovation on five livelihood capitals i.e. natural, social, human, financial and physical.

2.1.3 Innovation Quality Management (IQM): It is the amalgamation of quality magnitude of innovations and innovation performance. The IQM matrix is structured as an analytical tool for mapping and exploring the relationship between quality magnitude and innovation performance with respect to innovations in agricultural sector.

2.2 Identification of Constructs for Innovation Quality Magnitude

From the analysis of available literature, 95 items (sub dimensions) of innovation quality were identified. These related to various dimensions such as, innovation inputs, process, output, quality, leadership, etc. The hierarchical cluster analysis was employed to group these 95 items into 11 major dimensions on the basis of grouping by five experts. The dimensions developed are given in Table -1.

Table 1: Constructs and dimensions

Main dimensions	Variable	The Construct Examines
Organization Infrastructure	X_1	Impact of organization resources and structure on IQ
Leadership	X_2	How the organization's leaders guide and sustain the organization.
Governance System	X_3	It establishes roles, responsibilities, authority, focus, and control within the organization.
Knowledge Management System	X_4	Management of knowledge in organizations for supporting innovation quality
Strategic Quality Management	X_5	Impact of developing policies and plans regarding quality management
Human Resource Management	X_6	Impact of employees skills, empowerment etc on IQ

Organization Culture	X_7	Impact of Values and beliefs of organization on IQ
Innovation Inputs	X_8	Impact of inputs to the innovation process on IQ
Process Management	X_9	Impact of work process, collaborations and feedback system on IQ
Output Performance	Y_{10}	Relationship of output value and commercialization to IQ
Social Relevance	Y_{11}	Relationship of social development to IQ

2.3 Conceptual Framework

To measure innovation quality and innovation performance, two constructs were developed for this research study. For innovation quality, the dimensions and items (sub dimensions) were identified (Figure-2). It included nine dimensions of innovation quality (IQ) as independent variables (X_1 *to* X_9). The importance attached to each of the dimensions of IQ may varies from organization to organization. The evaluation of dimensions indicates the level of IQ within an organization. The two outcomes of innovation were considered as the dependent variables (Y_{10} *to* Y_{11}).

The evaluation of the constructs indicates an organization's ability to focus on innovation quality and its performance. The relationship pattern between the identified independent and dependent variables was investigated. A conceptual framework (Figure-1) was developed to depict the hypothesized relationship between independent and dependent variables.

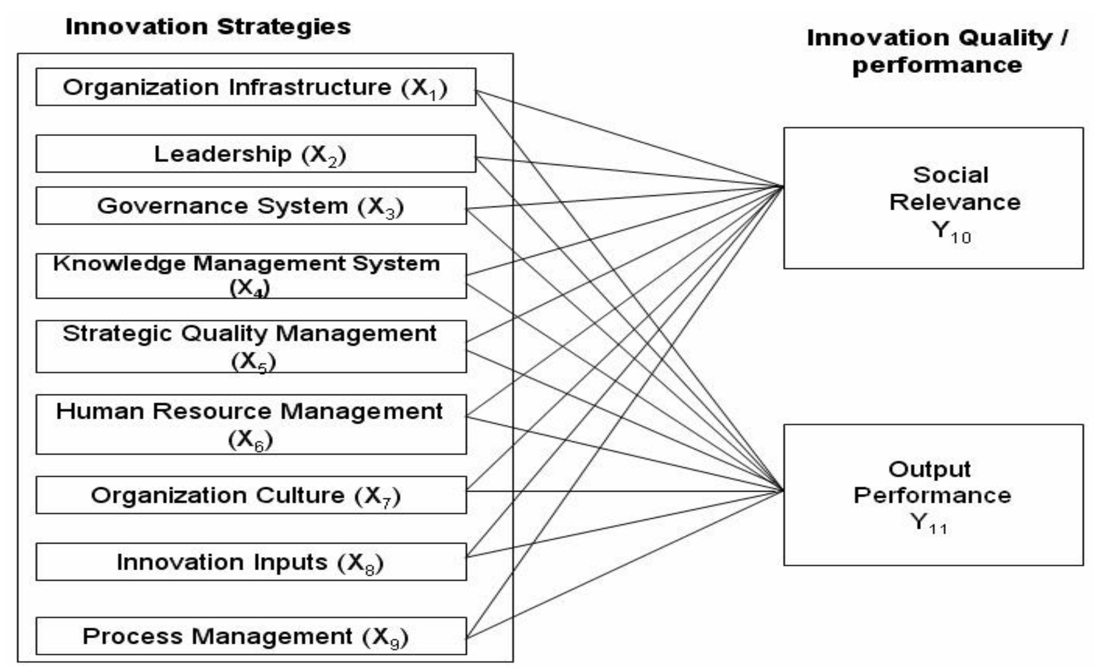

Figure 2: Conceptual Framework for Innovation Quality Magnitude in R&D organizations

2.3 Reliability and Validity of the Measuring Instrument

By using the judgmental and purposive sampling method, the research institutes of the Indian Council of Agricultural Research (ICAR) that have made contributions towards Innovations and Innovation Quality were selected. The details of research were explained to the researchers and they were asked to fill in the questionnaire developed for the research study. Data were obtained from 613 researchers working in the selected agricultural research organizations through small group interactions rating the relevancy of 95 sub dimensions in public sector agricultural R&D organizations. This primary data was analyzed for finding out the reliability and validity of the questionnaire developed for the construct of quality magnitude of innovations.

2.4 Reliability – Cronbach Alpha

Reliability is an assessment of the degree of consistency between multiple measurements of a variable (Hair, *et al.*, 2007). A commonly used measure of reliability is internal consistency, which applies to the consistency among the variables in a summated scale. Cronbach alpha is a reliability coefficient that assesses the consistency of the entire scale. The generally agreed upon lower limit for Cronbach alpha is 0.70 although it may decrease up to 0.60 in exploratory research (Hair, *et al.*, 2007), (Flynn etal. 1990)(Nunnally, 1978). The Cronbach alpha scale reliability value was calculated for all the variables using SPSS-16.0. It can be seen from the table-2, that the measurement scale is highly reliable, with Cronbach alpha values ranging from 0.644 to 0.91, which is above the minimum acceptable level of 0.60 for exploratory research (Flynn etal., 1990).

2.5 Validity – Confirmatory Factor Analysis

Validity is the extent to which a scale or set of measures accurately represents the concept of interest. (Hair, J.F. Jr., et al., 2007). Confirmatory Factor Analysis (CFA) seeks to determine if the number of factors and the loadings of measured (indicator) variables on them conform to what is expected on the basis of pre-established theory. In the groundwork, assumption was made that each dimension is associated with a specified subset of indicator variables. Churchill's (1979) and Neter *et al.*'s (1989) recommendations were followed and the sample was randomly split into two halves: Sample 1and Sample 2.

From the analysis of the two data sets, it was concluded that sufficient number of correlations exist between the items, giving evidence on the existence of underlying latent constructs, therefore confirming the choice of factor analysis (West and Anderson, 1996 and Darroch, 2003). Indicator variables were selected on the basis of prior theory and variables assigned to nine independent and two dependent dimensions were subject to confirmatory factor analysis to ensure the reliability of the variables (Nunnally, 1978 and Hair, J.F. Jr., et al, 2007).

A minimum requirement of confirmatory factor analysis is to hypothesize beforehand the number of factors in the model (Satish & Srinivsan, 2009). The 11 dimensions derived from hierarchical cluster analysis were hypothesized as factors. Factor loadings are the correlation coefficients of the respective variable with the composite index. For establishing the validity of the construct, the interpretation of the factor loadings was done. As there is no concrete cutoff limit (0.30 by Nunnally, 1978 & Hair, *et a.l*, 1992, 0.70 by Hair, *et al.*, 2007), loadings in excess of ±0.65 were considered as indicative of a well defined structure. In the current research, the number of factors i.e. the construct of innovation quality was specified as variables and the items as sub variables. The results of confirmatory factor analysis are shown in table- 2. It gives the factor loadings obtained for both independent and dependent variables respectively and the retained number of items after eliminating the poorly loaded items. For testing and predicting the model construct, correlation and regression analyses were carried out. The dimension loadings were created by averaging the retained sub dimensions loadings in each main dimension. The bivariate correlations using Pearson method in SPSS-16.0 was employed for obtaining the correlation matrix and level of significance. Table -3 depicts the descriptive statistics and Pearson correlation coefficients which show the bivariate relationship strength between the nine independent and two dependent variables.

Table 2: Results of the Factor Analysis

Construct of Dimensions					
Variables	Original No. of sub dimensions	Retained sub dimensions	Cronbach Alpha	Minimum Factor loading	Maximum Factor loading
X1	10	4	0.828	0.652	0.688
X2	6	5	0.644	0.651	0.722
X3	5	3	0.682	0.675	0.808
X4	10	4	0.834	0.665	0.779
X5	15	2	0.901	0.650	0.780
X6	10	3	0.910	0.660	0.673
X7	7	4	0.881	0.664	0.744
X8	9	2	0.889	0.681	0.727
X9	9	5	0.893	0.665	0.765
Y1	6	4	0.902	0.685	0.756
Y2	8	3	0.860	0.687	0.759
Total	95	39	0.982 (for 95 Variables)	-------	------

It clearly reveals that independent dimensions - Organization Infrastructure (X_1), Leadership (X_2), Governance System (X_3), Knowledge Management System (X_4), Strategic Quality Management (X_5), Human Resource Management (X_6), Organization Culture (X_7), Innovation Inputs (X_8) and Process Management (X_9) were significant and positively interrelated with each other and to the dependent dimensions - Output Performance (Y_{10}) and Social Relevance (Y_{11}).

Hierarchical regression analysis (Gowen III et al., 2008) was used to predict the model. The regression analysis was carried out by entering the independent and dependent variables in two sets i.e. for Y_{10} and Y_{11} individually. The F statistic was calculated to check the significance level of change in variance by the additional variables. Results of regression analysis model for dependent variables Y_{10} and Y_{11} are presented in table- 4.

Table 3: The Descriptive Statistics and Pearson correlation and Alpha coefficients of 9 independent and 2 dependent variables.

	Mean	SD	X1	X2	X 3	X 4	X 5	X 6	X 7	X 8	X 9	Y10	Y11
X 1	7.91	1.17	(0.82)										
X 2	7.72	.87	.626**	(0.64)									
X 3	7.41	1.11	.385**	.474**	(0.68)								
X 4	7.62	1.19	.499**	.519**	.574**	(0.83)							
X 5	7.97	1.18	.559**	.524**	.277**	.402**	(0.90)						
X 6	7.65	1.28	.619**	.594**	.287**	.378**	.462**	(0.91)					
X 7	7.57	1.23	.565**	.609**	.517**	.607**	.544**	.730**	(0.88)				
X 8	7.70	1.36	.578**	.573**	.453**	.533**	.564**	.674**	.754**	(0.88)			
X 9	7.39	1.09	.454**	.538**	.488**	.681**	.464**	.583**	.743**	.701**	(0.89)		
Y10	7.83	1.31	.462**	.560**	.563**	.666**	.383**	.550**	.684**	.624**	.735**	(0.90)	
Y 11	8.08	1.23	.650**	.699**	.523**	.646**	.424**	.654**	.681**	.681**	.719**	.805**	(0.86)

1. ** Correlation is significant at the 0.01level (2-tailed)
2. Value in parentheses along the diagonal are Alpha coefficients

N=613

3. Results

The results of the regression analysis presented in table 4 reveal that the empirical model [Figure 3] significantly represents innovation quality magnitude and is relevant to the index for measuring innovation quality in R&D organizations. The Output Performance (Y_{10}) is dependent on Governance System (X_3), Knowledge Management System (X_4), Strategic Quality Management (X_5), Human Resource Management (X_6), Organization Culture (X_7), and Process Management (X_9) at 0.05 level of significance. Social Relevance (Y_{11}) in the model is predicted by Organization Infrastructure (X_1), Leadership (X_2), Knowledge Management System (X_4), Strategic Quality Management (X_5), Human Resource Management (X_6), Innovation Inputs (X_8), and Process Management (X_9). From the data, it can be predicted that dimensions of the model can be used to evaluate the level of innovation quality in R&D organizations. The above dimensions of the validated model were used to develop a reliable and valid questionnaire consisting of all the dimensions of the model.

Table 4: The Regression Analysis Model for Dependent Variables Y_{10} and Y_{11}.

Depend variable Y10					**Depend variable Y11**		
	Standardized Coefficients				Standardized Coefficients		
Variables	Beta	t	Sig.		Beta	t	Sig.
X1	-.049	-1.193	.233		.205	6.234	.000
X2	.100	2.056	.040		.289	7.411	.000
X3	.159	4.685	.000		.045	1.652	.099
X4	.229	5.654	.000		.137	4.223	.000
X5	-.091	-2.609	.009		-.175	-6.235	.000
X6	.115	2.769	.006		.132	3.964	.000
X7	.111	2.265	.024		-.034	-.857	.39`2
X8	.072	1.847	.065		.127	4.046	.000
X9	.351	7.420	.000		.274	7.218	.000
R	.995				0.997		
Overall R^2	.990				0.994		
F	1.036				1.400		
Adjusted R^2	.990				0.994		
F Change	5.106				14.339		
Predictors of Empirical Model for Y10: X9, X3, X7, X4, X6, X5					Predictors of Empirical Model for Y11: X2, X9, X1, X5, X8, X4, X6		

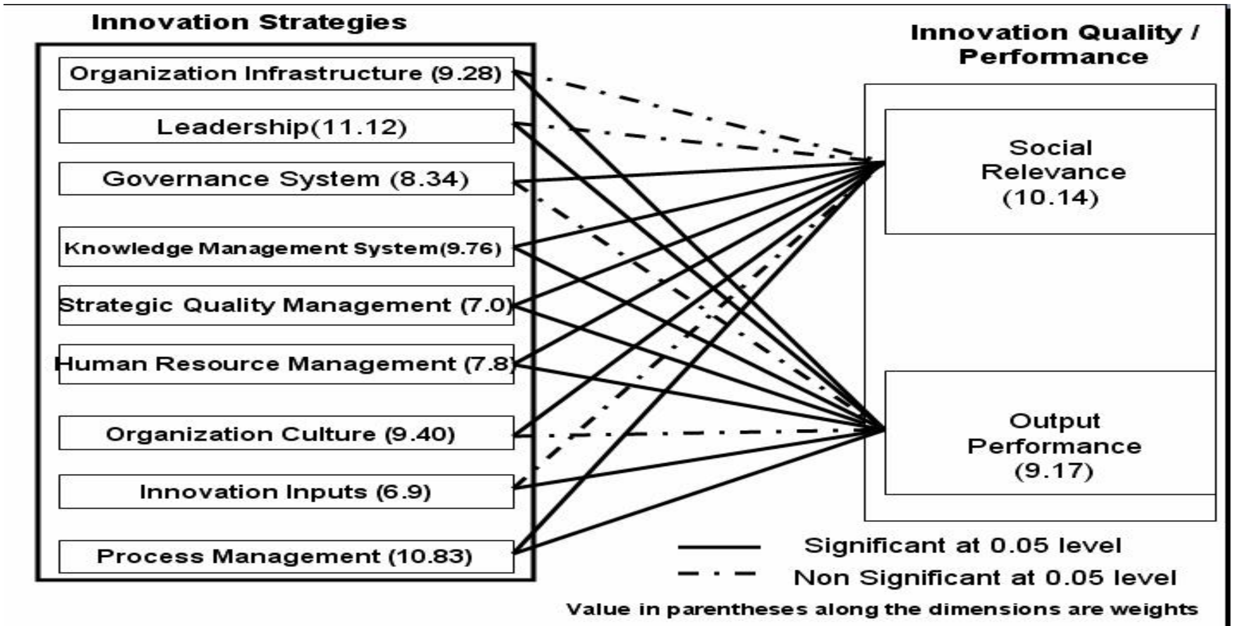

Figure 3: Empirical Model for for Innovation Quality Magnitude in R&D organizations**.**

3.1 Innovation Quality Magnitude Index

In calculating index for innovation quality magnitude, the subjective weights for dimensions were obtained from the 35 experts and objective weights from factor analysis. The final dimension weight was calculated by integration of subjective and objective weights of the dimensions (Liu et al.2010). The final weight of the each dimension was calculated by the equation:

$W_i = \alpha * a_i + (1- \alpha) b_i$

where a_i is the subjective weight, b_i is objective weight of the dimensions and $\alpha = [0 \leq \alpha \geq 1]$. In this case, the value of α is taken as 0.50. The final weights for each dimension in giving in Figure -3. The dimension score (Si) is calculated by the formula:

$$\frac{\text{Total Score of the dimension} - \text{Average mean of the total score}}{N-1} * \frac{100}{5}$$

Where N is the no. of questions representing that dimension in the questionnaire.

The magnitude of dimension is calculated by integration of dimension weight and scores obtained from survey i.e. W_i*Si

Where W_i is the final weight and Si is the score of the dimension from the questionnaire

The quality magnitude index can be calculated by using the formula given below:

∑(magnitude of the dimension X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, Y_{10}, Y_{11})

3.2 Construct for Innovation Performance

3.2.1 Calculation of Performance Index for innovations

The index gives the value to the performance and importance of innovation (Katia, 2007) in terms of its:

- Reach i.e. individual, local, regional, national and international,
- Significance i.e. in terms of Livelihood capitals (DFID, 2000) [natural, social, human, financial and physical]
- Potency i.e. direct, indirect or null.

The Performance Index score can be calculated by formula:

Innovation Performance Index = Innovation Extent * ½ Reach

Innovation Extent = ∑ (Significance *Potency)

The scaling of dimensions can be done as shown in Table-5:

Table 5: Scaling of the Dimensions

REACH	**WEIGHT**		**Significance**	**Weight**
Individual	1		Natural	1, 2, 3, 4
Local	2		Social	1, 2, 3, 4
Regional	3		Human	1, 2, 3, 4
National	4		Financial	1, 2, 3, 4
International	5		Physical	1, 2, 3, 4
POTENCY			**WEIGHT**	
Null			0	
Indirect			1	
Direct			2	

3.3 Matrix Development

Presently most approaches for measuring innovation performance and quality use gauges that are quantitative from conventional tangible dimensions. This has encountered with criticism as they do to take into account intangible dimensions or qualitative indicators. A qualitative method for mapping innovation performance and quality of agricultural research and development organizations ARDO's through Index matrix has been suggested. An "index" is the composite of more than one dimension. A composite index for innovation performance and quality magnitude was constructed using the techniques like summing/averaging, weighting, and normalization (Downing et al, 2000, Geller and Moss, 2007).

Considering the range of versatility in ARDO's as well as agricultural innovations, the performance behaviour and quality magnitude must be addressed on case to case basis. The proposed matrix (Figure-4) may not cover all aspects related to given innovation, its quality and performance although it presents a generic approach for innovation performance evaluation and analysis. As there is always scope of improvement, the users are encouraged to refine/customized the model according to need by required alterations in parameters and/or their weights. This matrix will help in mapping and predicting the relationship of quality management and Innovation performance. The mapping of these will help in increasing the organization's operational efficiencies resulting in sustainable innovations with higher rate of success and quality

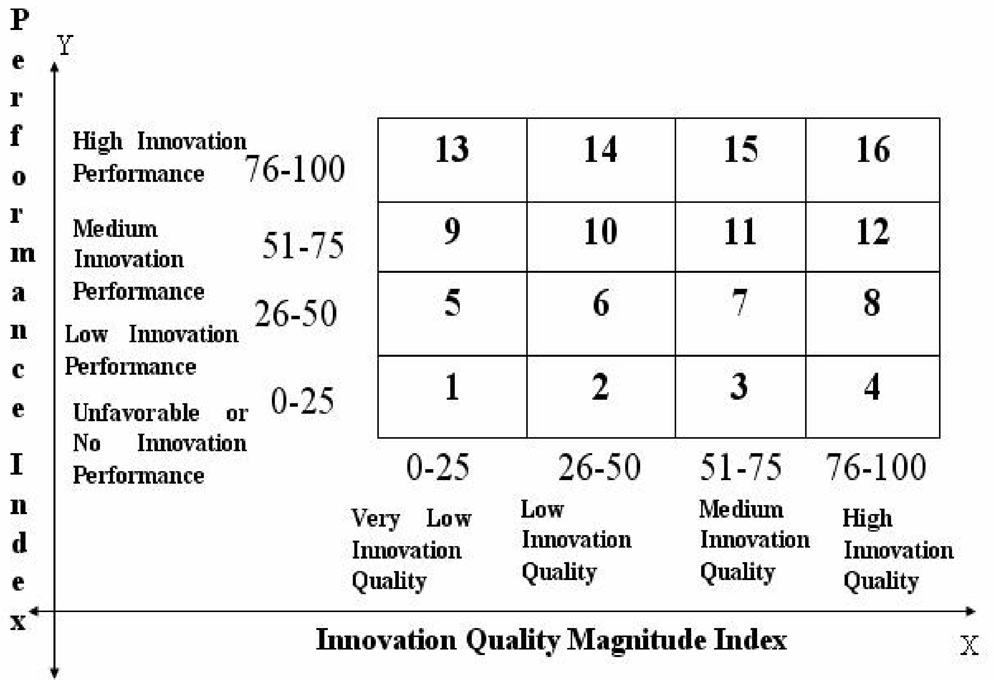

Figure 4: Proposed Matrix for Quality Magnitude & Performance of Innovations

4. Conclusions

The interrelationship between the level of quality management in the R& D and the performance of resultant innovations in an organization is a complex one. The exploration and understanding of this interrelationship is important from the prospects of effective R&D management. The quality management dimensions are internal to the organization where as the performance of innovation depends on many extraneous factors. In case of agricultural innovations, these include variability in agro-climatic conditions, management practices, etc. Both the internal and external dimensions need to be amalgamated and analyzed in a holistic approach for innovation quality management. The methodology followed and discussed in this paper measures the innovation quality management through 11 weighted dimensions. The performance of innovation is quantified considering three major elements i.e., the reach, significance and potency. These two concepts are integrated in a 4X4 relational matrix to project overall innovation quality scenario. The sixteen cells of the matrix represent combinations of scenarios ranging from the least preferred one (very low innovation quality and very low innovation performance) to the most desirable (high innovation quality and innovation performance). Mapping and positioning of an organization and the innovation in any of these sixteen cells, facilitate in assessing the current status and drawing up strategic plan for necessary intervention to quality and performance of innovation. Though the matrix is developed using data from agricultural research organizations, the matrix could be adopted for similar R&D organization in other disciplines.

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