MANAGEMENT STRATEGY FOR SUSTAINABLE TECHNOLOGY CREATION AND ACCURACY IN ADOPTION : R&D PERSPECTIVE

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If an R&D unit is in the process of generating a technology, its success (or) failure may determine the future of the unit based on the pertinence and applicability of technology. Therefore, a need for developing highly accurate technology and its sustainability to certain location (or) group is essential. The accuracy criterion should be considered in a relative sense: how accurate must the technology be for the specific location (or) crisis management? In brief, technology accuracy for agri-commodity business (ACB) sector must be assessed relative to the importance of the adoption, the adaptation and consequences of non-adoption. Even if technology possesses all the characteristics, it is of no use unless it is relevant to current market and crisis situation. The issue of accuracy is important for those planning for, or crisis management activities to build sustainability within the system.

Technology creation, acquisition, adoption and management are a major factor in gaining competitive advantage. It can create a whole new industry and dramatically alter the landscape in existing industries. The development and innovative use of technology can give an enterprise a distinctive competence. Competitive advantage comes not just from creating new technology, but also by integrating and managing existing technologies. Thus technology takes many forms, beginning with ideas, knowledge, and experience and then utilizing them to create new and better ways of doing things. Technology acquisition deals with how far back in the R&D work gets involved (basic research, applied research, or development) to secure new technologies and which options it uses to do so. Technology creation and adoption attempts to explain decentralized technology development (client-driven R&D) and enhancements of accuracy in implementation of appropriate technology.

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Primary Areas of Technology & Management

Within the R&D sector, technologies reflect what scientists are working on and what they use to do that work. The most widespread view of technology is that of *production technology*, which an R&D research group develops when creating new products and services. Another view is that of *process technology*, which an R&D unit uses to do their work. A third area, which is becoming increasingly important, is *profit technology*, which the clients of R&D use to acquire, process, and adopt for sustainable business excellence. The way in which a specific technology is classified depends on its application.

Corporate managers and SML entrepreneurs are interested in all three aspects of technology. Product technology is important because the production system must be designed to produce products and services spawned by technological advances. Process technology is viable because it can improve the methods currently used in the production system. Profit technology is essential because it can operate the production system to achieve profitability.

According to Krajewski & Ritzman (2000), different types of technologies is mind-bogging, and yet managers & SML entrepreneurs must be knowledgeable about the technologies used in their operations. This paradox raises the questions: What does a manager (or) an entrepreneur need to know about technology? One view is that the manager merely needs to understand what a technology can do, including its cost and performance possibilities. An alternative view is that such understanding isn't enough; that the effective manager must also understand how the technology works and what goes on in the technology's "black box". Whatever the firm, managers are less effective when standing at arm's length from the technologies that make up a firm's current and future core competencies. They must invest the time to learn more about these technologies and at the same time develop good sources of advice or sustainable technology to meet a variety of goals within the systems.

Defining & Coalition Building on the Term Sustainable and Technology

The concerns of scientists, public & producers over such complex, inter-related problems with the term "sustainable" in relation to R&D, agriculture, environment, human body, atmosphere, etc have led to the increased use of system approaches to solve these problems. The term sustainable requires the balancing of a variety of goals, which means that often no single goal in R&D be maximised because it might totally preclude the achievement of one of the other goals of sustainability in farming system. The ultimate goal of sustainability is to resource the team of multidiscipline to work on existing natural systems such as agriculture (or) environment and evolve appropriate technology. The quest for sustainable has received much criticism because by nature "agriculture is sustainable". Francis and Hildebrand (1989) have stated that agriculture in tune is a practice of using the local resource base renewable inputs and regarding to have potential for sustained production and profits further into the future of agriculture within eco-systems. Therefore, the impediments to sustainability is not "an Agriculture", it is an inappropriate policy, technology and process of economic intervention into the agricultural system. Much of the debate on sustainability has been based on societal considerations. While sustainability in agri-sector may also be a societal goal, but the practices that will provide sustainability can only be implemented in an agricultural system, where they must form sustainability. To insure relevancy of the farming systems - "the farmers-the scientists"- must be involved in the R&D leading to design and development of appropriate technology for furthering the sustainability in agriculture and its system.

Theoretical Framework

The theoretical dimension of this research is focussed on socio-technical system (STS) theory as a diagnostic theory for R&D design and service through appropriate technology for sustainable business performance. The primary aim is to contribute to the development of STS theory relevant to R&D and more specifically to extend it to the phenomenon of R&D organizational learning. In this section, the article builds on the theoretical dimensions of STS and its application in the commodity sector of R&D.

Socio-technical systems (STS) theory was originally developed from open systems theory (von Bertalanffy, 1950). Taylor and Felten (1993) refers to STS as a philosophy and a methodology. Gerwin and Kolodny (1992) refers to STS as a "paradigm" consisting of a conceptual scheme, a methodology, a design process, a set of values about work, contextual conditions such as interdependence with the environment, and a historical traditional built on psychology, sociology and workplace research. Emery (1993a) refers to STS as a generalized model of the dimensions of social and technical systems. Classical STS relies heavily on a detailed variance analysis method for determining which variances need to be controlled and how the organization should be designed to facilitate the control.

The third concern raised by the abstractness of STS principles is that STS researchers and organizational scientists often ignore each other's literatures. STS researchers rarely refer to empirical research generated by organizational scientists on the characteristics of effective teams, jobs, performance, management systems, organizational strategy, human factors, design of technology, and organizational culture. Moreover, organizational scientists rarely compare and scientifically test the STS principles against principles of design advocated by organizational scientists (Fry and Smith, 1987). As a result, organizational scientists and STS researchers marginalize each other at great cost to both parties. For STS, it means decreased diffusion and failure to incorporate recent empirical work into future development. For organizational science, it means a failure to adequately consider quality of work; as well as an inability to effectively integrate into their theories such issues as comprehensive organizational design, the need for variation-control features, and the likelihood of continuous change.

Matthews (1997) argues that the STS tradition would benefit by incorporating new "rationalist/functionalist" approaches associated with institutional and evolutionary economics and "neo-rational choice" approaches to the study of complex adaptive systems (e.g., Teece, 1986; Nonaka and Takeuchi, 1995; Anderson, 1999). Rationalist/functionalist approaches, following Simon (1976), assume that human rationality is bounded and argue that modern economic institutions are structured so as to ensure greater economic efficiency and productivity. Neo-rational choice approaches envision agents with different kinds of cognitive maps or scheme operating in and adapting to particular local environments by making "rational choices" within the constraints presented by these local environments.

The interdependence of the social and technical systems of organizations was one of the core insights of the socio-technical systems (STS) tradition associated with the Tavistock School (Trist and Murray, 1990, 1993; Trist et al., 1997). Though this basic insight is now routinely accepted in organization and management theory, in recent years, several authors have questioned the usefulness of the STS tradition as a source of continuing theoretical and practical insight into problems associated with stability and change in complex STS. These authors have argued that the STS tradition - because of an outdated focus on industrial production and industrial relations - has been difficult to apply a topics such as organizational learning and socio-technical innovation in the emerging organizational forms of the information age. These authors offer a variety of suggestions for updating the STS tradition to make it more applicable to these problems.

To accomplish this, echo van Eijnatten (1993) called for a "middle-range" (Merton, 1968) theory of STS, one that can bridge the abstractions of STS theory and the particulars of STS practice, and one that can render those abstractions in a form amenable to empirical testing. Mainstream management thinking suggests that in the era of mass customization, we need "technology organizations".

The learning organization is one that can adapt quickly to new customer demands and market place changes, but how do we design a technology learning organization ? What should it look like ? Where are the relevant organization boundaries for creating technology teams that can learn ? What hierarchical relationships, if any are useful ? What is the appropriate division of labour ? For all this interest in developing the STS tradition, there has been very little explicit comparison of the different approaches to the study of large STS. In this paper, we argue that for the study of STS to move "beyond STS theory", to describe a R&D programme aimed at the development of such a middle-range theory. It outlines the resulting theory, describes the process of its development, highlights the prospects for its further development, and identifies present and potential contributions to STS theory and practice relevant to R&D organizations.

Methodology

The sample space for the present study comprises three categories of agripreneurs classified on the basis of their land holding size (less than two ha; two to twenty ha and more than twenty ha). The stratified proportionate random sampling technique was followed for the selection of respondents. In this method, the population was subdivided into small (<2 ha), medium (2-20 ha) and large (>20 ha) agripreneurs and a random sample was drawn based on the proportion of sample. The study was conducted in the states of Kerala and Karnataka. Four districts in Kerala and one district in Karnataka were selected based on the availability of different category of respondents-. Kottayam, Kasargod and Thrissur was selected for small and medium agripreneurs and Mangalore & Kozhikode for large agripreneurs.

Instrumentation

The instrumentation utilized in the study was developed by the researcher related to review of literature on accuracy in adoption, consultation with agripreneurs and RRII scientists. The instrument was divided into two sections. Part A asked the respondents to indicate accuracy in adoption of technology. Part B enquired the respondents' agreements on joint participatory research for technology generation (JPRTG), demographic characteristics, influence of production technology system on adoption, influence of technology adoption with market, rapport building between scientists & clients, eco-friendly plantations and value & satisfaction with RRII service.

Field Research

The research team visited four districts in Kerala and one district in Karnataka. The visits to those districts took place from January to April 2002. At each site, the research team observed and diagonised accuracy in adoption of technology based on the recommendations of RRII.

Analysis of Data

The data was analysed utilizing SPSS package. The data was reported frequencies, percentage, mean, odd ratio analysis, chi-square test, rank to describe extent of accuracy and inaccuracy. Overall accuracy was measured by using Engelhard (1996) model of measuring accuracy. The details are given below:

$$\text{Overall accuracy (\%)} = \frac{\text{Actual score of the respondents x 100}}{\text{Maximum possible score in terms of accuracy}}$$

After calculating the overall accuracy in the adoption of technology for each respondent, accuracy levels were classified into <70%; 70-80% and >80% accuracy.

Chi-square

Chi-square test was used to find the association between *"land size"* and *"accuracy in adoption"* of technology.

Null Hypothesis

Null hypothesis : There is no association between the land size and accuracy in adoption of RPP technology.

The null hypothesis is accepted, if the chi-square value is less than table value. The null hypothesis is rejected, if the chi-square value is more than the table value.

Odd Ratio Analysis

Odd ratio analysis revealed ratio of probabilities in accuracy of adoption. It was used to test the probability ratio of accuracy at different levels.

Findings

The term *accuracy* refers to the adoption of particular technology at the entrepreneurs' field, based on the recommendation of RRII. *Inaccuracy* deals with the adoption of technology either above or below the recommended level and adoption of own (indigenous) practices by the entrepreneurs. The term *non-adoption* assumes the non-adoption of technology.A. Accuracy in Adoption of Technologies

Twenty five (A to Y) technologies related to rubber production and processing were identified in consultation with RRII scientists to assess the accuracy of adoption by small, medium and large (SML) entrepreneurs in the field. Table 1 reveals the results related to accuracy, inaccuracy and non-adoption. Figure 1 represents the data on an overall adoption of technologies by the entrepreneurs. According to Table 1, entire large entrepreneurs (>20 ha) accurately adopted the technology of plant density & manuring (fifth year onwards - legumes ground cover and without legumes ground cover) for production practices, followed by processing technology such as use of formic acid, wet sheet dried in shade and washing. In case of medium entrepreneurs (land holders 2-20 ha), shown accuracy in adoption of secondary leaf fall (Technology J) and use of formic acid for processing. In contrast, the category of small entrepreneurs had not shown highest percentage of accuracy in adoption of either production or processing technologies.

Comparing the components of all rubber production and processing technologies across different categories of entrepreneurs, the highest accuracy in adoption of various technologies was found in case of large entrepreneurs, followed by medium entrepreneurs. The major reasons for accuracy in adoption of technologies by all the respondents was productivity and quality as the prime factor followed by profitability and compatibility.

B. Inaccuracy in Adoption of Technologies

Inaccuracy in adoption of RRII technologies viz., D_3 tapping system for the sustainability of rubber trees ranged from 25 to 88 percent of the respondents from large and small & medium entrepreneurs respectively tapped the trees under D_1 & D_2 system. The reasons for inaccuracy are indicated below:

(a) Entrepreneurs believed the number of trees available per unit area for tapping was minimal. Therefore, to fetch daily income they tapped these trees under D_1 or D_2 systems. In view of providing daily employment opportunity to tappers, respondents were forced to follow D_1 and D_2 method than D_3. Besides they believed that D_3 system of tapping consumes more bark than D_1 and D_2.

(b) Manuring of 300 kg/ha for rubber under tapping was recommended

Table 1. Accurate, Inaccurate and Non-adopters of RRII Technologies by Small, Medium and Large (SML) Entrepreneurs (N=103)

Title of Technologies	Accurate adopters			Inaccurate adopters			Non-adopters		
	S (<2 ha) n=46	M (2-20 ha) n=35	L (>20 ha) n=22	S (<2 ha) n=46	M (2-20 ha) n=35	L (>20 ha) n=22	S (<2 ha) n=46	M (2-20 ha) n=35	L (>20 ha) n=22
A	87	94	100						
B	43	60	82						
C	84	79	76						
D	64	57	100						
E	70	67	100						
F	55	56	86	43	44	10			
G	34	41	68				66	59	27
H	71	83	86						
I	50	67	43				38	33	43
J	0	100	0						
K	85	88	100						
L	67	60	0						
M	80	71	0						
N							100	0	100
O	4	11	5	94	89	95			
P	56	53	20				44	44	65
Q	14	13	70	82	88	25			
R	75	77	84						
S	78	100	100						
T							100	100	100
U	4	0	0				96	100	100
V	23	38	100				38	41	0
W	36	64	90						
X	16	38	82				68	48	9
Y	39	49	100				59	46	0

Inaccurate adopters

Q= Type of Tapping (D_1 & D_2)

F= Fertilizer application for rubber under tapping (225-250 or 250-300 kg/ha-NPK/chicken feed application.

O= Michie Kolledge

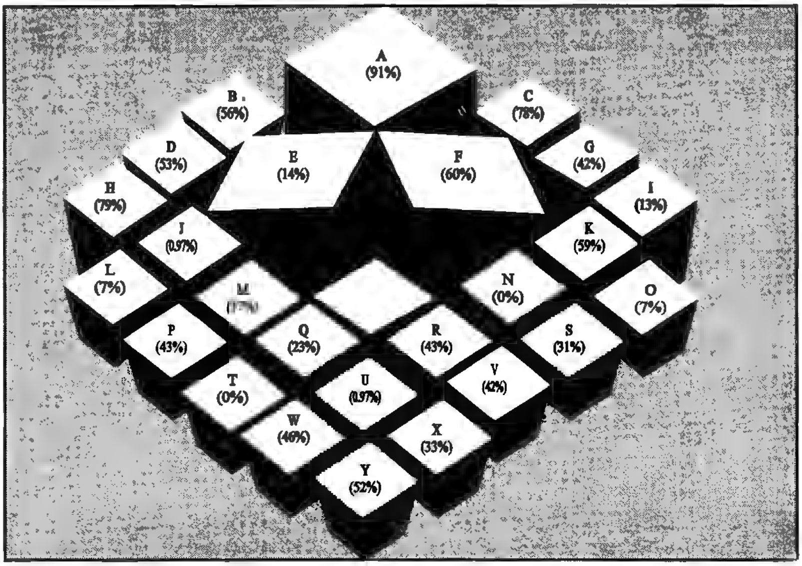
S = Small entrepreneurs

M = Medium entrepreneurs

L = Large entrepreneurs

B.N. Please refer to the Figure 1 for the title of technology represents from alphabets A to Y.

Figure 1. 25 RPP Technology with Accurate Recommendations



A	PlantDensity 420-500 plants/ha	N	Powdery Mildew (Bavistin 0.05%)
B	Pit Manuring 12 kg FYM/compost + rock phosphate 175 g/pit	O	Knife Used (Jebong)
C	Manuring First 4 years 10:10:4:1.5 g/plant (or) 12:12:6:15 g/plant	P	Type of Tapping (Controlled Upward Tapping)
D	5th year Onwards (legumes ground cover) 10:10:10 NPK 300 kg/ha/year	Q	Tapping System (D_3)
E	5th year Onwards (without legumes ground cover) 15:10:6 NPK 400 kg/ha/year	R	Formic Acid (Same day sheeting) (1.5 ml diluted to 300 ml with water)
F	Rubber Under Tapping NPK 300 kg/ha/year	S	Formic Acid (next day sheeting) (2 ml diluted to 400 ml with water)
G	Discriminatory Fertilizer Application based on Soil and Leaf Analysis	T	Sulphuric Acid (Same day & next day sheeting)
H	Weed Control (Integrated)	U	Catalyst AC for Coagulation (100 ml of 5% AC solution for making 500 gm)
I	Abnormal Leaf Fall (Usage of copper oxychloride paste)	V	Wet Sheet Dried in Shade (2-3 hours)
J	Secondary Leaf Fall (Copper fungicide)	W	Thickness of Sheet (3 mm)
K	Pink Disease (Bordeaux paste)	X	Adding Diluted Sodium Bisulphide (1.2g/kg drc)
L	Leaf Spot (Bavistin-0.02% / Bordeaux mixture-1% or Dithane M-45)	Y	Washing (While sheeting and after sheeting)
M	Brown Bast (Complete rest)		

B.N. Alphates indicates name of the technology and accurate recommendations. The number indicated within the parenthesis represents the percentage of respondents who adopted accurately for the concerned technology among the total respondents. For example, plant density had adopted accurately by 91% of respondents. In case of powdery mildew control (Technology N) non of the respondents adopted.

by the RRII. It is known from the study, nearly forty four percent of small and medium entrepreneur followed the alternative technologies indicated below:

- NPK mixture (200-250 kg/ha/yr) (or)
- Chicken feed application (or)
- NPK mixture (250-300 kg/ha/yr)

The reasons behind the application was high cost of chemical fertilizer and low price for rubber.

(c) In the case of Jebong knife, 89 to 95 percent of the entrepreneur adopted alternate knife (Michie Kolledge) for the important reasons: viz., (1). Traditionally practiced (2) Not aware of Jebong knife, (3) Knife edge of the jebong was not sharp.

C. Non-adoption of Technologies

Regardless of category, 100% of the entrepreneurs had not adopted the technologies viz., control of powdery mildew and sulphuric acid. The respondent believed that they were not able to adopt control measures for powdery mildew due to ineffectiveness of Bavistin to control the above disease followed by higher cost of fungicide.

More than sixty percent of the small entrepreneurs emphasized that they had not adopted the technologies viz., adding sodium bisulphide before coagulation and discriminatory fertilizer applications. Similar observation had been noticed when the percentage of respondents ranged from forty six to fifty nine percent of medium entrepreneurs for the technology of discriminatory fertilizer application, adding sodium bisulphide and washing. In case of large entrepreneurs, sixty five percent of the respondent believed that they had difficulty in adoption of controlled upward tapping. The reason for not adopting above technologies were non-availability of resources to adopt technology, lack of communication, limited impact on technology adoption and believed that technology was not suitable for existing farming system.

D. Validation of Accuracy in Adoption and its Association with Land Size / Entrepreneurs : Chi-square Perspective

An analysis on chi-square test was used to asses the comparisons between two or more nominal or categorical variables (land holdings of <2 ha, 2-20 ha and >20 ha) as well as comparisons between frequencies rather than mean scores to validate overall accuracy in adoption and its association with land size.

The Hypothetical Statement indicates that there is no association between the land size and accuracy in adoption. The null hypothesis stated that, there was no difference between land size (<2 ha, 2-20 ha and >20 ha) and accuracy in adoption of technology. Therefore, entrepreneurs with different landholdings were expected to have similar accuracy in adoption. The above null hypothesis is accepted, if the chi-square value is less than table value at 5 percent significance level and rejected, if the chi-square value is more than the table value. Chi-square test was conducted to understand whether there is any association among the large, medium and small entrepreneurs regarding the accuracy in adoption of overall 25 technologies using the following formula:

Chi-square value was obtained using the formula:

$$x^2 = \frac{\Sigma\ (f_o - f_e)^2}{f_e}$$

where f_o = the observed frequency (Frequency observed in the study)

f_e = the expected frequency (Note[1]:) (Estimates of values to be expected under the hypothesis.

$S^3_{i,j=1}\ (n_{ij} - n'_{ij})\ /\ n'_{ij}$ follows Chi-square distribution with (3-1).

(3-1) degrees of freedom.

i.e., $S^3_{i,j=1}\ (n_{ij} - n'_{ij})\ /\ n'_{ij} \sim X^2_4.$

[1] *Expected frequencies were computed with the observed one. The greater the differences between them, the large will be the value of x^2. The sampling distribution (Table value) of the x^2 is determined by (1) level of significance and (2) the number of degrees of freedom. Let us select for the problem under illustration, a level of significance of 0.05% which means that only if the calculated value is larger than what would be expected is not more than 5 out of 100 of our samples, then the null hypothesis be rejected.*

The number of degrees of freedom of the x^2 distribution is set by the number of cells for which the expected frequencies can be selected freely.

The formula used in df = (r-1) (c-1)

Where r = the number of rows

c = the number of columns

In a 3x3 table, df = (3-1) (3-1) = (2) (2) = 4.

Observed Probability Table

Variable	Category of %	Land Size < 2 ha	2 - 20 ha	> 20 ha	Total
Accuracy in overall	< 70%	0.184466	0.097087379	0.009709	0.291262
adoption of	70-80 %	0.194175	0.106796117	0.019417	0.320388
Technology	> 80%	0.067961	0.13592233	0.184466	0.38835
Total		**0.446602**	**0.339805825**	**0.213592**	**1**

The theoretical probabilities are given by $p_{ij} = n_{ij} / n$,i,j=1,2,3 (here i represents land size and j represents accuracy level). We have tested whether there is any association among the large, medium and small entrepreneurs regarding the adoption of all technologies.

H0: $p_{i1} = p_{i2} = p_{i3}$ (i.e., no association) for all i = 1,2,3. Vs H1: not all pij 's are equal for all i = 1,2,3'.

Under H0 common p_{1j}=0.291262, p_{2j}=0.320388, p_{3j}=0.38835, for all i=1,2,3.

Expected Frequency Table Under H0 :

Variable

Variable	Category of %	Land Size < 2 ha	2 - 20 ha	> 20 ha	Total
Accuracy in overall	< 70%	13.39806	10.19417476	6.407767	30
adoption of Technology	70-80 %	14.73786	11.21359223	7.048544	33
	> 80%	17.86408	13.59223301	8.543689	40
Total		46	35	22	103

For example expected frequency under H0 is $n'_{11} = 49.p_{11}$

The result value of the test statistic = 31.82508 and the critical chi-square value at 5% level of significance is $X^2_{0.05,4} = 9.488$. Clearly the value of the test statistic was greater than the critical chi-square value. Therefore, the null hypothesis was rejected at 5% level of significance. This means farm size and overall accuracy in adoption of technology was not independent (association). That is, as the land size increases accuracy in adoption also increases.

E. Odd Analysis to Predict the Probability on Different Percentage of Accuracy

Further analysis on odds ratio (Note:[2]) was instrumented for assuming probabilities at different levels of accuracy among entrepreneurs.

Under this analysis, the land sizes are antecedent for accuracy in adoption i.e., one of the two characteristics being studied is antecedent to others.

a) Estimated odds that small entrepreneurs will be < 70% accurate in adoption.

$$O_A = \frac{P_{11}/P_1}{P_{12}/P_1} = \frac{P_{11}}{P_{12}}$$

$$O_A = \underline{0.70}$$

Estimated odds that medium entrepreneurs will be < 70 % accurate in adoption.

$$O = \frac{P_{21}}{P_{22}}$$

$$O = \underline{0.40}$$

Odd ratio of small growers will be less than 70% accuracy in relative to medium growers

$$\frac{O_A}{O} = \frac{0.70}{0.40} = 1.76$$

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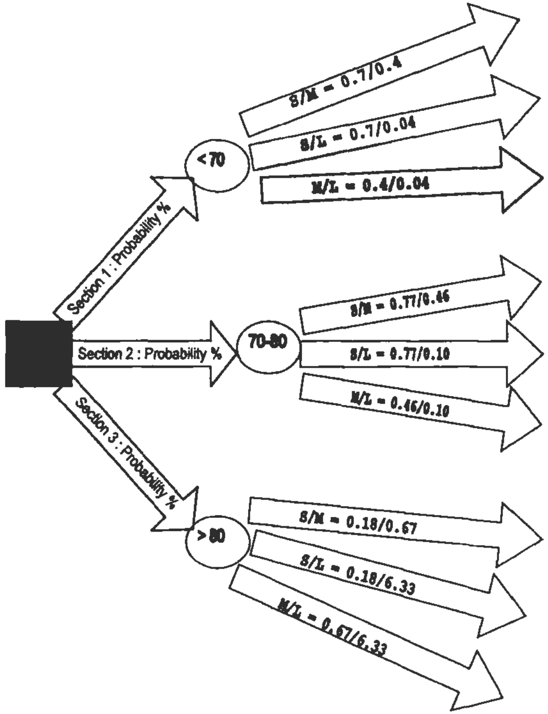
[2] *Odds ratio : The ratio of the odds for a binary variable in 2 groups of subjects. For example, if the two possible states of the variable are labeled "success" and "failure" then the odd ratio is a measure of odds of a success in one group relative to that in the other.*

Odd ratio result shows that odds of small entrepreneur for < 70 percent accuracy are 1.76 times those of medium entrepreneurs and the value close to one shows that hypothesis was accepted, that is land size and accuracy is not associated (No much difference between the land sizes and accuracy of adoption). Hypothesis : If odds ratio is very close to 1 or log of odds ratio is very close to zero, hypothesis of independence between the two factors was accepted.

Estimated odds from *Figure 2* were calculated for small, medium and large entrepreneurs at different levels of accuracy (<70, 70-80 & >80%). The

Figure 2. Odd Ratio Analysis to Predict Probability on Accuracy among SML Entrepreneurs



Odds ratio	Ln (odds ratio)	Estimated variance	SD	Test statistic	Hypothetical result
1.76	0.56	0.23	0.48	1.18	Accepted
17.5	2.69	1.14	1.07	2.53	Rejected
10.0	2.13	1.19	1.09	1.95	Rejected
1.7	0.52	0.22	0.47	1.10	Accepted
7.7	2.04	0.64	0.80	2.55	Rejected
4.6	1.52	0.68	0.83	1.84	Rejected
0.27	-1.31	0.29	0.54	-2.45	Rejected
0.03	-3.56	0.55	0.74	-4.79	Rejected
0.1	-2.25	0.51	0.71	-3.17	Rejected

Note: S/M-small & medium entrepreneurs; M/L – medium & large entrepreneurs.

procedure to calculate different percentage level to measure accuracy is illustrated in Annexture No. A. Odd ratio analysis was conducted for small entrepreneurs relative to medium and large entrepreneurs at different accuracy level. Similar analysis was done for medium entrepreneurs relative to large entrepreneurs. The results from Figure. 2 further reveals odd ratio, log odd ratio and result of hypothesis related to independence between the two entrepreneurs. Out of nine hypothetical analysis across small, medium and large entrepreneurs accuracy in adoption, two hypothetical statements were accepted. The first probability percentage reveals under section 1, there is no association between small and medium land size/entrepreneurs and level of accuracy (<70) in adoption of technology. Moreover under section 2, similar results were indicated with odd ratio of 1.7 that no association between small and medium land size/entrepreneurs in accuracy (70-80) of technology.

F. Chi-square (Note: [3]) test for assessing individual technologies and its association with land size

Table 2 presents the results of chi-square (X^2) test on null hypothesis for twenty-one individual technologies out of 25. The remaining four (1. control measures for secondary leaf fall, 2. control measures for leaf spot and 3. AC catalyst and 4. Sulphuric acid for coagulation) technologies were eliminated

[3] *Chi-square test in this study is not a measure of the degree of relationship, but is only a test of whether or not a null hypothesis of no association should be rejected (Best, 1981, p.287; Thompson, 1994).*

In multiple linear regression, the proportion of variance shared between the dependent variable and the predictors is reported as the coefficient of determination, R^2. A similar proportion of shared variance interpretation is possible in contingency chi-square applications when all variables are categorical. Thus the interpretation of R^2 in the general linear model may be carried over the analysis of contingency tables (Leitner, 1979). That is, the omnibus chi-square value calculated from a contingency table can be converted into a proportion of shared variance by dividing it by the total sample size, N, i.e., x^2/N. As the omnibus chi-square value is the sum of all the individual cell chi-square values, for each cell we can estimate the corresponding R^2 value (by dividing the cell chi-square value by N).

Table 2: Association of Land size and Accuracy for Individual Technologies

N = 103

Sl. No.	Technologies	Chi-square	R-square (X^2)	d.f (X^2/n)	Statistical influence on Ho
1.	Density in Planting (400 - 500 plants/ha)	4.338457	0.042534	4	Accepted
2.	Pit Manuring	9.367927	0.092752	4	Accepted
3.	Manuring (first 4 yrs)	2.023679	0.020441	4	Accepted
4.	Manuring (from 5th yr onwards Legumes with ground cover)	13.22646	0.171772	4	Rejected
5.	Manuring (from 5th yr onwards Legumes without ground cover)	1.742857	0.087143	4	Accepted
6.	Manuring (Rubber Under Tapping)	9.284615	0.093784	4	Accepted
7.	Discriminatory Fertilizer Applications Based on Soil and Leaf Analysis	11.58467	0.118211	4	Rejected
8.	Weed Control Method (Integrated)	21.11381	0.297378	4	Rejected
9.	Control Measure for Abnormal Leaf Fall	1.760073	0.073336	4	Accepted
10.	Control Measure for Powdery Mildew	2.453768	0.10224	4	Accepted
11.	Control Measure for Pink Disease	3.363933	0.050208	4	Accepted
12.	Control Measure for Brown Blast	0.3532	0.016055	2	Accepted
13.	Knife Used for Tapping (Jebong)	2.842736	0.028146	4	Accepted
14.	Types of Tapping (Controlled Upward Tapping)	13.28881	0.13423	4	Rejected
15.	D_3 Tapping System	29.78814	0.310293	4	Rejected
16.	Formic Acid (same day sheeting)	5.677428	0.101383	4	Accepted
17.	Formic Acid (next day sheeting)	4.5	0.125	2	Accepted
18.	Adding Dilute Sodium Bisulphide (1.29 per kg drc) in Latex Before Coagulation	23.9155	0.291652	4	Rejected
19.	Thickness of Sheet (3mm)	16.51536	0.203893	4	Rejected
20.	Washing (while sheeting and after sheeting)	24.02673	0.250278	4	Rejected
21.	Wet Sheet Dried in Shade (2-3 hrs)	37.38549	0.397718	4	Rejected.

from the test due to insignificance value. The null hypothesis was tested for no difference between the land sizes and its association in accuracy in adoption for 21 technologies related to field operations and processing.

The difference between the landholders category and accuracy in adoption on the following 9 technologies have been observed:

1 Manuring from fifth year onwards (with ground cover)

2 Discriminatory fertilizer application based on soil and leaf analysis

3 Weed control method

4 Type of tapping (Controlled Upward Tapping)

5 Tapping system (D_3)

6 Adding dilute sodium bisulphide (1.2 g/kg drc) in latex before coagulation

7 Thickness of sheet (3mm)

8 Washing before and after sheeting

9 Wet sheet dried for two to three hours in shade.

The technology with highest X^2 value for the following reveals that accuracy in adoption and landholding had wide variation across three categories. This indicates that above technologies were mostly adopted by large-scale rubber entrepreneurs who owned landholdings of 20 to 200 ha.

1 Wet sheet dried in shade for two to three hours (x^2 - 37.4)

2 D_3 tapping system (x^2 - 29.8)

3 Washing before and after sheeting (x^2 - 24.03)

4 Adding dilute sodium bisulphide (1.2 g/kg/drc) in latex before coagulation (x^2 - 23.92)

5 Weed control method (x^2 - 21.1).

For example, the highest chi-square value (X^2-37.4) (high difference between observed and expected frequencies) was noticed in accurate adoption of wet sheet dried in shade (2-3 hrs). This result was supported by data, which shows a wider variation between the categories of respondents and accuracy of adoption (i.e., 100% accurate adopters in large entrepreneurs and 23 to 38 percent accuracy by the small and medium entrepreneurs respectively). The data fulfills the reason for adoption of technology were the availability of infrastructure facilities and resources. In case of small and medium entrepreneurs, respondent (n=10) indicated that non availability of shade areas and lack of market value were the prime reasons for inaccuracy in adoption.

In contrast, the hypothetical statement indicates that there is association between the land size and accuracy in adoption of technologies indicated below:

1 Density in planting
2 Pit manuring
3 Manuring (first four yrs)
4 Manuring from fifth year onwards (without ground cover)
5 Manuring for trees under tapping
6 Control measures for abnormal leaf fall
7 Powdery mildew
8 Pink disease
9 Brown bast
10 Knife used for tapping (jebong)
11 Formic acid (same day sheeting)
12 Formic acid (next day sheeting).

To sum the findings from sections A to F, it reveals that the prime factor for adoption of technology accurately is the land size i.e., large entrepreneurs tend to adopt available technology accurately as per the recommendations of RRII. The above statement has been validated by percentage analysis, chi-square and odd ratio analysis with special reference to the association between land and twenty five technologies.

In contrast, the results from chi-square test, while assessing individual technology and its association with adoption of technologies indicates the following: An assessment to validate the performance of individual technologies on accuracy reveals that there is significant difference in adoption of accuracy in large/medium/small for 9 technologies mostly representing post-harvest. The reason being that the requirement of labour, local resources, infrastructure, cost for overall production for the technologies are high in nature. Factors such as resource requirement and status of entrepreneur had shown significant reluctance from small and medium entrepreneurs to adopt technology accurately.

Twelve field based technologies indicate that there is no association between the land size and accuracy in adoption of technology (i.e.,) there is no difference in adoption of technology accurately across entrepreneurs. The influence of RPS on supply chain input network and training facilitated small and medium entrepreneurs on par with large entrepreneurs to adopt certain technologies accurately.

The rubber plantation sector in India is dominated by small holdings. There are about one million small holdings in the country and 87% of the production and area are accounted for by small holdings with an average holding size of less that 0.5 ha, which points out socio-economic relevance of this sector in the country (Krishna Kumar, 2001).

According to the study, most of the field based technologies were accurately adopted by large and other entrepreneurs due to the requirements of minimal labour and cost of operations. However, the technologies related to harvest and post-harvest renders high amount of labour, money and management operations. The study further reveals that accuracy in adoption of technologies requires not technology as a tool but integration of technology with local resources, market trend, etc. Moreover, technology on tapping and use of rubber processing chemicals induce ergonomic related problem such as muscle ache and infection respectively. Therefore, an understanding on the integration of technology with small and medium entrepreneurs' livelihood system is the prime importance for technology generation.

Conclusion

Entrepreneurs' participation in R&D and education has been recognized for several decades as vital to the ultimate adoption and adaptation of improved technologies. There are many examples to capitalize on entrepreneurs' experience, knowledge and innovations in order to ensure that improved technologies are compatible with entrepreneurs' management priorities, production systems and environmental constraints. The concept of Joint Participatory Research for Technology Generation (JPRTG) on rubber addresses the integration of users into technology development and provide insight into the technology itself. It is important to note that the "users" of technology must get a detailed knowledge of the technology development process. Participatory design methodologies that all seem to share a value in explicitly "representing" users in the design. Broad description of "participatory design" integrates the end users into the process by which that system is designed for the adoption of technologies accurately.

The JPRTG approach has its unique characteristics, which influences client-driven institutionalization process in rubber sector. It is research based learning process and it has weight in decisions about technical innovation by entrepreneurs. The study further reveals that entrepreneurs had proposed the following aspects to enhance participatory R&D:

- RPS/estate must serve as a nodal agency to RRII for technology generation.
- The RPS/estate & rubber community willing to contribute a part of its revenue to R&D activity and to promote emergence of clients leadership in R&D.
- The RPS/estate willing to generate extramural funding to influence JPRTG between RRII and Clients.

The small entrepreneurs strongly perceived that non-recognition of their indigenous knowledge (IK) in R&D activities was the most important barrier for lack of participation in JPRTG. In case of medium and large entrepreneur. the reasons they felt were that generation of technology with no location specific and irrelevant to the group. The other related barriers for participation in JPRTG are:

(a) Social and political status quo between the entrepreneurs and scientists.

(b) Non-availability of time both for the scientists and clients

(c) Lack of organizational support for participatory research.

Important features of JPRTG is to integrate scientists, clients and research organizations based on accountability sharing. The members (estate/RPS/researcher) involvement became liable for relevance and quality of technology generation and diffusion process. A necessary feature of this approach is of client-driven or market demand led R&D. In this system, clients have a right into or sell out of a research programme through their network over a significant proportion of resources needed for JPRTG.

In order to institutionalize participatory, client driven technology development in rubber R&D, an assessment on participatory research system was conducted with small, medium and large entrepreneurs. The research team identified four types of participatory research systems, which comprise the "4C" (i.e., contractual, consultative, collaborative and collegial). The result indicates that majority of the small and marginal entrepreneurs with mean value ranged between 1.7 and 1.1 respectively expressed their desire under the category of *"collegial"*, which means RRII scientists must facilitate both small & medium entrepreneurs and RPS for informal research and development system based on indigenous technical knowledge of clients. They preferred the concept of entrepreneur-first and entrepreneur-last under R&D activities to play an active role in R&D.

In case of large entrepreneurs, the selection sequence for R&D activities was *"collaborative"*. It means that large entrepreneurs expressed their willingness to collaboratively work with scientists in research decision and technology development process. However, the system of contractual and consultative R&D research approaches were categorized under the least important R&D system by the respondents. A model on JPRTG in Figure 3 illustrates the degree of willingness among the SML entrepreneurs in the involvement of seven components related to JPRTG. It further conclude that JPRTG approach has been perceived as the participatory action research as an emergent process by SML entrepreneurs within the components of JPRTG viz., collaborative and collegial. Moreover, the respondents had strongly indicated high category of participation in research design and serving as nodal agency between R&D and rubber community. Incase of contractual category, i.e, the research done by the scientist alone without active participation of the entrepreneurs, results had shown unwillingness across the small, medium and large entrepreneurs. In placing on a continuum ranging from "expert research" to JPRTG. In the "expert research" approach, all authority and execution of research is controlled by the expert researchers (or) scientists. In JPRTG, authority over and execution of the research is a highly collaborative process between expert research and members of JPRTG clients and RPS.

Implications

The most challenging issue in R&D participatory research is how to institutionalize sharing of accountability between scientists and small, medium and large entrepreneurs. One option is providing an opportunity to link a clients group with an established RRII team called "Multidisciplinary Scientist Team for Participatory Research (MSTPR)" for recognizing client driven research on rubber production and management. The research policy of RRII must have explicit procedures to define particular clients or organizations who participate, whose agenda is a derived process and what organization innovations are needed to put their policy decisions at the heart of R&D.

In the design and execution of JPRTG on rubber, the RRII and extension team may orient their joint efforts towards the active participation of SML entrepreneurs in different phases of R&D activities, rather than educating them. In other words, for technology production and process in rubber, R&D and extension effort to "educate" SML entrepreneurs in the use technologies must be replaced, for technology-generation for accuracy purposes, by joint participation (e.g., JPRTG) of entrepreneurs, extension officers and scientists in all the phases of technology development and diffusion process.

To overcome accuracy in adoption of technology failure on small-scale sector and its variants : the concept of Entrepreneur-First-and-Last and Entrepreneur-Back-to-Entrepreneur, provides an alternative approach. This approach sets apart the level of entrepreneurs' involvement and its holistic or systems logic in JPRTG approach. JPRTG is called upon to encourage and enable small-scale entrepreneurs themselves to identify priority research issues. The technology generation should be geared to meet entrepreneurs' perceived problems and encourage entrepreneurs to think of experiment & diffusion process as their own.

An effective diffusion of technology has two components: know how & know why; know-how is using the technology productionlization in a way it envisages. Learning to operate tapping knife, establishing fertilizer application procedure, overcoming pest problems, meeting rubber product specialization, etc are all part of know-how. The concept of know-why is understanding

Figure 3. Degree of Willingness among SML Respondents to Involve in JPRTG Process

RD Research Design : To what extent do you agree, effective research design involves entrepreneurs in the process of design, treatment, operation, evaluation and validation ?

NA Nodal Agency : To what extent do you agree, RPS/estate must act as a nodal agency to integrate the research institutions for effective technology generation ?

SB Stake Building : To what extent do you agree, Joint Participatory Research approach promote RPS/estate for stake building capacity (community may contribute part of its revenue) ?

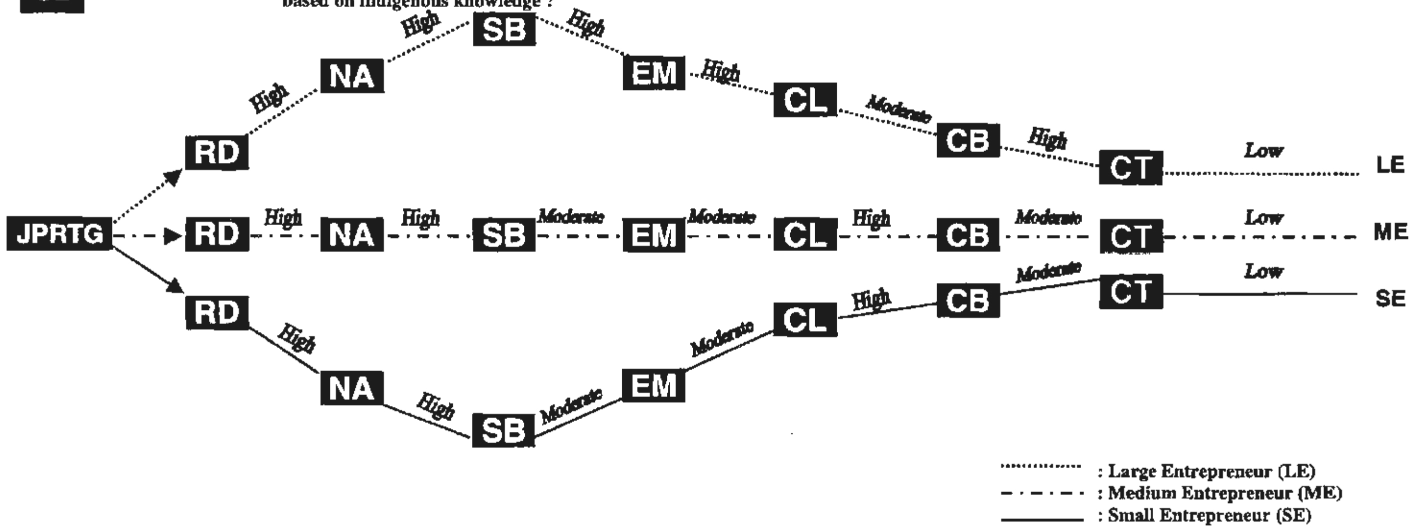
EM Extra Mural : To what extent do you agree, RPS/estate managed R&D system to generate extra mural fundings ?

CT Contractual : How important is the research done by the scientist alone without active participations of the growers ?

CB Collaborative : How important is the research done by the scientists and entrepreneurs as the collaborative partners ?

CL Collegial : How important is the research facilitated by the scientists and done entirely by the entrepreneurs based on indigenous knowledge ?

Entrepreneur	Response to JPRTG
LE	Disagree CT
ME	Disagree CT, SB & EM
SE	Disagree CT, SB & EM

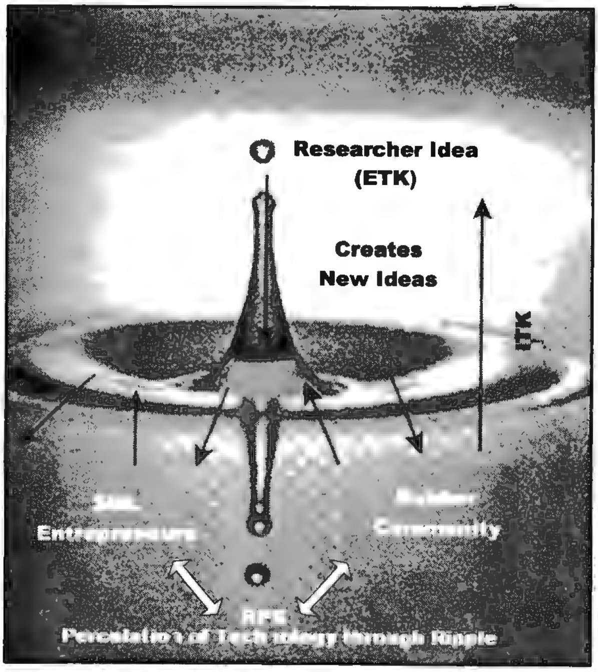


the technology : it is knowledge-specific, finding out what is inside the black box i.e., practicality of the technology and its relevance to livelihood system and marketability of SML entrepreneurs.

According to the study, most preferred diffusion of technology (DOT) strategy is humanware and infoware. The humanware and infoware indicates that diffusion of technology must be based on experimental learning through *"entrepreneur to entrepreneur"* communication for effective adoption followed by regular information sharing between R&D and clients. The modified model of ripple effect to this point can be imagined in diffusion of RPP technologies as discussed below: the research idea(s) are as a stone thrown into the pond and the water in the pond represents RPS. The initial contact group such as RPS (or) enlightened entrepreneurs are within the first circle of ripples and the idea(s) are transferred through the widening ripples. The subsequent ripples are a result of the first ripple or group. Under this model, the idea of R&D percolated to rubber community and SML entrepreneurs through RPS to integrate research idea (ETK) with entrepreneurs' value to the technology (ITK) for the sustainable process of R&D system. Consequences of this development model is that the widely adopted trial and error approaches such as conventional technology transfer, subsidy centered technology push, farm and home visit and demonstration ought to be replaced by R&D centered grassroots organization (e.g., RPS) approaches based on new insights as illustrated in Figure 4 are becoming significant factors in DOT.

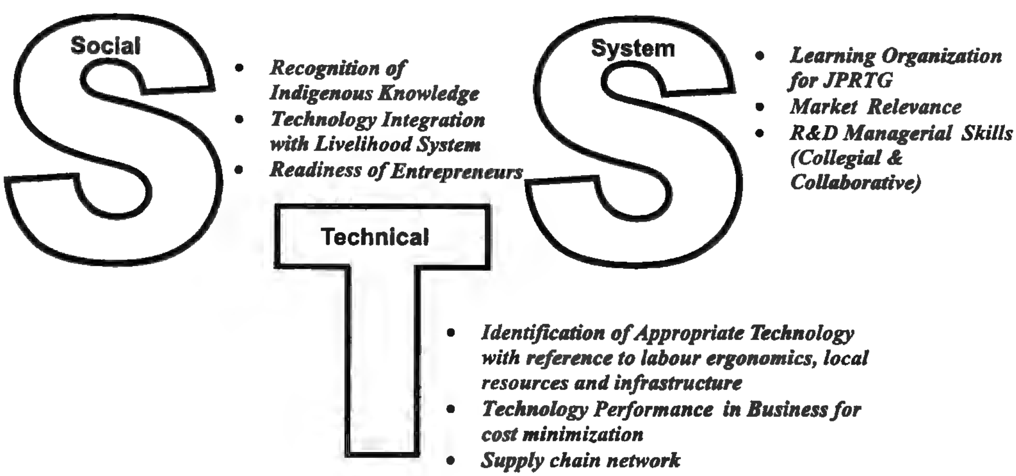
Ultimately, it is believed that RRII would reach a level for not only affecting technology assessment and transfer but would also facilitate DOT process through RPS to RPS and clients group to client group to extend the benefit of accuracy in adoption of technology to the entire community through ripple effect. In the current scenario, an entrepreneur and customer demands play a predominant role in development of new technology, often referred to as process. chain reversal in technology. In the past, the main aim of new technologies and diffusion process was to achieve higher productivity extend the adoption. Given a change towards a customer oriented approach, the parameters of accuracy in adoption will enhance the profitability and risk avoidance in commodity led extension system. Thus development and introduction of new technology from R&D to extension and community will lead to more

Figure 4. Modified Version of "The Ripple Effect" Image for R&D



Note: Image Courtesy by Damon Hart-Davis/DHD Photo Gallery.
ITK: Indigenous Technical Knowledge of Rubber Community
ETK: Exogenous Technical Knowledge of RRII

Figure 5. Implications of R&D based on Modified Range Theory of SPS



reliable and sustainable market led production system. Figure 5, illustrates the implications of middle range theory on STS with different dimensions relevant to participatory R&D approach, as part of findings of the study. The interaction of R&D system with the social, technical and system perspective is becoming increasingly important on technology design, process and diffusion process.

Annexure A

Engelhard (1996) defined Accuracy as the match between ratings obtained from the operational raters (respondents score) and those obtained from an expert panel i.e., bench mark ratings (researcher score). The bench mark ratings assigned by the research & expert panel can be used to evaluate the accuracy of operational raters (or) respondents. Closer the correspondence between the operational ratings and bench mark ratings, higher the level of accuracy.

This method of accuracy measurement differs in several important ways from earlier indexes of accuracy. Many of the previously proposed quantitative indicators of accuracy in adoption are based on group level data including the level from low to high. Previous indexes of rater accuracy generally involve 2 step processes i.e., the calculation of the rater accuracy index for each rater and then a separate examination of difference between the raters (respondents). The formula used for calculating the overall accuracy level for study is given below:

$$\text{Overall Accuracy (\%)} = \frac{\text{A Actual score x 100}}{\text{Maximum possible score in terms of accuracy}}$$

Example:

Maximum possible score for twenty five technologies = 25 x 3 = 75 Possible maximum accuracy score for a respondent

For example, calculation of percentage of overall accuracy indicates the level of accuracy in adoption of technology by a respondent. If a respondent adopts twenty five rubber production and processing technology (RPPT) accurately the total accuracy score will be seventy five. The numerical value of seventy five has been derived by multiplying number of technology with maximum adoption score value of three. The following illustrates that if a rubber entrepreneur adopts fifteen technologies out of twenty five technologies, the overall score (15x3=45) will be 45 out of 75.

Actual score obtained by a respondent for accurately adopting fifteen technologies = 15 x 3 = 45.

Actual score 45 out of 75.

$$\text{Overall accuracy (\%)} = \frac{45}{75} \times 100 = 60 \text{ percent.}$$

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