Designing and Managing R&D Projects to Achieve Outcomes from the Outset

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Abstract

Too often, research and development (R&D) investors and projects target research outputs rather than outcomes. They settle for developing new knowledge, information packages, publications, or a new or improved practice that, if used or 'adopted' could provide benefits. They fall short of setting targets of outcomes such as measurable improvements in family and regional income, environmental sustainability, energy efficiency or regional social infrastructure.

We report on the design and management of R&D projects that have achieved outcomes early in the projects, as well as regularly and frequently throughout the life of the projects. In particular we focus on the implications that targeting outcomes from the outset have on the technology development and integration component of the project. This paper discusses the concept of outcome-focussed projects, and how the technology development and integration components of these projects can be designed, managed and improved. It describes tools that can make it easier to develop technologies that contribute to outcome achievement. It also provides examples from a project in the Philippines of the benefits and challenges of this type of approach.

Please note a glossary of key terms is included at the end of this paper.

Keywords

Research and development (R&D), technology, outcomes, design, management

Introduction

Worldwide investment in agricultural, rural and regional research and development (R&D) is large, and generally these investments are managed using time-limited projects. R&D is perceived to be the major source of development, innovation, improvement and growth for regions and nations (Guthrie and Warda 2002). The corporate documents of many R&D organisations show that there is an expectation that R&D projects will contribute to the achievement of significant 'outcomes' (see glossary). These outcomes include reduced poverty, raised standards of living, improved livelihoods and better lives of rural populations (ACIAR 2001; AusAID 2001a; FAO 2005); sustainable development in developing countries (AusAID 2001a); increased long-term profitability of agricultural businesses (Australian Wool Innovation 2004); and improved management of natural resources for the greatest possible long-term social, environmental and economic benefits for everyone in the nation (Land and Water Australia 2001). However, few organisations overtly target their investment towards outcomes (e.g. AusAID 2001a; AusAID 2001b; FAO 2005). Still fewer organisations target projects that are designed and managed to achieve outcomes 'effectively' and 'efficiently' (see glossary), and sustain outcomes (e.g. AusAID 2001a). Some organisations, even if they mention ultimate outcomes in their corporate documents, largely report on 'outputs' achieved (see glossary) such as knowledge, information packages, publications, technologies, techniques, policy analyses, databases, standards or benchmarks (e.g. Land and Water Australia 2001; RIRDC 2004; ACIAR 2001). Despite the efforts of regional and international bodies, little progress has been made within agricultural R&D institutions in instilling a mentality, culture and awareness of the need to achieve high-impact outcomes (ISNAR 2003).

The need for outcomes from R&D

Given issues such as accelerating population growth, environmental degradation, and increasing global competitiveness there is a great need to focus R&D on the achievement of outcomes rather than the production of outputs. The real benefits, and therefore the return on investment (ROI) from R&D, depend on: (1) the size of the outcomes flowing from the adoption of the outputs of R&D per enterprise (e.g. improvement in profit, efficiency or the environment); (2) the rate of adoption; and (3) the extent or scale of adoption. These factors have been reviewed extensively in both the scientific and economics literature (Griffith and Vere in press; Alston et al. 1995; Pannell 1999; Marshall and Brennan 2001). If R&D projects result in outputs but no outcomes then, however efficient the projects may have been, they are not effective and it is therefore difficult to justify public investment in them. The simple fact is that a new agricultural technology has no actual economic value to an individual until it is adopted by that individual end-user, or to an industry until it is adopted by a large number of industry end-users (Griffith and Vere in press).

R&D paradigms and models influencing the achievement of outcomes

Many agricultural, rural and regional R&D projects are based on linear thinking and methods from traditional military, engineering or manufacturing project planning and management. This linear model (Figure 1) involves project initiation, planning, implementation and evaluation (Meredith and Mantel 1985; Adams and Kirchof 1997; Anon 2002). In this model most effort is focussed on acquiring inputs, conducting activities and delivering outputs. The model implies that: (1) once outputs are delivered the achievement of outcomes requires little investment; (2) outcomes are only achievable at the end, or after the end, of a project rather than throughout the life of the project; and (3) issues, needs, outputs and outcomes can be well-defined and agreed in the planning phase, and achieved without ongoing adaptation and improvement (Patterson 1993; Gieskes and ten Broeke 2000).

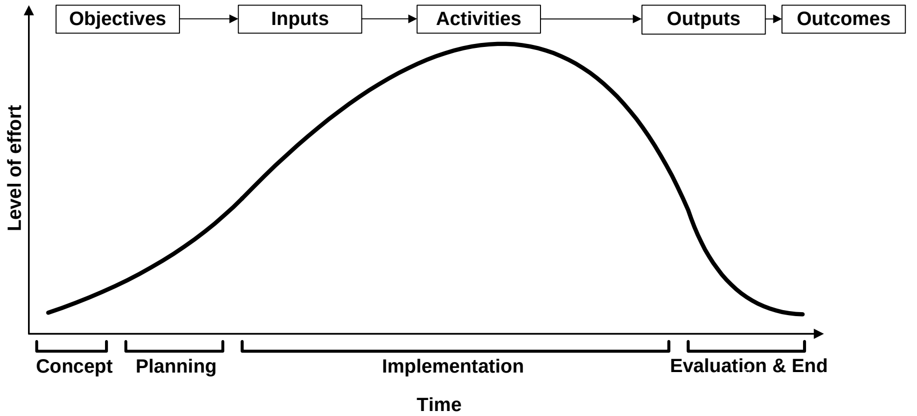

Figure 1. Traditional project planning and implementation components (derived from Meredith and Mantel 1985; Adams and Kirchof 1997; Anon 2002)

Meinzen-Dick et al. (2003) propose that agricultural research has generally assumed a particular causal pathway from research to outcomes such as reduced poverty, but that this assumption is not always valid. Rogers' 'Innovation-Development Process' (Figure 2) is one representation of this linear pathway (Rogers 1995). This model often assumes long delays between initial investment in the development of research outputs and realisation of benefits in the real world because of 'research lag periods', 'development lag periods' and 'adoption lag periods' (Alston et al. 2000) (Figure 2). This 'linear' innovation model is based on assumptions that good R&D outputs are the focus and the target and that these can, and will, be converted into outcomes by simple 'technology transfer' activities at the end of the R&D. This paradigm also assumes that technologies can be successfully researched and transferred at the end of a research project without end-user involvement in the development and improvement of the technology, or end-user contributions to new and improved technologies and 'technology throughput' (see glossary).

In agriculture the adoption process is often disconnected from the innovation or 'research' phase. That is, research and adoption are not integrated with mutual feedback (Figure 2). This disconnection is particularly associated with the 'Transfer of Technology' approach (Jiggins 1993; Woods et al. 1993), which assumes that technology is the output of research, and is transferred by transfer/extension agents to end-users.

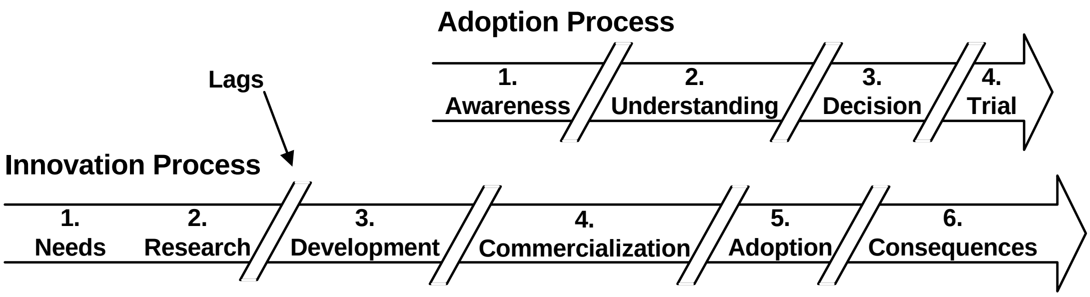

Figure 2. The Innovation-Development Process (Rogers 1995) and the 'lags' that delay the achievement of outcomes in the real world (Alston et al. 2000). The potential lags and separations between phases and steps influence the effectiveness and efficiency of achieving R&D outcomes.

There is a large amount of literature on the constraints to adoption at the end-user (farmer) level of using the 'Transfer of Technology' approach. Some of these constraints are: the extent to which the farmer finds the new technology complex and difficult to comprehend; how readily observable the outcomes from adoption are; the financial cost; the farmer's perception of the relevance of the new technology; the intellectual outlay; the loss of flexibility; the farmer's beliefs and opinions towards the technology; the farmer's level of motivation; the farmer's attitudes towards risk and change; and culture and local subcultures (Guerin and Guerin 1994; Vanclay 1992). There are also numerous reports on the constraints to adoption at the whole of R&D system level (Russell et al.1989; Macadam et al. 2003).

In addition to not dealing with constraints, our experience shows that the 'Transfer of Technology' approach has the following important short and long term costs and opportunity costs: (1) It does not encourage collaborative innovation and technology development; (2) It is dependent on a small number of scientists and 'transfer agents' and therefore has limits to the rate and scale of adoption, technology throughput, and outcomes it can achieve; (3) It does not build and sustain effective innovation partnerships; and (4) It does not build the capacity (knowledge, tools, skills and mutual support) of people to achieve ongoing improvements and innovation in partnership with others within and across sectors and R&D projects.

Miller and Morris (1999) advocate 'Fourth Generation R&D' (Figure 3) as a model for achieving: (1) proven products; (2) new products; (3) new products for new customers; and (4) greater efficiencies. This model is distinguished by: the sharing of knowledge gained through trials which involve all the people in the outcome–achievement chain, and take place in the research process itself; developing the innovation capabilities of end-users, developers and researchers; its emphasis on feedback and partnership as opposed to a linear R&D model; and the fact that when an innovation reaches product development its value has already been proven to all stakeholders. This model appears to have value in the commercial sector, though it does not claim to achieve real world outcomes of the kind expected from public investment. It does, however, achieve ongoing improvement and innovation of products and services.

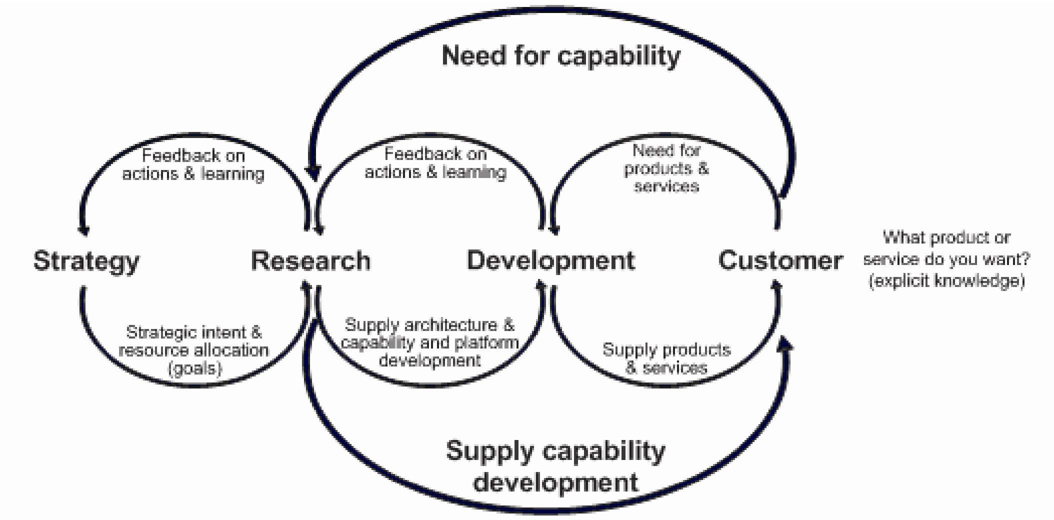

Figure 3. In Fourth Generation R&D people from throughout the outcome–achievement chain participate in a process of learning about what is possible and what works. In this way end-user needs and technological capabilities evolve linked to one another (Miller and Morris 1999).

We have researched and developed a model (Figure 4) to enable project and sub-project participants and partners to continuously adapt and improve project effectiveness and efficiency. This model is based on project and inter-project continuous improvement and learning research (Barthezzaghi et al. 1997; Gieskes and ten Broeke 2000). The key assumption behind this model is that if there is no continuous improvement and learning within and across projects, then 'lessons learnt' may become individual 'tacit knowledge' but there is no systematic diffusion of improvements within organisations or across organisational boundaries, for instance to new projects (Gieskes and ten Broeke 2000). This model is not easy to establish in environments where: (1) the orientation is on 'successful completion of projects', 'technical aspects' and/or 'value improvisation' more than putting effort into 'continuous improvement and learning'; and (2) projects are organised to order, and the result is a temporary alliance for a specific purpose and time frame in which participants are partners and in a state of constant competition at the same time. Partners may feel that it is not in their best interest to share lessons learnt (Gieskes and ten Broeke 2000).

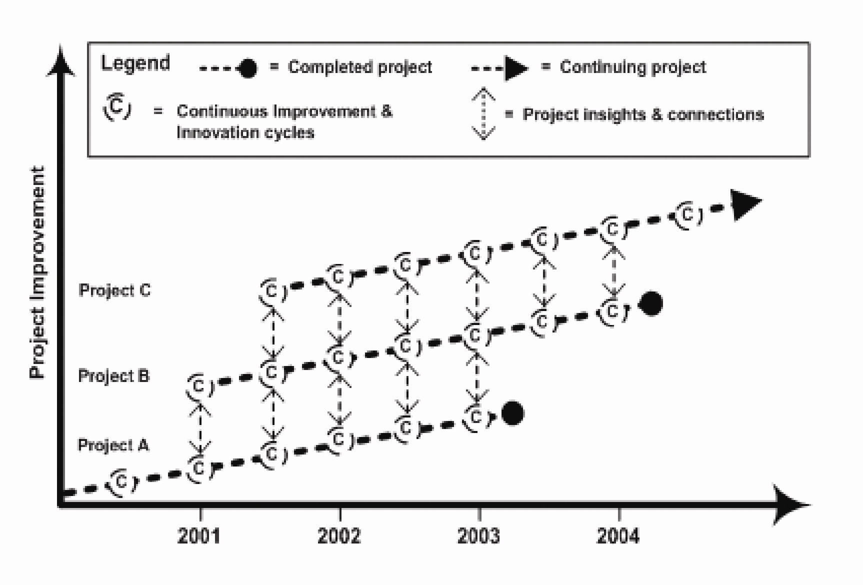

Figure 4. A model to achieve continuous improvement and innovation within and across projects and sub-projects for impact on project effectiveness and efficiency

Designing and managing R&D for outcomes

There is a large amount of evidence that many agricultural R&D projects do not achieve high levels of adoption and outcomes, by which return on investment (ROI) is measured, within their three- to six-year time limits; this indicates a real need for emphasis on the design of R&D for outcomes and better ROI. Designing and managing R&D projects for outcomes requires a fundamentally different approach to planning and managing for production of outputs. The ROI from a project will be greater if the volume of outcomes achieved is maximised for the available inputs. For example, if the target outcome is improved profit from agricultural enterprises in a region, the annual rate of improvement in gross margins and the number of enterprises involved (that is the scale of improvement), contribute to the volume of outcomes (profit) in the region, and therefore ROI. There would be an even higher benefit if the rate of industry 'innovation' and 'technology throughput' was also increased, and sustained. It is our assumption that if outcomes, accelerated adoption, high ROI and innovation are to be achieved, they have to be explicitly targeted in R&D projects, and the projects have to be designed and managed to achieve these outcomes.

From our experience, designing and managing projects for outcomes requires recognition and management of the following six principles and assumptions:

1. 'Technology' is only one of the key contributors to achieving outcomes. Clark et al. (2005a) describe the following eight elements of a system to achieve outcomes: (1) Outcome-Focus and Shared Mental Models of Targets and Roles; (2) Design and Management of Key Methods and Processes; (3) Capacity Building; (4) Technology and Information Development and Integration; (5) Infrastructure/Partnership Design and Management; (6) Continuous Improvement & Innovation (7) Performance, Communication and Momentum Management; and (8) System and Policy Management. Technologies need to be developed and integrated as part of a total project system that ensures all the key elements required to achieve the outcomes are in place, inter-connected and functioning well (Clark et al. 2005a).
2. The quality of project design (as compared to 'planning') has a major impact on project effectiveness (AusAID 2001b). A well-designed project provides the basis for ongoing effectiveness, while the

difficulties created by poor design are often difficult to rectify. The '10,000 Times Rule' reminds us that if we do not invest sufficient time and skill in good design, it will result in up to 10,000 times greater cost to recover from the poor design (Anderson 1990). The same design rule applies to technologies developed within a project.

3. Technologies and outputs focussed on contributing to outcome achievement can be developed, improved, adapted, integrated and adopted throughout projects. This continual development and improvement of technologies can result in improved quality of technology, increased technology throughput and higher ROI.
4. End-users and others in the outcome achievement chain have significant roles to play as partners in the whole 'R&D for Outcomes' process. Everyone involved in the outcome achievement chain needs to have the capacity to fulfil their roles, and be engaged in ways that enable them to make effective contributions (De Boer et al. 1998; Miller and Morris 1999). Building a 'social infrastructure' of teams, partners and networks is essential for effective R&D (Susman and Evered 1978; Clark et al. 2005a).
5. The design and selection of effective channels and methods for engaging end-users and partners is crucial to achieving outcomes and high ROI. Figure 5 shows simple categories of channels and methods to engage target audiences. If project target outcomes cannot be achieved by 'awareness', 'understanding' and/or 'skills' alone it will require the active involvement of R&D partners (with a high proportion of end-users) in 'improvement' and/or 'innovation' partnerships (Figure 5). In the design and management of R&D for outcomes it is assumed that a mix of methods will be required, however the links between awareness, understanding and skills, and the achievement of real world outcomes have to be made, measured and managed — not just assumed.
6. Agricultural, rural and regional R&D projects take place within complex and dynamic (ever changing) systems. Projects need to be managed using continuous improvement principles and methods to ensure adaptation and improvement (Spedding 1988; Gieskes and ten Broeke 2000; Clark et al. 2005a).

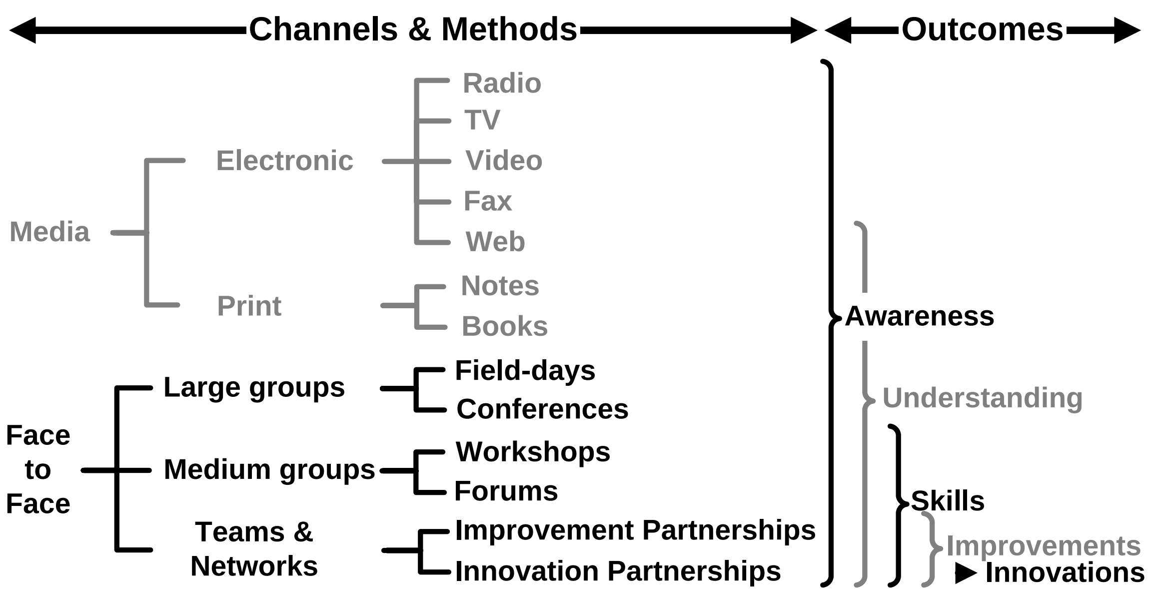

Figure 5. Categories of communication and/or engagement channels and methods to achieve different outcomes. 'Improvement Partnerships' achieve ongoing improvements, 'Innovation Partnerships' achieve ongoing innovations

Results from an 'R&D for Outcomes' approach

We have been involved in two major agricultural R&D projects that have been designed and managed to achieve outcomes at the business and regional industry level, and high ROI. Both projects also achieved continuous improvement and innovation of the project as a whole, and their sub-projects, and drew on insights from each other and other projects, as per the model in Figure 4.

- The Leyte Livestock Improvement Project (LLIP) in the Philippines. LLIP was a partnership project that ran from 2000 to 2004. The LLIP target outcomes were: "To enhance the wellbeing of smallholder families in western Leyte by increasing the capacity of farmers to continuously improve their pig and chicken production systems to achieve an average of 5% improvements in profit, environment and energy efficiency per year, and every year".
- The Beef Profit Partnerships (BPP) project in South Africa. The BPP project started in 2002 and finishes in 2006. BPP's target outcome is: "To achieve 5% improvement in profitability per annum for beef businesses in the Limpopo and North West Provinces".

We use examples from both projects to demonstrate the effectiveness of the model (Figure 4).

LLIP 'Pig Profit Improvement' sub-project in (PPI)

This sub-project was designed and managed to achieve impact on: (1) the level of profit of individual pig businesses; (2) the rate of improvement in business profit; and (3) the scale of improvement, i.e. the number of businesses in a region achieving the improvement. Similar approaches were applied in other LLIP sub-projects and in the BPP project.

PPI had the target outcome of achieving an average of 5 per cent improvements in gross margin within a purposefully created regional partnership called the 'Leyte Improvement and Innovation Network' (LIIN) (Toribio and Espinosa 2004). For the majority of farmers who participated in the PPI sub-project, the profitability of their pig enterprises increased over the duration of the project. Their understanding of the key elements of pig production and marketing systems, capacity to assess the relative merit of alternate management practices and technologies in relation to profit, and their ability to implement and monitor the effectiveness of a chosen action or technology on pig profit improved considerably over the course of the project (Clark et al. 2005b).

For farmers who had multiple production cycles during the project, 79 per cent of the weaner producers achieved an average increase in gross margin per weaner of equal to or greater than 5 per cent. Sixty-three percent of the porker producers achieved an average increase in gross margin per porker of equal to or greater than 5 per cent. As farmers viewed their pig enterprises as a source of household income, the increase in profitability achieved by many farmers made a valuable contribution to the economic position of their families. Farmer participants have developed a more critical and entrepreneurial approach to identifying and acting on opportunities to achieve an increase in pig profit, and are better able to work in partnership with researchers and technologists (Clark et al. 2005b).

Specific processes and tools used in the Pig Profit Improvement Sub-Project

From the outset of both the LLIP and the BPP projects it was critical to develop a shared understanding (shared mental model) of the outcomes to be achieved, the key concepts that underpin the outcomes, and shared processes and tools to achieve the outcomes. This shared understanding needed to be at the created at the project team, individual business and regional industry levels. To achieve this shared understanding, and to have an effective process to engage pig farmers as business managers, the Pig Profit Improvement Process (PPIP) was designed and improved throughout the project (Toribio and Espinosa 2004).

The process involves teams of farmers interested in improving the profitability of their pig enterprises working in partnership with specialists (researchers and technologists), service providers, other farmer teams and supply chain partners (such as butchers and restaurant owners). The 'Pig Profit Improvement Process' is based on a process of continuous improvement and innovation (Timms et al. 2005), which ensures that all partners in the outcome-achievement chain (including researchers and technologists) complete improvement and innovation cycles regularly and frequently throughout the project (Figure 4). This was integral to the development and integration of technologies to achieve outcomes throughout the project and increase the use and throughput of technologies.

The 'Pig Profit Improvement Process' has been developed into a resource kit that is being used by service providers and specialists in other localities. The key features of the process are shown in Table 1 (Toribio and Espinosa 2004). Tools were designed and developed to make each step of the PPIP effective and efficient. Each tool was developed as a prototype and trialled with a small number of farmers before being more widely used. The process and tools were also continually improved with feedback and assessments of value from users. The tools and the PPIP were designed and developed to be effective at the project, business and regional industry level.

Table 1. The steps and features of the 'Pig Profit Improvement Process' (PPIP)

Steps	Feature
1. Focusing Thinking & Action	Develop a shared understanding and mental models (through the use of tools and techniques) of the outcomes to be achieved, e.g. 5% improvement in profit/year, and the key concepts that underpin the outcomes
2. Business Systems Thinking & Analysis	Develop a shared understanding of the real world business system in which the outcomes are to be achieved, and the relative impact of the different elements of the system on profit
3. Key Performance Indicators	Identify the Key Performance Indicators (KPIs) of high impact action to improve profit, and existing and new technologies or concepts that have most impact on the KPIs
4. Measuring and Reporting Impact & Promoting Innovations & On-going Improvement	Measure and record the impact of management actions and technologies implemented; report for mutual support to partners and specialists.

In Step 1 of the PPIP (Table 1) the 'Profit Thinking Tool' (Figure 6) has proved highly effective in focussing thinking and action for impact on profit (users give it high scores for value). It is used to understand the generic components of profit and the changes required in these to increase profit. This tool has enabled project teams and regional livestock industry partners to work more efficiently together.

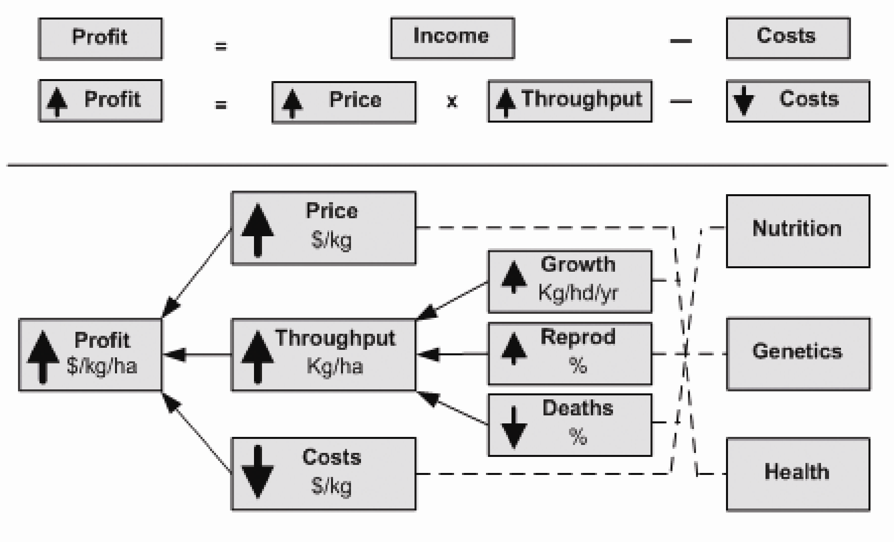

Figure 6. The Profit Thinking Tool based on the concept of Focusing Frameworks (Timms et al. 2005)

In Step 2 of the PPIP a 'Pig Profit System Mapping Tool' based on 'System Design and Analysis' (Timms et al. 2005) was used with gross margin/financial analysis to identify the components of the 'real world' business system that impact on profit. These tools were effective in achieving a shared understanding of opportunities for action that would have real impact on profit. This step of the PPIP is critical to overcoming many of the constraints to adoption listed by Guerin and Guerin (1994) and Vanclay (1992). Table 2 shows seven components of pig business systems that were identified to achieve impact on profit. Agreement by all R&D partners on the key focuses for action to achieve outcomes is critical to success.

Table 2. Seven components of the pig business system identified through the Pig Profit Improvement Process for action to impact on profit

Targeted system components	Opportunities according to type of pig enterprise	
	Sow/weaner	Porker
1. Business management	Business system analysis using the Pig Profit Improvement Processes and tools including gross-margin/financial analysis, and Continuous Improvement & Innovation tools	
2. Feed cost	Reduce feed cost	Reduce feed cost by corporate purchase of swine commercial feed and by feeding mix of swine commercial feed and other feedstuffs
3. Pig nutrition	Improve sow nutrition	Improve porker nutrition and management by feeding swine commercial feed only and by feeding swine commercial feed only and provision of vitamin supplement and de-wormer
4. Pig management	Improve sow management and piglet management	Improve porker management by provision of vitamin supplement plus de-wormer or mineral supplement or vaccination
5. Inter-farrowing interval	Reduce weaning-to-mating interval and farrowing-to-weaning interval	
6. Pig housing	Provide creep area and improve sow pen	Improve pig pen, e.g. pen area per pig, drainage
7. Pig and pork prices	Cooperative marketing and retailing and restaurant market establishment and promotion	

In Step 3 of the PPIP Key Performance Indicators (KPIs) of pig profit, and management actions, existing technologies and concepts for new technologies that would have most impact on these KPIs were identified. The KPIs can be used to eliminate from further consideration actions and technologies that, while perhaps being popular or interesting, would not make a significant contribution to improving profit. The project team developed a 'Profit Indicator Tool' and equipped farmers to use this tool in combination with other tools such as partial budgets and impact analysis tools. As a result of using the 'Profit Indicator Tool' participants identified a small number of key management actions and existing technologies they were confident would contribute to increasing profit. The tool can also be used to conceptualise new technologies that will contribute to increasing profit.

In Step 4 of the PPIP (Table 1) a number of shared tools were used to enable the regional industry to benefit from the results of the thinking and action done by businesses, local teams, project teams and the Leyte Improvement and Innovation Network (LIIN). Key tools in this context were easy-to-use 'recording sheets', and 'reporting and support' sessions and tools (Toribio and Espinosa 2004; Timms et al. 2005). Individual LIIN farmers and LIIN teams were enabled and supported to report and promote their results and methods at least every 180 days. Creative thinking tools were used to develop new opportunities and set targets to be achieved in the next 180 days.

Beef Profit Partnerships

This project targets improved profits for previously disadvantaged beef cattle farmers on resettled farms and Communal areas of Limpopo and North West provinces of South Africa. These farmers own 40 per cent of the breeding herds and yet they are the poorest of the poor, as shown in Table 3 below.

Table 3. The case study based on the herd size of 25 breeding cows

	Previously disadvantaged farmers*	**Established commercial farmers***	**Elite Farmers***
Average calving percentage	40	65	85
Pre-weaning mortality (%)	50	4	2
Post-weaning mortality (%)	15	2	2
Calves weaned per annum	5	16	21
Calves available for sale (after replacement)	2	16	20
Average weight (kg)	150	180	205
Price per kg (Rand)	R3.50	R8.00	R8.25
Potential monetary value (Rand)	R1 050	R21 600	R33 825
Potential monthly income (Rand)	R88	R1 800	R 2 818

* Broadly speaking, the term 'previously disadvantaged' farmers refers to black farmers, who were significantly disadvantaged under apartheid laws. These 'emerging farmers' businesses are also referred to as the 'Second Economy'. 'Established commercial' and 'elite' farmers of the 'First Economy' are mainly previously advantaged (white) farmers.

The project was designed to achieve outcomes from the onset, using the model shown in Figure 4. It included capacity building, which focussed on improving farmers' thinking by exposing them to the methodology of Continuous Improvement & Innovation and the tools to focus and adopt technologies that improve their livelihoods. The project was also designed to address the scientific gaps that contributed to devaluation of their animals in the marketplace.

BPP's design was based on the understanding of the formal beef commodity chain system and the challenges facing previously disadvantaged farmers. Beef profitability was improved significantly in this sector in the second year of the project by increasing access to new markets, better market and pricing information, and cost reduction initiatives. In addition, feedlot growth performance and meat quality studies helped improve perceptions of the quality of their native cattle breeds in terms of growth and meat traits, and gave access to the lucrative feedlot market. Their animals were also screened for availability of genes for meat quality. Improved prices resulted in more animals sold; now most farmers are focussed on improving herd throughput (Figure 6).

Income started to increase from the onset with a rapid improvement of price as a result of farmers' improved understanding the beef marketing system in South Africa (Table 4). There is a considerable improvement in other beef profit drivers like reproduction rate and survival (Figure 6); these improvements are designed to continue in a sustainable way throughout the project, and in the future.

Table 4. Achievements from the onset of BPP

	Previously disadvantaged farmers	BPP Initiative	Time-frame	Elite farmers
Average calving percentage	40	64.4	2005	85
Pre-weaning mortality (%)	50	3.8	2005	2
Post-weaning mortality (%)	15	5	2005	2
Calves weaned/annum	5	16	2004	21
Calves available for sale (after replacement)	2	6	2004	20
Average weight (kg)	150	120	—	205
Price/kg (Rand)	R3.50	R7.03	2003	R8.25
Potential monetary value (Rand)	R1 050	R5061.6	2005	R33 825
Potential monthly income (Rand)	R88	R421.8	2005	R 2 818

It was an explicit target of both LLIP and BPP that outcomes be achieved and sustained. In the design and management of the PPIP, partnerships were negotiated with clear roles across the outcome achievement chain. Capacity-building to achieve and sustain improvements and innovations was an integral part of the process.

The specific challenges for R&D agents in targeting and achieving outcomes are these:

1. Recognising that the production of outputs/technologies is not enough to achieve outcomes. Technologies have to be integrated with processes, tools and end-user feedback to achieve outcomes. Both technologists and end users need to take responsibility for achieving outcomes.
2. As well as achieving the target outcomes for which the technologies were employed, further improvement and innovations to technologies should be expected, created and achieved, using further thinking and adaptation from R&D agents and end users (see Figure 4). This thinking and action doesn't happen by chance; it requires rigorous design and management, for which managers are responsible.

Conclusions

In designing and managing R&D projects to achieve outcomes from the outset and high return on investment, it is useful to start with the simple fact that 'improvements' and 'innovations' have to be adopted by individual end-users, and a large number of industry end-users. The following factors are considered critical to success:

1. Ensure project participants and partners start with the outcomes in mind rather than starting with ideas about what technologies to develop or apply. That is, a culture of outcome-focussed technology rather than technology-driven activities.
2. Have regional boundaries for target outcomes so regional support systems and networks can be built to ensure that individual and industry end-users achieve adoption and target outcomes

3. Achieve shared understanding of specific 'real world' opportunities to achieve high impact in the short and medium term (as well as long term) on the target outcomes
4. Ensure that R&D outputs are integrated into a shared process, with tools and interactive feedback, specifically designed to achieve measurable impact on KPIs within 180-day periods. End-users need to be able to experience 'success' (outcomes) every 180 days in this type of R&D project. Integrating technologies into interactive processes facilitates the 'social embedding' of the technology into real world business systems. Regular feedback is essential to the successful development and use of technologies
5. Enable improvements and innovations to be reported on regularly (every 180 days) for feedback and support, and the promotion of proven improvements and innovations to large numbers of industry end-users and project partners to achieve high rates and scales of improvement (adoption)
6. Build the capacity of partners (including end users) to achieve high rates of improvement and innovation.

Investors in agricultural R&D often prefer apparently cheaper, mass communication methods for communicating about R&D outputs, e.g. the media-based or large group based methods in Figure 5. These methods may require less investment but they should be assessed in relation to whether they actually achieve the desired real world outcomes.

The challenge for people who aspire to design and lead outcome-focussed R&D projects is to create and maintain a project culture that values partnerships, outcome-focussed technology, performance measurement, and continuous improvement and innovation, and to bring together people who are motivated and wanting to be part of this type of project. They also need to find supporters and investors who appreciate and value these same things, and understand what is needed to achieve them.

We encourage others who aim to achieve sustained outcomes at project, business and regional industry levels in agricultural R&D to consider the approach to R&D design and management for achieving outcomes presented in this paper, including the model to achieve continuous improvement and innovation within and across projects and sub-projects.

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Glossary

We agree with Miller and Morris (1999) that to be able to work effectively you must have some language that allows you to effectively represent and discuss certain levels of thought. We think it is vital to have a ‘shared understanding’ of the following words/concepts.

Accelerated adoption — Increase in adoption rate per unit time, where adoption rate means the number of businesses implementing technologies and/or management practices and achieving the benefit/impact from these per unit time

Adoption — To decide to make use of a technology/strategy as the best course of action available to achieve an outcome.

Awareness — An initial, subjective state of being conscious of something

Capacity — People equipped with the necessary knowledge, skills, technologies, processes, tools, support and resources, and the capability to integrate them to achieve specific outcomes.

Commercialisation — Taking technologies or products into the marketplace, workplace and/or community.

Continuous Improvement & Innovation — Individuals in teams, networks and partnerships regularly and frequently focussing their thinking and action to achieve improvement and innovation, now and in the future.

Development — The incorporation of knowledge and relevant results from research into complete technology packages that are usable and of demonstrable value in achieving specific outcomes in the workplace, market place or community.

Design — To conceive and outline a set and sequence of elements and steps, and the relationships between these, which will achieve a specific targeted outcome.

Effectiveness — The degree to which specific target outcomes are achieved relative to the inputs invested.

$$\textbf{Effectiveness} = \frac{\textbf{Outcomes}}{\textbf{Outputs}}$$

Efficiency — The degree to which specific target outputs are produced relative to inputs invested.

$$\textbf{Efficiency} = \frac{\textbf{Outputs}}{\textbf{Inputs}}$$

Focus — A specific area and target outcomes on which to concentrate attention, thinking and action.

Gross margin — The difference between the gross income and the variable costs directly associated with a particular activity or enterprise. It excludes fixed or overhead costs.

Improvement — Enhanced practices, processes, systems, products, services, outputs and outcomes.

Innovation — New practices, processes, systems, products and services in use and of value in the marketplace, workplace and/or community.

Key Performance Indicators — The specific, agreed measures that are of most value in measuring and assessing performance.

Mental model — Implicit beliefs about how the world works, used to translate incoming information and filter it selectively to make sense of the world. Mental models differ between

	individuals and groups. Shared mental models are critical for effective group work; they must be developed collaboratively, checked regularly, and improved as necessary (Abel et al. 1998, Sterman 1994).
Methods	Orderly way of achieving outcomes to fulfil needs: involving principles, systems/processes/ practices, tools, inputs and Key Performance Indicators.
Network	A purposeful infrastructure of value-adding partnerships based on reciprocal transactions between partners to achieve agreed outcomes.
Outcome	The end result from converting inputs through systems, processes, products and services to fulfil a need.
Output	The interim results from converting inputs through systems, processes, products and services to fulfil a need, e.g. research outputs would include knowledge, information packages, publications, new technologies or techniques, policy analyses, databases, standards, benchmarks.
Partnership	Interdependent (business-like) relationships between people for a specific purpose involving clear rights, roles and responsibilities.
Performance	The level of achievement as measured against a specific criterion or indicator.
Planning	Scheduling resources to complete a task.
Process	A logical set and sequence of interconnected steps (with associated activities and tools) to achieve a specific outcome.
Product	Anything that can be offered to a market that might satisfy a want or a need. It is a complete bundle of attributes or benefits that buyers perceive they will obtain if they purchase the product.
R&D	Research and development. A tightly coupled process of research and development of new practices, processes, systems, products and/or services to achieve a specific outcome in the workplace, marketplace or community.
Research	A process of inquiry leading to new knowledge and/or technology.
ROI	Summary measure of value of returns versus value of costs incurred. Returns are calculated using the level of economic impact (gross margin) per business by the total number of businesses achieving each level of impact.
Scale	The number of people achieving target outcomes per unit time.
Service	Work for others where no transfer of goods is involved. A process that creates benefits by facilitating either a change in customers, a change in their physical possessions, or a change in their tangible assets.
Sustainable	Capable of being sustained. Being able to continue into the future. In terms of projects, the continued achievement of outcomes continues after the project finishes.

System	A set of interconnected, interacting, interrelated and interdependent elements that form a complex and unified whole that has a specific purpose. Every system contains a number of key processes.
Target	A set level of achievement to aim for.
Technology	Development and application of tools, machines, materials and processes that help to address needs and problems. A technology consists of two components: a ‘hardware’ aspect — the tools, materials or mechanisms that embody the technology, and a ‘software’ aspect — the information base or process in which the tool is embedded.
Technology throughput	Number of technologies or innovation developed and integrated into industry use per unit time (per year).
Tool	An instrument that makes achieving outcomes more effective and easier.
Understanding	The process of perceiving, comprehending and appreciating the nature, meaning and significance of something.

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