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Scoring Methods for Prioritizing and Selecting Innovation Projects

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***Abstract*--An approach for designing multi-factor scoring systems for evaluating and selecting early stage innovation projects is presented. A project is a piece of work of finite duration with finite resources, aimed at a defined outcome. Innovation projects have the extra complication that all of these aspects will be somewhat uncertain and knowledge of them is liable to change as the project proceeds. Clearly different assessment factors are required for different organizations, and for different types and stages of project. There is little guidance in the literature on how to choose the factors and how best to structure the scoring process. The approach is presented in the form of managerial guidelines, targeted at those who have to implement innovation project selection systems. Design aspects are discussed, including structure of the tool, choosing the factors, scaling statements, weightings, risk, uncertainty and confidence. Management aspects are considered, including preparation, scoring, decisions and outputs. The method is positioned in terms of theory and practice, with reference to both literature and industrial case studies. The paper concludes with a discussion of practical and theoretical contributions, and highlights areas that would benefit from further research.**

I. INTRODUCTION

Strategy and innovation require potential options (‘projects’) that an organization might pursue to be identified, assessed, prioritized and implemented. Collectively these activities fall under the banner of ‘portfolio management’ [4, 19], which seeks to *maximize the value* of the new product project portfolio, achieve a *balanced portfolio* of new product projects, and ensure *alignment with business strategy* [4].

Portfolio management activities are typically organized as part business processes, such as the annual strategy & budgeting cycle, and new product, service and system development and introduction. Such processes deploy a range of management tools and frameworks, ranging from scenario planning, roadmapping, valuation techniques and portfolio matrices, which need to be integrated and aligned with the business processes they support [8, 16, 19].

The business process context for project selection is shown in Fig. 1, with the innovation ‘funnel’ emphasizing the evaluation and selection of ideas in the early stages of the process leading towards a formal new product development (NPD), typically governed by a stage-gate process [4, 5, 21]. The way in which projects are evaluated depends on the type of project, and the stage within this process framework, shifting from more qualitative to quantitative approaches as projects progress. The focus here is on the earlier stages of technological innovation and new product development, where uncertainties are high and knowledge imperfect.

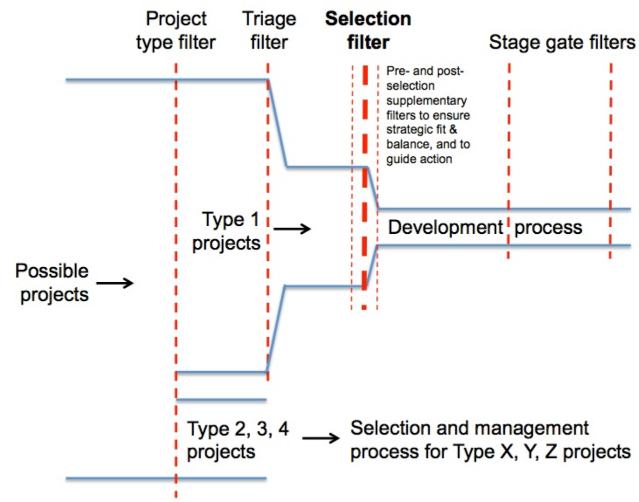

Fig. 1 – Business process context of project selection

Organizations can pursue many types of projects, ranging from small-scale product improvements to large-scale corporate acquisitions. Different appraisal and selection approaches are needed for different types of projects, and for distinguishing between them. Thus, the first filter shown in Fig. 1 is concerned with separating projects into different types, which may require different management approaches – for example, incremental vs. radical innovation, small vs. large projects, technology vs. project innovations. This is emphasized by the separation of technology and product development processes by Cooper [5] - see Fig. 2, aiming to de-risk technology before product development.

A range of methods can be used to distinguish between different types of projects – for example the top-down ‘strategic buckets’ approach [5], where the business strategy drives the portfolio. Here senior management allocate resources in accordance with some high level view of priorities – for example how investments should be spread between different customer segments or capabilities. Many ‘2x2 matrix’ management matrices can be used to distinguish between different types of projects – for example the Ansoff matrix that separates incremental from radical market and technology innovations [2].

If there are many options to choose from, the second filter shown in Fig. 1 is intended as an efficient ‘triage’, to reduce a long list of potential projects to a shorter more manageable one, for closer scrutiny. The triage filter is a lighter version of the subsequent selection filter, which is the focus of this paper. It is assumed that projects that pass through the main filter can progress into a managed new product development or similar process, such as those described by Cooper (2001), and implemented in many firms.

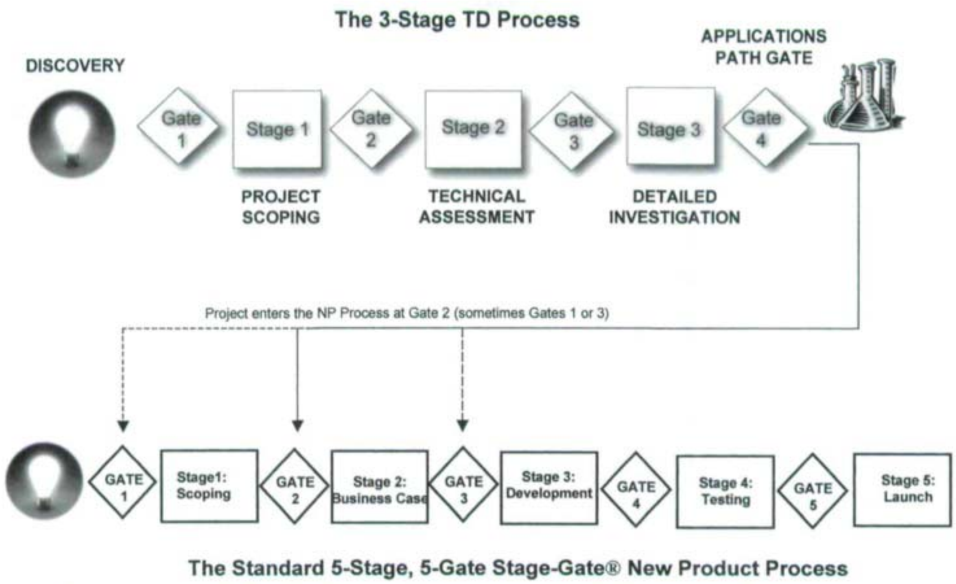

Fig. 2 – Technology and product development stage-gate process [5]

The primary selection filter considers each project in its own right, leading to a ranked list of prioritized projects. However, other aspects may need to be considered also – for example, the balance of the portfolio in terms of time to market, competence, market, and risk. Again, a range of 2x2 matrix tools can be used to assist with this. Such tools can also provide strategic advice for the projects being considered – such as whether to manufacture in-house or to outsource (the make-or-buy decision [18]). More than 850 '2x2 type matrix tools have been identified and explored by Phaal *et al.* [15], with approximately 40 designated as business and technology portfolio matrices.

In addition to project selection and portfolio tools, many other management frameworks and tools are used to support strategy and innovation, and it is important to understand how they relate to each other as part of an integrated toolset [12]. Roadmaps can play a key role in such toolkits, with their holistic and flexible structure providing a 'platform' for tool integration [1, 16].

The relationship between portfolio methods and roadmapping is illustrated in Fig. 3, with the portfolio selection filter linking roadmapping at two levels: portfolio (e.g. business or program) and option (e.g. project or innovation) levels. The portfolio roadmap helps to show how various projects and options relate to each other, supporting alignment, while the option roadmap provides more granular detail of how the components of the project (e.g. product and technology) strategy relate to each other, supporting alignment. The selection and portfolio matrix filter helps to prioritise which projects and options to choose and map in the portfolio roadmap, while the project roadmap helps to 'unpack' the projects depicted on the portfolio matrix, to understand them better, and to position them with more confidence on the portfolio matrix.

This paper focuses on specific techniques used to differentiate and select which innovation projects to pursue during the early stages of the new product development process, as part of the product and technology portfolio process. However, the principles are anticipated to be applicable to other similar processes, appropriately adapted. Management guidelines have been produced, introduced in Section II and presented in Sections III and IV. The paper concludes with some reflections on theoretical and practical aspects of the approach, and highlights areas that would benefit from future research.

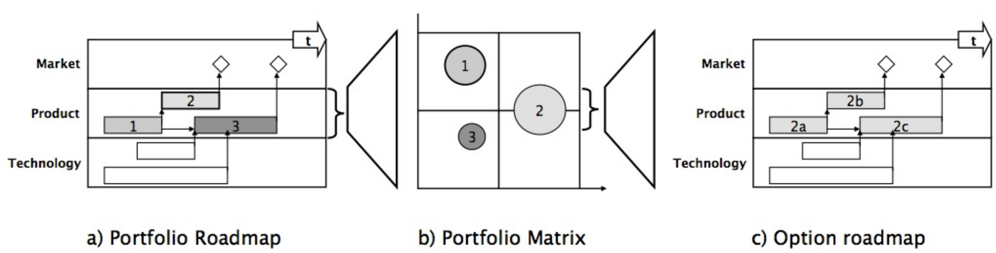

Fig. 3 – Relationship between portfolio matrix and roadmaps

II. INTRODUCTION TO MANAGEMENT GUIDELINES FOR PROJECT SELECTION

This paper concerns ways of valuing and selecting innovation projects. A project is a piece of work of finite duration with finite resources, aimed at defined outcome. Innovation projects have the extra complication that all of these aspects will be somewhat uncertain and knowledge of them is liable to change as the project proceeds.

In an ideal world one would select projects by calculating the benefit to be expected and the investment required for each one; and then deciding between them on the basis of which promises the best Return on Investment ratio (ROI). However, in the early stages financial information is usually incomplete or unreliable – or more likely, both. This fact is well attested by research: in a wide-ranging study, Robert Cooper and co-workers [6] found that of all the possible ways of selecting projects, practicing managers had the least faith in purely financial projections, even though they were the most frequently used.

A common approach is just to rely on intuition, which after all is the way the human mind deals with everyday decisions involving uncertain information. Intuition can be wonderfully effective if it has been developed through confronting many examples of the problem in hand – as is the case for doctors and art historians. But researchers such as Kahneman, Tversky and others [11, 20] have shown that in less familiar circumstances - and innovation projects must surely be so - our intuition can be surprisingly easily misled. It is important to supplement it with as much logical structure as possible.

The limitations of financial projections and distrust of unfettered intuition has led companies to look for more robust approaches in which financial data is augmented in a structured way by information on the other factors known to be pointers to success. For example, for a new product introduction project answers to such questions such as: is the market growing or declining? what is the level of competition? is the proposed product well-differentiated from others?, can give very clear pointers to the likely success of the project. There is also the important argument that these measures will be at least somewhat uncorrelated with each other so that a collection of several uncertain indicators ought to be more reliable than a single measure.

Clearly there cannot be one set of factors suitable for all circumstances. Those for selecting early-stage technology projects are bound to be different from those for choosing new sales outlets; and there will be differences between companies. What is sought here is a logically consistent way of building a scoring tool for a particular purpose and allowing it to evolve coherently if need be as projects move toward maturity - always remembering, of course, that formal financial methods must become increasingly prominent as more data becomes available.

Scoring tools have two purposes that should be considered separately. The first to make the best possible *estimate* of how attractive the various possible projects are; the second is to make *decisions* about what actions to take.

The list of relevant factors may have considerable value simply as a check to guide the review process, ensuring that nothing is left out and nothing over-emphasized. However the decision to start or stop a project is never a trivial matter and often involves a commitment of significant resources, so it is worth taking some trouble to get it right. A first step is to allocate a score against each factor and so arrive at an overall rating for each project, giving a clearer sense of priorities.

A scoring tool used by DuPont for prioritizing new product developments is shown in Table 1 (Cooper, 2001). Scores are allocated against each of seven factors, using the 'scaling' (also called 'anchoring') statements in the boxes as guidance, and the results are added to give an overall score for the project. DuPont's approach was to start with the conventional financial measures, NPV and Time to Break Even and augment them with broader considerations.

The guidelines presented in this paper are the result of several years of research, discussion and practice. While portfolio methods and matrices are widely used – the ubiquitous 2x2, there are many variants and examples, good and bad [15]. More than 40 examples of business and technology portfolio matrices were examined, with the majority (about 60%) shown to be instances of a generic form designed to support the prioritization and selection of opportunities and projects to pursue [17]. This generalized form relates the scale of the opportunity to the feasibility of obtaining it. Other forms support portfolio balancing and provide strategic advice – such as the well-known AD Little risk-reward matrix [6] and Boston Consulting Group (BCG) business activities portfolio matrix [10].

TABLE 1 – PROJECT SCORING TOOL USED BY DUPONT [7]

Rating scale	**10**	**3**	**1**
Factor			
Strategic alignment	Fits Strategy	Supports	Neutral
Value differentiation	Significant differentiation	Moderate	Slight
Competitive advantage	Strong	Moderate	Slight
Market attractiveness	Highly profitable	Moderately profitable	Low profitability
Fit to supply existing chain	Fits current channels	Some change, not significant	Significant change
Time to break even	<4 years	4-6 years	>6 years
NPV	>$20m	$5-20m	<$5m

Building on this prior research, a scoring method for prioritizing and selecting innovation projects has been developed. Masters and PhD research has helped to identify factors suitable for establishing selection criteria [3, 9]. Two sets of industry engagements provided the opportunity to develop and test the method:

- An academic-industry consortium for research, networking and sharing of best practice across industry sectors: www.ifm.eng.cam.ac.uk/research/ctm/stim.
- A program for SMEs and start-ups in the East of England, funded by the European Regional development fund: www.ifm.eng.cam.ac.uk/services/prisms.

The main part of the paper, Section II, sets out the guidance note resulting from the above industrial engagements, divided into two parts:

1. Designing a customized scoring tool: structuring the tool, choosing the factors, developing scaling statements and weightings, treatment of risk, uncertainty and confidence, and other considerations.
2. Managing the scoring process: preparation, scoring the projects (estimation stage), the decision stage, and outputs from the process.

III. DESIGNING A CUSTOMIZED SCORING TOOL

Checklists and scoring tools always have to be customized for the job in hand so before proceeding further it is important to define carefully the kind of project to which the tool will apply. In a later section the way in which the factors and weightings may change as projects mature is discussed.

When designing a scoring tool for a particular purpose, one faces a number of issues:

1. Structure. Is a single list appropriate, and should the factor scores be added rather than multiplied?
2. Factors. How many factors are needed and how should they be chosen?
3. Scaling statements. How many are appropriate, and how should they be designed?
4. Weightings. Should the factors all count the same or is there a case for giving a higher emphasis to some – for example by applying weighting factors. If so, how should the weightings be chosen? The DuPont tool uses a non-linear scale. What is the justification for this and how non-linear should it be?
5. Risk. Is it possible - or worthwhile – to accommodate risk and uncertainty in the process?

Some decisions can only be made when considering the *set* of possible projects, not just a single one. For example, in addition to selecting projects that are favorable in themselves one may seek a balance in terms of novelty, time to delivery or market segments, as discussed in Section I.

A. Structure of the tool

Adding the scores from different factors implies that a high level of one can compensate for a low level of another. Clearly this is not always so. A fundamentally uninteresting opportunity is not improved by being easy to do; and the size of the opportunity is irrelevant if it requires competences that the organization does not have. Factors describing the size of the opportunity presented by the project need separate consideration from those that describe the competence of the organization to address it. Thus there are two roughly separate, or orthogonal, considerations, and a separate set of factors is required for each:

- Opportunity: The magnitude of opportunity plausibly available to this organization.
- Feasibility: How well prepared the organization is to grasp the opportunity.

The same distinction is implicit in many appraisal tools such as McKinsey's Market Attractiveness/Business Strength; A.D. Little's Risk/Reward; and the familiar SWOT analysis (Opportunities-Threats and Strengths-Weaknesses). Opportunity is a measure of the value that may result from the project, while the Feasibility (or strictly its inverse, Difficulty) assesses the investment that may be required to bring it to fruition. Thus the product of the two scores Opportunity x Feasibility is a rough indication of potential Value / Investment, or ROI.

B. Choosing the factors

In choosing the factors it is helpful to start by clarifying the generic ways, or *Dimensions* by which the projects under consideration might add value to the organization, or which might affect feasibility. This helps to ensure that the factors chosen for Opportunity and Feasibility are balanced, and cover the full scope appropriate for the task. Examples suitable for projects designed to lead to a defined commercial outcome are given below, but each application must be considered separately.

- **Opportunity**
  - Volume
  - Profitability
  - Platform for future benefits
  - Intangibles
- **Feasibility**
  - The Deliverable
  - Skills and knowledge
  - Facilities and processes
  - Organizational backing

Once the generic Dimensions for the type of project have been established the next step is to select a small group of Factors to represent each of them. These should be as precise and objective as possible and their numbers should broadly reflect the relative importance of the dimensions. Tables 2 and 3 provide examples of factors for Opportunity and for Feasibility from the literature and from practical experience. These may be used as a starting point but it is vital to consider carefully which are appropriate and to alter them or add others as necessary. The lists provided are focused on product-related projects and may need considerable adaptation for other cases.

Ideally one should aim for a relatively large number of factors in total so that the uncertainties tend to cancel out. However the more there are, the less attention will be given to each one. Five to ten for each list seems about right, but within reason, more is better.

C. Scaling statements

The scaling statements should be as clear and objective as possible. There are two reasons for this. The first is that scoring is best done by a group of people who pool their views, and they need to have a shared understanding of what each statement means. In the DuPont case, for example, two people may have similar views on the competitive position of the product but one would describe it as Slight and the other Moderate simply because their perspectives are different and the terms are not precise.

The second and more important reason is that the scaling statements actually define what the factors mean and how important they are. Considering the DuPont tool again, a ‘Moderately profitable’ market scores the same as ‘Some change, not significant’ to the supply chain. This implies that they are equally important for the success of the project, but it is not clear why this should be so. More precise definition of the scaling statements can ensure that equivalent scores for different factors mean the same in terms of impact on the project. In fact good scaling statements are the key to a coherent scoring tool.

For some factors the equivalence can be arranged fairly straightforwardly. For example Sales, Increased Gross margin and Product Cost reduction are frequently used factors for Opportunity and are all measures of potential cash generation. Extra sales of X units generate cash of X*G where G is the typical fractional gross margin; a fractional margin improvement, or product cost reduction of Y generates cash of S*Y where S is expected sales volume. Clearly, equivalent scaling statements can easily be designed for these three factors.

In the general case a more subjective approach is required. The best approach here seems to be to start with one factor, the *Base* factor, for which fairly clear and objective scaling statements can be designed. Then choose the midpoint, or *Pivot* statement which would indicate an unexceptional but

TABLE 2 – SUGGESTED FACTORS FOR OPPORTUNITY

Dimension	Factor	Explanation
Volume	Market size	Size of potential market, or number of potential adoptions, reasonably available to us
	Our sales potential in a given time	Sales volume or number of adoptions anticipated in a defined time (say, 5 years)
	Synergy opportunities	Possible additional benefits to other projects or activities; or the possibility of new opportunities in combination
	Customer benefit	Identifiable benefit to customers (internal or external) or potential adopters
	Competitive intensity in market	Number or significance of the competition
Margin	Increased margin, or benefit per unit	Improvement in product margin (e.g. by cost reduction or price premium) compared to existing products; or benefit to us per adoptions
	Business cost reduction or simplification	Contributes towards cost reduction or simplification of business process
	Industry / market readiness	How easy will it be for customers or adopters to take up the product; do they have to change their behaviour or processes?
Platform for future growth	Market growth	Anticipated growth rate of market
	Future potential	Product is a platform for future products or could open new markets beyond the project timeframe
Intangibles	Learning potential	Will improve the knowledge or competence of the business
	Brand image	Will improve the image of the company with investors, customers or other stakeholders
	Customer relations	Project is important for retaining key customers

TABLE 3 – SUGGESTED FACTORS FOR FEASIBILITY

Dimension	Factor	Explanation
Characteristics of the product	Product differentiation	How well the product is differentiated from those of major competitors
	Sustainability of competitive advantage	Our ability to sustain our competitive position (e.g. IPR, brand strength)
	Technical challenge	How confident are we that the proposed product is technically feasible at all?
Skills and knowledge	Market knowledge	Our understanding of size and requirements of the market
	Technical capability	Do we have the required technical competences to complete the project?
Business processes	Fit to sales and/or distribution	Fit to our sales competences and/or distribution chain
	Fit to manufacturing and/or supply chain	Ability to manufacture or supply the product
	Finance	Availability of finance for the project
Organisational backing	Strategic fit	How well does the project fit our company strategy?
	Organisational backing	Level of staff or management backing at an appropriate level

worthwhile project – an ordinary, or 'Bread and Butter' opportunity. Next, choose scaling statements for the two outer levels and for two intermediate points, making 5 in all. It is important not to make the outer statements too extreme because this will reduce the range available for the majority of projects, making it difficult to distinguish between them. They should represent conditions that might be met occasionally, not impossibilities. If, in unusual cases, scorers need to rank projects outside these limits they can be allowed to give scores outside the suggested 0 – 12 range.

Once the statements for the base factor have been defined, the others are chosen by reference to it. Imagine two projects, one described only by the base factor and one described only by a second factor. Then for each scaling statement of the base factor, choose one for the second factor that is equivalent; that is to say, is at a level that would make it difficult to decide between the two projects. This may not be an easy task but it is important to do ones best. This matching should be possible for most of the statements but it may be that some factors could never deliver as much benefit as others. For these the upper scaling statement(s) may just be left blank. If it seems very difficult to define the levels of any factor this may be an indication that it is not a good choice and it would be better to choose something else. Three scaling statements is a minimum; 5 can give more precision. A scale of 0 to 12 is recommended, which allows for integer values for each statement: 0, 3, 6, 9, 12. Tables 4 and 5 offer examples of scaling statements for our proposed Opportunity and Feasibility factors. These may be helpful for reference it is emphasized that scaling statements must always be customised for the job.

D. Weightings

Many authors propose that the factors in a scoring tool should be allocated different weightings to reflect their relative importance. Clearly, this makes sense only in relation to some assumed scale for each factor, so why should the scales not be chosen to be equivalent, as described above? This makes separate weighting unnecessary. The exception is perhaps when financial factors are included, such as Time to Break Even and NPV in the DuPont tool. These are summary measures and it is arguable that they should be accorded steadily greater (and eventually, unique) weighting as projects mature.

It is also sometimes proposed (for example in the DuPont tool cited above) that a non-linear weighting should be applied to all scores, giving extra emphasis to high levels. It is not clear how such weighting should be chosen, and, again, it seems that careful choice of scaling statements should make this complication unnecessary.

E. Risk, uncertainty and confidence

The level of risk implicit in a project must obviously be included in the decision process but the treatment is difficult and controversial. The underlying problem is that the definitions used are often too imprecise – 'Technical Risk', 'Commercial Risk' for example. Such broad statements conceal two separate (though possibly linked) considerations:

1. The range of uncertainty in one or more of the outcomes.
2. The possibility of some undesirable result, such as an outright technical failure, personal injury or damage to the brand image.

TABLE 4 – EXAMPLES OF SCALING STATEMENTS FOR OPPORTUNITY

	Scaling statements				
Factor Score	**0**	**3**	**6**	**9**	**12**
Market size	< 5,000 units	25,000 units	50,000 units	100,000 units	200,000 units
Our sales potential In a given time	> 1,000 units in 5 years (gross margin £300k)	3000 units in 5 years (Gross margin £1M)	10,000 units in 5 years (Gross margin £3M)	20,000 units in 5 years (Gross margin £6M)	50,000 units in 5 years (Gross margin £15M)
Synergy opportunities	None	Little	Will help to complete product portfolio	Important	A key part of a major initiative
Customer benefit	No obvious benefit to customers.	Some benefit to some customers	Clear customer benefits within existing norms; work visiting existing customers to promote	A significant advance in more than one key feature of interest to customers	Eye-catching new benefits; a talking point at shows; entry to competitor accounts
Competitive intensity in market	4 or more strong competitors	2 strong competitors	Usual competition; or 1 strong competitor	We will be alone in the market	
Increased margin, or benefit per unit	Benefit worth <£300k	Benefit worth £1M	Benefit worth £3M	Benefit worth £6M	Benefit worth £15M
Business cost reduction or simplification	<£300k	£1M	£3M	£6M	£15M
Industry / market readiness	No expressed demand OR requires major change of customer behavior	Some customers have asked for this but requires some change in customer behavior	Definitely attractive to most customers; no change to customer behavior required	There is pent up demand for this	
Market growth	Stagnant market	<5% per year	5-10% per year	20%a year	>50% per year
Future potential	Update of an existing product	May lead to further variants of applications	Will definitely lead to further product variants or applications	Could lead to a new product line or several applications	This is the beginning of a major new business OR many further applications are foreseen
Learning potential	None	Useful learning	Corrects one or more core competences where we are currently weak	Class leading learning in competences vital for 50% of future business	
Brand Image	No impact	Little impact	Will help retain the image of our company	Would expect favorable press comment; special feature in annual report	
Customer relations	Existing customers may be worried about this	No impact	This will help retain key customers	Failure to do this could endanger business from an important customer	Project is vital to retaining customers for 25% of the business

TABLE 5 – EXAMPLES OF SCALING STATEMENTS FOR FEASIBILITY

Factor Score	**Scaling statements**				
	0	**3**	**6**	**9**	**12**
Product differentiation	No features that are better than competition	At least one feature is better than offered by the competition	We have some minor features that are better than the competition	At least one important feature is significantly better than the competition	Several important features are s much better than competition
Sustainability of competitive advantage	Key differentiating features will be easy to copy. Or serious concerns about IP against us	We are 6-12 months ahead of the competition. No serious IPR concerns.	Competitive advantage can be maintained with continuous effort	We are at least 2 years ahead of the competition	Key features are protected by IPR or unique capabilities that are not easy to copy
Technical challenge	Key features not yet demonstrated by us or others. Or >3x change in a important parameter	Step change in at least 1 important parameter. OR some key features not demonstrated but we're confident they can be	Key features have been demonstrated in prototype, but others remain	All features have been demonstrated in prototype	
Market knowledge	Market size not supported by data and requirements not yet checked with customers	Market estimated within a factor of 2 or 3 with some data support	Enough data to size the market to +/-50% and requirements are supported by discussions with sales force	Market size known to +/-20% and customer view established by formal survey	
Technical capability	We will have to buy in new major capabilities, OR recruit a new technical team, OR rely on a partner.	We lack some important capabilities and a plan is needed to acquire them.	Existing staff can acquire capabilities in 3 months or less, or by recruiting one or two new people.	Some new skills required but they can be acquired in time.	Well within our capability. No new skills or knowledge required
Fit to sales and/or distribution	Entirely new distribution channel required. OR requires new sales skills that at least half the sales force will struggle with.	Changes to sales or distribution will need special attention	>75% of sales force could sell it with training or >75% of existing distribution applicable	Some changes to sales or distribution but within our capabilities in the time	Well within competence of existing sales and distribution
Fit to manufacturing/ supply chain	New production technology required or major change of supply chain	Adaptation of manufacturing process or change to supply chain that will require special attention	Changes required but within our capability in the time	Minor changes to manufacturing or supply chain well within usual expectations	
Finance	Extra funding will be required and possible source not yet identified	Outside budget but justifiable	Within budget	Well within budget or some external funding available	External funding available for the entire project
Strategic fit	Project is clearly outside our strategic intent and fits no product vision	Some doubt about how this fits into existing strategies	Fits strategic intent and a specific product vision	Fits strategic intent at a high level of ambition and meets more than one specific product vision	
Organizational backing	There is opposition from several stakeholders.	We have some persuading to do.	We do not anticipate trouble gaining support for this	Strong support from all important stakeholders	

Decision theory [13] makes a clear distinction between risk and uncertainty. The term *risk* is used when probabilities of the various possible outcomes are known, either *a priori*, as for most card games, or from objective data, as would be the case for health risks for exposure to toxic chemicals. *Uncertainty* is used where no such objective probability data is available. Clearly, innovation projects, being unique, fall into this category, as there is always a level of subjective judgment about what outcomes are possible and how likely they are.

By identifying all possible outcomes and assigning confidence levels to them one can in principle obtain probability distributions of the Opportunity and Feasibility for any project. It is tempting to take the average (or *expectation value*) as a figure of merit but this is misleading. An average is a good measure only for the outcome of a large number of trials, such that outcomes at one end of the distribution will eventually be balanced out by outcomes from the other end. For individual projects or small portfolios this does not apply and the best approach [14] is to select the most reasonable upper and lower extremes – the plausibly best and worst case values, or *confidence limits* – as measures. This retains very important information that would otherwise be lost.

The range of uncertainty is very likely to change as a project progresses – indeed reducing uncertainty is a core reason for most research and pre-development projects. Therefore the outcome of the decision-making process should be not only the selection decisions with statements of the key assumptions, but also with a list of issues to be addressed by the next decision point.

F. Other considerations

Managers may decide that, regardless of any other consideration, particular projects should be rejected if they do not meet certain threshold levels on certain criteria: for example if they do not adequately fit the supply chain or if payback time is too long. Such 'Show stopper' thresholds can be noted in the tool. Equally, certain categories of projects may be given overriding importance and so might bypass the decision process altogether. Projects to deal with legal, health and safety or acute competitive issues might be examples. The process for developing a scoring tool is summarized in Fig. 4.

The process of designing a scoring tool should draw on the knowledge of a group of experts rather than relying on a single person. Steps 2 and 3 should first be done individually for reasons outlined in the next section. Participants may wish to propose extra factors appropriate to the task in hand. They should then meet as a team to review their inputs and complete the design. The same team should review the tool occasionally in the light of experience.

IV. MANAGING THE SCORING PROCESS

The overall project scoring process is shown in Fig. 5, and summarized below.

A. Preparation

Step 1. Project briefs

Multi-factor scoring is used when there is inadequate information for a more analytic approach. Nevertheless it is obviously important to make use of all the knowledge that is available so the first step is to assemble as complete a description as possible of each project including all the relevant factual information. These descriptions should be as objective as possible so it is a good idea for each one to be reviewed by at least one additional person. The whole process is only as good as the information on which it is based.

Step 2. Review projects for compatibility

Remove any projects that do not fall within the definition adopted for the scoring tool. Also reject any that are regarded as essential for whatever reason and so outside the decision process.

Step 3. Choose the scoring team

In using a scoring system there is great value in tapping into the different experiences and intuitions of several people so that as large a range of relevant knowledge and experience as possible is brought to bear. Certainly there are pitfalls in relying too heavily on a small number of experts who may feel commitments to certain projects. Of course all those chosen must be knowledgeable enough to make a valid input.

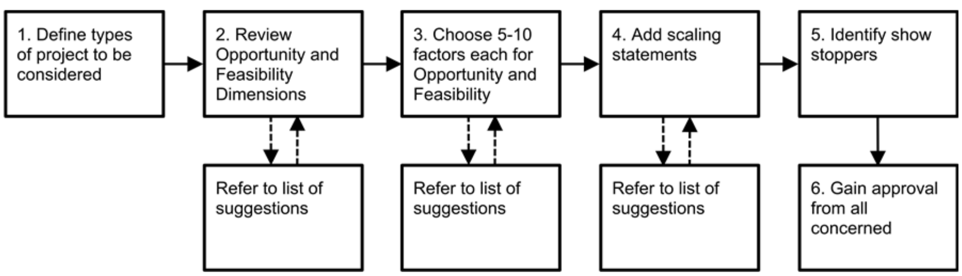

Fig. 4 – Process for designing a customised scoring tool

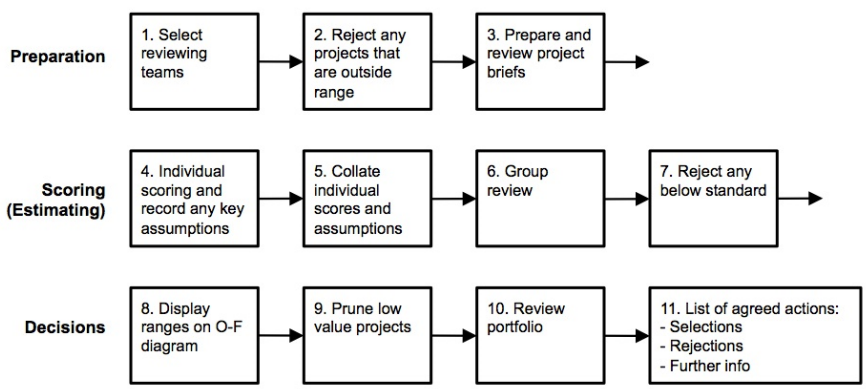

Fig. 5 – Summary of the scoring process

B. Scoring the projects (the estimation stage)

If there is a large number of projects on the table (the second or Triage, filter in Fig. 1) one can make a quick assessment by assigning a 'best guess' score each one, simply using the lists of Factors for reference, and then rejecting any obviously poor candidates. However it is worthwhile to hold on to some of the 'least bad' candidates for re-consideration later in case too many projects are rejected by the full process;

Step 1. Individual scoring

This is a very important activity and participants must be able and willing to allocate time and care to it. Each participant should be given the briefing papers and time to study them. It is important that individual team members should first form their own opinions and record their ratings before holding a group discussion. There are two reasons for this. The first is simply to give people time to think and if necessary look up relevant facts. The second is that any group may readily be biased by assertive or talkative individuals or even (an uncomfortable but well-attested fact) simply by the first to speak. So it is best if everyone has time to formulate their thoughts beforehand.

Team members should choose upper and lower scores for each factor, using non-integer values if they wish, and for each project. If the tool has been well defined all scores will lie between 0 and 12. However scores above 12 or below zero may be used if it seems right. Truth is better than conformity. Any key assumptions should also be recorded.

Step 2. Group discussion

The participants should then meet in a small group or workshop to discuss and review their scores and assumptions, factor by factor so as to arrive at agreed upper and lower values for each factor and for the project as a whole.

There can be up to four outputs per project from this process:

1. Agreed plausible best case and worst case scores for O and F.
2. A note of any project that is likely to violate one of the Show Stopper conditions and so to be a candidate for immediate rejection.
3. A list of the key assumptions made.
4. A note of any factor for which either the range of scores is particularly wide indicating that more information should be gathered.

C. The decision stage

Each project is now defined by two scores. The product of these can simply be used as a figure of merit, being a rough proxy for ROI. However, better use can be made of the information by using the Opportunity-Feasibility grid shown in Fig. 6. Each project is represented by its best case (highest O, highest F) and worst case (lowest O, lowest F) scores.

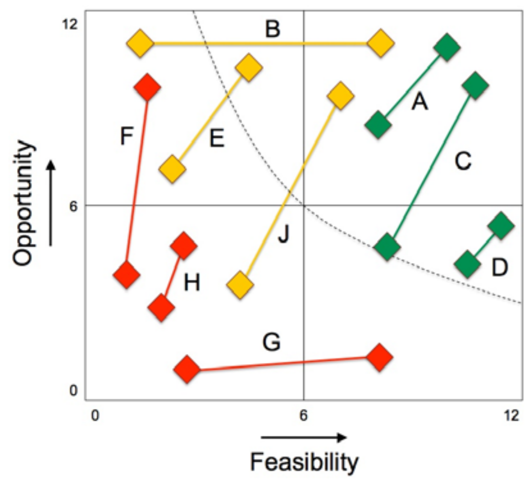

Fig. 6 – Types of project on an Opportunity-Feasibility diagram

The curve shown dotted is the locus of the product of Opportunity multiplied by Feasibility is a constant that passes through the midpoint of the diagram where O=6 and F=6. (So O x F= 36). If the scaling statements have been well chosen this curve separates the diagram into two regions representing, roughly, projects whose return on investment is acceptable or unacceptable. Those falling entirely below the line will generally be rejected and those entirely above the line will be candidates for acceptance. The projects that scan the line may need further investigation. Where the key uncertainties lie may be seen from the details of the scoring.

If a further distinction between projects is required, the upper and lower scores may be combined to give a single figure of merit by which projects may be ranked, depending on how aggressive a portfolio is required. For example, if the primary motivation is to avoid missing any good opportunities, projects may be ranked simply according to their upper scores. This is the so-called Maximax solution, maximising the upside potential of the portfolio. Alternatively, ranking by the minimum score minimises the downside risk of the portfolio. This would be the Minimax solution.

Between these extremes is a range of possible selections obtained by combining the upper and lower scores with different weightings. For example a somewhat aggressive portfolio may be obtained by ranking the projects according to their values of:

$$(\text{Lower score} + 3*\text{Upper score})/4$$

While scoring for a conservative portfolio would be:

$$(\text{Upper score} + 3*\text{Lower score})/4$$

However, managers may choose factors other than 2 if a more or less aggressive stance is a required. Typical results are shown in Table 6.

TABLE 6 – COMBINING SCORES TO GIVE AGGRESSIVE AND CONSERVATIVE PORTFOLIO RANKINGS

Project	Lower score L	Upper score U	Conservative scoring (3*L+U)/4	Aggressive scoring (L+3*U)/4	Conservative portfolio rank	Aggressive portfolio rank
1	90	100	93	97	1	5
2	45	130	66	109	5	1
3	60	110	73	98	3	4
4	80	105	86	99	2	3
5	35	50	39	46	7	7
6	35	125	58	103	6	2
7	65	85	70	80	4	6

After an initial selection has been made it may be helpful to display the resulting portfolio using just the average values for the projects. The shape or colour of the icons for each project can then be used to add extra information: for example the size may represent the proposed investment in the next phase and the colour may be used to show how close the project is to fruition or some other characteristic. This allows further review of the balance of timing, resourcing etc, and may suggest adjustments. An example is shown in Fig. 7.

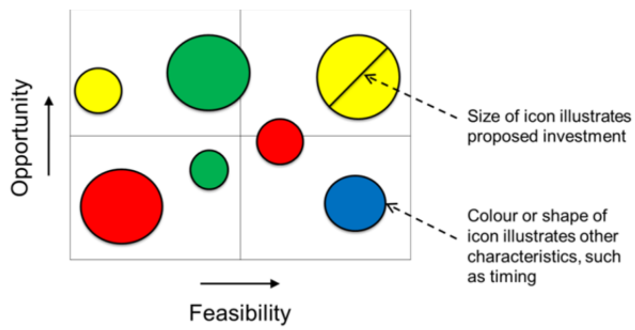

Fig. 7 – Portfolio illustrated on Opportunity-Feasibility diagram

D. Outputs

The first review of a group of projects is unlikely to result in completely clear-cut choices. Some clear decisions may be made but there may still be a need for further work the process is likely to show up cases where further information is needed before a to clarify uncertainties. In fact all projects for which a scoring tool is appropriate will be in their comparatively early stages, so even for those projects where confidence is high an acceptance is likely only to mean permission to proceed to the next stage of investigation. Therefore, apart from clear rejections, the key outputs of the scoring process will always be lists of actions to be taken to address risks and further reduce uncertainty in each project. Techniques such as roadmapping can be used to explore interesting project opportunities in more detail, as shown in Fig. 3. Workshop approaches are particularly useful for stimulating cross-functional dialogue necessary for successful innovation – see Fig. 8.

V. APPLICATION

The approach presented in this paper builds several years of research and application, including many industrial engagements [16, 17], together with Masters and PhD research to identify factors suitable for establishing selection criteria [3, 9]. Two specific sets of industry engagements provided the opportunity to develop and test the guidance:

- An academic-industry consortium for research, networking and sharing of best practice across industry sectors: www.ifm.eng.cam.ac.uk/research/ctm/stim-2013.
- A program for SMEs and start-ups in the east of England, funded by the European regional development fund: www.ifm.eng.cam.ac.uk/services/prisms.

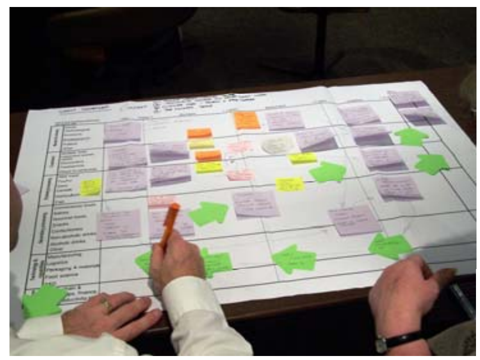

Fig. 8 – Workshop approach for exploring a project opportunity using roadmapping technique

A. Selection criteria

The selection criteria in Tables 2-3 have been tested in six case studies over a period of six months, as summarized in Table 7. The case studies were part of innovation and strategy innovation workshops, typically of up to one day in duration. Most company case studies were small (less than 50 employees), including very small early technology ventures (1-4 employees), but with one large company included for comparison (>25,000 employees).

The selection factors chosen by companies as being of most importance are shown in Fig. 9 and 10, for Opportunity and Feasibility, respectively.

In terms of Opportunity, ‘market size’ and ‘market growth’ were identified consistently as being the most important factors, for selecting which projects to pursue by case study companies. Other important factors include ‘margin’, ‘benefit per unit’ and ‘impact on key customer relations’ seem to be important for SMEs with an established customer base. The ‘industry / market readiness’ factor is important for start-up ventures mostly concerned with the timing and adoption of their products or services by the market. The three lowest scoring Opportunity criteria, for both start-ups and SMEs, were ‘impact on brand image’, ‘learning potential’ and ‘future potential’.

TABLE 7 – SELECTION CRITERIA AND SCALING STATEMENT CASE STUDY SUMMARY

Company type	Industry / sector	Number of employees	Workshop type	Location	Sample (number of participants who selected criteria)
Start-up	Logistics	1	Strategy	UK	1
Start-up	Alternative energy	3	Strategy	UK	2
Start-up	Consumer products	4	Strategy	UK	2
SME	Food processing	14	Innovation	UK	3
SME	Industrial heating	50	Innovation	Ireland	6
MNE	Agricultural equipment	27,000	Innovation	UK / International	1

For Feasibility, 'market knowledge' was considered to be important for all types of companies, with the two lowest scoring criteria for all companies being 'technical capability' and 'fit to sales and / or distribution'. There was no overall consistency in opinion for the other six Feasibility criteria, probably reflecting the existence of different internal organizational constraints for the case study companies. Broadly, start-ups favored Feasibility criteria relating specifically to the product, whereas SMEs also considered process dimensions.

The perceived importance of the Opportunity and Feasibility criteria the start-up and SME companies are shown in Fig. 11 and 12.

B. A practical example

Several design sessions were held with companies to support the development and testing of the guidance presented in Section IV. This section highlights some of the key learning points from one of these engagements, with a large European manufacturer of electromechanical components and systems to design a process to select technology and new product developments.

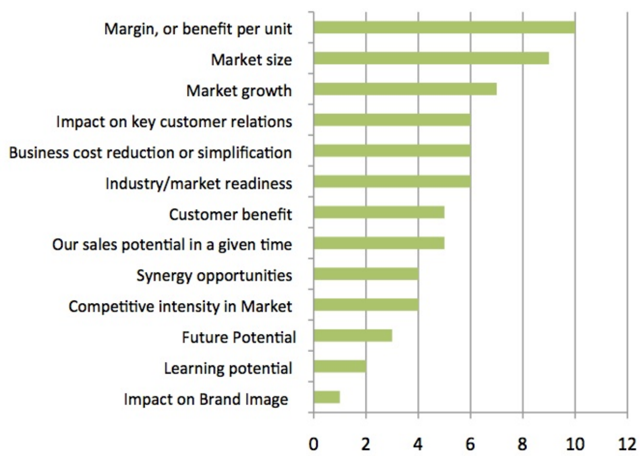

Fig. 9 – Opportunity selection factors considered to be most important by respondents

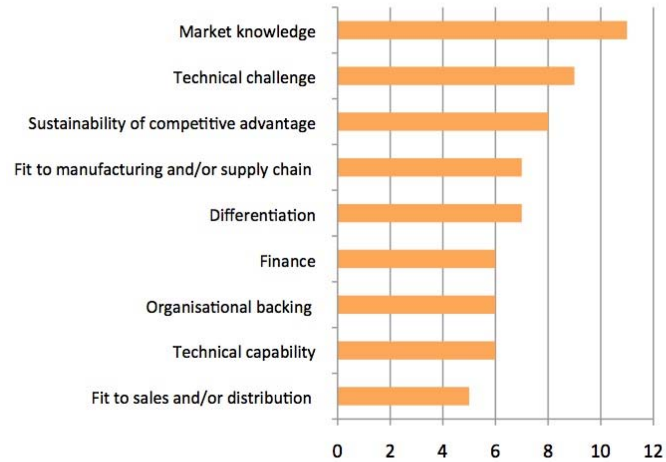

Fig. 10 – Feasibility selection factors considered to be most important by respondents

C. A practical example

Several design sessions were held with companies to support the development and testing of the guidance presented in Section IV. This section highlights some of the key learning points from one of these engagements, with a large European manufacturer of electromechanical components and systems to design a process to select technology and new product developments.

The company makes a distinction between relatively long-term Strategic projects and shorter-term Tactical ones. Different management and governance processes are used for each type and the first requirement was for a simple but objective method to allocate proposed projects between the two streams. A single factor set was used for this, based on the following considerations:

- How would the project fit into the development organization later on?
- How well is the project defined?
- How well would the potential offering fit the sales process?
- How well would the existing distribution channels fit the offering?
- How well would the offering fit existing supply chain and production?
- How new would any service aspects be to the company?

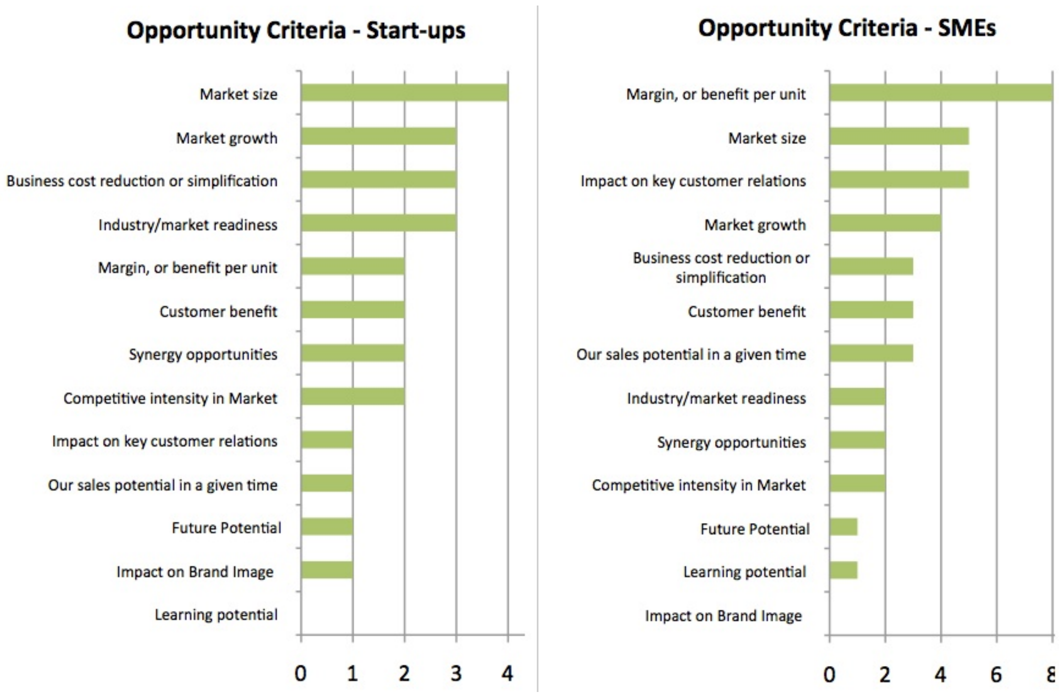

Fig. 11 – Opportunity criteria for start-up and SME companies

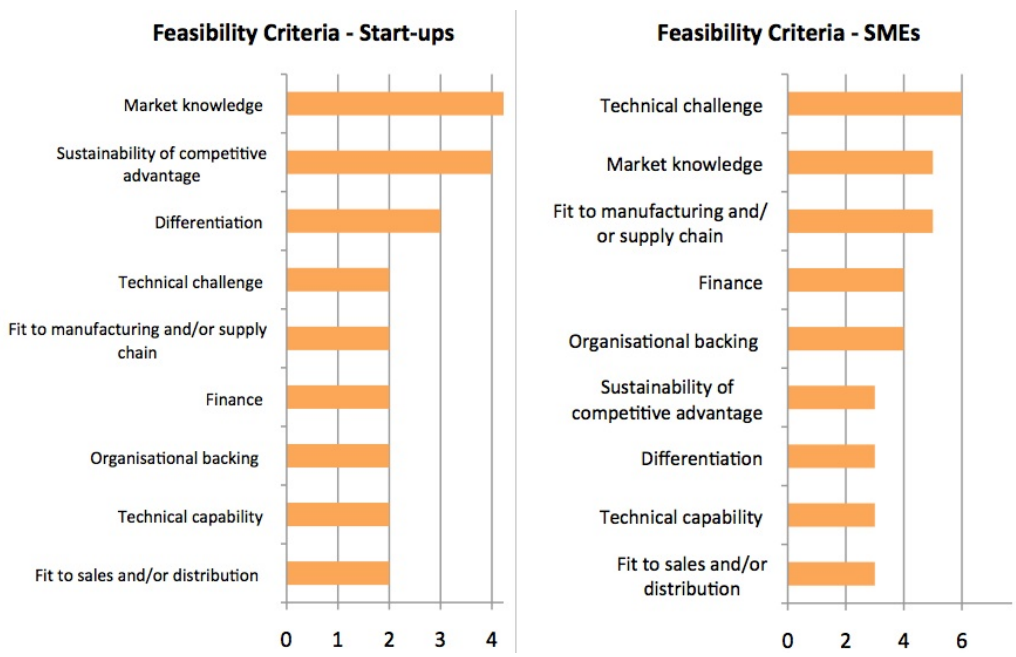

Fig. 12 –Feasibility criteria for start-up and SME companies

The central scaling statements were chosen so that for each factor it was felt that higher scores would suggest a Strategic project and lower scores a Tactical one. This was the origin of the Pivot Statement idea used in the developed tool. Subsequently the company used the method to design factor sets and scaling statements for Opportunity and Feasibility separately for their Strategic and Tactical projects.

Notable aspects of their experience in using the method were:

1. Information on each project was carefully collected and circulated in advance. The company already had a standard form for this.

2. The Opportunity and Feasibility factors and scaling statements were based on those given in this paper with some customization, particularly of the scaling statements.
3. Scoring typically took team members about 30 minutes per project. This was thought to be quite efficient compared with the time that would normally be spent in debate, and some participants even queried whether it was enough time to spend on such an important matter.
4. The scaling statements were critical for people to score quickly and efficiently.
5. Participants much valued being able to give a range of scores rather than a single one. Moreover it was found to be easier in the team discussion to agree on upper and lower bounds than to agree on single values.
6. It was helpful to allow scoring outside the range, where appropriate.
7. Scoring separately was important as it allows people to access information that they didn't know rather than be embarrassed by not knowing and having to make a guess.
8. Constructing scoring tools gets easier with practice. When the company wanted to create a tool for a new type of project they were able to choose the factors quickly by modifying those already agreed. Adding the scaling statements took half an hour.

VI. CONCLUSIONS

While portfolio management and project selection methods are established methods in industry, and the subject of many publications, surprisingly rather little attention has been paid to the theoretical foundations of these approaches, and little practical guidance is available. In response to these gaps, an coherent and well-founded approach for scoring and selecting early stage innovation projects has been developed on the basis of both literature review and practice. Scoring is a valuable way to bring clarity to the decision making process when choices have to be made on the basis of relatively sparse information backed by professional judgment. The process described in this paper is designed to provide managers in industry with a practical approach for devising their own scoring and selection framework and process, customized to suit their particular context.

It must be emphasized that the results are inherently imprecise and should never be applied blindly. Such processes should be 'decision-aiding' rather than 'decision-making', in that they should stimulate cross-functional dialogue and deepen understanding. They should give way to more traditional analysis as soon as enough information is available.

Further research is needed to deepen and extend the approach described in this paper, including:

- Extension of the scoring and selection approach to other project types, such as early stage pre-commercial technology portfolios.
- Integration of portfolio management and project selection methods with other related tools and techniques for supporting technology and innovation management, such as roadmapping, quality function deployment and scenario planning.
- Integration of other decision factors, such as portfolio balancing dimensions (for example, balance in terms of timing, risk, competence and customer segment).
- Improved understanding of the psychosocial dimensions of project selection and portfolio management – particularly in terms of how cognitive biases affect decision making and cross-functional workshop processes.

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