User Driven Stimulation of Radical New Technological Steps In Surface Transport

From Invention to Innovation: A guide to developing and evaluating your inventive idea

Prepared by Dr Sally Caird and Professor Stephen Potter, Open University, UK.
October 2010

This guide is prepared for the U-STIR (User-Driven Stimulation of Radical Technological Steps in Surface Transport) programme, which is funded under the CEC Framework 7 initiative to support the transport innovation policy measures needed to achieve the transition to an ultra-low carbon transport system by 2050, by examining the way in which organizations facilitate the development of radical transport innovation concepts (http://www.u-stir.eu).

Acknowledgement

This guide draws significantly on material presented in Block Guides and course materials from the Open University course *Innovation: Designing for a sustainable future* (T307). For details on this course (available throughout the EU) see: http://www3.open.ac.uk/study/undergraduate/course/t307.htm

From Invention to Innovation: A guide to developing and evaluating your inventive idea 1
Acknowledgement 1
Introduction 3
Is your inventive idea original? 4
Can you create designs from your inventive idea? 5
Design diary or blog 6
Design brief 6
Performance specification 6
Can you develop your inventive ideas to be user-centred and to achieve the best chance of market success? 6
Market specification 6
Importance of user-centred design 7
Design for markets 8
Is your inventive idea technically feasible? 10
Generate alternative design solutions 10
Assess the technical feasibility 11
What issues should be considered in developing your inventive ideas for manufacturing? 13
Choice of Materials 13
Optimum Manufacturing 14
Eco-design Strategies 14
Manufacturing specification 15
What costs are associated with bringing your inventive idea to market? 15
The price-minus costing technique 16

The cost-plus costing technique 16
Using investment appraisal methods 17
The Payback Investment Technique 18
The Return On Investment (ROI) technique 18
Winning support from financial institutions 19
How will you proceed to develop and market your inventive idea? 19
Championing your inventive idea 19
Working with others 20
Know Thyself 20
Managing risk 20
Summary 21
Background to your inventive idea 21
User-Centred Design and Design for markets 21
Technical feasibility 21
Materials and manufacturing process 22
Costing the process of developing and marketing your inventive idea 22
Operating effectively to develop and market your inventive idea 22
References 22

Introduction

It is important to realise that an inventive idea is just the first step towards developing a commercial innovation. Thomas Edison famously stated that:

> *Genius is 1% inspiration, and 99% perspiration.*

Having an idea for an invention is often easy compared with transforming it into a marketable innovation. After the inventive idea, other crucial steps move the invention towards becoming a successful product or system[1]. You need to go through an innovation process to bring an invention to the market, including idea generation, prototype testing, manufacturing, marketing, and selling the product or system. Your inventive idea has to be produced using materials and manufacturing processes appropriate to the product and the anticipated market demand. Once an innovation is available to potential customers, how well it will sell and how rapidly it is likely to diffuse or spread will depend on the design and technology of the innovation itself, conditions of the market, including any relevant regulations.

This guide is an assessment tool for people who have an inventive idea and are thinking about how to proceed to develop an innovation to be ready for markets. It will help you to develop and assess your inventive idea and is based around these questions:

1. Is your inventive idea original?
2. Can you create designs from your inventive idea?
3. Can you develop your inventive ideas to be user-centred and to achieve the best chance of market success?
4. Is your inventive idea technically feasible?
5. What issues should be considered in developing your inventive ideas for manufacturing?
6. What costs are associated with bringing your inventive idea to market?
7. How will you proceed to develop and market your inventive idea?

Further free support for helping you to develop your knowledge of innovation is available online from the Open University's OpenLearn website at http://openlearn.open.ac.uk/mod/oucontent/view.php?id=397861.
Further free support for helping you to develop your knowledge of business and entrepreneurship is available online from the Open University's OpenLearn website at http://openlearn.open.ac.uk/mod/oucontent/view.php?id=397405&direct=1

Next steps- If you wish to develop your knowledge further about design and innovation, the Open University offers a number of courses that are available throughout the EU. These include:

- ***Innovation: Designing for a sustainable future (T307)***

See: http://www3.open.ac.uk/study/undergraduate/course/t307.htm

- ***Design and Designing (T211)***

See: http://www3.open.ac.uk/study/undergraduate/course/t211.htm

- ***Investigating entrepreneurial opportunities (B322)***

See: http://www3.open.ac.uk/study/undergraduate/course/b322.htm

[1] In this guide the term product is used to refer to products, processes, devices or systems.

Is your inventive idea original?

Are you the first to have this idea? Sometimes identifying who had the idea first is not straightforward. Invention is an ongoing process rather than a one-off event. There are also many cases of synchronicity in invention where different inventors simultaneously develop a technology. You will need to research the history of your inventive idea to help to clarify the originality of your idea.

How would you characterise your inventive idea? Inventions may include developing:

- new materials
- new more efficient manufacturing processes
- new/improved products that are produced more efficiently with lower labour and manufacturing costs, and with less overall environmental impact. Inventive products should bring qualitative additional value to existing/new customers or to new customers through reduced prices.

It is more usual that inventive ideas are based on evolutionary or incremental changes to existing technologies rather than revolutionary or radical technological change. Rather than creating complete novelty, inventive ideas more usually involve making minor or major modifications to existing products or systems or re-engineering their functionality to improve performance, efficiency, standards and value to the customer.

You could establish the history and family tree of inventions that relate to your inventive idea, by researching patents and registered designs through the Patent Office for example in the UK http://www.ipo.gov.uk/home.htm, the EU http://www.epo.org/patents/Grant-procedure/About-patents.htm and the US http://www.uspto.gov/, This would help you to explore the originality and potential marketability of your inventive idea, and may even provide you with more inspiration for developing its evolutionary potential. This could help to identify partners holding innovative patents of value to you. It also would help you clarify the Intellectual Property Rights (IPR) associated with your idea, which will be important for when you try to secure support and funding.

Approximately €20billion per annum in the European Union is wasted on R&D for technology already in patents. So it can be cost-effective for organisations to begin innovation activity with database searches and checks. By comparing your inventive idea with other patents and designs in the same Invention Family Tree, you will be more able to answer the following questions:

- Does your inventive idea respond to a market need not already addressed by existing inventions?
- Does your inventive idea come from developments in technology that will improve functionality or reduce costs compared with other products?
- Were some patents and designs in your Invention Family Tree more successful than others in reaching the market in the first place and following market-launch? If so can you think of the reasons for this?
- Does your research reveal any patent disputes over IP ownership or resistance from industry or markets that raise issues for you to consider as you proceed to develop your inventive idea?
- Does your research reveal that Governments and regulatory factors have shaped the markets for the inventions that you have mapped out in your Invention Family Tree?

- Have the patents and designs in your Invention Family Tree led to any related or spin-off products that may suggest additional directions for developing and marketing your inventive idea?

If you wish to develop your knowledge further about IPR we have developed a guide to Intellectual Property Rights in transport innovation which is available on the U-STIR website http://u-stir.eu/docs/USTIRIPRadviceFinal2010-2.pdf

Can you create designs from your inventive idea?

This section outlines the invention process and presents some Design Tools for developing your inventive ideas. An invention is an idea, concept or design for a new or improved device, product or process that is available as concrete information in the form of a description, drawings or prototype model with the potential for practical application. The process of invention usually involves several steps that you may recognise if you have developed an invention already.

Step 1 (a) – identification of the problem that is either unsolved or has an unsatisfactory solution.
Step 1 (b) – identification of possible new uses for existing products or processes.
Step 2 – exploration to understand the problem better and design initial solutions.
Step 3 – incubation of the idea which is aided by periods of relaxation to allow subconscious thought to repattern information leading to breakthrough insights.
Step 4 – The flash of inventive insight portrayed by the Eureka moment, or the moment of realisation of a problem solution, is an important component of the inventive process. The act of insight with an inventive solution is brought about by associations of ideas, knowledge and techniques from different areas: through bisociation, adaptation, transfer, combination, analogy and chance. These terms need some explanation:

- Bisociation is the process of associating two apparently unconnected ideas which can lead to inventive solutions to problems.
- Adaptation is where a solution to a problem in one field is found by adapting an existing solution or a technical principle from another
- Transfer is where a technology, manufacturing process or material is transferred to another field to provide the basis for an invention.
- Combination is where two or more existing devices are combined to produce something new
- Analogy draws on similar situations or similar objects that possess desirable qualities to provide ideas for invention and design
- Chance where one thing is looked for but another found– perhaps people working on one technology stumble on the principles behind another.

Step 5 – critical revision to explore, test and revise your idea into a workable invention, involving further acts of insight.

Invention might be a short process or it could take years and involve a detailed search for information, experimenting with different designs, even redefining the problem as a result of this activity. You may find that you are drawn into cycles of invention as you proceed to develop your ideas for market.

The design process is central to the development of your inventive idea for practical application in manufacture and use. Design comprises drawings, instructions or models that contain all the information for the manufacture of a product or the introduction of a process or system. You will probably find that your designs evolve to incorporate more

perspectives, as your focus moves from design, to prototype development, to costings for manufacture, to market analysis, manufacturing and marketing. As you refine your designs you may consider if the final designs that emerge:

- are robust and suitable for different uses
- perform adequately to meets the needs of many different types of users.

These are the characteristics of the **Dominant Design**, which is the product that out-competes other similar products and whose appearance and function have evolved to become the accepted market standard.

Some useful Design Tools are outlined below. These include a diary or blog, a design brief and developing a performance specification. These offer useful tips for developing your inventive ideas.

Design diary or blog

Keep a detailed design diary or blog. In this diary you should record your ideas, information, thoughts and reflections about the design process as you progress. This may seem obvious, but often key thoughts and understandings get forgotten.

Design brief

Develop a design brief which is a statement of the problem or opportunity that you are trying to address. A good design brief boils down the problem or opportunity to its essential features, distinguishing what is really important from lesser features or wishes. The design brief describes the:

- design goal
- design context
- relevant constraints
- important criteria, such as making the product affordable.

Performance specification

Write a performance specification of what your new product or system should be able to do to satisfy potential purchasers and users. These are the product's essential, functional characteristics. A fundamental requirement for successful innovation is that the invention must work and it must be capable of being transformed into a working prototype with specified materials. It must be designed to be easy-to-use and reliable, attractive, safe and environmentally friendly.

Can you develop your inventive ideas to be user-centred and to achieve the best chance of market success?

This section outlines some important concepts in design, such as user-centred design, design for markets. This supports the development of a market specification which is a useful tool for inventors and designers.

Market specification

This states which market sector and segment the product should be designed for. This includes information on the following:

- Sources of information about potential users and markets.
- Information on competing or comparable products and their strengths and weaknesses.

- Characteristics and requirements of your target market.

Importance of user-centred design

Drawing up specifications and developing your inventive idea requires attention to user requirements as user-centred designs have a greater chance of becoming successful dominant designs in the market-place. User-Centred Design advocates user participation in each phase of product development to support appropriate design, development and effective diffusion. User participation assists organisations in meeting different user requirements, and with designing usable products that are easy-to-use in the most effective way.

User participation in your design work can help to fine-tune your designs and prototypes which will support evolution to successfully satisfy many types of customers. In one of the standard works in this field, Rogers (2003) identifies five characteristics of an innovation which reflect the way customers and users assess new products and systems. These characteristics affect how quickly and to what extent your innovation will sell:

- **Relative advantage:** Your invention or design should have a competitive advantage over existing comparable products or systems. In what way does it achieve this? (Is it cheaper to make? Is it cheaper to buy? Is it cheaper to run? Does it perform better than other products? Does it offer functionality not previously possible? Does it offer more features? Is it easier to use? Is it more reliable or safer?)
- **Compatibility:** Your design should be compatible with the experiences, values and needs of its potential buyers.
- **Complexity**: Your design should not be perceived to be difficult to use.
- **Observability & Trialability:** People will be more likely to buy your design if they can see it being used and try it out before buying (particularly if it is a high cost product).

Most traditional techniques for engaging users are associated with market research to refine a product launch, involving information collection on user requirements. Once this information on customer requirements is gathered, it needs to be translated into statements of product requirements to help you to draw up performance and market specifications. Ulrich and Eppinger (2000) offer some useful guidance for taking customer statements and translating them into statements of product requirements:

- State what the product has to *do*, but remain open to different possible technological solutions
- Include reference to the specific *detail* of customers' requirements
- Use *positive phrasing* rather than negative
- Note customer statements that request *desirable attributes* for the product
- When translating customer statements *avoid prescriptions* for what the product must or should do. Customers are usually willing to make trade-offs with their requirements. Some of their requirements may not be technologically possible or cannot all be designed into one product.
- The next step is to classify customer requirements and to *identify a hierarchy of primary, secondary and tertiary customer requirements*. This hierarchy of needs helps to focus on essential product requirements, as distinct from product attributes that would be nice to have if there was time and resources available.

Performance and market specifications should identify the essential product requirements but allow freedom to explore as many alternative technical solutions or design concepts as you wish, as long as they meet the performance and market requirements.

These specifications will help you to move forward to consider design solutions, and to build prototypes, simulations or mock-ups, and refine the technology for your inventive idea. User observation studies and usability laboratories are useful for considering product usability issues and identifying latent, non-rational or unstated user requirements to support better designs and further technical refinement of prototypes.

User-centred design may incorporate and capitalise on user innovation to develop more innovative products for emerging markets. New trends in user-led innovation show that users are innovating independently of organisations. Consequently it may be useful to consider engaging users and user communities with your innovation process. Douthwaite (2002) uses an analogy with natural selection to observe that most successful innovations were co-developed by manufacturers and users who determine innovation fitness and adaptation potential. You may be aware of the use of web-portals to gain access to user innovation using techniques such as

- crowdsourcing, which refers to outsourcing a task to an open community sometimes through competitions;
- open-sharing or free-revealing of product components & architecture and offering tool kits;

These techniques may help you to access users to contribute to the technical refinement of your innovation with product Mock-ups and Mashups, where users recombine existing products into new forms; and Modding where users make modifications. Working with lead users is important as they are highly motivated to participate in innovation because they are currently experiencing needs that will later be experienced by mass users in that market.

Lead users can be important. They are at the leading edge of important market trends, and include firms, groups and individual consumers who expect to gain most from innovative solutions. Identify who your lead users may be and find out ways of linking to them. They will be among your first customers and can be useful in championing an innovative product.

Design for markets

Another key point for innovative design is that customers and users clearly differ in terms of how ready they are to adopt an innovation. The characteristics of consumer groups will affect the uptake of new products, systems or services by consumers. Rogers (2003) named the consumer groups: innovators, early adopters, early majority, late majority and laggards.

Some people will always try to be among the first to buy a new product – Rogers (2003) calls people in this group *'innovators'*, but they include the 'lead users' noted above who will gain most from an innovative design. Rogers notes that *innovators* are typically young, affluent, well-informed, receptive to new ideas and willing to take risks. This innovator group and the next group, called early adopters, are excited by complex technologically innovative products. They are often influenced by fashions and information gathered from friends and colleagues and from reviews of new products in the technical press, specialised publications and the internet.

But the majority are more cautious consumers and inclined to wait for a product to be established with any performance problems solved. They may be less patient with products that are difficult to use and more concerned with costs and value for money. Intensive advertising campaigns are required to target the majority of consumers to speed up the rate of a new product's diffusion. The most cautious consumers, known as laggards buy a product close to the end of its life cycle, often shortly before it is replaced by an improved or new product. So it is important to think about the appeal of your invention to different consumer groups and whether you can design your idea to be more appealing, easier-to-use and more affordable to more people.

Although lead users, such as Rogers' innovators and early adopters, offer exciting opportunities for innovation, other types of users have an important role in successful innovation diffusion, as they represent the majority. These more passive users have needs and characteristics, and usability requirements that can differ significantly from that of lead and innovative users but if an innovation fails to meet their requirements it is unlikely to achieve market success. The innovation will be stuck with a small niche market of devotees.

Market timing is important for successful market diffusion. Inventions can emerge before their time when the technology isn't sufficiently developed to deliver a reliable product. In other cases though, the inventive idea doesn't take off because the market need for it is not yet established. This may be a particular issue for the most radical innovations. Policy-led techniques such as the Strategic Niche Management[2] technique can be utilised to create 'protected niches' for radical innovation concepts to bring stakeholders together with users in the emerging industry, to allow experimentation and learning to take place, and linkages to develop within a group of advocates ready for market trials and launch.

It is also important to think about whether the existing infrastructure is in place to support market diffusion of your innovative idea. Some inventions may depend on developments in related technological innovations or systems before they can be diffused sufficiently to achieve widespread market adoption. For example, the electric vehicle industry in the UK relies on a supportive infrastructure for its development and is stimulated by government regulations and legislation associated with carbon reduction targets as well as proposed subsidies to encourage consumer purchase. An innovative vehicle design without the means to refuel will fail!

Innovation may be classified in terms of impact on the market as well as its technology-base, with both affecting market diffusion. Innovations with the biggest market impact are called disruptive innovations. This challenges existing companies to operate in a new way in the market. Disruptive innovation affects the market in unexpected ways sometimes destroying the value of an existing technological base, range of products, systems or services, and/or organisational practice competencies. These disruptions may lead to lower priced performance improvements, or with new product designs that attract a new consumer market. Sustaining innovation by contrast with disruptive

[2] See, for example, Hoogma et al (2002): *The Approach of Strategic Niche Management* available online at: http://books.google.co.uk/books?hl=en&lr=&id=bakUFUp72sEC&oi=fnd&pg=PR7&dq=Strategic+Niche+Management,+workbook&ots=1-_1Z4n_rC&sig=NlfHsqPy-dAvkGNni4o2QTuXTug#v=onepage&q=Strategic%20Niche%20Management%2C%20workbook&f=false

innovation bring improvements to the performance of established products and benefits companies. If your inventive idea is likely to have a disruptive impact on the market then market entry may be more difficult as incumbent organisations are likely to compete to protect their market value.

Douthwaite (2002) maintains that effective innovation diffusion is supported when organisations develop a system for catalyzing an innovation process, which includes:

- Finding a product champion, which is an individual or group committed to promoting the development of a certain product, process or system.
- Working with innovative partners on a small-scale
- Setting up unbiased selection mechanisms to help the technology to evolve, and minimising patent monopoly practices which reduce the rate of novelty generation.

Successful innovation diffusion at a societal level depends on complex interactions between socio-technical, cultural, regulatory and psychological factors, which involves many agents. While it is difficult to analyse the reasons for successful innovation diffusion, Douthwaite (2002) believes that users (and other stakeholders) should be involved in a co-development role in order to help an innovation to evolve and survive, particularly at the pre-launch product formulation stage with market trials or technology-niche exploration. Early work by Abernathy and Utterback (1978) identified that the early stages in emerging new technological paradigms are characterized by diverse technical approaches and fluid designs until a dominant design is established. The key message is that involving users and stakeholders in a network of stakeholders can enhance the emergence of successful designs and innovation.

Is your inventive idea technically feasible?

Questions of design, materials and manufacture, and markets are as important for innovation diffusion as basic technical feasibility. This section aims to help you to work on developing the technical feasibility of your inventive ideas and provides some ideas and tools for this purpose.

Generate alternative design solutions

The design specifications do not usually include solutions or designs because most product ideas can be embodied in many alternative technical solutions and design concepts. Sometimes it is easy to ‘jump’ to a solution to a problem, only to find later on that there is a much better approach if only you had sat down and thought more carefully. It is a good idea to think laterally and generate alternative design solutions.

Assess each design solution as objectively as possible using a range of criteria, based on the performance and marketing specifications that you have already developed. An example matrix is presented below to help you to evaluating alternative design solutions

Example Matrix: Evaluation of Alternative Design Solutions

Performance specification	**Design Solution 1**	**Design Solution 2**	**Design Solution 3**
Criteria 1 E.g. Functional			
Criteria 2 E.g. Attractive			
Criteria 3 E.g.Easy-to-use			
Criteria 4 E.g. Reliable			
Criteria 5 E.g. Safe			
Criteria 6 E.g. Low environmental impact			
Market specification	**Design Solution 1**	**Design Solution 2**	**Design Solution 3**
Criteria 1 E.g. Address specific customers/users requirements			
Criteria 2 E.g. Comparison with other products			
Criteria 3 E.g. Supportive market infrastructure			
Criteria 4			

Rank each alternative design idea using the design specification criteria and think about the Pros and Cons for each alternative before you make your preferred selection of the design solution that you will continue to develop.

You may return to some of your alternative ideas at a later point if you wish.

Assess the technical feasibility

Your answers to the following questions will help you to assess the technical feasibility of your selected design solution

- Will the idea work?
- Are the technologies required currently available?
- Are the necessary materials and components available?
- What technical problems have to be solved?
- Could the product, process or system be made economically?
- Is the product's performance likely to be good enough to compete with rival products?
- Does it pose problems of human use, safety, maintenance, pollution?

Later sections in this guide will help you to think more about materials, manufacturing and costing issues. The feasibility of your design solution may be assessed by conducting state-of-the-art reviews and modelling. State-of-the-art reviews include:

- searching the literature for related ideas, products, and so on
- looking for similar products, components, and so on in shops and catalogues
- finding an annual review article in an appropriate specialist or trade publication
- searching for patents in the field
- talking to experts and specialists.

As you develop your product idea in more detail, there are more questions concerned with technical refinement and manufacture:

- Which key components or assemblies are similar to those used in other products? This will help you to think about sourcing materials and manufacturing issues.
- Are there any components that are technologically innovative? If so, is developing them likely to be technically and economically feasible? If not, could the concept be modified to use available components?

You may test the feasibility of your ideas using different types of models as follows.
Graphical models include **s**ketches and diagrams that illustrate the basic concept of an idea, and are used to develop alternative design configurations.
Physical models

- Principle-proving models are made to test the basic function of a new design or invention and to demonstrate how an inventive idea works.
- Scale models and mock-ups are visual aids and help to put the product in context. They demonstrate design features and explore different design configurations. They are made of easily manipulated materials such as wood, cardboard or plastic.
- Prototypes and mock-ups demonstrate the functions and appearance of a product. A functional prototype is normally required to convince others to support your product idea.

Electronic models can demonstrate functions and appearance, for example computer simulations.
Mathematical models include **c**alculations and analysis to test the principles behind an idea or invention.
Producing design specifications, developing feasible design solutions will help you to move forward to develop your idea further with sketches, diagrams, prototypes, simulations and mock-ups. You may find that you need specialist knowledge, skills or information to develop and assess the technical feasibility of your product idea.

The use of ***Computer-aided design*** (CAD), or computer-aided drafting and design (CADD) computer technology can support the innovation process from conceptual design and layout of products to identifying appropriate manufacturing processes. This software provides input-tools which help to streamline design and manufacturing processes, leading to benefits such as lower product development costs and shorter innovation cycles. CADD software environments can work with information, such as on shapes, materials, processes, dimensions, tolerances, and photographs, and can support 3 dimensional and even dynamic mathematic modelling. (See http://en.wikipedia.org/wiki/Computer-aided_design).

What issues should be considered in developing your inventive ideas for manufacturing?

Given the technical complexity and the level of investment required for large-scale manufacture of most innovative products, it is necessary to be able to predict and control the manufacturing process precisely. It is important to understand how an invention works, or how a material behaves under certain conditions, or how a particular manufacturing method is carried out, in order to be able to control the overall process. The choice of materials and manufacturing process for a new product may make a big difference to the success or failure of your innovation process.

Choice of Materials

The materials chosen for the early prototypes of an invention may not be best suited for the larger-scale economic manufacture of the innovation. To the buyer the prototype might not be attractive or easy-to-use. To the manufacturer the materials may not be suitable for volume manufacturing, or meet safety, performance standards or regulations or be cost-effective for processing. Difficulties with finding suitable materials and manufacturing processes may lead you to further inventions.

The choice of materials can affect the performance, quality and economic manufacture of new products, and specialist assistance is often needed to help make wise choices. Here is a checklist of a range of materials' properties that inventors and designers need to consider:

- performance – behaviour of the material in the finished product
- processing – behaviour of the material during manufacture
- economic – cost and availability of material
- aesthetic – appearance and texture of processed material
- environmental impacts –This includes the energy consumed and pollution produced in the extraction and pre-processing of raw materials. It includes the final processing of materials into a product; and the effect of chosen materials on the life of the product; the potential for recycling and disposal at the end of the product's life.

The 'UglyPoints' system developed by Edwin Datschefski (2001, p. 155) is a rough quantitative technique for avoiding harmful materials, and thinking about the environmental impact of the materials that you use in developing a product. Datschefski argued that the mass of material used is proportional to the environmental impacts arising during its manufacture, use and disposal, therefore if you know the weight of each material in your product, you can compare the relative 'hidden ugliness' of different materials and components.

The 'UglyPoints' system helps designers quickly to spot the main problems with materials and gives scores of 1, 5, 15, or 50 UglyPoints per kilogram for the following materials.

'UglyPoints' scores for rating the environmental ugliness of materials

'UglyPoints' scores	Materials
Low = 1	Bioplastic, brick, cardboard, ceramics, concrete, stone, wood
Medium = 5	Carpet, glass, leather, most plastics, paper, rubber, steel, textiles
High = 15	Aluminium, electronics, light bulbs, paint, polycarbonate, polystyrene, stainless steel
Very high =50	Batteries, brass, cadmium, chromed steel, chromium, copper, gold, lead, nickel, zinc

To calculate the relative environmental impact of the different materials you are using or intend to use, simply multiply the mass of your chosen materials by 1, 5, 15, or 50 as appropriate. From these figures you can rank the materials and prioritise your design choices.

Optimum Manufacturing

Manufacturing processes have strengths and limitations that inventors and designers need to be aware of. Here is a checklist for thinking about the criteria that influence the optimum manufacturing process for your new product or system.

- Cost – including new equipment capital costs; dedicated tools costs, such as moulds; labour costs of setting up and operating the process; and assumed rate of depreciation for tools and equipment. Will the equipment be dedicated to one product design or several?
- Cycle time – how long it takes to process one item (part, component or product). What is the planned volume production?
- Product quality – the standards required in terms of performance properties, surface finish and dimensional tolerances, and maintaining quality over time.
- Flexibility – how easy it is to produce different designs on the same equipment?
- Materials utilisation – the amount of waste material generated during processing. This will be subject to increasingly stringent environmental regulations.

Eco-design Strategies

Eco-design strategies go beyond the choice of materials and manufacturing processes to cover distribution, use and the life-cycle impacts of the product or system that you develop. The good eco-design strategies outlined in the UN Environment Programme's 1997 Eco-design manual presents a detailed checklist to support eco-design (Brezet and van Hemel, 1997, pp. 144–158). This is summarised here

Good eco-design strategies include the selection of low impact materials that are

- cleaner, renewable, low carbon, recycled and recyclable

Good eco-design strategies include the reduction of materials usage with

- reduction in weight
- reduction in space or volume required in transport

Good eco-design strategies include the optimisation of production techniques by:

- Using cleaner production techniques
- Reducing the number of steps in production where possible
- Utilising low and zero carbon energy in manufacturing processes
- Minimising production waste
- Using fewer and cleaner consumables in production

Good eco-design strategies includes the optimisation of the distribution system with

- Less, cleaner or reusable packaging

- Energy-efficient transport mode
- Energy-efficient logistics

Good eco-design strategies include reduction of impact during use with

- Lower energy consumption
- Cleaner energy sources
- Fewer consumables needed
- Cleaner consumables
- Reduce wastage of energy and other consumables

Good eco-design strategies include the optimisation of the initial lifetime of the product with

- Reliability and durability
- Easier maintenance and repair
- Modular product structure, allowing upgraded by adding new modules or functions at a later date.
- Classic design with lasting appeal
- Stronger long-term product-user relationship

Good eco-design strategies include the optimisation of end-of-life system with

- Reuse of the product
- Remanufacturing or refurbishing
- Recycling of materials
- Safer incineration of toxic materials

Manufacturing specification

A useful tool for inventors is to write a manufacturing specification which states how your working prototype may be manufactured on a scale that makes it economic to produce and to buy. Your manufacturing specification includes the choice of materials and manufacturing processes, distribution, use and the life-cycle impacts of the product or system that you develop.

What costs are associated with bringing your inventive idea to market?

Development of your idea for market calls for careful consideration of the commercial aspects, market characteristics and sales potential – the likely costs of manufacture, transport, distribution and retail, as well as the size of market, sales price, selling strategy, and profit margins. It is important to think about and to try to estimate the economic viability of your idea. The affordability of innovative products is important; this is related to the relative affluence of buyers, but the innovative product must be affordable also to the chain of firms involved in the manufacture, distribution and marketing of the product.

Your preliminary market research should help you to estimate the potential sales volume. To help you provide information on the economic viability of your idea you need to identify possible costs as realistically as possible. Some tips for beginning this activity follow:

- Look for sources of information. For example, you may use internet searches, undertake a quick telephone survey with key suppliers and manufacturers, or examine other relevant material from competitors or others in a similar market segment.
- Research similar products and try to obtain actual data on prices and costs relating to a similar product.

- Find out how much your target market might be willing to pay for your new product.

Remember that costing is a specialist activity normally carried out by accountants, so this guide presents approaches that will provide a basic and simplified idea of the costs and viability of your product idea. Several costing and investment appraisal techniques are outlined below.

The price-minus costing technique

The price-minus approach begins with your estimate of how much your target market might pay for your new product. This may be important if you need to match or undercut the price of an existing dominant product. With the price-minus approach you work backwards from a target sales price subtracting retailer profit margin, distribution costs, manufacturer profit margin and development costs, to arrive at a cost of manufacture at which the product would be financially viable.

Price-minus costing
Estimate the Target Retail Price: The target sales price is set by the price of similar or competing products. You estimate this following a survey of the prices of existing or similar products/systems. In order to compete what price will your product need to sell at?

Subtract the Retailer Margin (30–50%, e.g. 40%), of Retail Price. The retailer margin is what the retailer will expect to earn from selling your innovative product.

Equals = The Wholesale Price (retail price -retailer margin)

Subtract Transport and Distribution Costs (of about 20% of Wholesale Price)

Equals = The Factory-Gate Price (Wholesale Price minus Transport And Distribution Costs)

Subtract Manufacturer (i.e. your) Profit Margin (of about 40% of factory-gate price)

Equals = Target cost of manufacture

The rule of thumb is that a typical manufacturing price will be in the region of 25%–35% of the price to the eventual consumer. In simple terms, to obtain a ***target manufacturing cost*** divide the ***retail price*** by a factor of 3 or 4 , – or for up-market products divide by a factor of 5. The question is can your product be made at this cost?

The cost-plus costing technique

The cost-plus approach helps to answer this question by beginning with your costs. The choice of what costs to include is clearly important for the estimation of unit costs. With the cost-plus approach you estimate the costs of developing and making the product, including one-off and ongoing costs, plus a profit margin in order to determine the manufacturing unit cost.

Cost-plus approach
Estimate the one- off development and manufacturing costs For example:
Research, design and development investment costs
New equipment and tooling
Market research and launch costs
Add these costs to give you an idea of just how many units you would need to sell (the unit volume) in a year to cover repayment for these on-off costs

Estimate ongoing direct costs per unit which are for activities or services directly associated with your specific projects For example:
Labour costs for project staff
Materials and component costs required for a particular project

Estimate ongoing indirect costs per unit which are associated with activities or services that benefit more than one project For example:
Overheads and administration

The price of a product or system is estimated from ***one-off costs***, ***direct and indirect costs***, and then converted to ***per unit costs*** for the product and added to an additional predetermined ***percentage*** to provide a ***profit margin***.

The cost-plus approach can be difficult, even impossible, to undertake at an early concept stage because there are so many uncertainties, such as the different materials, manufacturing methods and production volumes. Estimating the overheads to be allocated to the product can be a complex matter – there could be administration, rent, depreciation, and so on. Price-minus costing is far easier than the cost-plus approach, especially if you are at an early stage of your project.

Other disadvantages associated with cost-plus pricing are that it based on the costs of product and therefore ignores important market issues which affect profits, such as the role of consumers, alternative lost market opportunities and competitor activity on pricing for example. In an extreme case, applying cost-plus pricing to a commodity could lead to no sales if the cost-plus price was above the market price available from competitors. This technique also makes assumptions about production efficiencies and outputs which may need to be more variable and responsive to market demand.

A good way of estimating the costs of developing and making the product is to show a prototype to a potential manufacturer. The largest costs will normally be in tooling up for full production, initial production of stock, distribution and marketing. The very early stage of product development involving design, prototype development and technical refinement typically involves only perhaps 2–10% of the total cost of developing a new product and launching it onto the market.

Using investment appraisal methods

Generating a prototype of an invention is relatively cheap compared with the resources needed to produce and market an innovation. The independent inventor or designer may be able to rely on family and friends for financial backing in the early stages. Seed capital is sometimes available in the form of innovation grants from government bodies, such as the Department for Business Innovation and Skills (BIS) in the UK, which offers development funding to individuals and small businesses.3 Some other EU states

[3] UK Innovation Investment Fund

operate similar support systems. Eventually, however, most inventors need to access significant funds that can be provided only by a company or a venture capitalist. Some standard investment appraisal methods are outlined to help you to think about investment issues and how to convince others to make a financial investment in your idea.

The Payback Investment Technique

The simplest form of investment appraisal technique is the payback method. The payback period is the number of years required to return the initial investment in a project out of subsequent sales income.

To work this out you would first need to estimate how much it would cost to develop your idea and manufacture the finished product. Estimates using the cost-plus approach can help you to estimate the capital investment.
Then you would need to estimate how many products you would expect to sell per year and what profit you would be making on each. You can use your preliminary market research estimates on the number of units you would expect to sell per year at a specific retail price to estimate your annual profits. Both the price-minus and cost-plus approach (outlined above) also can help you to estimate your production and marketing costs that will be subtracted from your expected annual profits.

Payback method
Number of Years for Payback =Capital Investment/ Annual Profits

The Return On Investment (ROI) technique

The Return on Investment (ROI) technique measures the performance of an investment relative to another investment.

Return on Investment (ROI) = Profit/Capital Investment
ROI is expressed as the percentage return over an associated time period, usually one year.

An investment is more desirable if the cost of an investment can be recovered more quickly. But a shorter payback period does not always mean that one investment is more desirable than another, as the payback method is not a true measure of the profitability of an investment but is based on estimates instead.

An issue with both the payback method and ROI standard methods for investment appraisal is that they do not consider the ‘time value of money’, which would suggest that cash inflow received several years in the future should be valued differently from cash inflow received immediately. Advanced methods of investment appraisal, such as Discounted Cash Flow (DCF) analysis is a valuation method that addresses the time value of money by estimating and discounting the sum of all future cash-flows (both incoming and outgoing) to estimate the net present values of cash flow. There are a

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The Department for Business Innovation and Skills (BIS) created the UK Innovation Investment Fund in 2009. The fund invests in technology based businesses with high growth potential in areas such as digital and life sciences, clean technology and advanced manufacturing. See http://www.bis.gov.uk/policies/innovation/business-support/ukiif

number of Discounted Cash Flow tools available online together with business manuals on using this technique.

Winning support from financial institutions

Financial institutions with interest in investment will utilise more advanced methods of investment appraisal, such as Discounted Cash Flow (DCF) techniques, and/or 3–5 year projected cash-flow statements, forecasts of profits and losses and balance sheets. As you appraise the economic viability of developing your inventive idea you will need to be aware of investors' concerns with payback and return on investment.

If you seek funding to develop your idea from a bank or venture capitalist, or your employer, you would need to prepare a **business plan** giving:

- evidence of the technical feasibility of your idea, including working models and prototypes
- cash-flow forecasts and investment appraisals
- detailed costing for production
- full details of the market for the product and sales forecasts
- detailed proposals for marketing and promotion
- evidence of managerial ability

Potential financial backers may not have the imagination to foresee how a new technology might be used as they are not directly involved with the development of the technology. They may lack the technological knowledge to understand if your invention works. They need to be convinced that an innovation has a competitive advantage and can succeed over existing technologies or products before they will invest.

How will you proceed to develop and market your inventive idea?

Championing your inventive idea

Much invention and nearly all innovation nowadays take place inside organisations – from small start-up companies to well-established multinationals. This is mainly because increasingly invention and innovation require access to technology and resources beyond the scope of most individual inventors. But it is also because competitiveness and survival depend on the continual improvement of a company's products and processes. This provides a strong incentive for companies to invest in both the incremental improvement of existing products and the invention of new products.

If you are developing an inventive idea for your employer it can help you to champion your idea by understanding the reasons why organisations invent. Organisations invent:

- As part of the business strategy to survive and compete effectively
- To improve existing products and processes to address market demand and compete effectively
- To use new materials to address market demand and increase efficiencies
- To use new technologies and manufacturing processes to increase efficiencies
- To address changes in government policy, legislation and regulations to enable survival

If you are developing an inventive idea outside an organisation you will still need to work with other organisations and individuals and to convince them of the merits of your inventive ideas.

Working with others

It is important to give some thought to how you will work with others, such as manufacturers, designers, marketers, investors, competitors, customers and users, and other organisations involved in the supply-chain or infrastructure to support the successful market diffusion of your idea. These can all be agents of innovation. Fostering such linkages stimulates and enables innovation, and can help an inventor to avoid the technology-push trap of pushing a product onto the market and just hoping for success. Successful innovation depends on responsiveness to market demands and developing the infrastructure required to support successful market diffusion.

Know Thyself

In their classic book The Sources of Invention (1969) John Jewkes, David Sawers and Richard Stillerman observe the following characteristics of inventors, which applies to inventors working outside or inside an organisation.

- Inventors tend to be absorbed with their own *ideas* and to feel strongly about their importance and potential.
- Inventors can be impatient with those who don't share their *optimism*.
- Inventors are often *isolated* because they are *engrossed* with ideas that are resisted by the status-quo.
- Inventors can be *right* when others are eventually proved wrong. But they can appear *eccentric* because they have a minority view that challenges existing ideas.
- Inventors are unworldly and often *lack business knowledge*. If so they will need special help in this aspect of innovation.

The ability to focus on a problem to the exclusion of everything else, the single-mindedness and determination to produce a solution, and the optimism that the solution is viable are clearly useful characteristics during the process of invention. But some of these very characteristics can become liabilities when applied to the process of innovation which requires forming linkages and teamwork. The skills of working with others become more important, for example, the ability to persuade others of the worth of the invention; the patience to accept criticism; the flexibility to compromise and change the design if required for manufacturing; the open-mindedness to accept other expertise in finance and marketing etc.

Managing risk

There is probably a greater chance of success if there are more people and organisations working together and committed to the risks of making your inventive idea succeed. Working with other agents of innovation can help you to share the risks, not just the financial risks, but the risks associated with the time, work and emotional energy that are needed for success. These linkages can provide you with feedback and help you to be more objective in your appraisal of any problems that emerge as you develop your idea.

How you feel about the risks associated with developing and marketing your inventive idea will clearly depend on whether you are working for a company that is shouldering most of the risks or whether you are operating outside an organisation. It is a challenge and significant commitment to develop an inventive idea into a successful design and innovation. It has been estimated that no more than two per cent of inventions go on to become innovations. And for every successful innovative product there are many that

do not achieve commercial success and are eventually (or quickly) withdrawn. Invention and innovation is a risky business. You have to decide on how much of your personal and financial resources to commit to developing innovation, how to manage risks and when/if to accept failure and move towards an exit strategy.

Support for innovation is usually available from government bodies, such as the UK's Department for Business Innovation and Skills (BIS) which provides a comprehensive range of support for business involved with research and development and innovation (RDI), including expert advice and guidance. (See http://www.bis.gov.uk/policies/innovation/business-support/research-and-development/business-support).

There are organisations that provide eco incubator consultancy services and it may be worth your while to draw upon their experience. An example of such specialist company is Enviu Innovation Services, based in Spain (http://enviubarcelona.com/), but do a web search to see what specialist support is available in your country, both commercially and through public programmes.

Summary

This document provides guidelines and tools for the development and evaluation of an inventive idea. A checklist of tips is outlined below to summarise this guide.

Background to your inventive idea

- Outline the background to your inventive idea and how you identified the problem or opportunity.
- Describe the advantages and disadvantages of your idea compared with existing products, processes or systems.
- Clarify the technical novelty of your idea and present the results of your searches on related ideas or products. Is your idea patentable?
- Keep a **design diary or blog**
- Outline your **design brief** and **performance specification** of what the product should do.
- Describe your inventive concept, product, or system in words, sketches, drawings, diagrams, photographs of mock-ups, models or prototypes.

User-Centred Design and Design for markets

- Outline your **market specification** – including the target market and the customer needs that you expect your product to satisfy.
- Specify the sources of information you used to obtain knowledge of the market.
- Key notes on any user research that you carried out in the development of your product idea and how this contributed to the design.
- Describe plans you have for marketing your product
- Appraise the economic viability of your idea from a market perspective.

Technical feasibility

- Generate the **alternative ideas** you considered and clarify how you selected your chosen design.
- Evaluate the **technical feasibility** of your chosen idea using models. If you made a mathematical model, graphical model or physical model of your concept, describe the modelling process and keep photographs.

- Identity areas of uncertainty where further information is required, and any limitations due to technical problems or technological constraints.

Materials and manufacturing process

- Outline the materials you have chosen for production, how you selected them and why you chose them, including environmental considerations.
- Discuss whether the product or system can be made practically and if there any special production requirements – machines, test equipment, or facilities that would be required.
- Discuss any supply, production or distribution issues that you have identified.
- Develop a **manufacturing specification** including the choice of materials and manufacturing processes, distribution, the impact of the product in use, and the product life-cycle impacts of the product. Can your product be economically produced?

Costing the process of developing and marketing your inventive idea

- Appraise the economic viability of your idea, using preliminary estimates of costs and profits from expected sales.
- Consider Return On Investment (ROI) and payback issues for investors.
- Identify areas of uncertainty or where further information is required.

Operating effectively to develop and market your inventive idea

- Develop a **business plan** and strategy to convince investors and potential collaborative partners that they should invest and work with you. This should include details of technical feasibility, cash-flow forecasts, investment appraisals, production costing, sales forecasts and marketing proposals.
- Think about how you are going to work with manufacturers, designers, marketers, investors, competitors, customers and users, and other organisations involved in the supply-chain or infrastructure for your inventive product.
- Develop linkages and build teams of individuals and organisations to support the development of your invention and successful market diffusion.
- Remain open to innovation, including the potential for continuous improvements to performance and innovation in manufacturing technology and materials.
- If you are a classic inventor then try to be patient with the people you meet who don’t understand or lack the imagination to appreciate the potential of your invention. Focus on the skills that they can bring to the innovation process.
- Try to share the risks associated with innovation with other agents of innovation and stakeholders.
- Seek advice and support to help you to manage risks and reduce the uncertainties associated with developing innovation.

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