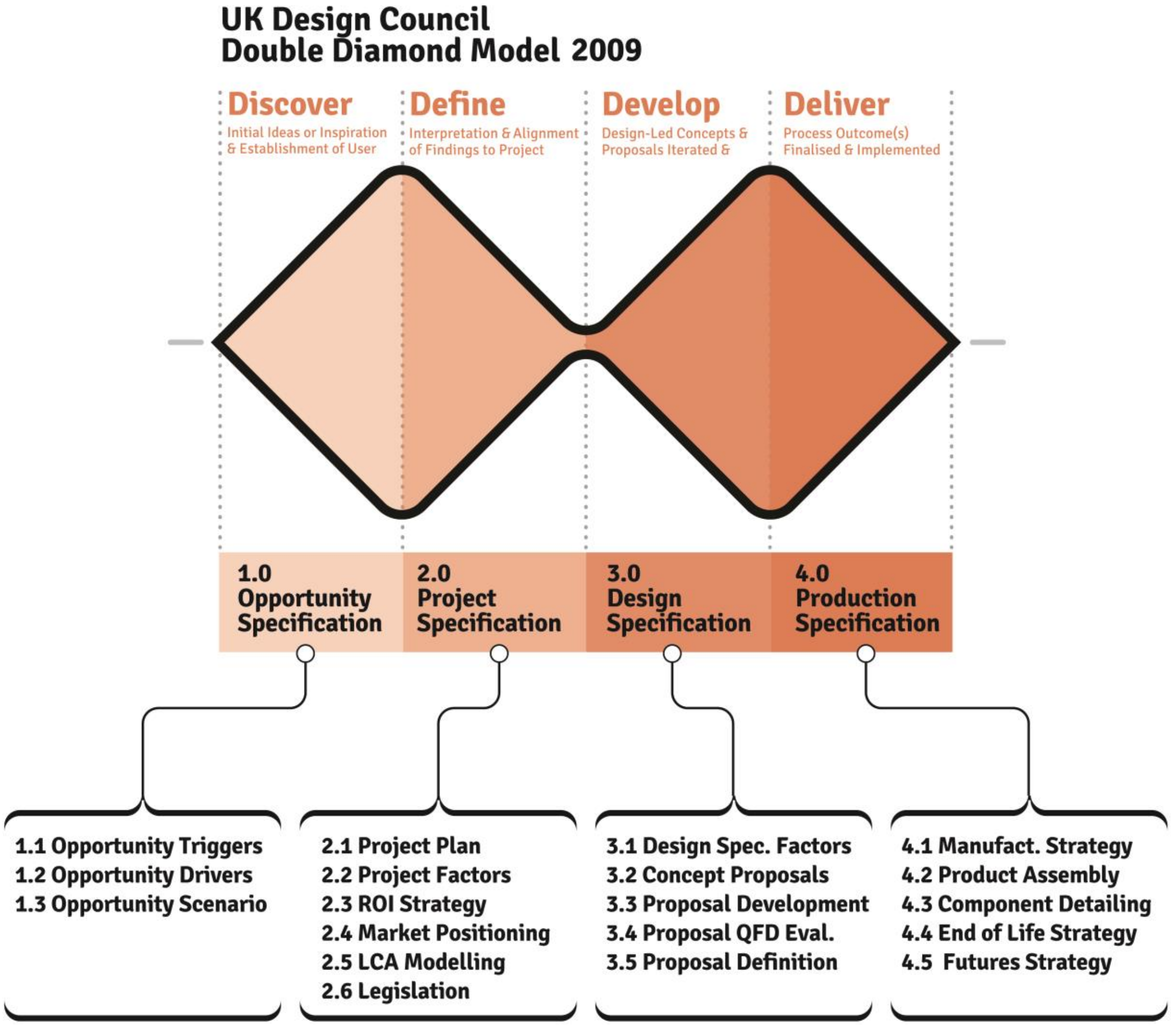
Project Specification Issues

1.0 Opportunity Specification
2.0 Project Specification
3.0 Design Specification
4.0 Production Specification



1:0
Opportunity Specification

Opportunity Drivers
General
There can be many sources for a new project initiative, both external and internal, and they may emanate from anywhere in the organization.
The most common are market-pull, technology-push, customer requests, and any organizational circumstances that create opportunities to develop new products.
Triggering a new product
In broad terms, the most suitable opportunity or idea needs to be identified. Everyone in the organization should be encouraged to report potential triggers for new product ideas, and

such initiatives should be communicated both upwards and downwards in the hierarchy. A checklist of possible triggers for a new product is given below.
These factors might initiate additional studies that could include specially commissioned reports on market research, warranty, and servicing and competitor activity.
The outcome of this stage should be recognition that there is an opportunity for a new product to be formalized in a project proposal

a) An enquiry from a customer.
b) A response to a perceived market need (market-pull).
c) Government initiatives and charters.
d) A research finding, perhaps associated with the development of a new technology (technology-push).
e) A new way of applying technology that may result in an innovation.
f) A license or franchise agreement.
g) A creative thought from any source.
h) A change of company assets providing an opportunity to redesign the product.
i) Problems, failures or deficiencies with existing products.
j) Loss of sales to competitors or a decline in orders.
k) Improvements to existing products to simplify, rationalize or "stretch" the design.
l) Complaints and ideas from, or surveys of, customers, sales staff, dealers, etc.
m) Published market research findings.
n) New patent applications.
o) Inventors, academics, scientists and consultants.
p) New regulations, legislation, standards and codes of practice.
q) Economic trends.
r) Suggestion schemes (including customer suggestion schemes).
s) Observation, imitation or improvement of competitors' products.
t) Environmental issues.
u) A change in the organization's or a competitor's vision or image.
v) Augmenting the product to get closer to the customer (e.g. direct delivery).
w) Increased leisure time.
x) Community welfare need.
y) Experience and intuition.
z) Natural change (e.g. the tooling of an old product needs replacing).
   New materials become available.
   Change in consumer behaviour/style.
   etc.

Opportunity Feasibility Study

Undertaking a feasibility study

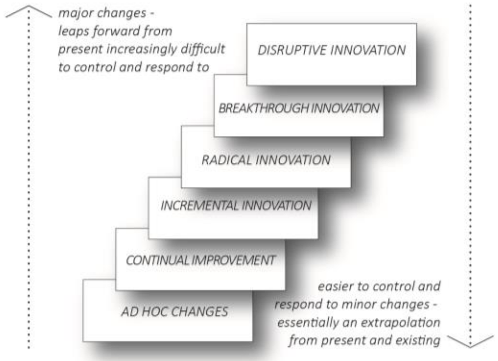
The purpose of this stage is to establish whether the proposed development is viable and aligned to the objectives of the organization and its design programme. The output of the study will confirm that it is practicable to satisfy the product

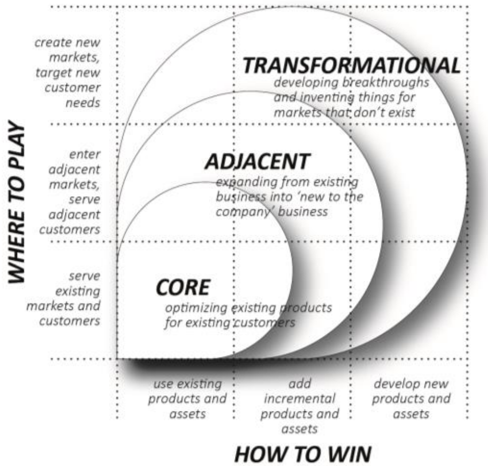
a) a product audit of current capabilities, suppliers and distributors;
b) market research;
c) competitor analysis;
d) benchmarking;

e) identification of barriers to entry;
f) cost benefit analysis;
g) discounted cash flow (DCF);
h) risk analysis;
i) decision trees;
j) timescales and milestones;
k) project appraisal;
l) project network planning techniques (see BS 6079 for further guidance).

The project manager should prepare a report on the feasibility study, which should make a case for proceeding with the proposed development. More questions might be raised that will refine the feasibility study. These need to be answered before moving to the next stage of the process. On completion of this phase, the organization should have sufficient confidence to commit resources to create the product. If the project is judged to be not feasible, it may be reassessed or abandoned.

Operational		User scale		Sector		Transformational	
Deign characteristics	Business Attributes	Deign characteristics	Business Attributes	Deign characteristics	Business Attributes	Deign characteristics	Business Attributes
Driven by internal insights to deliver efficiency, effectiveness, and profitability for the business Creates or changes organizational structure and processes Brings efficiencies that benefit everyone Improves work life Improves productivity Improves financial performance Should improve customer experience	Focuses on improving the company's operations More detail oriented/metric focused Productivity driven Allows for cost savings that can benefit company and customer Improves the company's business case Oricn1ed toward sustainability Dominated by left-brain thinking Has tightly predictable financial returns The lowest-risk type of innovation	Driven by competitive market needs Generally defined by new features or benefits Creates new ways 10 delight the customer or consumer Impacts multiple categories Keeps category innovation fresh and current Anticipates or creates market changes	Often achieves incremental revenue Tends to be the most profitable Is fast to market Doesn’t have to be core product or service-can be an in and out proposition Is exciting for everyone company and customer Maximizes cross-functional participation Focuses on left-brain creativity Can impact business short term but also has long-term potential	Driven by understood or anticipa1cd customer needs and insights Builds on or stems from transformational innovation Involves breakthrough of applications instead of invention Guided by a valid business case A I lows for follow-on innovation at the marketplace and operational levels	Potential to be profitable Predictable rcve11ue and 1imclincs Fits with Wall S1rcct expectations Often led by marketing more than technology Mos1 successful when there is fluid interaction between mnrkc1ing and R&D focuses on whole brain creativity More manageable risks than transformational innovation	Driven by curiosity and discovery Changes society and life as we know it Provides benefits to our culture and communities Disruptive and revolutionary in scope; sustainable in dimension Cascades into follow-on innovation at category. marketplace, and operational levels Becomes something we depend on	Difficult to define in terms of full market potential Has no defined P&L or timeline Has a risk-reward ratio exponentially higher than any other type of innovation Has an unclear adoption rate Can't survive in a large corporate environment unless protected from standard success metrics Dominated by right-brain thinking and creativity





Strategic development

Get organization into shape, then maintain its fitness to innovate

- Future vision
- Innovation planning
- Innovation highway
- Culture / values
- Policies / practices
- Research and development of critical competencies
- Alliances
- Generating / capturing / vetting / archiving ideas
- Training / development of new skills sets
- Intellectual property
- Corporate software /
- Knowledge Management
- Competitors

Creation of right offerings and processes

Select and transform the right ideas into viable product opportunities to achieve objectives and deliver plan

- Opportunities selected for exploitation
- Customer-Product
- Experience Cycles
- New product creation / development procedures
- Project configuration
- Harnessing external expertise
- Design origination
- Design development and detailing
- Prototyping / testing
- Whole-life assessment
- Customer satisfaction
- Safety
- Sustainability
- Business model
- Competitors

Procurement of expertise and inputs

Process inputs to organization

- Availability / access to expertise
- Sourcing supplies
- Delivery / timing
- Storing
- Internal handling
- Quality control
- Relationships with suppliers and other partners
- Shrinkage / waste / obsolescence
- Buying department
- Negotiation
- Contracts
- Licensing

Preparation / Fabrication of offerings

Actual production of products / preparation to deliver services

- Fabrication
- Assembly / Bringing together all components of service
- Testing
- Packing
- Storing
- Operations management
- Quality control
- Protection of intellectual property
- Minimization of waste and effluents
- Enhancing efficiency of energy use
- Negotiation
- Contracts
- Licensing and other revenue streams

Distribution / Access

Get the product safely to the right points of sale, and deliver services without adding unnecessary costs

- Order placement and processing
- Selection of channels
- Options for delivery
- Delivery environment
- Accessibility
- Scheduling
- Warehousing
- Delivery to market
- Backup during delivery
- Chain of command
- Training

Marketing / Sales / Customer experience

Present offerings effectively so as to widen appeal and maximize revenue potential

- Marketing
- Display
- Pricing
- Selection of outlets
- Product presentation / point of Sales material
- Relationships with retailers / partners
- Advertising
- Incentive schemes
- Negotiation
- Contracts
- Intellectual property / licensing
- Training
- Buying experience
- Out-of-box experience
- First use experience
- On-going use
- Re-purchase pattern
- Customization
- Influence on user practices
- Next generation wishlist
- Competitor response

Customer and market support

Support products and customers in the market

- After-sales service
- Query and complaint processing
- Spares supply
- Training
- Analysis of customer processes / practices
- Anticipate customer needs and aspirations
- Customization
- Observation / Customer feedback
- Build on lessons learnt
- Reliability / safety record
- Termination / Phasing out / Disposal
- Waste reduction
- Disassembly and recycling
- Re-use
- Intellectual property / licensing

Enterprise Strategic Drive

Many reasons make innovation an imperative for organizations, particularly those of small and medium sizes. Its importance is linked to survival, sometimes expressed as the only sustainable strategy for growth. Others consider innovation a vital force that motivates staff and gives them a considerable sense of pride.

Research also confirms that the most frequent catalysts of innovation are customers and partners in the value chain. Addressing their needs, seeking to make life easier for them and helping to improve their businesses, all act as drivers of innovation. However, observed difficulties, declared requirements and complaints have to be translated into intelligence that helps generate sensible solutions.

The principal reasons why innovation should be among an organization's core competencies are summarized below:

a) To improve current situation:

- reduce costs and raise margins, hence profitability;
- protect market share and survive adverse operating circumstances;
- stimulate staff with interesting and challenging work;
- provide stability for the workforce.

b) To open new horizons:

- reposition and alter perceptions of an organization;
- exploit avenues with greater potential;
- gain competitive advantage and lead the market;
- reduce the influence of competitors.

c) To reinforce compliance:

- comply with legislation (current or anticipated);
- fulfil social and environmental responsibilities.

d) To enhance organization's profile:

- enhance reputation and raise its market profile;
- attract extra funding;
- to attract those with good ideas and potential alliance partners;
- to attract and retain higher calibre staff.

Enterprise Productivity Drive

To gain competitive advantage in circumstances where resources are necessarily constrained, it is crucial for organizations to focus efforts on opportunities that yield greatest operational, psychological and financial benefits.

The curiosity of staff members, customer requests (or dissatisfaction), and competitive pressures all act as spurs to do things differently and better. However, special efforts should be made to generate high productivity innovations that:

a) solve more problems than originally envisaged;

b) spawn further innovations;

c) set new benchmarks, price points, etc. that competitors struggle to match;

d) interest and inspire more people;

e) are easy to sell, internally and externally;

f) colleagues grasp quickly and make their own;
g) present real and enjoyable challenges to those who develop them;
h) arise out of trouble-free development;
i) are more readily implemented and integrated into host
organizations;
j) have fewer shortcomings that are rectified easily at minimal cost.

‘Newness’ of Innovation

- Continual improvement of product offer
- Incremental + Reconfigured Functions + Functions
- Radical Paradigm Innovation

The spectrum of changes that might be introduced through innovation extends from “new to the world” at one extreme through to “new to an individual” at the other.
The former encompasses changes that have never been seen or done before as far as can be ascertained. The latter might encompass existing technologies and practices that are familiar to others or common in different situations.
The former also holds the potential to generate the greatest impact and returns; while those arising out of the latter can be severely limited. As change in the former is relatively greater and less familiar, the risks in seeking and implementing such newness are considerably greater; those associated with the latter are commensurately lower. These are crucial factors when determining the kinds of innovations to be pursued.
The sources of newness might be personal to individuals, relate to one
or more groups within an organization, or derive from whole Organizations.

Broadly, change and newness should not be anticipated if there is no motivation to do things better and differently. If an organization makes no changes in the way it goes about its work, it should not expect innovation to result.
Sources of newness should be sought in the following:

a) Perceptions and ambitions:
• vision of the future and willingness to extend planning horizon;
• how the future is linked to the present;
• attitude towards opportunities, constraints and threats;
• where boundaries are placed;
• commitment and drive at top levels.

b) What is done:
• areas of interest;
• class of problems tackled;
• where boundaries are placed.

c) How things are done:
• project configurations;
• mix and calibre of people involved, disciplines and bodies of
knowledge brought to bear, how they interact and networks tapped;

- language, processes and techniques used;
- assignment of resources (equipment, etc. used);
- innovation management infrastructure;
- way work is financed and outcome is evaluated.

Newness might be at the core of a product or process and suffuse it; or it might be superficial and confined to a minor part. For example, the adoption of a new manufacturing process might require radical changes to the design and assembly of a product's components. However, these significant changes might be invisible as the external appearance of the product and the way it is operated might remain unaltered. By contrast, simply changing the materials and colours of a product casing to ones that are unique in the market might transform it in the customers' eyes.

Value Chain Innovation

Research reveals consistently that success with innovation requires attention to far more than the technical content of products, for it is the experiences with products and the originating organization that form a customer's satisfaction. Though technology is often critical to the success of products, it is not always understood by customers or they might take it for granted; technology is rarely uppermost in their minds.

Potential innovations should be sought throughout the value chain, not just in the technical aspects of product development, for example, by examining how an organization operates, the way it creates new products, its sourcing and fabrication processes, marketing and after-sales support, through to final disposal and recycling of products.

Such a perspective is essential to evolve carefully integrated solutions that are increasingly essential in highly competitive markets. Working throughout the value chain is often the best way to safeguard the integrity of solutions through to launch and on to disposal.

Third parties in the value chain (suppliers, contractors, sales outlets, etc.) can have a major impact on the overall customer experience. They could be encouraged to become partners in innovation which would expand expertise and resources brought to bear in exploiting opportunities, sharing work and costs, facilitating buy-in, and reducing time to delivery.

Opportunities for innovative exploitation across the value chain are listed in the figure below

Also see 'Ten Types of Innovation' Doblin

Occasionally, step changes in performance are achieved through advances in existing technologies, ergonomics and business practices, or the introduction of new technologies and procedures. Such phases of radical innovation tend to be followed by stable phases where incremental enhancements are introduced until a further radical change becomes necessary.

Radical phases might herald new generations of products though, in reality, most innovations are sub-innovations that do not transform the overall product even when one or more components are substantially altered.

Basis of Innovation Opportunity

The following list summarizes key actions in effective innovation management:

a) Organizational stance:

• Acknowledge responsibilities then drive innovation policy and activities from the top.

• Formulate a clear long-term vision plus specific tangible innovation objectives and strategies closely aligned to organization's objectives and strategies, then ensure that short-term work ties in seamlessly with long-term investments.

• Maintain a genuine and visible commitment to effective innovation through quality and reliable design, and ensure that innovations are exploited to their full potential.

• Establish an innovation-nurturing culture with the fundamental belief that the future can be planned then created over the long term.

• Evolve a blame-free environment that underlines the power of learning from failure.

• Place staff on the front line of innovation and promote their ability to contribute to the organization's innovation programme.

b) Scanning the environment:

• Be aware of competitors' innovative activities as well as relevant activities relating to innovation in other fields.

• Monitor progress and trends in markets, technologies and intellectual property.

• Develop and/or harness appropriate technologies.

c) Problem-solving approach:

• Adopt an holistic approach to products.

• Encourage the generation and efficient processing of ideas even where there is minimal competition by providing a stimulating work environment that allows some personalization of work and spaces.

• Seek to be innovative when articulating customers' needs, interests, aspirations and defining problems. Creative briefing goes a long way towards the formulation of creative solutions.

• Encourage imaginative configurations of projects, not least in the expertise and resources brought to bear on a problem.

• Promote innovative, comprehensive solutions to consumer and business needs. Copying becomes considerably more difficult when creative solutions cover greater ground and engage target audiences emotionally.

• Plan and rehearse customer experiences over complete product lifecycles as the basis for design work.

• Assess opportunities and risks, particularly in relation to timing and degree of innovation.

d) Management system:

• Understand organizational capabilities and limitations.

• Introduce a system for undertaking innovative work that is accessible to, and understood by, all employees.

• Establish a gateway review system to monitor progress at opportune intervals, allow opt-outs, revisit previous failed initiatives, and tailor work to changing circumstances.

• Plan introduction and sustenance of innovations.

• Maintain confidentiality of innovation plans and programmes.

• Determine, protect and exploit intellectual property.

e) Resources allocated:

• Make effective use of the skills, knowledge and experience within the organization (the corporate software).

- Develop skills needed to put together innovative projects; set up training programmes to upgrade innovation management skills and innovation performance.
- Use advances in information technology to raise the effectiveness of communication throughout the organization in terms of speed and wider exposure.
- Ensure innovations are properly supported, and adequate resources (personnel, funding and facilities) are committed throughout the value chain.
- Promote innovation through teamwork to expand opportunities tackled and increase overall benefits; encourage internal and external networking.
- Form innovative alliances to reinforce market positioning and reduce the impact of competition; establish protocols for sharing information (see 5.11.2 and 6.9).

f) Build on experience:

- Evaluate the contribution of innovation to an organization's performance.
- Capture experience to draw greater insights and build a distinctive competency in managing innovation.
- Build a reputation for achievement as a serial innovator to encourage outsiders to submit ideas and predispose them favourably to collaborating when approached.
- Undertake reviews of innovation and innovation management practices periodically and refine as appropriate.

Compatibility with Enterprise's Current Vision

Before planning the future, the current situation should be identified and quantified (wherever possible) in a broad-ranging review led by principals, covering all an organization does in relation to innovation, e.g. its activities, procedures, culture, resources assigned, financial commitments, and achievements. Reviews should also analyse:

- market trends, anticipated demand, positions of current products in their lifecycles;
- future turnover and profits, hence potential gaps in overall performance;
- strengths, weaknesses, opportunities and threats;
- existing intellectual property that could be exploited to better effect; as well as existing skill sets.

Results can then be compared with competitors and the best organizations in an industry or particular activity to gauge the potential for improvement. As such, they provide the context and indicate the groundwork and infrastructure necessary to enhance performance.

All reviews (internal and external) help to build, and communicate, the business case for adopting a more professional approach to innovation.

This identifies the prime reasons for change and the likely costs of maintaining the status quo. It also provides preliminary assessments of the opportunities to exploit, resources to be committed and anticipated benefits.

The assistance of experts (and lead users of products) might be required to flesh out key issues, develop the necessary skills, complete assessments and support internal champions.

Create future vision

Innovation Opportunity as a driver for company vision

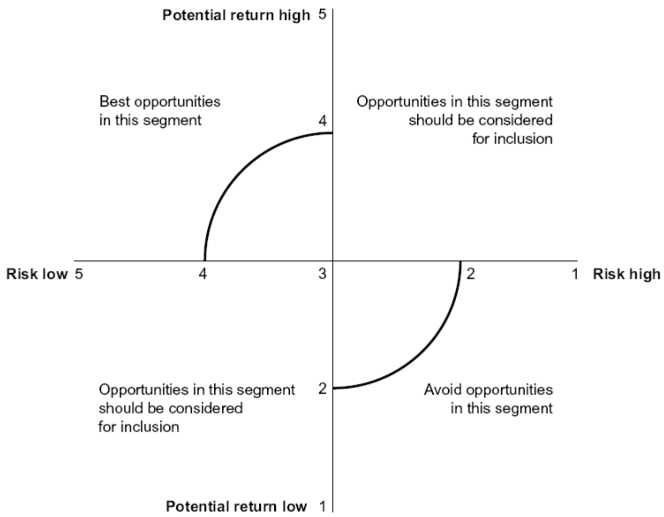
The creation of a future vision should follow the wide-ranging review of an organization's current capabilities and potential for improvement.
This helps to formulate a clear, challenging innovation brief that guides and inspires colleagues throughout the organization to come forward with appropriate propositions for improvements and development into long-term products.
A vision of the future which, perhaps, principals evolve over a series of brainstorming sessions, should be informed by:

- how people go about their lives, as well as changes in the natural and built environments;
- core technologies as well as developments in business practice and society generally;
- key characteristics of target markets;
- main drivers of customer needs and activities, perceptions and expectations, purchase decisions, satisfaction and loyalty;
- analyses of customer experience with the organization and its products;
- development of leading best practices;
- competitor analyses;
- anticipated changes in legislation;
- scenarios envisioning desirable futures (events, markets, technologies) as well as potential adverse factors; and
- how the organization intends to position

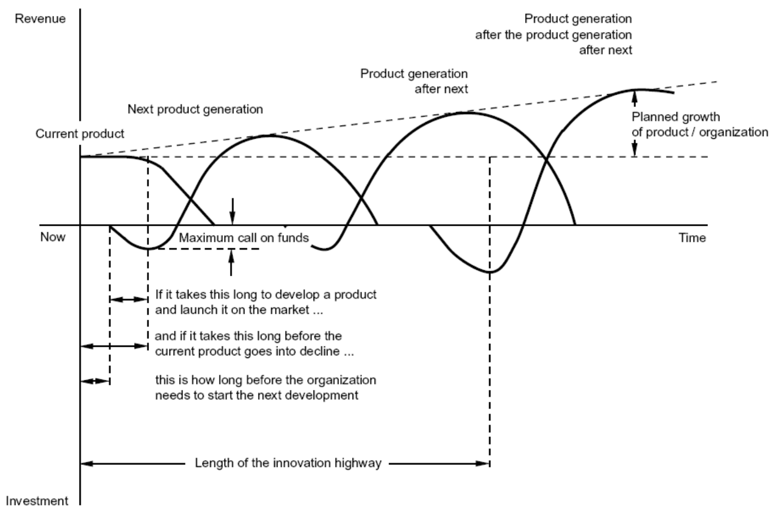
Draw up mission statement relating to innovation
Principals should formulate a statement of their organization's innovation mission to enhance and give greater practical meaning to their business mission. This should articulate the organization's general stance, or philosophy, towards innovation, the prime reasons for promoting innovation, and its contribution to overall performance.
This statement, together with the organization's innovation objectives and strategies, are prime determinants of what is acceptable to an organization in terms of innovative activities and investments.

Developing a Portfolio of Innovation Opportunities (follow-on Product Generations)
Draw up master innovation programme
NOTE This sub-clause will facilitate the fulfilment of 7.5 in BS EN ISO 9001:2000.
All potential + follow-on innovative activities (long- and short-term) should be co-ordinated within a master innovation programme that details work on each potential product, technology or process broken down into stages (with deliverables, budgets, schedules and reviews) (see 6.6).
Work to be executed entirely in-house should be identified together with that requiring external help (bought-in, out-sourced or possible bases of alliances). Skills and other resources to be committed should be set out under each stage, together with outcomes and contributions towards attaining the organization's objectives.
To reinforce context and direction, the programme could usefully summarize the organization's innovation mission statement, objectives and strategies. It is important that all

those involved and interested in innovation have access to this programme in a formal, easily accessible working reference.
The criteria that guide the search for innovative ideas should be clearly stated and familiar across the organization. Initiatives should be approved onto the master innovation programme by means of a formal procedure that is transparent and fair.
It is essential that principals nurture a pro-active attitude among colleagues, for example, staff should have an open invitation to put forward innovative suggestions. Guidance should also be provided to assist staff to formulate proposals and gain appropriate backing.
Timely, meaningful responses from superiors are further encouragement for staff to invest time formulating proposals; wherever practicable, users and specialists should be consulted to validate them.
It is advisable to maintain a balanced-risk portfolio of longer-term development projects with a good mix of high risk/high return and low risk/lower return projects (see below). Projects with low risks and high returns are most favoured; those with high risks and low returns should be avoided.



Determining the width of the innovation highway



The width of the innovation highway identifies the terrain to be covered, e.g. industries, markets, technologies and specific niches where attention and resources should be concentrated, as well as the kinds of products that might be targeted for development. It might even provide parametric product briefs.

The parameters that circumscribe the development of longer-term products might include:

a) financial factors such as the maximum that can be invested in any project, minimum return on investment or maximum payback period (see Figure 18);

b) maximum development time to bring a product to market;

c) performance and risk measures against which ideas and project proposals are judged (see 7.10);

d) target customers, basic means of satisfying their needs, price points, production costs and margins;

e) specific benefits sought, perhaps to enhance customers' experiences of the organization and its products;

f) emerging technologies and practices that hold particular interest and promise;

g) statutory requirements in different countries and standards in different markets;

h) strengths to build on, e.g. core technologies and practices that need to be boosted and protected;

i) weaknesses to be eliminated;

j) sources of likely threats and counter strategies.

Care should be taken when specifying parameters. If too restrictive, they might stifle opportunities to innovate; if too vague, those in development have insufficient direction.

Financial Strategy

A proper balance should be established between funding activities from, say, departmental revenues and making new funds available from central funds. Principals have to make clear which activities are to be sustained entirely from central funds; which are to be financed

entirely from departmental budgets; and which parts of an organization are expected to contribute a proportion of the budget. These should be agreed beforehand.
Moreover, the required funding should be split between capital and revenue accounts. Capital allocations should be made for anticipated changes in facilities and equipment to take advantage of enhancements in technology and systems.
All these factors should feature in the master innovation programme setting out clearly when funds will be required. Where appropriate, figures should be discounted to allow for the passage of time and reveal net present values.
Capital assets earmarked for innovation should not be utilized for operational purposes if such use jeopardizes the innovation programme. However, where feasible, sharing facilities and expenses can help to offset the capital cost of, and optimize the returns from, innovation activities.
Costing and financial planning should be facilitated by an easily comprehensible system of budgeting. Guidelines on appropriate expenditure on different elements and the fair allocation of overheads also help.
Financial plans should include details of:

a) level, timing and nature of cash demands;
b) size of markets and anticipated shares;
c) revenues to be generated over a specified time;
d) anticipated margins to be achieved;
e) profits or surpluses to be generated;
f) payback periods;
g) rating of risks involved;
h) budgetary constraints;
i) cost-benefit analyses;
j) returns on investment and/or capital employed;
k) maximum project budgets;
l) monitoring of expenditure;
m) budget revisions where necessary.

Resource plans

Resource plans should specify the resources to be committed to addressing innovation and innovation management issues. Particular attention should be given to the following questions:

a) Does the proposed activity make good use of, and stretch, in-house expertise?
b) Will new technologies be developed, bought in or contracted out to specialists and suppliers?
c) Will new equipment or design aids be developed specifically for the organization or could standard versions be used, perhaps with minor customization?
d) Is adequate accommodation available (for example, space, location and controlled work environments) to allow team members to operate effectively?
e) Are administrative systems in place to enable the activity to progress smoothly to completion? Are these systems adequately coordinated across the different functions and disciplines of the organization?

f) Are ancillary resources and activities planned to avoid cross-functional difficulties, especially at the transitions between stages where responsibilities might transfer between functions?

End-of-life consideration

End-of-life consideration (ELC) is part of the broader concept of Life Cycle Analysis, sometimes referred to as “cradle to grave” analysis, or more recently “cradle to cradle” analysis. Cradle to cradle expresses the idea that resources should be part of cyclical systems, so that the quality of processing at end-of-life is high enough or appropriate enough to feed into new high quality products. This in turn has implications for how materials are processed for first use.

This technique is used to investigate the negative impact of products on the environment, from which a relative weighting can be determined for the manufacture, transport, use and disposal of the product. Further development of the product can then be focused on those stages identified as having greatest negative impact on the environment.

The technique relies on accurate data concerning the level of negative impact to the environment being obtained for each stage in the product’s life cycle.

A life cycle analysis has three distinct phases. These phases are as follows:

a) *Phase 1*

Description of the product’s life cycle: identification of inputs, transformations and outputs for each stage in the life cycle.

b) *Phase 2*

Analysis of each stage in the product’s life cycle: identification of the basic purpose of each stage in the life cycle with measures of cost and value being apportioned.

c) *Phase 3*

Identification of opportunities for improvement: possible environmental or general improvements in the design of the product.

The following five criteria are the main ones used as a basis for life cycle assessment.

• Sources and system of energy used.
• Emissions to air.
• Emissions to water.
• Level of toxicity of materials used.
• Level of scarce material used.

NOTE This list is not necessarily exhaustive. See Figure 1 and Figure 2.

On completion of a life cycle analysis/assessment the designer should be aware of the product’s impact on the environment (materials, energy, chemicals, water use and biodiversity), and the opportunities for product improvement with respect to costs, customer value, manufacturing efficiency and ease of transport.

NOTE Further information on ELC is given in Ciambrone [16], EMAS [17], Huang [15], Hundal [18], Lewis and Gertsakis [19] and Molina et al. [20].

2.0 - Project Specification

2.1 Project Plan

Project Development Plan
Project Development Inputs
Project Resources

2.2 Project Factors

Project Parameters
Project Proposal [Brief]
Project Criteria
Project Fit

2.2. ROI – Return on Investment Strategy

Product Cost (Investment) Factors
- Cost Strategy
- Value Analysis
- Manufacturing Scenarios
- Business Process Engineering
- Development costs

2.3. Market Positioning

Customer Motivations
Customer Needs

2.5 LCA Modelling

Life Cycle Consideration
Materials + Component Sourcing
Manufacturing Processes
Product Use
Disposal

2.6 Legislation

2.7 Project Proposal Specification

1. technology - production
2. technology - performance
3. enterprise model
4. market
5. ux - ui - sx
6. lifestyle

2:0
Project Specification

Design Factors

General

The detailed characteristics of the product now need to be established.
The outcome of this product definition phase should be a completed requirements specification that describes a framework to which any chosen solution should conform. This specification should define requirements and constraints (e.g. regulations), but should not dictate solutions. In certain instances, a case may be made for excluding particular approaches or solutions.
The process up to this point should have been principally concerned with defining the product from the customer's point of view.
Subsequent phases will focus on the process of developing and delivering an acceptable product to customers.

Researching and analysing requirements

The project manager should now establish the details of the perceived opportunity.
Research on how the opportunity could be satisfied should now be undertaken to establish the general functional requirements for the new product, for example:

a) key functions;
b) description and block diagram;
c) statements that describe what the product has to achieve;
d) ergonomic and aesthetic/graphic considerations (shape, finish, colour, graphics, etc.);
e) patents that might constrain the product;
f) user interface considerations;
g) inclusive design considerations;
h) environmental issues;
i) required life-span;
j) level of reliability;
k) requirements for robustness, waterproofness, shock, vibration, acceleration, temperature (both operational and ambient), chemicals, etc.;
l) requirements for materials (e.g. particular grades);
m) compatibility with other products or systems either in its use, function or appearance;
n) manufacturing strategy;
o) testing strategy, to determine how testing will be performed to prove conformity to the specification;
p) customer acceptance criteria;
q) strategy for product disposal.

Any design solution is inevitably a compromise between various factors, so the identification and selection of the best option may depend on evaluating many considerations, including some of those listed below.

Return on Investment

Product Cost Factors

Controlling product cost

The cost of the product should be carefully evaluated and controlled during the design programme, and the following should be considered:

a) design strategy to achieve cost targets;
b) design approach (use of standard parts and/or modular construction);
c) material selection;
d) value analysis;
e) selecting manufacturing techniques appropriate to the design and volume;
f) process analysis to determine factors that add value (business process re-engineering).

Market Positioning

General

Customer satisfaction arises out of an overall experience with a product and its associated services, and so careful attention needs to be paid to every element that contributes to this experience. Senior executives should ensure that all these elements are identified and defined, understood, familiar among staff, and contribute to the intrinsic qualities of the product such that it can achieve the desired position in the marketplace. Procedures and appropriate resources should be in place to be able to position products competitively in the marketplace.

Coordinating the visual identity of products

Those who manage design should take account of brand identity and the public's perception of the organization's product range, care should be taken to ensure that the designs of products and associated outputs reflect and enhance brand identity, and that design and design management procedures are coordinated and in harmony with the current or intended product range.

Principals should decide the extent to which products are to be coordinated visually. That key decision might be influenced by factors such as:

a) the strength of an organization's visual identity;
b) the split of product ranges into brands with distinct identities;
c) the commercial benefits of being clearly differentiated from the competition in terms of consumer preference, greater market recognition and loyalty, and opportunities for cross-selling;
d) the additional costs imposed by being distinctive and sustaining that distinction;
e) the cost savings to be made by rationalization and adopting modularity of product configurations;
f) the cost savings to be made through consistency of presentation.

Visual identity is conveyed on products by:

a) colours;
b) materials;
c) textures;
d) shapes and styling of casings, disposition of controls and components;
e) graphic identification through use of company logos, symbols and typefaces;
f) presentation of information and instructions on casings and visual displays;
g) packaging and user manuals.

Researching customer attitudes and needs

Research into customer and user attitudes and aspirations, work and lifestyle is essential. Particularly instructive is the observation of how users interact with products from the moment that they first perceive a product (or perhaps take it out of its pack) to final disposal. Ergonomic factors such as simplicity of design, user-friendly interface and ease of use by the infirm and disabled should be considered. Care should be taken to establish whether expressed needs or other factors are those that most influence purchase decisions, especially as these might vary between first and subsequent purchases. All these might suggest opportunities for new products, improvements to existing products and different ways to present products to the market.

Among the most powerful sources of ideas for new or improved products is the understanding of the following:

a) customer perceptions (especially of their needs and wants);
b) what triggers purchase decisions;
c) how decisions to purchase are reached; and
d) how customers use products and services.

Keeping close to customers and markets in this way is critical to success. Principals can do much to raise performance by insisting that such marketing and design research is undertaken continuously and that findings are acted on without undue delay. A powerful way of achieving such closeness is to establish strategic partnerships with key customers, distributors and suppliers.

Promoting environmentally sensitive design

Environmental factors influence purchase decisions, and many consumers appreciate buying from organizations known to be responsible members of the community, especially in their attitude towards the environment. In addition, legislation, as well as the impact of voluntary pressure from trade bodies is forcing organizations to re-assess their outputs. Consequently, organizations should adopt a “cradle to grave” approach to monitor practices, performance and impact from source of raw materials (their “chain of custody”) through to final disposal and recycling of products. Senior managers should define clear organizational environmental objectives, and should address environmental issues relating to product design and development to achieve the following:

a) a reduction in consumption of energy in their manufacturing processes;
b) a reduction in their products’ consumption of energy during use;

c) a reduction of material waste (e.g. during manufacture and in packaging);
d) a reduction or elimination of adverse impacts on the environment through emissions and discharge of waste;
e) the simplification or optimization of fabrication and assembly procedures (for example, by reducing unnecessary variety in materials and components used);
f) improvements in the performance of bought-in materials, components and equipment, as well as in the practices of suppliers;
g) the identification of uses for the by-products of the manufacturing process;
h) the introduction of recycling of materials and spent components (and facilitating their collection);
i) continuity of a product range, allowing compatibility when upgrading without the need to replace;
j) the extension of the durability and life of products by designing for refurbishment and designing-out unnecessary obsolescence;
k) increases in the efficiency of distribution by reducing size, and improving stackability and storage;
l) the containment or reduction of costs (including those for disposal of used or obsolete products).

NOTE Attention is drawn to the Environmental Protection Act, 1990 [1] and BS EN ISO 14001 for detailed guidance on environmental requirements.

Customer-product experience cycles

Customer satisfaction arises out of experiences of a product, from first awareness through to final disposal. Success, for industrial and consumer products alike, is achieved by conceiving and managing those experiences.

All customer-product experience cycles have common phases such as awareness, interest and information gathering, purchase, first use, on-going use with developing proficiency, and disposal/recycling. Each phase has considerable potential to delight or antagonize customers and users. All can be analysed in detail to map out likely sequences of key events and range of responses.

Understanding those experiences forms the soundest foundation for designing products that resonate with target audiences with valued highs planned in and debilitating lows eliminated as far as possible.

Rehearsing the acquisition, ownership and use experiences, ideally through role-playing featuring all relevant parties, can help distil how and at what points innovation and design can facilitate and enhance those experiences. The way target audiences (particularly key customers) react to proposed new product concepts, features and improvements can provide insights into how they value those propositions as well as their perceived priorities.

Project Resources

With the increased complexity of technology, the pace of product creation and the demands on capital, organizations should look beyond their in-house resources when undertaking development projects.
Consideration needs to be given to harnessing the skills and experience of suppliers, distributors and customers around the world. All these parties may legitimately be considered members of the organization's design team whether or not collaborative initiatives and longer-term alliances are formed.
Resource plans should be prepared which specify the resources to be committed to design and design management issues. Particular attention should be given to the following questions.

a) Does the proposed project make appropriate use of in-house knowledge, skills and experience?
b) Will new technologies be bought in or subcontracted to design specialists and/or suppliers?
c) Will new equipment or design aids be developed specifically for the organization or could standard versions be used, perhaps with some minor customization?
d) Does the accommodation provide the necessary space and technical services (e.g. clean conditions and environmental control), to allow team members to operate effectively?
e) Are systems in place to enable the activity to progress smoothly from initiation through to completion? Are these systems adequately coordinated with the systems of other functions/disciplines?
f) Are the necessary ancillary resources and activities in other functions planned so that product design progresses smoothly without cross-functional difficulties, especially at the transitions between phases/stages where responsibilities transfer from one function to another?
g) Is training provided to raise awareness of design and the design processes among staff, and enhance design management skills?

Where an organization seeks to sustain a close working relationship with customers and suppliers, consideration should be given to offering them the opportunity to join in such training, as those who train together often relate and work better together. Substantial benefits could derive from better understanding between the parties and a common language, as well as a convergence of attitudes and approaches.

LCA Factors

Disposal

When a product line is withdrawn, discontinued or replaced, contractual and legal liabilities and warranties will remain in force for products still in use.
There may also be a continuing demand for after-sales support, spare parts and consumable items.
The factors that need to be attended to at this stage should have been considered in the concept and feasibility stages of the project, described in the product design brief and specification and included in the project plan.
These factors may include:

a) warranty;
b) disposal;
c) waste management;
d) biodegradability;
e) service and maintainability;
f) provision of spares;
g) skills provision;
h) continuing safety and security;
i) recycling;
j) social and environmental impact;
k) transfer or sale of the project;
l) upgrading of product;
m) intellectual property rights.

After considering the need for continuing sales support, remaining stocks of products, spares and consumable items might be sold to a specialist dealing in discontinued products.
With regard to k), if consideration is given to selling the remaining assets of the project to another party, then legal advice should be sought regarding liabilities and intellectual property. It is important not to give away intellectual property that might be needed for future products.

Life cycle considerations

In order to minimize environmental impact throughout the life cycle, product design shall address the issues relating to the environmental impact of the product, namely:

a) materials and components sourcing;
b) manufacturing processes;
c) product use and maintenance;
d) de-manufacturing processes;
e) costs, savings and income.

The output from this process shall be a set of documents which identify the extent to which life cycle impact has been addressed, the methods used and the reasons for subsequent design decisions.

NOTE Annex C provides a checklist of issues that should be considered in relation to life cycle.

Legislation

All organizations operate to standards, many of which are imposed from outside by factors such as legislation, customer demand and professional regulation. Senior principals should ensure that all such standards are complied with and, where cost-effective, exceeded to achieve competitive advantage.
In addition to these externally imposed standards, the organization should implement its own internal practices and procedures to govern the product development process.
The legal dimension of product design is of crucial importance, due to the potential for litigation in the civil courts in respect of allegations made against products and associated manufacturing processes. It is also essential to protect the organization’s intellectual property rights.

Copying products has become an easier and more rapid process.
Counterfeiting and infringement of intellectual property rights is also more frequent and widespread. Consequently, there is a need for considerable vigilance to ensure that an organization conforms to local requirements wherever it operates, and profits for as long as possible from its intellectual assets.
There should also be formal procedures in place to:

a) maintain records of key decisions, actions and changes that affect the product design, (for use, among other things, as potential evidence in case of disputes and litigation);
b) check that similar designs, patents, trademarks and service marks have not already been registered;
c) register designs, patents, trademarks and service marks;
d) ensure that the design is documented and controlled from the start of the project;
e) ensure that potential customers and suppliers sign non-disclosure agreements before being supplied with commercially sensitive design information;
f) detect counterfeiting and other infringements quickly, and take strong action to stop them;
g) deal with product failures and customer complaints;
h) recall products from the market whenever necessary;
i) check conformity with all relevant standards, testing procedures, health and safety at work requirements, and requirements concerning the disposal of packaging and products after use;
j) keep track of new legislation in all countries where the organization has interests;
k) make appropriate representations to influence the debate about proposed new directives, regulations or laws;
l) ensure that the organization is prepared well in advance to conform to new legislation;
m) use recyclable materials and reusable or refurbishable components wherever possible.

Design Criteria

Auditing activities and procedures

Periodic audits and associated reviews should be adequate where lead times and project time scales are relatively long and there are few product changes over that period. Where lead times and project time scales are short, and many changes are made to products, half-yearly or quarterly reviews should yield keener insights and allow greater control through faster response times.
These audits should be included in the organization’s design programmes, and staff involved in design work should participate.
Outcomes should be formally documented and circulated widely within the organization, especially to those who can act on the information to improve performance.

Audits should cover the following:

a) products and associated outputs (e.g. packaging, promotional literature and user manuals, point-of-sale material);
b) facilities (such as exterior and interior environments of workshops, showrooms, offices, warehouses);
c) equipment, other design aids (both hardware and software), and ancillary support;
d) design and design management procedures of suppliers and, wherever possible, of key customers and competitors;
e) the range of design and design management skills, knowledge and experience, (whether in-house or bought in), recruitment and selection, training, sources of outside advice;
f) competitors' products and associated outputs and services;
g) existing and emerging technologies (to check new developments and trends);
h) standards (internally generated or externally imposed) i.e. documentation, compliance, sanctions applied to ensure conformity);
i) the effectiveness with which the organization's resources are used.

Evaluating design activities

The organization's design objectives, strategies and programmes should be reviewed periodically to check their continuing relevance and effectiveness.
Evaluation at the organizational level should encompass multiple aspects of managing product design, the most significant assessments being:

a) the outcomes of design activities, especially the extent to which design and organizational objectives have been fulfilled, or how well progress is being made towards their achievement;
b) the overall organization's design programme (including control of progress, addressing design requirements, proper resourcing of activities, effective integration of design with other disciplines, effective release of products and reinforcing the position of design within the organization);
c) the contribution of the design programme to the organization's performance, especially in terms of financial results and the support of strategy, policy and objectives.

On completion of projects, final reviews should be conducted to identify any areas of improvement that might benefit subsequent investments in design, not least in relation to the objectives set and strategies pursued.
Principals should ensure that the lessons learnt from evaluations are properly documented and disseminated. Such sharing of experiences should help avoid mistakes being repeated and the unnecessary duplication of work. Problems should be anticipated or diagnosed earlier so that prompter and more effective action can be taken. Finally, the performance of executives with responsibilities for design should be evaluated.

Definition of Project Parameters

The design brief shall collate the set of requirements and limits, which identify and define a perceived market need, the satisfaction of which requires specific design input. These are common to all product areas and the design brief shall include the following, which are further expanded in the table below.

- Establishment of market need including target selling price and required time to market.
- Determination of technical feasibility (with particular reference to available and possible manufacturing/verification facilities).
- Assessment of serviceability.
- Consideration of end-of-life implications.

Each of the elements identified in the table below shall be given positive consideration, even if it is subsequently set aside as having no relevance to the project, since parties involved in the preparation of the brief are advised not to make assumptions about the relevance of particular aspects.

PARAMETERS FOR CONISDERATION IN THE PREPARATION OF A DESIGN BRIEF			
MARKET NEED	***TECHNICAL FEASIBILITY***	***SERVICEABILITY***	***LIFE CYCLE***
Market sensitivity *Sales potential* *Competition* *Opportunities* *Aesthetics* *Product Cost Value Rubrics* *Potential for on-going development* *Impact on company image* *Performance* *Potential benefits of sale as a function rather than a product* *Confidentiality* *Time scale* *Quantity required* *Inclusive design*	*Material (Suitability and performance)* *Currently Available Processes* *Potentially Available Processes* *Health and Safety* *Design verification* *Process Conformance testing* *Function Verification* *Risk Assessment* Milestones	*Level (eg. module/component) within a product.* *Ease and practicality of access to relevant level* *Required tools (cost and availability)* *Health and safety* *Skills Requirement* *Return to use processes* *Upgradability* *Spare Stock Implications*	*Materials (minimization, surf ace area, density, recyclability, recycled content, renewability)* *Manufacturing processes (materials/ energy consumption, pollution, toxicity)* *Product operation (energy sources and systems [renewable, low carbon], energy consumption)* *Life cycle assessment* *Legal constraints* *Whole life costs (production, use, end-of-life)* *Health and safety* *Recovery (materials)* *Recycling (materials/energy)* *Recovery (energy)* *Reuse* *Ease and practicality of disassembly*

NOTE 1 The process by which a design brief is prepared varies with the size of the organization undertaking the project and the nature and relative size of the project itself. However, the process should be as consultative as possible in order to obtain the input of all disciplines likely to be involved in the ultimate realization of the resulting design concept, at the earliest practicable stage.

NOTE 2 The detail of any given design brief varies from project to project with specific elements varying significantly in their level of importance within the brief and indeed, not appearing at all in some instances. Table 1 is presented in the form of a check-list of subjects to be considered as potential elements of a design brief that may be included, as appropriate. This list is not necessarily exhaustive for any particular project and the format is provided by way of example only although it might be of assistance to users.

Project Brief

A proposal for the new product development should be prepared to take the suggested ideas forward. The proposal should detail:

a) the availability of resources;
b) the synergy with current product operations;
c) anticipated and acceptable timescale for completion; and
d) the availability of design resources.

Estimated cost and profit should be compared to the required return on investment, or other financial performance measures, as necessary. The proposal should provide a preliminary definition of the new product, and conform to the organization's objectives.

This proposal for the project is not the product specification: that will emerge later – see below.

If the project is deemed viable, the outcome of this stage should be that the defined criteria can be met. If it is not viable, the project may be revised or abandoned.

The project proposal should be evaluated by principals. This will include appraisal of the outline of the envisaged product, and some consideration of:

a) project objectives;
b) market segments for the proposed product;
c) the need for regional or niche market variants;
d) potential demand;
e) outline characteristics;
f) environmental considerations;
g) phases and completion timings;
h) project costs;
i) capital requirements;
j) subcontract requirements;
k) documentation requirements;
l) the project contribution to the organization's turnover, profit and return on investment.

The project proposal should include provisional details of the product, any research requirements and methodology, milestones, timescales, financial resources and costs.

For those product concepts that are worthy of a more searching feasibility study, the topics shown in listing below, should be considered and evaluated.

The outcome of this stage is formal approval for continuation, the need for changes to the proposal, or a decision to abandon the proposed project. If the project is approved, principals need to commit the necessary resources to proceed with a feasibility study.

1) The operational brief.
2) Project plan and breakdown of project stages.
3) Product lifecycle.
4) Demographics (including the area and boundary of the prospective operation).
5) Competition.
6) Market segment.
7) Size of market.
8) The need for regional or niche market variants.
9) Customer and user standards.
10) Anticipated customer/user experiences.

11) Personnel requirements (including skills and experience).
12) Personnel availability.
13) Technology requirements.
14) Risk assessment.
15) Manufacturing process requirements.
16) Manufacturing resources requirements.
17) Manufacturing resources available within the organization and among suppliers.
18) Materials required.
19) Budgetary requirements, financial resources needed and available.
20) Return on investment, or other financial requirements.
21) Price and costs.
22) Timescale for product delivery and availability.
23) Reliability and maintainability.
24) Ease of use.
25) Frequency of purchase.
26) Speed of response to market and the organization's business needs.
27) Guarantees.
28) Special needs and product requirements.
29) Environmental considerations.
30) Legislation.
31) Socio-political market considerations.
32) Conformity to relevant standards, charters and codes of practice.
33) Shipping, delivery and erection restrictions.
34) Commissioning and decommissioning.
35) Disposal and potential for recycling.

Planning Design Development
7.3 Design and development

7.3.1 Design and development planning
The organization shall plan and control the design and development of product.
During the design and development planning, the organization shall determine
a) the design and development stages,
b) the review, verification and validation that are appropriate to each design and development stage, and
c) the responsibilities and authorities for design and development.
The organization shall manage the interfaces between different groups involved in design and development to ensure effective communication and clear assignment of responsibility.
Planning output shall be updated, as appropriate, as the design and development progresses.

7.3.2 Design and development inputs
Inputs relating to product requirements shall be determined and records maintained (see 4.2.4). These inputs shall
include
a) functional and performance requirements,
b) applicable statutory and regulatory requirements,

c) where applicable, information derived from previous similar designs, and
d) other requirements essential for design and development.
These inputs shall be reviewed for adequacy. Requirements shall be complete, unambiguous and not in conflict with each other.

PROJECT PROPOSAL SPECIFICATION

1. **TECHNOLOGY - PRODUCTION**
2. **TECHNOLOGY - PERFORMANCE**
3. **ENTERPRISE MODEL**
4. **MARKET**
5. **UX - UI - SX**
6. **LIFESTYLE**

TECHNOLOGY – PRODUCTION

Understanding how to manufacture the product

Once the detailed design has emerged (realization phase) product parameters can be finalized in the specification. The product's architecture and detailed design can now be recorded fully in the design documentation.

Criteria for manufacturing should be established in as much detail as practicable including methods of manufacture and test. Manufacturing staff (including those from any major sub-contractors) should be involved in this. Any special criteria for bought-in parts or sub-assemblies should be recorded gives a recommended checklist for use when considering how to manufacture the product.

PRODUCT IMPLEMENTATION

- Specify the way in which the product is going to be made (manufacturing strategy, e.g. make in-house or subcontract, test in-house or subcontract).
- Select and use appropriate software implementation and maintenance tools and techniques (e.g. reviewing, issue tracking, version control, integration, testing, release, baseline management).
- Specify what arrangements are necessary to ensure that the product is safe.
- List any special materials requirements.
- Check that there are not likely to be any special/long delivery materials or services necessary, or make the necessary provisions in the plan.
- Specify the materials and bought-out items that should be purchased (purchasing specifications).
- Define packaging requirements (e.g. size, shape, graphic design, labelling, protection), both individual product and bulk (where applicable).
- Specify requirements for user instructions and information for installation, storage, use and disposal, etc.
- Ensure the product documentation embodies all last-minute changes or modifications.
- Ensure production can match the customer's planned volumes.

MANUFACTURING PLANS

- Prepare a manufacturing plan.
- Specify the manufacturing processes.
- Specify the manufacturing quality control arrangements.
- Specify inspection points.
- Select the manufacturer(s)/supplier(s).
- Ensure the production processes are "capable''.

PRODUCTION SET-UP

- Specify the manufacturing tooling.
- Specify any special requirement for jigs and fixtures.
- Specify requirements for validation of manufacturing processes where necessary.
- Specify the minimum required manufacturing yield, and/or other parameters as necessary.
- Establish whether occupational health and safety requirements will have any effect on the product or manufacturing process.

Understanding how to support the product

Criteria for supporting the product should be established as early as practicable. The nature of the design itself and the thoroughness of any instructions for use can have a bearing on the amount of support customers need. Arrangements for dealing with warranty claims, criteria for associated costs, response times and helpdesk performance should all be established, as applicable.

Table 8 gives a recommended checklist for establishing product support.

POST MANUTACTURING SUPPORT

- Establish what should be covered in the user instructions (remember requirements of any relevant Standards) These should be written at the earliest practicable opportunity.
- Establish what product support arrangements are to be provided.
- Establish how any complaints are to be handled.
- Establish how customer feedback is to be obtained and handled.
- Define helpdesk or customer support arrangements where applicable.
- Ensure instructions or product packaging includes "helpline'' telephone number or support address (which could be that of a specialist subcontractor).
- Define any staff training that is necessary.
- Define spares provisioning.
- Ensure continuing availability of spares for the life of the product.
- Define warranty terms.
- Define how data from customer returns is to be gathered, analysed and fed back for future product improvement.
- Define how any embedded software is to be maintained or upgraded (e.g. bug tracking, implementing upgrades, documentation).
- Prepare a recall procedure.

Understanding how to dispose of the product

More and more importance is being placed on the need for proper disposal of all products, rather than simply throwing them away, either through reclamation or the practical recycling of their materials.

Manufacturers have an ever-increasing responsibility in this process. Attention is drawn to the fact that some legislation already exists and more is being drafted and contemplated.

DISPOSAL

- Consider the options for product recovery.
- Consider what remediation equipment or supplies might be required.
- Determine if any materials are suitable for recycling.
- Establish the process for disposal.
- Describe disposal/recycling procedure in user instructions.
- Determine if any hazardous parts (e.g. batteries) have to be disposed of in a defined way.
- Consider the use of degradable material.

TECHNOLOGY - PERFORMANCE

Understanding which legislation and standards are applicable

For many products EC Directives or other national legislation are applicable and it is necessary to establish which Directives and thus which regulations and standards may have an impact on the design. In some cases the design approach may dictate whether particular Directives or standards are relevant.

EXAMPLE

A mains electricity powered product will usually be subject to the Low Voltage (L.V.) Directive (requiring a technical file, and CE marking) whereas the same product running from a mains adaptor will not be subject to the L.V. Directive (although the adaptor itself will be). Thus taking the latter approach might considerably loosen constraints on the design and manufacture of the product.

The specification should include reference to any standards it has been decided the design shall meet (e.g. ISO, EN, BS). If these standards in turn impose particular requirements that are not already implicit in the design then these requirements should be listed in the specification (e.g. a requirement for limited flammability printed circuit board material, UL 94v0, in an electronics product). If the standards impose requirements that will be met by default then these requirements should also be listed in the specification.

- Clarify the category of the product (e.g. IT equipment, machinery, toy, pressurized system, electrical).
- Identify and list the major hazards associated with the product (e.g. electrical, mechanical, and chemical).
- Define the end-user market in terms of standards regimes (e.g. Europe, US, Canada, Japan, rest of world).
- Identify the applicable legislation (e.g. EC Directives, national regulations) (refer to Annex C and
- Annex D).
- Identify the relevant regulatory bodies.
- Identify the relevant safety standards or codes of practice for each market region using the appropriate standards body catalogue and by consulting expert bodies (refer to Annex G).
- Record the applicable standards in the specification.
- Obtain each standard identified and understand the implications of each.
- Make the contents of the standards available to the designer(s).
- Set out the requirements in the specification.
- Ensure that the product conforms to relevant standards and ensure the requirements are met by checking the design at reviews. (Do this at each stage of the design it is always much cheaper to correct a design or incorporate a new requirement at the earliest stage.)
- Record whether CE marking is a requirement.
- Record the route to CE marking (if applicable).
- Record who will certify/approve the product: self or third party. If the latter, which approval body?
- List the required contents of the product technical file.
- Specify requirements for product approval testing/type testing.
- Specify required content of CE Declaration of Conformity/prepare draft.
- Define what user/public liability risks there are.
- Specify requirements for product labelling to meet both legislative and commercial requirements.

ENTERPRISE MODEL

MARKET OPPORTUNITY

- Establish the potential size of the market.
- Establish if the market is growing or declining.
- Define the slice of the market you are aiming for (product positioning).
- Predict the level of sales (at least the minimum necessary for viability).
- Define how the product will reach the customer (direct selling, agents, distributors, and retailers).
- Understand the needs of any distribution network to be used.
- Identify what promotional effort will be needed (both in terms of developing links with those selling your product and those producing your product advertising/literature).
- Establish what you should know and do for direct selling, including the use of e-commerce (e.g. internet, email and website).
- Consider how branding might assist in selling the product.
- Determine in which countries the product will be sold (it may be necessary to make changes to the product in order to conform to local regulations).
- Address the possible consequence of making product changes for different countries (if a single solution cannot satisfy all standards and regulations).
- Understand the formalities and procedures associated with exporting.
- Understand how you intend to market and sell your product in these countries.
- Understand the likely effect of fluctuating exchange rates on the product price.
- Record any requirements for point-of-sale packaging and product presentation.

MARKET

Researching and understanding the market

In order to assess the commercial viability of the product the size of the market, the competition, budgetary requirements, financial resources, return on investment, the window of opportunity and time to market should be understood. This information leads to conclusions about how and where to sell the product, the time-scales required, reliability and quality. All of these conclusions are criteria to be included eventually, as applicable, in the specification.

MARKET COMPETITION

- Identify competitors and/or potential competitors.
- Record what you know about them and their products.
- Investigate the price of competitive products. Compare competitors' product performance with what you are proposing to offer. Is there likely to be a threat? Can you enhance differentiation?
- Assess what future developments there are likely to be in competitive products before the launch of your product.
- Establish if the competition is based in the UK or overseas.
- Do you have a unique selling point (USP)?

COMMERCIAL VIABILITY

- Establish the "window of opportunity'', i.e. the timescale in which the product should be launched in order to capture the desired market share.
- Estimate what financial resources will be required for product development.
- Estimate the cost of sales and marketing (this is almost certainly a significant contributor to the overall selling price).
- Estimate the cost of distribution.
- Estimate the cost of after-sales service and training (where applicable).
- Try and establish what price the market will stand.
- Check that the selling price can realistically accommodate product development, manufacturing and sales costs and provide adequate profit margins (exporting, or using different approaches to selling, can affect sales costs significantly).
- Check that the product can be made or bought-in at a viable cost (adequate margin).
- Ensure you have adequate knowledge of trends in the market or new developments, technological or otherwise, that may affect the product.
- Establish if there might be any political ramifications associated with the product.
- Establish proposed warranty terms (period and extent) and ensure they are viable.
- List any unresolved risks and concerns (to revisit later).
- Consider the cost of not proceeding with the development, e.g. commercial damage through competitor opportunism and/or loss of potential business.
- Is there a real need for this product?
- Is it financially justifiable?
- Does it look possible?
- Can you take the market share you need?
- What is its growth and development potential?
- Decide if you should proceed with the project.

UX:UI:SX

Understanding the potential product

In this phase the preferred product design begins to emerge and it becomes clear how the concept is to be implemented. Decisions are made about the final look and feel of the product and its performance.

Trade-offs quite often need to be made between the customers' perceived needs and what is feasible within technical, financial and time constraints. Trade-offs might also be necessary in order to reach the best overall solution. Any relaxation of requirements should be checked for impact on the commercial or technical viability of the product.

PRODUCT CHARACTERISTICS

- Where the product is dependent on scientific, technological, or engineering principles and know-how, ensure that they are understood and properly applied.
- Document an overview of the product including (as required): key functions; the architecture (the configuration and partitioning of the design); a description and block diagram; statements (to match the recommendations in Table 2) that describe in detail what the product has to achieve.
- Establish requirements for any embedded software, and document the architecture.
- List the ergonomic and aesthetic/graphic considerations.
- Establish if there are any relevant patents that might constrain the product.
- Consider patenting the idea yourself.
- Consider licensing.
- Describe user interface considerations, including design of labelling (size of font, permanence etc.).
- Record what environmental issues should be considered throughout the product lifecycle:
- resources used; energy consumption; emissions to air; emissions to water; waste; migration of hazardous substances; impact on soil; risk to the environment from accidents or misuse.
- Record the product's required life span in overall terms.
- Record what level of reliability is required.
- Record any special requirements for robustness, waterproofness, shock, vibration, acceleration, temperature (both operational and ambient), chemicals, etc.
- Establish that the product shelf-life allows adequate time for storage, distribution, retail display and use by the customer.
- Record any special requirements for materials (e.g. particular grades, recyclable materials).
- Establish if the product needs to be compatible with other products or systems either in its use, function or appearance.
- Undertake technical analysis of competitors' products where warranted.
- Consider "reverse engineering" competitor products to establish values for technical criteria.
- Establish a manufacturing strategy.
- Establish a testing strategy, to determine how testing will be performed to prove conformity to the specification, including for software.
- Confirm the technical feasibility.
- Define the customer acceptance criteria that should be met.
- Establish a strategy for product disposal (consider degradability/recycling).
- Consider methods of increasing life-span and designing and supplying easily replaceable parts.
- Consider the environmental impact of the product.

PRODUCT DEFINITION

- Record any technical limitations.
- Record any possible trade-offs (what priority the various requirements have).
- Establish the favoured technical solution and its feasibility.
- Analyse requirements for any embedded software and prepare system/module specifications as appropriate.
- Undertake the outline design.
- Consider manufacturability, serviceability, reliability and testability.
- Undertake analysis and/or modelling (as appropriate).
- Build prototypes and prove the viability of the design (as appropriate).
- Document the detailed design and ensure the level matches the needs of the customer.
- Consider how the design will be verified (see Table 6).

LIFESTYLE

Researching and understanding customer needs
In the preliminary phase information about customer requirements should be acquired. The criteria that are, or need to be, established should include those that will make the product a success. These are likely to be expressed in general terms but any limits on parameters such as size, weight, noise, power, colour or appearance should be included wherever practicable. Those product characteristics that give a market advantage over the competitors should be emphasized.
The concept of universal/accessible design should be embraced, considering the widest possible range of users, including children, older and disabled people.
A key issue is to ensure that the "voice of the customer′ is heard throughout the organization in particular by those contributing to the new product design.
Conducting market research helps to identify customer needs, new market niches and customer acceptability. Initiating prototype testing, user trials, focus groups and user groups, involving consumers where appropriate, assists in achieving final model acceptance.
It is important to identify the customer.

EXAMPLE
Who is the customer for the toiletries in hotel bathrooms? In 1986 a well-known toiletries manufacturer increased its market share in this area by 400 %

The company had believed that the hotel guest was its primary customer. But after listening to hotel managers the company realized that the hotel managers wanted the products to communicate their hotel's image. Without changing the product's content, the manufacturer redesigned the packaging, concentrating on image, and quadrupled its market share.

CUSTOMER NEEDS

- Go and talk to all those interested in your product
- Identify who exactly the customer and key stakeholders are.
- Form a team of key stakeholders to contribute to the design and its review.
- Probe customer needs, wants and preferred choices.
- Record the anticipated "hard'' requirements (objective and measurable) of the product (e.g. functional attributes, non-functional attributes and constraints).
- Record the anticipated "soft" characteristics of the product (e.g. look and feel, i.e. subjective guidance).
- Identify the main/unique selling features.
- Identify what will make a customer buy this product rather than that of a competitor.
- Define the target selling price on the basis of what the market will stand.
- Establish the standards or regulatory requirements that are likely to apply (are these known, understood and/or achievable?).
- Establish the desired lifetime of the product.
- List any unresolved issues and unknowns (to revisit later).

3.0 - Design Specification

3.1 Design Specification Factors

Formulating Design Specification
Enterprise Inventory Fit
Cost Factors

3.2 Concept Proposals

Concept Evaluation Matrix – see adjoining notes

(see below: prepare a separate page per concept – add additional pages as necessary)

Concept Proposal Description
Concept Proposal Evaluation

- *Enterprise*
- *User*
- *Market*
- *Technology*
- **FEA outline testing**
- *Static Stress Analysis*
- *LCA Evaluation*

Summary of Evaluation *(highlight Key Features + Attributes which contribute to the Design Proposal)*

3.3 Design Development

Prototype Design Description *(add design amends as necessary or desired)*
Prototype Design Evaluation

- *Enterprise*
- *User*
- *Market*
- *Technology*

Proposal Evaluation FEA, LCA,
User Evaluation

3.4 QFD Evaluation

Quality Function Deployment

3.5 Proposal Definition

Definition Phase
Realization Phase

3:0
Design Specification

Design Factors

Formulating the product specification

The project manager should arrange for the information compiled so far to be expanded into a complete product functional specification. The elements to be included vary depending on the type of product being designed. A typical list of elements is shown below.

1. Introduction.
2. Functional criteria.
3. Requirements.
4. Use/modes of operation.
5. Environmental conditions.
6. Performance criteria.
7. Operational performance.
8. Safety.
9. Manufacturability.
10. Availability.
11. Reliability.
12. Durability.
13. Adaptability.
14. Physical properties.
15. Interface requirements.
16. Manufacturing requirements.
17. Support requirements.
18. Supporting systems.
19. Maintenance.
20. Training.
21. Labelling and packaging.
22. Transport.
23. Safety.
24. Regulations and standards.
25. Verification and validation.
26. Cost.
27. End-of-life requirements.
28. Disposal.
29. Disassembly.
30. Recycling.
31. *NOTE See BS 7373-2:2001, Annex F*

The following process can be used for generating the specification:

a) consider each topic in order to determine whether it is relevant;

b) differentiate between elements that are essential and those that are merely desirable;

c) consider each topic from a customer's perspective;

d) document the details of each topic;

NOTE 1 Wherever possible, details should be quantified, though benefit can still be derived from qualitative descriptions.

e) where possible, put a tolerance on all quantities.

NOTE 2 Generally, the tighter the tolerance, the higher the cost of providing it.

NOTE 3 Further guidance on preparing specifications is given in BS 7373-2.

The outcome of this stage should be a completed functional specification that describes the technical details which the chosen option should fulfil. This specification should define requirements and constraints (e.g. regulations), that will steer the development of solutions. Only when at least one achievable design solution has been identified is the project viable. The project should be fully appraised and formally approved by principals for continuation, revision or abandonment. If approved, the necessary resources should be committed to follow through to the design and development phase.

Generating and selecting the concept

It is at this stage that the emphasis moves to the process of devising the product. Generating concepts provides a number of options to how the product might be designed. There could be several options that fulfil the requirements of the product design brief and specifications. The project manager should organize a brainstorming session to generate concepts. Initially, the aim should be to generate as many options as possible to fulfil the requirements of the product design brief and specifications. This is best undertaken in multi-disciplinary groups working in comfortable, undisturbed surroundings. Quantity of ideas is more useful than quality at this stage; finding original ideas takes time.

Each idea, whatever the source, should be assessed to establish whether it:

a) is compatible with the organization's objectives and strategies, and all other business criteria contained in the business plan;

b) has the potential to meet all technical and commercial objectives detailed in the project proposal;

c) can be made within all sourcing, manufacturing and distribution objectives contained in the project proposal;

d) will lead to a worthwhile return or benefit to justify the commercial risks or financial outlay specified in the business plan.

Design Development

7.3.3 Design and development outputs

The outputs of design and development shall be provided in a form that enables verification against the design and development input and shall be approved prior to release.

Design and development outputs shall

a) meet the input requirements for design and development,

b) provide appropriate information for purchasing, production and for service provision,

c) contain or reference product acceptance criteria, and

d) specify the characteristics of the product that are essential for its safe and proper use.

7.3.4 Design and development review

At suitable stages, systematic reviews of design and development shall be performed in accordance with planned arrangements (see 7.3.1)
a) to evaluate the ability of the results of design and development to meet requirements, and
b) to identify any problems and propose necessary actions.
Participants in such reviews shall include representatives of functions concerned with the design and development stage(s) being reviewed. Records of the results of the reviews and any necessary actions shall be maintained (see
4.2.4).

7.3.5 Design and development verification
Verification shall be performed in accordance with planned arrangements (see 7.3.1) to ensure that the design and development outputs have met the design and development input requirements. Records of the results of the verification and any necessary actions shall be maintained (see 4.2.4).

7.3.6 Design and development validation
Design and development validation shall be performed in accordance with planned arrangements (see 7.3.1) to ensure that the resulting product is capable of meeting the requirements for the specified application or intended use, where known. Wherever practicable, validation shall be completed prior to the delivery or implementation of the product. Records of the results of validation and any necessary actions shall be maintained (see 4.2.4).

7.3.7 Control of design and development changes
Design and development changes shall be identified and records maintained. The changes shall be reviewed, verified and validated, as appropriate, and approved before implementation. The review of design and development changes shall include evaluation of the effect of the changes on constituent parts and product already delivered.
Records of the results of the review of changes and any necessary actions shall be maintained (see 4.2.4).

Value engineering
Value engineering (VE) is a well established technique used in product design and manufacture, it is concerned with the evaluation of design and manufacturing criteria for new products. Value is measured in terms of quality, performance and reliability at an acceptable price.
The technique is applied at the design stage to assess a complete product, sub-assembly or individual component. It is concerned with improving the value and reducing the total cost of a well-designed product without compromising the design specification, and is most effective when undertaken as a team based activity. The technique and philosophy of value engineering is based on simple concepts. Normally there are six steps to be followed systematically when carrying out a value engineering exercise.
The steps to be followed are as follows.
• Selection of the product, sub-assembly or component for investigation.
• Information: assembly of all relevant facts about the product/sub-assembly/component.

• Analysis of the functions of the product/sub-assembly/component to rank in order of priority and assign as accurately as possible the costs attributable to each function.
• Speculation on ways of improving poor value items giving due consideration to new materials and manufacturing processes.
• Evaluation of detailed information on performance, cost and availability of alternative materials, and the costs of manufacturing criteria.
• Implementation of solutions generated through appropriate documentation.

On completion of a value engineering exercise the designer should have established a sound design based on the requirements of quality, performance and reliability at an acceptable price.

NOTE Value analysis (VA) is a very similar technique which follows the same sequence but is applied to an existing product, with the objective of producing the same or improved value at reduced cost. VA, and other techniques employed to assist with the improvement and/or cost reduction of products, are not specifically addressed in this British Standard which is focused entirely on processes and techniques necessary for the preparation of the initial, sealed design brief.

NOTE Further information on VE is given in Cross [6] and Younker [14]

Quality function deployment

Quality function deployment (QFD) is a product design philosophy that has been developed to ensure that the customer/end user needs drive the entire product design and manufacturing process in a company.

QFD is a team based activity and calls upon the expertise of marketing, design, manufacturing and other relevant people within a company, as well as external inputs.

The perceived benefits of QFD are that it is customer/end user driven, it reduces implementation time, it promotes teamwork and it provides documentation.

The stages or phases of QFD are as follows:

a) Phase 1: Product planning

The customer/end user's wants are translated into design requirements through an analysis matrix called the House of Quality.

b) Phase 2: Part deployment or component planning

Takes the critically important design requirements down to the level of part characteristics in a scaled-down House of Quality.

c) Phase 3: Process planning

Identifies key process operations that are related to the important part characteristics.

d) Phase 4: Production planning

Relates the key process operations to production requirements and results in prototype construction and production start-up.

The use of QFD aims to ensure that products brought to market fulfil, as far as possible, the needs of the customer/end user.

NOTE Further information on QFD is given in Baxter [10], Booker et al. [11], Cross [6], Inwood and Hammond [12], Kahn [7] and Pugh [13].

4.0 - Production Specification

4.1 Manufacturing Strategy

Production Format

JIT Strategy

Manufacturing Costs

Manufacturing Documentation

4.2 Product Assembly

GA Drawing

Assembly Specification

Assembly Process

Assembly Performance – VE – FMEA - FEA

Assembly Costs

Disassembly

LCA Considerations

4.3 Component Specification

Part / Component Drawing

Form Specification

Production Specification

Performance – VE – FMEA - FEA

Material Costs

Product Life Considerations - LCA

4.4 End of Life Consideration

End of Life Specification

End of Life Processing Costs

De-manufacturing Processes

Costs, Savings and income

4.5 Futures Strategy

4:0
Production Specification

Creating the detail design
The individual components of the product should now be detailed and procedures and methods for their manufacture and delivery identified and specified. These need to include machine and tooling design, production manuals and quality assurance specifications. This stage should also include the design of any literature.
The project manager should ensure that the design is verified by a testing and validation programme running concurrently with the final detail design process.
Where components have a long lead time, it will be necessary to place firm orders well before the manufacturing stage commences.
The project manager should also ensure that the means by which the product will be manufactured and delivered is defined, including agreement as to whether:

a) suppliers will be producing their components to their own specifications and designs; or
b) suppliers will be required to manufacture components according to detail designs passed to them by the organization; or
c) suppliers will be expected to respond to outline specifications applying their own design and manufacturing expertise.
A serious option to consider might be strategic partnerships with suppliers to create particular components in order to make use of the latest available technology.
Examples of information resulting from the detailed design stage are shown in below.

- a) Specification(s).
- b) Detail models/drawings of the assemblies that make up the total product.
- c) Detail models/drawings of the components that make up the assemblies.
- d) Material specifications (including environmental considerations).
- e) Manufacturing process specifications (including production equipment).
- f) Assembly instructions and processes.
- g) Bills of material/item lists.
- h) Approved suppliers.
- i) Preferred components.
- j) Target component costs.
- k) Tooling specifications for components and assemblies.
- l) Target weights.
- m) Detailed performance criteria.
- n) Reliability predictions.
- o) Launch date.
- p) Product test specifications.
- q) Test equipment requirements.
- r) Verification records.
- s) Validation records.
- t) Technical file and declaration of conformity to applicable standards.

The outcome of this stage should be a detailed design of the product with documentation and instructions on sourcing, manufacture, delivery, operation and support through to final disposal, for the guidance of staff, suppliers, customers and other interested parties.

Production Provision

7.5.1 Control of production and service provision

The organization shall plan and carry out production and service provision under controlled conditions. Controlled conditions shall include, as applicable
a) the availability of information that describes the characteristics of the product,
b) the availability of work instructions, as necessary,
c) the use of suitable equipment,
d) the availability and use of monitoring and measuring devices,
e) the implementation of monitoring and measurement, and
f) the implementation of release, delivery and post-delivery activities.

7.5.2 Validation of processes for production and service provision

The organization shall validate any processes for production and service provision where the resulting output cannot be verified by subsequent monitoring or measurement. This includes any processes where deficiencies become apparent only after the product is in use or the service has been delivered.
Validation shall demonstrate the ability of these processes to achieve planned results.
The organization shall establish arrangements for these processes including, as applicable
a) defined criteria for review and approval of the processes,
b) approval of equipment and qualification of personnel,
c) use of specific methods and procedures,
d) requirements for records (see 4.2.4), and
e) revalidation.

Verification + Validation

General

The project manager should ensure that verification and validation activities are considered in detail, embodied in the overall project plan, documented in a test plan and validation protocols, and that a validation report is issued on completion of the test plan.

NOTE Verification and validation are a recurring theme throughout the design process (see Figure 9), and although they should be integral to the various stages of the process, they are considered here for clarity as a separate clause.

The aim of verification and validation activities is to demonstrate that the product meets the specification, meets customer's needs and is safe (see BS 7373-2:2001, Clause 8 and Clause 9, and BS 7000-4:1996, Annex A).

Planning verification and validation activities

When planning these activities, it is recommended that the project manager considers using a risk-based approach. This involves prioritizing verification and validation resources according to the severity and likelihood of the outcome.

Protocols should be prepared to define the specific verification and validation activities in detail. A competent person should be nominated by the project manager to review the protocols.

A protocol should define:

a) the purpose of a test;
b) the section of the document or risk assessment which gives the requirement;
c) who will carry out the test;
d) the test instrumentation and set up;
e) evidence of calibration for test instrumentation;
f) preparation for use, including setting and adjustment;
g) the method of test;
h) precautions to protect against any safety hazards that might arise during the test;
i) the expected result;
j) any analysis of the results necessary;

k) the pass/fail criteria, as related to the requirement.

Verifying the design

Verification of the design is confirmation by examination and the gathering of objective evidence that specified requirements have been fulfilled. In design it concerns the process of examining the result of a given activity to determine conformity with stated requirements (see BS 7373-2:2001, Clause 8).

Verification should be applied at any point in the design process when design output is to be issued or incorporated into subsequent design processes. Verification activities should be shown as discrete tasks on the project plan, and will occur throughout the design process. The techniques used should include, for example:

a) testing, by field trials, pilot schemes, market testing, etc.;

b) independent verification of the design and any associated calculations;

c) design reviews;

d) repetition (i.e. design calculation repeated using an alternative method);

e) comparison with a similar proven design.

Validating the design

Validation of the design is the confirmation by examination and the gathering of evidence that the particular requirements for a specific intended use are fulfilled. It should establish that the design conforms to customer requirements. The process of examining a product to determine conformity with user needs should be carried out on an example of the final product under defined operating conditions. It might also be necessary at earlier stages and multiple validations may be carried out if there are different intended uses. Ideally design methods and sources of design data should also be validated.

Validation of the design may be by any of the following:

a) usage or trials;

b) review or observation;

c) testing.

A validation strategy should take into account particular features where they involve risk in respect of health, safety and the environment. The agreed validation protocol and results of the validation tests should be documented (see BS 7373-2:2001, Clause 9).

Failure mode and effect analysis

Failure mode and effect analysis (FMEA) is a well established technique that has been developed to minimize the possibility of poorly designed and manufactured products coming to market. It can be used to assess the design and manufacture of complete products, sub-assemblies or individual components.

It is a technique applied to the design and manufacture of new products at the embodiment and manufacturing design stages and is most effective when undertaken as a team based activity. It relies on the interpretation of historical records of product failure collected over a reasonable period of time, this information generally being presented as statistical data. This data is used to identify possible weaknesses in similar products currently being designed.

An FMEA is carried out systematically, generally through a ten step sequence of events, with the information being presented in tabular form. The steps to be followed are as follows.
• Listing of parts under investigation.
• Statement of the function of the parts.
• Identification of possible failure mode(s).
• Statement(s) of the effect(s) of failure.
• Statement(s) of the cause(s) of failure.
• Specification of an occurrence ranking index.
• Specification of a detection ranking index.
• Determination of a risk priority number.
• Statement(s) of the action(s) to be taken and specification of its/their status.
On completion of an FMEA the designer should be able to identify areas of weakness in the proposed product design and take corrective action.
NOTE Further information on FMEA is given in Booker et al. [11] and Huang [15].

Cost considerations

General

The design brief includes the target price for the product in accordance with Clause 5. The designer shall ensure that the overall product cost is consistent with the target price derived from the design brief, P_t, allowing for any required contribution, as shown in the following equation: where: P_c is that portion of the selling price contributing to the manufacturer's overhead cost and the required profit; C_{dev} is the cost of developing the product (for total anticipated quantity); C_{mkt} is the cost to market (including direct sales, delivery etc.) (for total quantity); C_{mat} is the cost of materials, components, etc. (per unit); C_{ma} is the cost of manufacturing and assembly (per unit); C_{de} is the cost of disassembly and end-of-life processing (per unit); Q_{at} is the anticipated total quantity of the product.
NOTE 1 It is often necessary to make trade-offs between technical needs and commercial needs, typically between unit cost vs. unit features and development costs vs. development timescales. If trade-offs have to be made, this should be done as early as possible in the costing process.
NOTE 2 Although operating costs have necessarily to be considered by the designer (see Clause 11) they do not constitute part of the calculation.

Development costs (C_{dev})

The cost of the product development project shall be estimated taking into account the following constituent costs.
a) Project planning and estimating effort.
b) Project management effort.
c) Patent agent research and patent related costs.
d) Effort in finalizing the design brief (see Clause 5).
e) Effort in using the design tools (see Clause 6).
f) Concept phase effort (see 6.2.2).
g) Realization phase effort (see 6.2.3).
h) Technical documentation effort (see 6.2.4) (including user documentation).
i) Industrial design effort (see Clause 8).

j) Detail design effort (see Clause 9).
k) Design verification effort (see Clause 12).
l) Prototype hardware build (materials and man-hours).
$P_t + P_c = [(C_{dev} + C_{mkt})/Q_{at}] + C_{mat} + C_{ma} + C_{de}$
m) Hire of specialist equipment for development/ testing and/or test house fees.
n) Overheads for facilities needed (where these need to be explicitly accounted).
o) Software development.
p) Software testing.
q) Regulatory compliance testing (where relevant).
r) Independent product evaluation or involvement of a Notified Body.
s) Packaging design and development.

Estimation of the cost of individual tranches of work, or sub-programmes, shall be undertaken by the staff responsible for those areas. Estimates shall be based as far as practicable on actual data gathered from similar previous development work.

NOTE 1 The resources required (i.e. number of staff) is dictated by development timescales, which might have a limit stated in the design brief. Alternatively the development timescale should be established by working back from the deadline by which the product is to be launched in order to capture the desired market share, making allowance for the time required for manufacture and distribution etc.

NOTE 2 The designer should consider options for reducing development costs, for example through variety reduction, simulation, rationalizing and standardizing commonly used components (such as fasteners), use of off-the-shelf mechanical hardware, subassemblies, electronics, software etc.

Marketing, sales and support costs (C_{mkt})

The costs of taking the product to market shall be estimated taking account of the following.
a) Product launch (one-off).
b) Marketing costs, including publicity in the press, promotional expenses, direct advertising.
c) Fees to agents.
d) Discounts to distributors.
e) Sales.
f) Export (including exchange rate variability).
g) Distribution.
h) After sales support.
i) Staff training.
j) Warranty.

Materials costs (C_{mat})

The costs of materials required to make the product shall be determined and typically comprise the costs of:
a) electronic/electrical components;
b) mechanical components;
c) structural items such as housing/frame/chassis/etc.;
d) bought-in subassemblies and assemblies;
e) raw materials;
f) special processing of parts, for example painting, plating, passivation;
g) consumable materials necessary for assembly/processing;

h) packaging materials;
i) unit based licences, for example software, patents.
NOTE Parts costs can be heavily dependent on the quantity purchased.
One or more purchasing specialists should be involved in establishing best prices for the items listed.
Manufacturing, assembly, disassembly, end-of-life processing costs
Manufacturing and assembly costs (*C*ma)
The manufacturing and assembly costs shall be estimated taking into account the following.

- a) Piece part manufacture.
- b) Piece part inspection/test.
- c) Assembly and associated processes.
- d) Sub-assembly and assembly testing.
- e) System integration.
- f) Product/system testing, functional and safety.
- g) Specialist equipment.
- h) Subcontractors packing and storage.

NOTE The non-recurring costs of making production tooling, jigs and fixtures, test harnesses, test equipment etc., should also be included if these have not be taken account of as part of the development.
Disassembly and end-of-life processing costs (*C*de)
End-of-life processing costs (if any element of these is borne by the manufacturer) shall be estimated taking account of the following.
a) Transport and collection.
b) Disassembly.
c) Disposal of harmful or toxic components (e.g. batteries).
d) Reprocessing or re-cycling parts.
e) Other disposal costs.

Requirements for assembly
Minimization of part count
The first stage in the application of design for manufacture shall be the minimization of the part count.
NOTE 1 Minimization of the part count is necessary because it is the major contributor to the part holding and handling costs. If a part is eliminated, it need not be ordered, received, catalogued, handled or assembled. There are various techniques available to the designer which may be employed to minimize the part count. The most widely used is the one proposed by Boothroyd et al. [1]. However, this technique was proposed before the disassembly and end-of-life processing stages became important. This clause is an adaptation of the Boothroyd and Dewhurst technique.
NOTE 2 The technique of reducing the number of assembly operations and calculating the assembly efficiency surrounds five basic questions which attempt to determine whether a part is absolutely necessary. If it is not then in theory the part can be either removed or amalgamated. When these questions are applied to all parts, the various answers lead to a minimum part count. This provides a baseline from which other calculations can be made.
For each part in the assembly, answers to the following questions shall be determined.
a) During operation, does the part move relative to other parts already assembled?

b) Is it necessary that the part be of a different material from other parts already assembled?
c) Is it necessary that the part be separable from all other parts for inspection, maintenance or adjustment?
d) Is it necessary that the part be separable for end-of-life disposal?
e) Is it necessary that the part be separable for end-of-life part processing?
For any part, if the answer to all the five questions is “no”, that part shall be a candidate for elimination. The designer shall then decide, in accordance with all other design constraints, whether that part can be removed or amalgamated. This produces an initial design from which assembly times shall be determined, in accordance with the mode of assembly to be used (manual or machine).
NOTE 3 Using standard data, handling and insertion times can be estimated for each of the individual parts to give the total assembly time.
The various designs shall then be compared and the most appropriate design selected. An appropriate method for comparing design
efficiencies, *D*e, with the average manual assembly time per operation
of three seconds shall be given by the following equation, see Boothroyd et al. [1].
where:
*N*min is the theoretical minimum number of parts;
*T*ass is the estimated time to assemble the selected design.

10.2 Parts in the assembly
The following shall be taken into account for each part in an assembly:
a) tolerances;
b) geometrical tolerancing;
c) surface finish.
Mating parts in the assembly require further consideration as follows.
• At the parts manufacture stage, the principles of tolerancing are applied to the dimensioning of the parts making up the product assembly. No part shall be manufactured without a tolerance because nothing can be made to an exact size, there is always variability and that variability shall be stated explicitly or implicitly.
Tolerances shall be specified in accordance with the IT grades given in BS EN 20286-1, in which numbers and letters are used to specify a tolerance band which is related to size. Therefore tolerances of mating parts shall be considered when reviewing the assembly of the product.
NOTE 1 BS 8888:2006, Clause 19 gives details of the tolerancing of linear and angular dimensions.
*D*e
[3**N*min]
= *T*ass
• At the parts manufacture stage, the principles of geometrical tolerancing are applied to the shape and form of the parts making up the product assembly. Geometric forms are defined using geometrical tolerancing in accordance with BS 8888:2006, Clause 20 which specifies geometric forms for single features like straightness, flatness and cylindricity and for features that are related like position, parallelism and concentricity. Geometrical tolerances of mating parts shall be considered when reviewing the assembly of the product.
• The surface finish of mating parts shall be considered since surface finish can influence assembly and cost.

NOTE 2 Details of the assessment and specification of two-dimensional surface finish are defined in BS 8888:2006, Clause 21 as is the way in which surface finish requirements are to be indicated on engineering drawings. Comprehensive requirements for the specification and assessment of three-dimensional surface finish are in preparation in the ISO/TS 25178 series of Technical Specifications. It is expected that these will be available for public comment by the beginning of 2007 and published by the end of that year.

10.3 Ease of assembly

The design of each individual part shall be considered with respect to its ease of assembly into the sub-assembly or product.

NOTE Many publications give part and product design recommendations and these should be followed in an analysis. Further information is given in Boothroyd et al. [1]; Nof et al. [2]; Jovane et al. [3]; Otto and Wood [4]; and Ulrich and Eppinger [5].

The following aspects shall be included in the consideration of manual assembly.

a) Maximizing reliability of each assembly operation through the use of chamfers, avoidance of sharp corners and the use of generous tolerances.
b) Aid individual part-orientation through either the use of symmetry or the use of significant asymmetry.
c) Use of cone or oval fasteners to aid assembly and the avoidance of rolled threads which hinder assembly.
d) Use the principles of modularity so that assemblies and sub-assemblies can be built and tested independently.
e) Use lower cost mechanical fastenings rather than high cost ones like rivets and screws.
f) Avoid the use of fasteners/fastening systems which mitigate against disassembly for end-of-life processing.
g) The use of permanent joining methods e.g. welding or adhesives, provided that the parts to be joined can be recovered through the same method or process.
h) Employ fool-proof techniques such that parts can only be assembled one way.
i) Use techniques such that if a part is mis-assembled, subsequent parts cannot be assembled.
j) Do not use procedures where the field of assembly view is restricted.
k) Avoid holding parts to maintain their position during their assembly or during subsequent part assembly.

In addition the following aspects shall be included in the consideration of machine assembly.

1) Use the principle of building onto a base part which is the equivalent of a jig or fixture.
2) Make the base part the heaviest part.
3) Ensure the base part has features to locate it readily in a stable position.
4) Build the assembly from the base part vertically upwards in a layered (pancake) fashion.
5) Avoid the use of parts which tangle, nest, shingle or jam in feeder systems.
6) Design for vertical additive assembly of parts.
7) Make parts self-locating if they are not secured immediately after insertion.

10.4 Ease of disassembly

The design of each individual part shall be considered with respect to its ease of disassembly into the sub-assembly or product. The aspects given in C.5 shall be included in the consideration of disassembly.

Verification of Regulatory Compliance

Verifying regulatory compliance

Pre-production prototypes should undergo testing and verification to confirm the performance of the product in all respects (e.g. that performance, safety, quality, reliability and maintainability requirements have been attained). This is a phase of the project where concurrent working can be exploited, as all details are finally chosen, tested and confirmed. Testing may take the form of accelerated life tests and field trials, preferably with typical customers.

Reference should be made to relevant parts of BS 5760, BS EN 60812 and BS EN 60300 for detailed guidance on reliability and maintainability management, testing and assessment, and also to BS EN 60706-2 with regard to maintainability of equipment.

Depending on the nature of the product and the countries where it will be sold, it will probably be necessary to formally test the product to the relevant standards (e.g. for electrical safety, mechanical safety, electromagnetic compatibility, etc.), and assemble the evidence of compliance in a technical file.

It might be prudent to involve an independent test house or notified body in conducting such tests independently. For some products this is a mandatory requirement of European Directives, or legislation in the country of sale.

Handover Phase

(finalization of design, approval and sealing of technical product documents)

Following completion of the manufacturing prototype stage, marketing shall lead the project into the product launch stage, during which all technical product documents shall be reviewed for completeness.

Verification of these technical product documents shall be completed during initial manufacture, and shall include checking whether the documents conform to the appropriate sections of BS 8888, particularly BS 8888:2006, Clause 19 and BS 8888:2006, Clause 20 for tolerancing, and BS 8888:2006, Clause 21 for display components.

As each technical product document is completed, it shall be deemed to have received final approval, and be transferred to the document controlled store. Once a technical product document has been stored in the document vault the relevant designer shall be released from the project.

The output of the finalization stage shall be approval for continued manufacture.

End-of-life documentation

End-of-life documentation shall include the following:

• Identification of materials.
• Reception location for any take-back scheme.
• End-of-life processing instructions.

A method shall be implemented by which access to the end-of-life documentation can be maintained for the foreseeable life of the product.
NOTE Some of this information may be in the form of codes on the product itself.

Manufacturing documentation
Manufacturing documentation shall be prepared, maintained and robustly archived so that records are available of how the product is made. If traceability is required, information about particular batches of the product shall be kept.
Manufacturing documentation shall include the following.
a) Drawings.
b) Bills of material.
c) Purchasing information.
d) Manufacturing process documentation.
e) Assembly instructions.
f) Test specifications.
g) System integration procedures where relevant.
h) Drawings/specifications for test equipment and tooling.
Also, where applicable, copies of test certificates or certificates of conformity and traceability information on the materials used shall be kept. Production records that provide evidence of compliance to specification (including where applicable safety testing) for batches or individual products shall be kept.

Design documentation
Documentation of the design shall be prepared, maintained, and archived so that the information is available for reference, maintenance and future development of the product. In the event of any query over the safety or integrity of the product, the design route and calculations are available, and any accusation of poor design or negligence can be investigated. The documentation produced shall be maintained and ultimately archived.
Design documentation shall include the following.
a) The design brief.
b) Specifications.
c) Design drawings.
d) Intellectual property rights implications (patents etc.).
e) Schematics (electrical, electronic, pneumatic, hydraulic etc.).
f) Software code.
g) Calculations.
h) Results of modelling.
i) Risk assessments.
j) Identity of legislative requirements.
k) Product life cycle assessment.
l) FMEA.
m) Minutes of design reviews.
n) Manufacturing drawings.
o) Items lists.
p) Instructions.
q) Test specifications.

r) Test results and acceptance criteria.
s) User instructions.
t) Maintenance instructions.
NOTE Also supporting information such as packaging design, marketing and sales material, and product brochures should be included. It is strongly recommended that records of the progress of the development project itself such as the project plan, the project team (who was responsible for doing what), minutes of meetings, project cost records, and acceptance or qualification of prototypes or pre-production models, user trials etc. also be retained. These records might be invaluable for support later in the product life cycle. The concept of strict liability means that when a manufacturer offers a product for public sale, they are representing that the product is suitable for its intended use. The documentation list can provide the evidence that this is the case and thus defend against litigation or any accusation of negligence in design.

5:0
Futures

Managing design updates
Improvement of production specification.
The project manager should ensure that the manufacturer continues with testing and information gathering in order to identify any areas where failure might occur in the longer term. This will enable early corrective action to be taken and effort made to eliminate or reduce potential problems.
Experience and statistics gathered during the manufacturing stage can also point to areas for improvement.
Types of issues that may result in feedback are as follows:
a) failures and rework in manufacture;
b) scrap levels;
c) deviations from the specification;
d) failures during in-house testing;
e) statistical process control results;
f) manufacturing yield;
g) product non-conformances;
h) audit noncompliance’s.

Evaluation + Continual Improvement
General
The product, the project and the whole design process should now be evaluated, and any areas for improvement identified in the design, the management of the project, or the organization’s underlying design process. This will be of benefit to future projects.
The project manager should arrange for the monitoring of in-use performance through feedback from customers and staff. This should provide valuable insights into possible improvements (refinement, retrofits, modifications or changes to the design), or generate ideas for new products.
The project manager should ensure that systems are in place for:
- a) monitoring delivery statistics;
- b) monitoring customer feedback;
- c) identifying problems and taking corrective action;
- d) identifying market changes.

The outcome of this phase should create the potential for continual improvement in the product and the design process.

Reducing time-to-market
Every attempt should be made to reduce the time for the product to reach the market. The advantages of this are:
- a) the product reaches the market ahead of the competition;

b) premium prices can be charged;
c) if money has been borrowed, it can be repaid in less time, so interest payments are lower and the cost of the product design is less;
d) design can start earlier for subsequent models and other designs;
e) it can improve company reputation and morale.
A reduction in time-to-market can be achieved by the following measures:
a) having a thorough and detailed design process model for the particular product being designed;
b) making management and design decisions early in the design process;
c) utilizing up-to-date design tools to the full;
d) reducing the number of design changes late in the design process (by getting things "right first time");
e) harnessing talent and employing effective communication by involving all those who have something to contribute;
f) using concurrent working.

Product evaluation

The three major interrelated areas of customer, in-house and independent evaluation should be considered:

a) Customer evaluation. Customer feedback should always be sought; it is a prime element of customer care and continual improvement.
It should include the customer's evaluation of the product itself (not only its function but ease of use), the user documentation, value for money, quality and reliability, customer service and the receipt or delivery of the product.
b) In-house evaluation. This is a self-analysis for which the criteria will normally include the rate and level of take up of the product, reaction of the competition, wastage, contribution to profit, meeting the company plan, training needs, return on investment, reports on complaints and recovery action taken, ease of operation within the organization, and changes in reputation and standing of the organization.
c) Independent evaluation. This may be carried out in accordance with independent standards (where such apply) and might, in some cases, be a legal requirement. Elements of this evaluation may include independent assessment to the appropriate product standards or regulations.

The outcome of this stage should create the potential for improvement in the design. Project managers should ensure that members of the design team contribute to, and are involved in, an evaluation of the product design.
They should also ensure that recommendations and necessary corrective actions arising from the evaluation are properly implemented and that the lessons learned are carried forward into future projects