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Design management systems –

Part 2: Guide to managing the design of manufactured products

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Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to ii, pages 1 to 40, an inside back cover and a back cover.

Foreword

Publishing information

This part of BS 7000 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 30 September 2015. It was prepared by Subcommittee TDW/4/7, *Technical product realization – BS 8887 design for MADE*, under the authority of Technical Committee TDW/4, *Technical product realization*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This part of BS 7000 supersedes BS 7000-2:2008, which is withdrawn.

Relationship with other publications

BS 7000 *Design management systems*, consists of the following parts:

- *Part 1: Guide to managing innovation;*
- *Part 2: Guide to managing the design of manufactured products;*
- *Part 3: Guide to managing service design;*
- *Part 4: Guide to managing design in construction;*
- *Part 6: Managing inclusive design – Guide;*
- *Part 10: Vocabulary of terms used in design management.*

Other parts may be added.

Information about this document

This part of BS 7000 is a full revision of the standard and introduces multi-lifecycle considerations, along with the recommendations given in BS 8887-1.

Use of this document

As a guide, this part of BS 7000 takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it.

Presentational conventions

The guidance in this standard is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Introduction

Creating and delivering excellent products with market appeal, and attaining high levels of customer satisfaction requires an integrated approach to design, from the board of an organization to project managers and their multi-disciplinary teams.

Excellence in design is an important differentiating factor between competing products, and can be the key to company survival in increasingly competitive world markets.

The complex intellectual challenges presented in the design of manufactured products demand that the process is managed effectively if the outcome is to be successful. The concepts, principles and quality system elements described in this standard are applicable to all forms of manufactured products. Applying the principles described facilitates the creation of products that are produced on time and within budget, meet customer and organizational requirements, and have a better chance of competing successfully in world markets.

This standard sets out the tasks and responsibilities for creating and implementing an effective design policy for:

a) senior executives, (see Clause **4**);

b) project managers and those involved in the design process (see Clause **5**).

In large organizations, these two sets of tasks and responsibilities are frequently taken on by different individuals or groups. In small organizations, they are often undertaken by a single person or small team but are, nevertheless, distinct and different. All those involved need to be aware of what is required of them.

1 Scope

This part of BS 7000 gives guidance on managing the design of all types of manufactured products. It deals with every stage of the design process from product concept through to delivery, use and end-of-life processing.

NOTE 1 This standard recognizes that small enterprises or those specializing in one-off products or special purpose end-of-life equipment often need to adapt the process to suit their method of operation.

It is intended for use by all relevant levels of management, from board level to individual project level, in all types of organizations involved in the design of manufactured products.

Guidance is given on the application of general principles and techniques to the management of design, raising awareness of management issues and emphasizing the need for an integrated approach to the design of products. This standard is not intended to define design techniques.

NOTE 2 For many products, particularly those that are complex, an integrated multi-disciplinary approach to design is needed. Documents recommended for guidance on general management techniques are listed in the Bibliography.

Guidance on the management of innovation, service design and construction design is given in BS 7000-1, BS 7000-3 and BS 7000-4 respectively.

NOTE 3 Guidance on procedures needed to meet statutory requirements, such as health and safety, or product certification and liability, is not intended to be comprehensive. Reference needs to be made to other documents where appropriate.

NOTE 4 This standard is intended to complement BS EN ISO 9001.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 7000-10:2008, *Design management systems – Part 10: Vocabulary of terms used in design management*

BS 8887-1, *Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – Part 1: General concepts, process and requirements*

BS 8887-2, *Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – Part 2: Terms and definitions*

BS 8887-211, *Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – Part 211: Specification for reworking and remarketing of computing hardware*

BS 8887-220, *Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – Part 220: The process of remanufacture – Specification*

BS 8887-240, *Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – Part 240: Reconditioning*

BS ISO 10007, *Quality management systems – Guidelines for configuration management*

3 Terms and definitions

For the purposes of this part of BS 7000, the terms and definitions given in BS 7000-10 and the following apply.

3.1 analogy
aid to creativity that compares a concept with something that exists elsewhere

3.2 audit
systematic examination to measure conformity with predetermined requirements

3.3 chain of custody
process whereby an organization monitors its products through every stage of the supply chain, including all stages of manufacturing, transportation and distribution

3.4 combination
utilization of two or more existing design methods to reach a design solution

3.5 configuration management
co-ordinated activities to direct and control configuration

NOTE Configuration management generally concentrates on technical and organizational activities that establish and maintain control of a product and its product configuration information throughout the lifecycle of the product.

[SOURCE: BS ISO 10007:2003, **3.6**]

3.6 design control
component of a quality system that ensures the integrity of a design throughout its lifecycle

3.7 design policy
general rules relating to design discipline within an organization

NOTE Can help to guide corporate behaviour in circumstances that tend to recur, though it might not prescribe for every eventuality.

3.8 design programme
specific activities and investments to be undertaken over a specified period, broken down into stages, with resources and associated timescales

3.9 design strategy
chosen path formulated to achieve business and design objectives, supported by an indication of how resources will be committed

NOTE Could relate to particular categories of design, types of project, sections of an organization and/or use of resources.

3.10 earned value analysis
determination of the monetary value of work performed in any stage of the design process through assigning a value to the achievement of project work completed and comparing this with the actual and planned costs of the project

NOTE Also known as "budgeted cost of work performed" (BCWP).

3.11 evaluation
systematic examination of the outcome of an activity to determine the extent to which specified objectives have been fulfilled

NOTE 1 Usually linked to a specific activity, e.g. system evaluation, project evaluation and design evaluation. Results are usually measured in terms of time, cost and achievement.

NOTE 2 Generally takes place at the end of an activity, but progress can be maintained by carrying out intermediate or stage evaluation, particularly where intermediate stage achievements have been planned.

3.12 general arrangement
overall scheme, usually a drawing, which shows the main components of a design

NOTE Also known as "design layout".

3.13 inversion
aid to creativity that considers the idea inside out or upside down

3.14 manufactured product
complete product produced singly, in batches, or in bulk by an industrial manufacturing system

3.15 product specification
reference specifying the features, characteristics and properties of a product, giving all the information that is required to create it

NOTE Sometimes referred to as a technical specification.

3.16 risk management
process whereby decisions are made to eliminate, mitigate or accept a known risk or hazard

3.17 specification
reference stating requirements that a product has to fulfil

NOTE 1 A qualifier should be used to indicate the type of specification, such as product specification, test specification, etc.

NOTE 2 Normally includes or mentions drawings, patterns and other references and indicates the means and criteria for checking conformity.

3.18 technical file
product technical information collated to satisfy the documentation requirements of European Directives applicable to the product (e.g. CE Marking)

NOTE Can comprise specifications, drawings, items lists, design descriptions, risk assessments, test reports, copies of instructions for installation, use and maintenance (this is not an exhaustive list).

3.19 test plan
plan outlining the test work to be undertaken to ensure that the performance requirements of the eventual product can be achieved

3.20 validation
confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled

NOTE 1 In design and development, validation concerns the process of determining a product's suitability and conformity with user needs.

NOTE 2 Validation is normally performed on the final product under defined operating conditions. It may be necessary in earlier stages.

NOTE 3 The term "validated" is used to designate the corresponding status.

NOTE 4 Multiple validations may be carried out if there are different intended uses.

3.21 validation protocol
statement of the method by which validation will be carried out, typically comprising a list of each product specification element, and for each a description of the nature of the validation

NOTE Could be an inspection, test or review.

3.22 validation report
written report describing the results and outcome of conducting validation

3.23 value chain
factors and activities undertaken by, or on behalf of, an organization that contribute to the value of its products as perceived by customers and users, from conception through to final disposal and recycling

3.24 verification
confirmation, through the provision of objective evidence, that the specified requirements have been fulfilled

NOTE 1 The term "verified" is used to designate the corresponding status.

NOTE 2 Confirmation can comprise such activities as:

a) performing alternative calculations;

b) comparing a new design specification with a similar proven design specification;

c) undertaking tests and demonstrations;

d) reviewing documents prior to issue.

4 Managing the design of manufactured products at organizational level

4.1 Taking organizational responsibility for design

The ultimate responsibility for the quality of designs produced by, or on behalf of, an organization, rests with the board of directors, owner-managers or partners.

It is the board's collective responsibility to ensure that the organization has a clear sense of direction with respect to design programmes, so that all contributions can be harnessed to their full potential. It is the chief executive's responsibility to ensure that this direction is followed effectively and that design programmes make a full contribution to the organization's performance. Chief executives might assign day-to-day executive responsibility for design to other members of the board or executives in the management hierarchy who report directly to them. A chief executive's design committee, or design policy group, can be established to oversee the management of design at the organizational level.

Senior executives should demonstrate their understanding of responsibilities for and commitment to design programmes through their statements and actions. In particular they should ensure that competent and committed teams are brought together to address design requirements. Design responsibilities should be clearly articulated and communicated to colleagues throughout the organization. Executives and staff should be given guidelines within which to operate. They should know who to turn to for guidance, authorization to proceed with a particular design idea or project, or other design-related decisions.

It is also vital that all executives who have design responsibilities, or otherwise get involved in design activities, should have these responsibilities and activities stated in their contract of employment. These factors should be reviewed periodically.

Organizations develop their competence in design management over time.

4.2 Checklist of design management responsibilities at organizational level

The following design management responsibilities should be carried out at organizational level:

a) establish clear ownership of design responsibility;

b) provide a vision of the future with clear objectives;

c) demonstrate genuine and visible commitment to effective design;

d) show awareness of customers' interests and needs;

e) formulate the organization's design strategy and policy;

f) establish and maintain the organization's design standards and guidelines;

g) provide organizational systems;

h) encourage an understanding of the environmental dimension of design;

i) ensure there is an understanding of the legal requirements of design;

j) establish the organization's design team;

k) provide for training in design management skills;

l) motivate staff involved;

m) harness appropriate technologies;

n) promote awareness of competitors and their external activities and innovations;

o) assess opportunities and risks attached to investments in design;

p) fund design activities;

q) provide adequate resources (personnel, equipment, information and facilities);

r) understand organizational capabilities and limitations;

s) ensure production capabilities and requirements and their consequent effects on design are understood;

t) demonstrate a commitment to quality and reliability;

u) audit the organization's design and design management practices;

v) understand the impact of design on corporate identity;

w) evaluate the contribution of design to corporate performance;

x) nurture an environment that encourages innovation and creativity;

y) address corporate social responsibility issues;

z) establish an archival system to record key design information to be made available for later use in the product cycle. (The archive should remain accessible for several product cycles, so should be in a format which will remain readable).

4.3 Organizational design philosophy, objectives and strategy

4.3.1 General

Given the strategic significance of design in the development of new products and services, design should be given serious consideration at board level. Using design on an ad hoc basis, or in an unstructured way, severely limits its contribution to the long-term success of the organization.

4.3.2 Organizational design philosophy

Consideration should be given to establishing the organization's design philosophy. The philosophy should include the organization's general stance towards design, the basic reasons for design discipline and its contribution to the organization's performance.

4.3.3 Formulating the organization's design strategy

The organization's design strategy should be drawn up as a prescription of approaches to be taken at senior level and how resources will be harnessed to achieve the objectives. These approaches might include setting up an appropriate system for re-using end-of-life products.

Where appropriate, these strategies might be developed into short- to medium-term design activities and longer-term investments in design that are reviewed before being sanctioned for implementation.

Design should be formally directed on a strategically planned basis; the following is a summary list of key actions.

a) Reinforce the strategic importance of design by addressing design management issues regularly at senior executive meetings.

b) Specify and periodically update the organization's design policies, objectives and strategies that facilitate the fulfilment of the organization's goals.

c) Formulate the organization's design philosophy and promote it enthusiastically.

d) Establish a design programme and control, review and update it at appropriate intervals to maintain its relevance to the fulfilment of the organization's objectives.

e) Ensure that the design programme complements, enhances and is compatible with the other major plans of the organization.

f) Establish corporate risks associated with design.

g) Determine the return on investment on all resources committed to design (not just capital).

h) Plan to provide the necessary finance and other resources to enable the organization's design programme to be implemented effectively.

i) Assign design responsibilities to competent and qualified executives, then motivate them to acknowledge these responsibilities and their ability to perform to specification.

j) Communicate the organization's design policies, objectives, strategies and programmes to all involved, and ensure that there is a common understanding of their substance and implications.

k) Introduce and reinforce an appropriate design management system and infrastructure to sustain design work to the required standard, ensuring that it is integrated with other disciplines.

l) Monitor and control expenditures against plans and time, and record achievements.

m) Use the most appropriate skills available and bring others up to the required standard of performance through design awareness and training in design management skills.

n) Underpin the importance of design as a strategic resource by maintaining a genuine and visible commitment to it.

o) Establish an appropriate branding strategy for families of products.

p) Establish policies which encourage a multi-lifecycle ethos typified by BS 8887 (all parts).

4.4 Providing investment

4.4.1 General

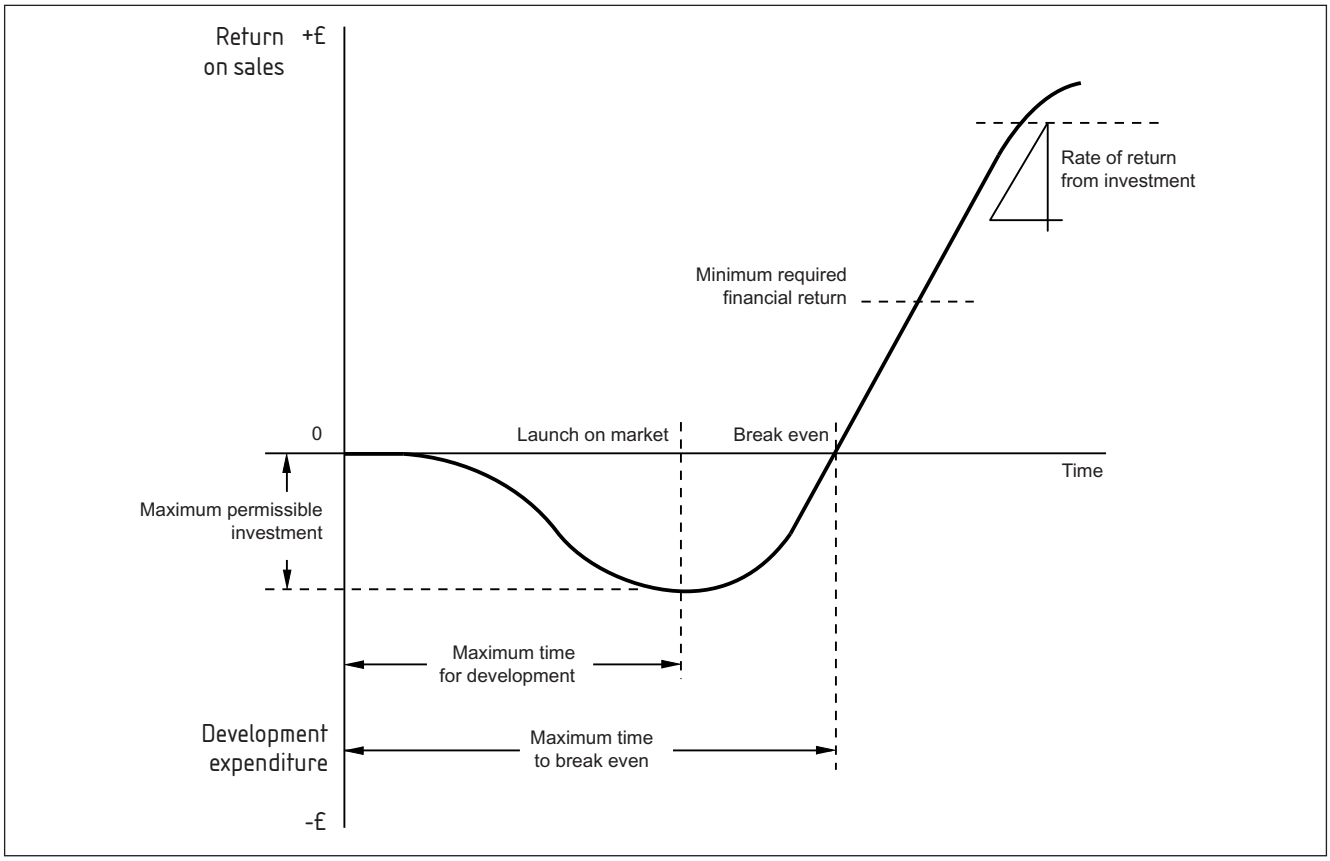
Senior executives should ensure that appropriate resources are made available when required to undertake the research, design and development work, as well as the associated training needed. Limiting investment in new product development is likely to jeopardize future competitiveness and profitability.

4.4.2 Formulating the organization's investment programme

The financing of product design activities should be written into the organization's business plan. The investment requirements and cash flow implications of design activities should be forecast and set out in the organization's design programme. Figure 1 shows that prudent investment in design has the potential to recover its initial costs and produce significant cash-flow.

The investment programme should set out all areas of design activity, the outcomes sought and the contribution to the attainment of the organization's objectives, considering the organization's available skills and resources.

Figure 1 **Profile of cash flow during project lifecycle**



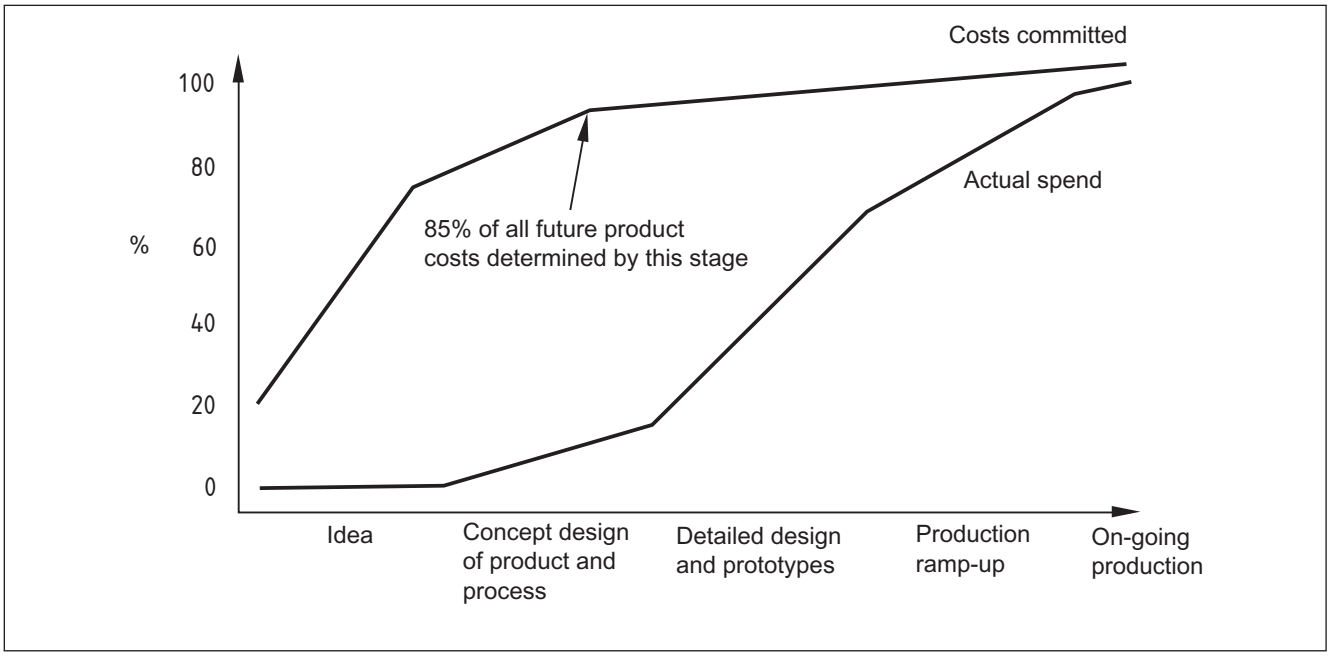
Senior executives should ensure that funds allocated to product design and development are spent as intended and not withheld or diverted unless there are overriding reasons. These should be clearly stated and carefully checked. If funds have to be reallocated, the impact upon the project and the overall design programme should be taken into consideration and the plans revised as necessary.

4.4.3 Budgeting

An example of the financial commitment incurred during design, development and manufacture of a product is illustrated in Figure 2.

An easily comprehensible system of budgeting, with approved benchmarks on typical expenditure for different elements of work as well as the fair allocation of overheads, should facilitate financial planning for and costing of new or improved products.

Figure 2 **Financial commitments during product design, development, manufacture and support**



4.4.4 Providing resources

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 brought 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?

4.5 Putting infrastructure in place

4.5.1 General

An effective system for managing design should be formally adopted and linked in with the management systems of other business disciplines.

4.5.2 Formulating and managing the product design programme

Proposals for investments in design should be coordinated within an organization's design programme. This programme should set out specific activities in all categories of design to be undertaken, the outcomes sought and their contribution to the attainment of organizational objectives. The programme should summarize design briefs and specifications, with the planned work broken down into appropriate stages. Skills and other resources to be committed and outputs to be generated at each stage should be specified, together with associated timescales. It is important that this programme can be referred to and influenced by those involved and interested in design, in a formal, easily accessible working document.

There should be a formal procedure by which the organization's investments in design are evaluated and sanctioned. That procedure should be formally documented, transparent and made available to all appropriate personnel within the organization.

There should be a formal procedure for monitoring the progress of the organization's design programme, with reviews scheduled into the programme itself. Reports of findings should be submitted to senior executives for information and debate. Where slippage or deviations occur in relation to set goals, the senior executives should be informed of these as well as the remedial action taken.

4.5.3 Managing risk

It is essential that risks are identified systematically from the early stages of planning a project. A system of risk management should be introduced that works effectively alongside the creative work.

NOTE BS 6079-3, describes a process for identifying, assessing and controlling commercial risk within a broad framework.

4.5.4 Meeting market expectations and dealing with legal issues

The legal dimension of 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 are 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 design, (for use, among other things, as potential evidence in case of disputes, litigation and end-of-life decisions);

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, including appropriate product marking;

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.

4.6 Market positioning

4.6.1 Coordinating the visual identity of products

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 with the current or intended product range.

Senior executives 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 (such as a logo, font, shape, packaging or colour scheme);

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.

4.6.2 Researching customer attitudes and needs

Keeping close to customers and markets is critical to success.

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;

d) how customers use products and services; and

e) how customers' expectations are changing as new products are introduced.

Senior executives can raise performance by insisting that marketing and design research is undertaken continuously and that findings are acted on without undue delay.

4.6.3 Promoting environmentally sensitive design

Environmental factors influence purchase decisions, and many consumers buy 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 pressure from trade bodies, is forcing organizations to re-assess their outputs.

Opportunities should be sought to recover and employ existing components from earlier ranges of products which have reached their end-of-life in service. Similarly, products should be designed to ease disassembly and reuse when they in turn reach their end of life. This gives a product a reuse value above its scrap value at its end of life, thus increasing its value to customers.

Records of design decisions and materials sources which would facilitate reuse, should be maintained and accessible. Components used through multiple lives should have a feature allowing individual identification and total use to be recorded. 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, or in their ultimate disposal;

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);

m) consideration of the needs of maintenance procedures to ensure ease of access for inspection or replacement of components.

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

4.7 Promoting and selling products

4.7.1 General

Senior executives should ensure that adequate resources are committed to product promotion and launch. Promotional activities should be considered well before completion of product development. Senior executives should ensure the organization's product development process produces the necessary inputs to initial promotion, product launch and subsequent promotional activity.

Before full marketing begins, a period of trialling/prototyping might be necessary to ensure that the product meets the needs of the customer.

4.7.2 Promoting the product

Customers' overall experiences with products are affected by many aspects inherent in the products and/or their value chains. The following should be considered when organizing the promotion of products.

a) advertising (including new opportunities available on electronic media);

b) promotional literature;

c) packaging;

d) user instructions;

e) presentations and displays in stores;

f) showroom environments;

g) the appearance, courtesy and knowledge of sales staff;

h) the professionalism of delivery, commissioning and after-sales service personnel;

i) other associated functions and facilities such as telephone help lines and customer support;

j) setting up service workshops (where necessary);

k) ensuring appropriate supplies of consumables are available.

Senior executives should insist that quality is maintained across all such elements of the product so that they are seen as part of a mutually enhancing, attractive whole.

For smaller businesses undertaking product manufacture, promotion might be achieved through developing relationships with larger companies, for example working closely with those who sell products to end users, such as retailers, or those who get the products onto shelves, such as distributors.

4.7.3 Launching a new product

Creating a new product or improving a current product is only part of the product's lifecycle. Success also depends upon an effective launch and support in the market throughout the life of the product. Senior executives should ensure that the launch of new products, and relaunch of improved products, are taken seriously by all involved. Communication links between design and marketing departments should be made early on in the design and development to supplement this critical stage. The project budget should make adequate provision for funding the product launch. Commitments should also be obtained from those responsible for launch activities, especially where launches are planned in several countries around the world involving subsidiaries, partners, agents, licensees and other interested parties.

4.7.4 Supporting the product and eventual disposal

Senior executives should ensure that the responses of customers to the product, and indeed competitors' reactions, are monitored. This should include examining the way customers use the product to determine if the original design objectives are being met. On-line opinion surveys, for example, linked to customer support or related sites can provide useful information in a standard forma. In the light of this customer feedback, senior executives should provide the necessary resources to support further development, e.g. to debug, refine and improve the product's performance to raise customer satisfaction.

Senior executives should ensure that there is an organizational infrastructure in place to provide the necessary level of customer support. This might be achieved, for example, by a customer services department, which might comprise a consumer helpline, or for more complex products, a technical helpdesk manned by staff with a more in-depth knowledge of the product.

There might also be a need for technical support at customers' premises and the provision of consumable items and spare parts. Senior executives have the responsibility for deciding the level of these resources, and if they should be made available in-house or subcontracted.

Where appropriate, guidance should be provided to customers and users for the disposal or recycling of products, especially where components might be hazardous or are subject to regulation (electronics, batteries, liquids). There is now a significant amount of legislation affecting the end-of-life disposal and disassembly/recycling of many types of product, and senior executives have a duty to ensure that the products their organizations offer to the market are disposed of responsibly in accordance with the law.

4.8 Planning and communication

4.8.1 General

Senior executives should ensure that all relevant design and design management issues are addressed during the business planning cycle, and that the results of deliberations are documented, communicated to appropriate staff and ultimately archived.

4.8.2 Developing business and product plans

The market which a company serves is continually developing, both in customer demand and technological expectation. The company's manufacturing capability should also evolve to meet the market requirements.

Consequently, market research needs to be carried out to ensure that future product manufacturing cycles are integrated with current manufacturing commitments. This analysis might reveal potential gaps in the organization's capability.

4.8.3 Communicating design policies, strategy, objectives and programme

The value of design plans can be enhanced if they are documented and communicated effectively. Executives and staff need to be fully aware of the direction and objectives set so that they work in unison. Design and marketing activities should be closely coordinated with planning and logistics of manufacture. Considerable benefits can be derived from informing virtually all staff of the essential features of plans through team briefings, staff conferences and newsletters.

All staff should be made aware of their individual responsibility for the successful implementation of plans, and efforts should be made to ensure responsibilities are clear.

4.8.4 External communication

It is important that investors and other interested parties outside an organization are kept appropriately informed of its overall intentions and strategies. This will give reassurance that detailed preparations have been made to ensure future prosperity, and that there is transparency (within commercial-in-confidence limitations) and clear sense of direction to turn those intentions into reality.

4.9 Evaluation

4.9.1 General

Senior executives are ultimately responsible for the quality of design work undertaken by, or on behalf of, their organization. This requires regular evaluation of outputs produced by different departments, facilities, subcontractors and agents. Such evaluations allow the creativity of ideas and the craftsmanship of their execution to be assessed, as well as their conformity to standards. Evaluation should be extended periodically to encompass reviews of design and design management procedures. The same applies to facilities (such as location, working environment, amenities and equipment).

4.9.2 Controlling procedures

Senior executives should ensure that the organization has procedures in place to cover design activities. The 'ownership' of these procedures should be clear, and there should be a formal method by which procedures are reviewed and approved, and subsequently maintained.

The process for generating, modifying, reviewing and approving procedures should be clearly stated with guidance to assist executives and staff in putting forward suggestions for improvement.

4.9.3 Auditing activities and procedures

Periodic audits are 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, frequent audits should yield keener insights and allow greater control through faster response times.

These audits should be included in the organization's design programme, and staff involved in design work should be encouraged to 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 (as necessary):

a) products and associated outputs (e.g. packaging, promotional literature and user manuals, and 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 competence, knowledge and expertise, (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.

4.9.4 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 organization's overall 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.

Senior executives should ensure that the lessons learnt from evaluations are properly documented and disseminated. Such sharing of experiences can help to avoid mistakes being repeated and the unnecessary duplication of work. Consequently, problem areas can 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.

5 Managing the design of manufactured products at the project level

5.1 General

There are two major aspects of the design process:

a) the function and manufacturing details of the product, including commissioning, operation, maintenance and end-of-life considerations, mainly undertaken by those with engineering expertise;

b) the human interface of the product, affecting aesthetics (including branding), operational expectations and ease of use, mainly undertaken by those with product design expertise.

For domestic and publicly visible products, product designers tend to lead the process. For more functional products or hidden components, and where complex manufacturing processes are necessary, engineers tend to lead. Management decisions at all levels should ensure that both aspects of design are given due consideration.

The incentive to undertake a design project might be the organization's own product range or the request of a customer or client. In both cases, an understanding of the reasoning behind the need for the project should be well understood. Any assumptions as to the product specification should be kept to a minimum to give the design team the maximum flexibility in their search for solutions.

Where the design of new products is contracted to another organization, responsibility for specifying the need and monitoring the progress still rests with the original organization, which should ensure that an appropriate flow of information is maintained throughout the project. The responsibilities of the design contractors should also be clearly stated.

The following is a summary of key actions to manage design at a project level, the following key actions should be followed:

a) understand customer requirements, always undertaking appropriate market research as part of the design process;

b) explore major alternatives during the relatively low-cost early stages of the design process, refining the specification as more information becomes available;

c) research opportunities to use components and sub-assemblies, available in sufficient quantity, from end-of-life products;

d) consider areas for concurrent working at the start of the project and assemble a multi-disciplinary team that includes all relevant specialisms;

e) review the design progress at regular intervals against the design brief and specifications;

f) control costs through continuous review against the budget, using techniques such as earned value analysis;

g) control the configuration of the design from the generation of the specification through to end-of-life processes;

h) take due consideration of the likely requirements for disassembly and end-of-life decisions of the product;

i) evaluate the project and deliverables on completion of the design activity, with a view to making improvements in the future;

j) identify any areas for improvement in management processes during the periodic reviews, audits and final evaluation, making changes as required for the benefit of future projects;

k) retain control over the design project at all times;

l) establish an archived record of design decision reasoning, material properties and key features to facilitate end-of-life decisions and other post-design activities.

5.2 Establishing the design management process

*COMMENTARY ON **5.2***

*The management of design at the project level is distinct from the process of managing design at organizational level, as discussed in Clause **4**.*

5.2.1 Choosing a design model

Many models have been proposed for the design process, ranging from basic and simple, to very detailed. Surveys (see Nigel Cross, "Design Methods" [2] for example) have shown that many can be useful for particular types of project, but there is no universal solution. Much depends on other managerial and organizational factors including the size of the organization and the market being served. However, it has been shown that choosing an appropriate model and following it enthusiastically brings a far higher chance of success than having no model at all.

For large, one-off projects, an appropriate model can be chosen from past experience or newly available developments. Where an organization produces a narrower range of products, perhaps in bespoke batches, it might be possible to formulate a design system, tailored for the organization, which fulfils the need (this should be reviewed periodically to ensure it retains a fresh approach to each design and has not become overly bureaucratic).

5.2.2 Beginning the design process

The design process begins upon receipt of a design brief from a client, which then leads to the production of a design specification with requirements for performance, price, etc. There can also be unspecified constraints of conformance to regulations on Health and Safety, pollution, or other factors. The specification might be subject to negotiation during the early stages of the design as more detailed information becomes available and the design evolves, but should be frozen as early as possible to avoid excessive costs or time slippage.

5.2.3 Design management and design cycles

Design management is a form of project management, but since design is a complex decision making process, the end result is unknown, so cannot be planned completely. Design management should therefore be a dynamic process, with decisions being made in parallel with, and partly in reaction to, the design process itself. Methods of project control, particularly with software assistance, can be very useful, even for small design projects. For larger projects, they become essential. However, they should be reviewed and modified as the project progresses, as new more detailed information becomes available.

Design management is a cyclic process. In some instances, proposed solutions to specific design challenges are analysed for their suitability for implementation and the results of this type of assessment can lead to a new understanding of the challenges. Solutions or modifications to the process can then be proposed. Occasionally, no solutions arise during the design process and steps are repeated until a new path can be found.

An initial design process selects the basic parameters of a likely solution. For all but the simplest of products, the process is then usually broken down into a parallel sequence of cycles looking at solutions for different components. At the same time, an overview should be maintained to ensure compatibility between component solutions and also a viable manufacturing and assembly pathway. Cycles continue until sufficient details have been determined to complete the manufacturing specification (for long lead-time components, their design might have to be completed earlier than the rest).

Figure 3 shows a typical single cycle of design, and the following list describes each of the steps in detail.

1) **"Formulate design constraints"** should include a review of what has gone before and the reasons why a viable solution has not been found. A conclusion should be reached as to the need for a modification to the existing proposal versus a different approach.

2) **"Propose new design solution(s)"** is the creative stage, when the design constraints are investigated to formulate potential design solutions. Various ways of facilitating this process have been proposed, but their effectiveness depends on the scale of the challenge and the individuals involved.

3) **"Analyse proposed solution(s)"** is the stage at which proposals are judged against appropriate criteria. In engineering design, this frequently involves a quantitative performance analysis against specified criteria and might require the use of functional tests. Questions of customer acceptability might also be raised, perhaps requiring graphics or model making to reach a conclusion. Manufacturability should also be considered, in consultation with a potential manufacturer if appropriate.

4) **"Is solution viable?"** is the decision point where the results of the analysis are used to decide the direction of the next action. Responsibility for this decision rests with the team manager.

Figure 3 **Typical single cycle of design**

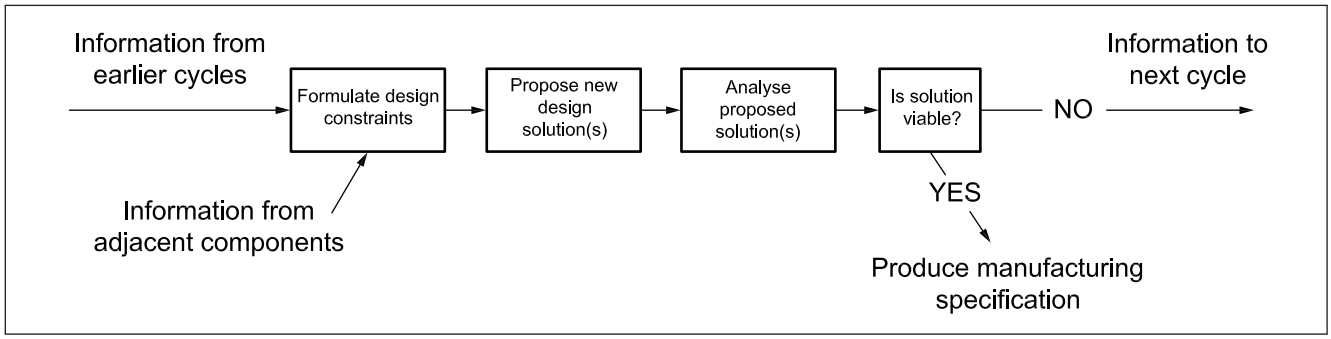
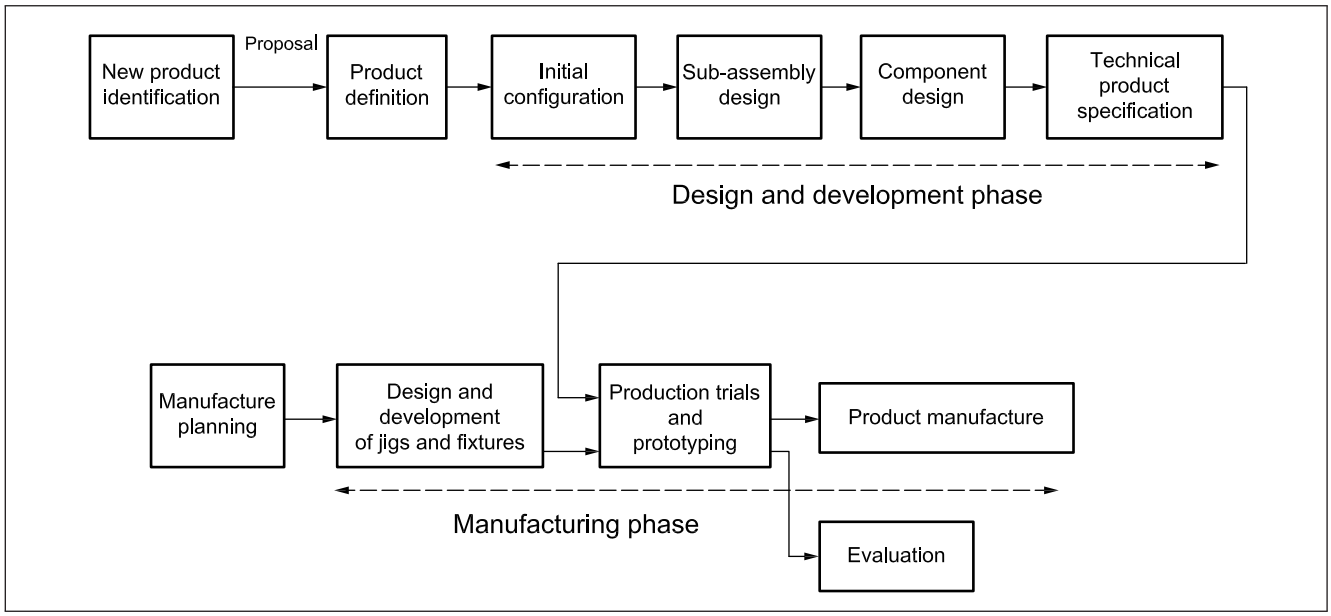


Figure 4 shows the progressive pattern of a typical design project of modest complexity. This is intended as a typical illustration and not an indication of a particular design method. At each stage, a number of interconnected design cycles will take place along a series/parallel network, depending on the complexity of each component. This pattern will be used to structure the rest of the design process. Activities such as "Verification and Validation" are carried out alongside much of the project.

Figure 4 **Sequential pattern of a typical design project**

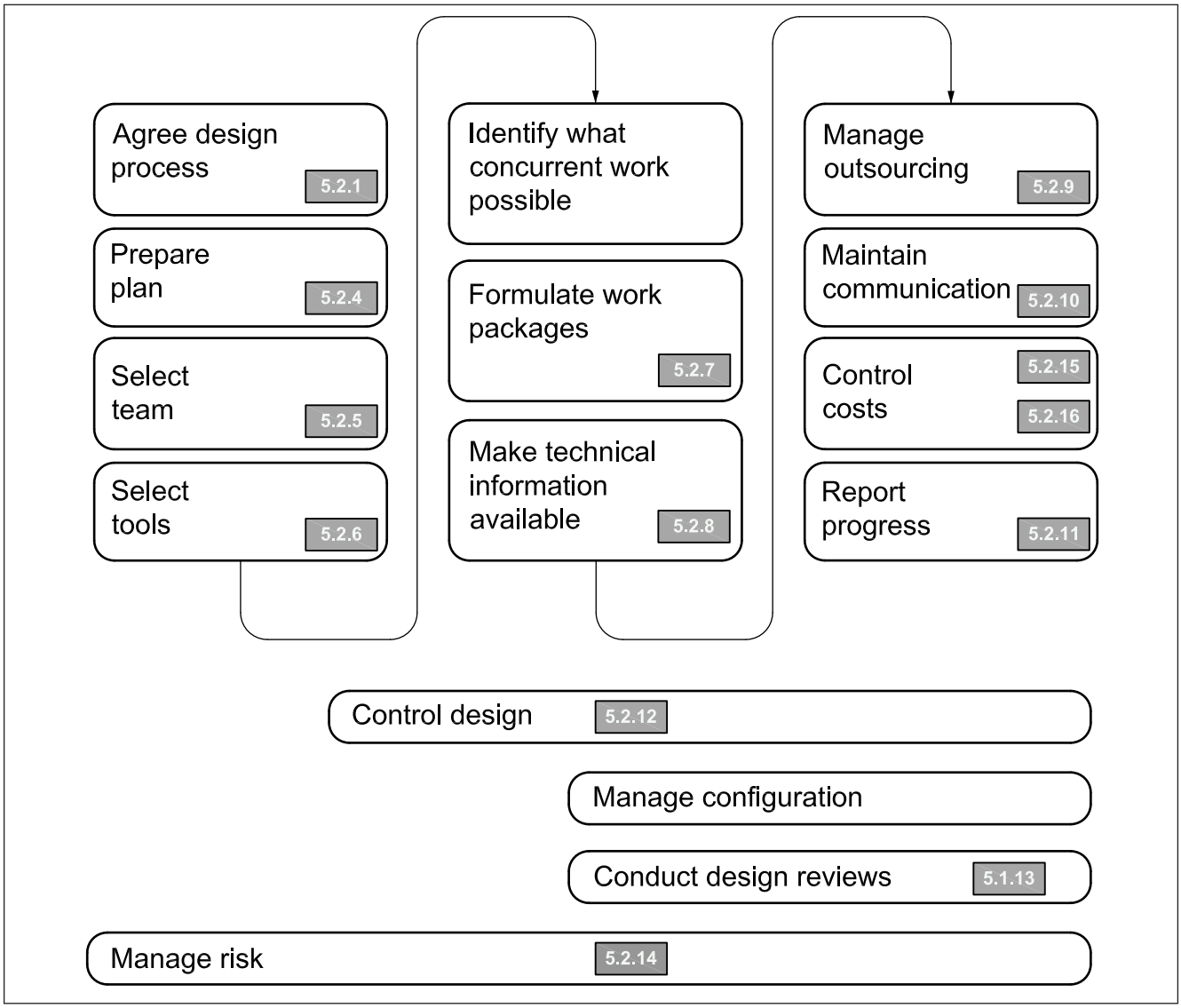


The main management tasks during the project cycle are to maintain the overall viability of the proposed solutions, along with continuous team management. Managers should be aware of any impacts of local design decisions on the interfaces with adjacent components (including, for example, the potential for corrosion between different materials, structural or system connections, or the effects of movement envelopes), the performance of the whole product, and the manufacturing and cost implications.

Design team members are, by definition, creative people and have their individual management needs, if they are to meet their potential. In a design-reliant business, the success of the organization relies on the management of its design teams to produce successful designs, even though only a small proportion of the workforce may be involved. Design is a relatively low cost activity, but it is where most of the costs of a product, both in production and use, and its end-of-life value are determined.

Figure 5 shows the typical tasks required to manage a design project.

Figure 5 **Managing design at project level**



Key tasks of design project managers:

a) Ensure team is familiar with the document control requirements.

b) Ensure the overall design process/model is understood and in place.

c) Record risks.

d) Prepare a project plan for the design activities.

e) Identify activities that could be undertaken concurrently.

f) Establish the design team needed for the project.

g) Ensure team responsibilities are clear.

h) Identify and acquire resources for any training that may be necessary.

i) Formulate work packages for the team consistent with the project plan.

j) Report on progress to the authorizer of the project.

k) Determine what work, if any, will be outsourced.

l) Ensure effective communication and decision making.

m) Control and monitor progress and costs.

n) Collate cost and time data.

o) Select or approve the use of specialists and subcontractors.

p) Be the focal point for communication between the team and other parties.

q) Ensure that the final design meets the design specification.

r) Manage the creation of design documentation, and review and sign off the design.

s) Prepare a final report, evaluating the performance of the project, and incorporating lessons to be learned and opportunities for improvement **5.1.** Agree the design process.

A design process model is discussed in more detail in **5.3**. A bespoke design model should be considered for each distinct product line and its circumstances. The relative importance and sequencing of activities might vary, and iteration between elements of the model is usually necessary.

5.2.4 Preparing the plan

The project management task is shown in Figure 6. The exact nature of all the tasks and their interdependencies should be established, so that the important paths can be mapped out. Where practicable, tasks should be undertaken in parallel.

The work needs to be organized so that orderly progress is achieved. Planning should include:

a) establishing the extent of professional or specialist contributions required, including identifying the competencies required to undertake the work, thus defining the composition of the design team;

b) identifying the need for other resources (such as development tools and equipment, work space, storage, technical information, instruments, computers and software);

c) establishing key dates for specific milestones, and the start and finish dates for tasks, to enable progress to be measured;

d) determining project costs and, if applicable, establishing when decisions have to be made to approve or reject demands for payment;

e) determining the structure of management information required for control purposes;

f) ensuring that intellectual property generated during the project is protected.

Planning requires input from all relevant departments. Those with an interest in the project should be informed of all matters that affect their work. This is likely to encompass marketing, sales, finance, personnel, purchasing, and manufacturing departments, as well as technical functions such as quality assurance and project management. Where appropriate, planning might also include suppliers and customers.

5.2.5 Selecting the design team

In the early stages of a project, a small number of staff might undertake preliminary work on an informal or part-time basis. Once the project has been approved, a design team with appropriate expertise should be established and the specific roles of each part of a team documented. For continuity, those involved in the preliminary work often form part of the project team.

It is important that the project team is chosen so that collectively they have a good understanding of the engineering principles inherent in the proposed new product, and sufficient up-to-date knowledge of the relevant technologies and applicable standards. The team should also include staff with the necessary commercial and marketing awareness. This can be achieved by bringing in expertise from elsewhere in the organization, using subcontractors, or training existing staff.

In larger project teams, it might be helpful to separate the role of project manager from that of technical leader. This can be done by nominating both a project manager to oversee the day-to-day management of the project, and a technical authority/chief designer, to monitor technical aspects.

5.2.6 Selecting appropriate design tools

The project manager should ensure that the responsibility for the choice of suitable computer applications, such as development tools and modelling tools, and design packages is clearly defined. The timing of the acquisition of such tools should be organized so that they can be installed and tested/validated, and staff trained in their use, before they are fully introduced to the project.

Procedures for the control and secure storage of design data and backup files should be defined and enforced by the project management team. Training in the use of new or enhanced software tools, and ongoing technical support should be provided by in-house specialists or system suppliers.

The risk of the design not performing to specification can be reduced through the greatest practicable use of simulation, modelling and testing tools. This might also reduce the cost and lead-time of developing complex and high technology products.

5.2.7 Formulating work packages

The project manager should agree on a suitable division of the work into coherent packages with the design team, making due allowance for the talent and expertise of the team members. Where a gap in the necessary expertise is apparent, either additional team members should be recruited or appropriate external consultants should be identified. The interfaces between packages of work should be defined and may be subject to agreed modification as the work progresses. A member of the team should be identified as the person responsible for the management of each identified package of work.

5.2.8 Making technical information available

The project manager should ensure that the necessary technical information is made available to the design team. This might include statutory instruments, standards, specifications, codes of practice, and commercial data sheets. Such information is available from one or more of the following sources:

a) an internal library or knowledge archive;

b) an external library or knowledge archive (including the internet);

c) suppliers;

d) specialist and proprietary sources (trade bodies, professional bodies, university research departments, etc.).

It should be the responsibility of the project manager to ensure that such information is verified before being incorporated into a design.

5.2.9 Managing outsourcing

Where expertise or resources are not available within the organization, an appropriate external subcontractor should be chosen. A number of things should be considered when selecting a subcontractor. These include:

- security, confidentiality, and protection of IP;
- detailed communication of requirements;
- robust contractual arrangements;
- a procedure for monitoring and auditing progess (to be included in contract).

All the requirements that a third-party is expected to fulfil should be clearly and comprehensively documented, including interfaces between both physical components and systems. For external contractors or suppliers this may be a combination of: contract, specification(s), drawings, plans, data files, emails etc. The information supplied should be under version control, and a record of versions distributed should be maintained, in order to understand those in current use.

A two-way communication with the third-party should be encouraged.

If modifications are required as the design develops, agreement should be reached between all parties. Appropriate documentation of the changes (e.g. updated spec, updated drawings) should be sent to the sub-contractor.

5.2.10 Maintaining good communication

It is the project manager's responsibility to ensure that the team is informed of all aspects of the project, and have up-to-date information with which to work.

Design team meetings should be organized to facilitate open communication between all parties. All members should be given an equal opportunity to contribute. If there is conflict between different design requirements, it is the project manager's ultimate responsibility to make a final decision.

Designers should be encouraged to communicate with the rest of the team both informally and formally through channels such as team meetings and design reviews. Significant outcomes from such communications, including the reasoning behind them, should be recorded and communicated with senior management.

Lines of communication should not be confused with lines of authority; communication may legitimately occur in any direction through an organization structure.

5.2.11 Report progress

The progress in each area of work should be reported by the designated manager (see **5.2.7**) at regular meetings, where any concerns about the interfaces between packages should be resolved. Records of progress should be made and summarized by the project manager for reporting to senior management.

5.2.12 Control of the design

The project manager should maintain control over the design as it progresses, and should retain responsibility for the result.

Design control is the methodical management of the design process and its inputs and outputs. It is intended to ensure that the necessary design steps are taken, including reviews, verification and validation, and that information is recorded. Design information should be put under configuration management to ensure that the design is properly controlled (see BS ISO 10007).

NOTE Configuration management is a discipline that applies technical and administrative control to a design. It provides ongoing recording and management of the "design so far". The process comprises the following:

a) identification of the items to be controlled, these become the "configuration items" which together define the complete design of the product;

b) The status of each configuration item is then recorded, reflecting the "completeness" of that item.

c) A configuration change control system should then be put in place to allow and track changes to the configuration items, bringing the necessary degree of control to the design.

d) For software and similar complex designs, a configuration release process should be put in place to record the versions of design that are put into service, or used subsequently in the ongoing design. This becomes the "version control" of the design.

The project manager should monitor the progress of work to ensure it remains focused on meeting the design brief and specification, especially with respect to performance, cost and timescale. Deviations from the plan should be approved or corrected swiftly.

Appropriate records, such as meeting minutes or design review documentation should be kept, and the status and distribution of working documents systematically controlled (for example by use of a formal quality management system).

A project identifier, for example a reference code or number, and a date, should be used on all project documents for traceability and control.

5.2.13 Conducting design reviews

At major milestones in the design process (e.g. at the end of each phase in Figure 7 [**5.3**]), the project manager should schedule formal, systematic reviews of the design. These design reviews should be identified on the project plan.

NOTE 1 BS EN 61160 gives further guidance on formal design reviews.

The purpose of a design review is to check that the design is progressing correctly and the specification is accurately implemented, and to identify and agree any changes required. Design review meetings should include members of the design team and be supplemented by others who have specialist technical expertise. It is often of great benefit to include suppliers, subcontractors and customers/clients at appropriate stages.

NOTE 2 A design review is not the same as a progress review; it concentrates on technical issues rather than project performance issues.

Participants should receive the agenda for a design review at least one week before the meeting. The agenda should include the following:

a) areas for review (technical solutions, risks, problem areas, potential shortcomings, gaps in the brief/specification that need rectifying), as well as areas where corrective action might be needed;

b) points on which decisions are required;

c) where the relevant technical information resides.

Minutes should be taken at design reviews to provide a traceable record of decisions made, and for product liability reasons these should be kept on file throughout the intended life of the product. The minutes of the meeting should contain a dated action list that includes the names of those responsible for ensuring that actions are completed satisfactorily. Follow-up action should be monitored by the project manager and reported at the next design review.

5.2.14 Managing risk

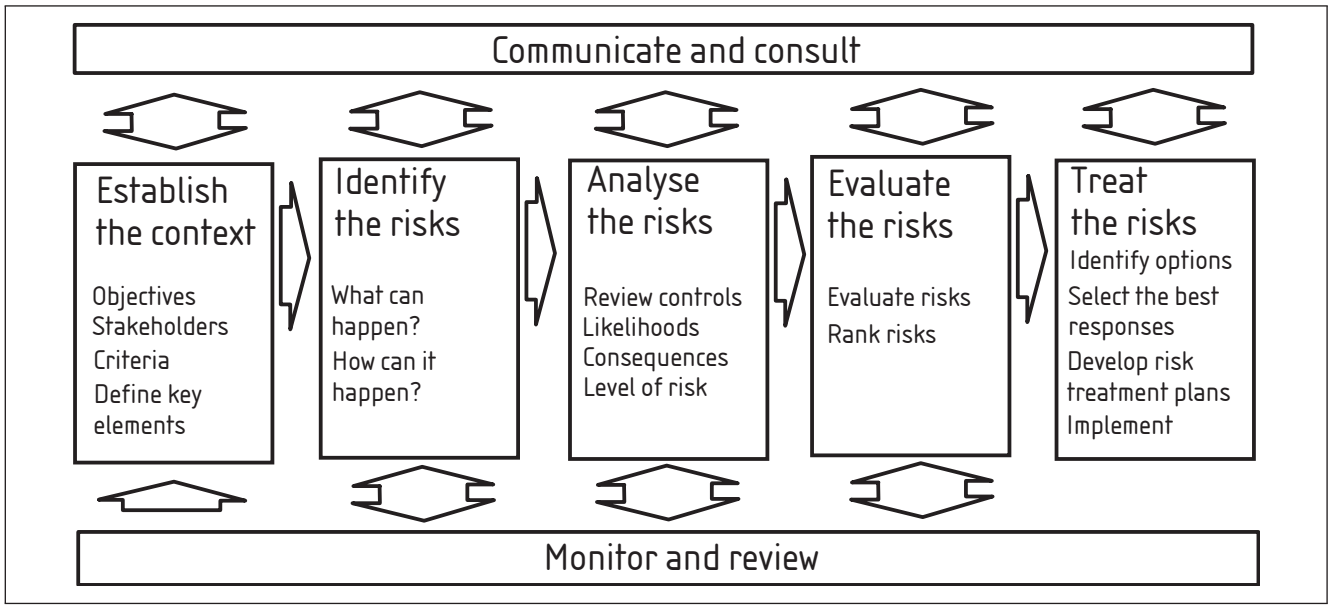
An increasing number of product safety standards require that risk management is applied to the design of new products.

Risk management is not a discrete stand-alone process, but should be integrated with overall project management. The implementation of risk management should be the responsibility of all the project team and they should participate actively in the process.

This is project risk management in the broadest sense, not to be confused with product safety risk assessments undertaken at the engineering level. Safety risk assessments, as an ongoing activity, should commence at the point the design solution is identified.

Detailed guidance is given in BS IEC 62198, from which the process model Figure 6 is taken.

Figure 6 **The project risk management process**



The project manager should commence risk management activities at the outset of the project, develop a risk management plan, and continue with risk management activities throughout the project lifecycle. The project manager should ask the questions given in Table 1.

Table 1 **Risk management questions**

Risk management process step	Question
Establish the context	What are we trying to achieve?
Identify the risks	What might happen?
Analyse the risks	What might that mean for the project?
Evaluate the risks	What are the most important issues?
Treat the risks	What are we going to do about them?
Monitor and review	How do we keep them under control?
Communicate and consult	Who should be involved in the process?

5.2.15 Controlling project costs

The project manager should ensure that procedures are in place to monitor expenditure against the budget. A budget should be allocated for each stage of the design plan; most project planning tools provide this facility. Details about costs can then be reviewed as the project proceeds, and compared with the predicted budget. The time and cost data acquired should be assessed at regular intervals throughout the project.

Any changes in costs should be made available to the project manager as soon as they are known.

5.2.16 Controlling product cost

The projected cost of the product should be evaluated and controlled during the design programme, and for example the following processes could be considered:

a) design strategy to achieve cost targets;

b) design approach (use of standard parts and/or modular construction);

c) material selection (including consideration of using recycled materials and end-of-life aspects);

d) selecting manufacturing techniques appropriate to the design and volume;

5.2.17 Reporting on project progress

The project manager should issue regular written reports on the progress of the project. The frequency, content and format of these progress reports should be agreed with all interested parties at the start of the project.

These progress reports should highlight the actual or potential deviations from the project plan and the reasons for such deviations. The project manager should be responsible for ensuring that corrective action is taken to resolve problems.

5.3 Design project management

A policy for the design process should be established at the outset.

This is intended to give an insight into the core design activities themselves, and set the context for design project management, as outlined in Figure 7.

NOTE 1 A more detailed design model might need to be developed to suit a particular product and circumstances. The relative importance and sequencing of activities can vary to some degree, and iteration between the elements of the model is usually necessary.

Figure 7 **The design process at project level**

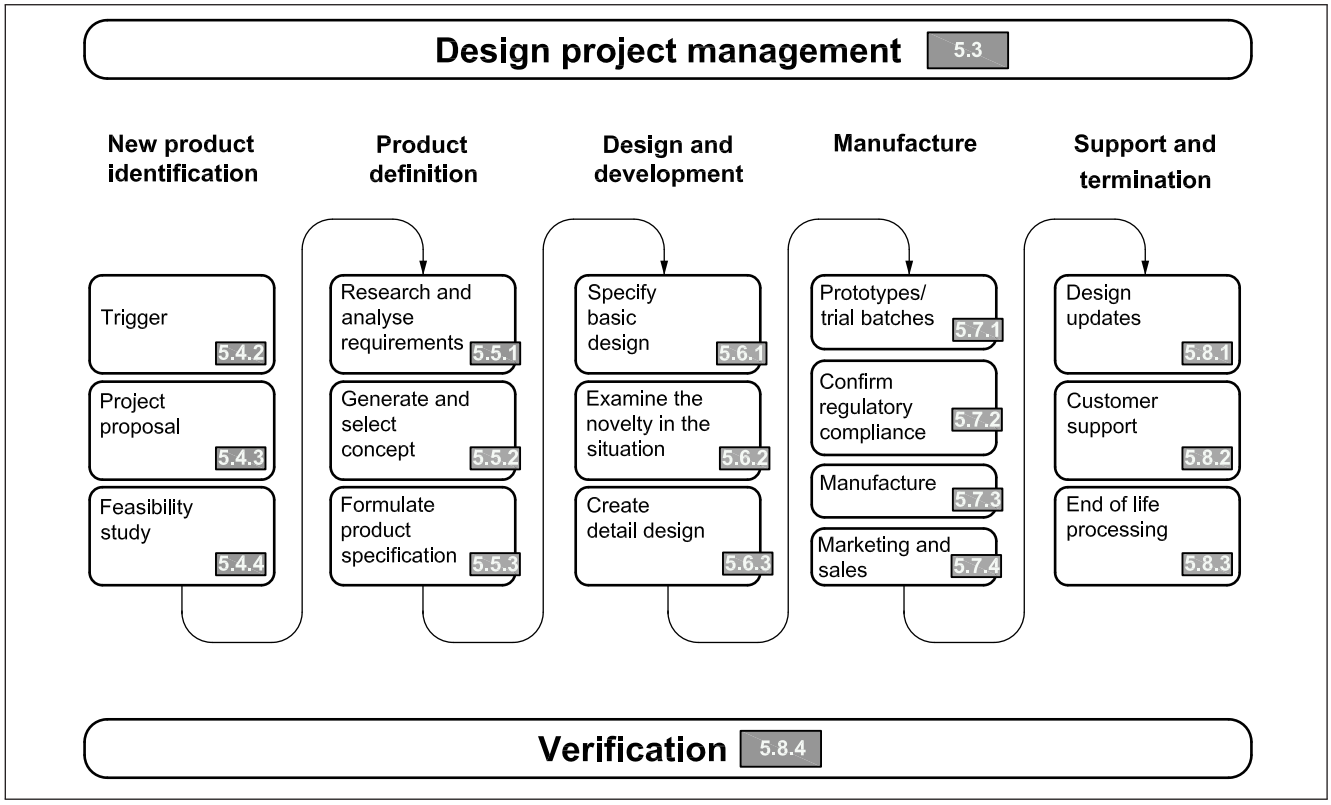


Figure 7 shows the design project management process divided into five phases. The verification thread shown at the bottom of the diagram includes the sanctioning of continuation to the next phase. Below is an outline of each of the five phases.

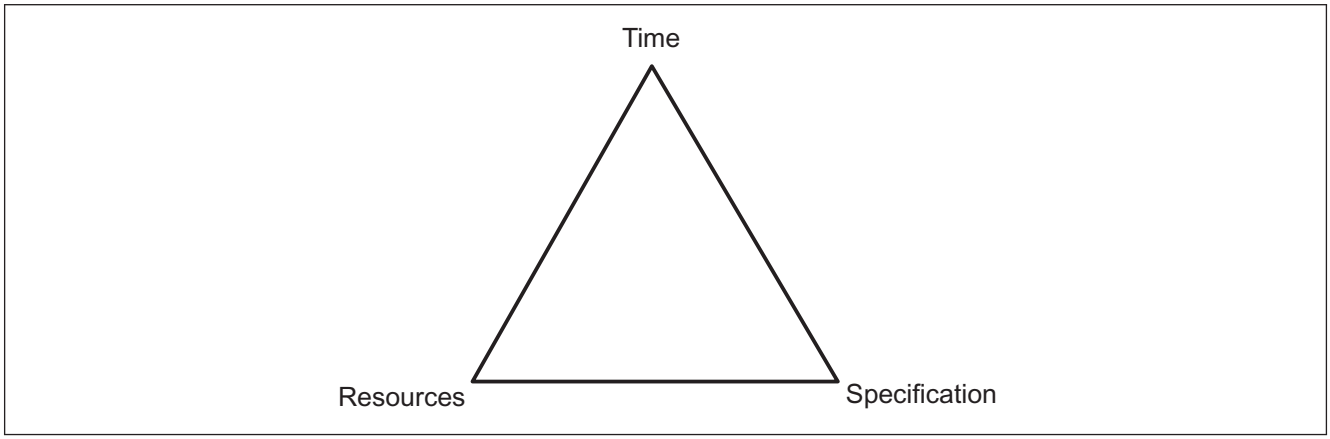
1) Phase 1 (new product identification) commences with the "trigger" which prompts the exploitation of an idea, and then goes on to investigate commercial viability and feasibility of the proposed project.
2) Phase 2 (product definition) establishes the overall product requirements, selects the preferred concept and generates the product specification.
3) Phase 3 (design & development) transforms the specification into a detailed design, while managing risks arising from innovative ideas or technology.
4) Phase 4 (manufacture) moves the design into manufacture, and supplies the product to the customer.
5) Phase 5 (support & termination) supports the product, and eventually considers withdrawal and disposal of the product.

There is the opportunity at the end of each phase for senior executives to decide whether to proceed with the next phase.

*NOTE 2 Guidance on the management of each phase is described in **5.4** to **5.9**. These phases can be iterative and might not occur in the order illustrated. Usually, elements of the process are undertaken in parallel, often referred to as concurrent (or simultaneous) engineering. This requires a thorough understanding of requirements to be available at the beginning of each activity. A challenging aspect of efficient concurrent working is synchronizing major milestones in parallel parts of the process. Concurrent working demands effective communication and it is important that all affected functions participate in decision making.*

Whilst the early stages of the design process usually incur a relatively modest proportion of the total cost, it is here that the key decisions are made that commit the project to particular technologies or solutions, timescales and costs. A balance needs to be achieved between the three key drivers: the specification, timescale and resources to be committed (implying cost). Establishing and maintaining awareness of risks to this balance during the project will define the chances of a successful outcome (see Figure 8).

Figure 8 **Balancing the key project drivers**



An effect known to design managers is that of "specification creep", where enhancements are continually proposed. For this reason, firm control should be exercised by the project manager, and any changes to one or more of the drivers should be accompanied by corresponding amendments to the others.

NOTE 3 Design and development quality management requirements are given in BS EN ISO 9001.

NOTE 4 More detailed guidance on project management is given in BS 6079.

5.4 Phase 1: new product identification

5.4.1 General

There can be many sources for a new project initiative, both external and internal, and they can 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.

5.4.2 Trigger

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.

These factors might initiate additional studies that could include specially commissioned reports on market research, warranty, servicing and competitor activity.

The outcome of this the "trigger" stage should be recognition that there is an opportunity for a new product to be formalized in a project proposal.

Some triggers that could lead to a new design project are:

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);

aa) new materials becoming available;

bb) new manufacturing methods providing a potential cost saving;

cc) changes in consumer behaviour/style;

dd) opportunities to create end-of-life value.

5.4.3 Project proposal

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

a) the availability of material 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 potential profit should be compared to the required return on investment, or other financial performance measures. The proposal should provide a preliminary definition of the new product in terms of its performance and user acceptability, and conform to the organization's objectives.

This proposal for the project is not the product specification. The product specification will be formulated in Phase 2 (see **5.5**).

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

The project team should submit the proposal, for evaluation by senior executives, which contains:

1) project objectives;

2) market segments for the proposed product;

3) the need for regional or niche market variants;

4) potential demand;

5) outline characteristics;

6) environmental considerations;

7) end-of-life considerations;

8) phases and completion timings;

9) project costs;

10) capital requirements;

11) subcontract requirements;

12) documentation requirements;

13) 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.

In formulating the proposal, the following needs to be considered (as appropriate):

i. the operational brief;

ii. projected plan and breakdown of project stages, including timescale;

iii. market size and segment (including regional or niche market variants);

iv. personnel requirements and availability (including skills and experience);

v. risk assessment (such as FMEA);

vi. likely manufacturing resources and process requirements;

vii. potential materialrequirement;

viii. projected cash flow;

ix. likely costs;

x. potential warranty responsibilities;

xi. special needs and product requirements;

xii. environmental considerations;

xiii. market considerations;

xiv. conformity to relevant legislation, standards, charters and codes of practice;

xv. potential end-of-life requirements.

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

5.4.4 Feasibility study

The purpose of the feasibility study is to establish whether the proposed development is viable and aligned to the objectives of the organization and its design strategy. The following is list of activities that the project manager can undertake when assessing feasibility at this stage:

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);

m) lifecycle assessment.

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 infeasible at this stage, it might be reassessed or abandoned.

5.5 The “product definition” phase

5.5.1 Researching and analysing requirements

The second phase in the design of products is the new product identification phase typified by Figure 9 (a subset of Figure 7).

The project manager should now establish the details of the product proposal.

Research on how the proposal could 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 can depend on evaluating many considerations.

5.5.2 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 might organize a brainstorming session, or similar methods, 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.

A preferred option should then be identified from the various concepts developed. Where appropriate, options that are particularly good at satisfying different aspects of the design brief should be combined.

Techniques to be used in this process could include rating, ranking, classification and risk analysis.

The outcome of this stage should be the preferred option that best fulfils the requirement described in the product specification.

5.5.3 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 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.

5.6 The design and development phase

5.6.1 Specifying the basic design

The project manager should ensure that the structure of the design is determined at this stage. For complex products or machinery, this stage can be very important in achieving a viable design. For example, to achieve the required safety or fault-tolerance, a certain interdependency or redundancy of modules might need to be designed in at the outset otherwise the design objectives might not be achieved. Care should be taken to ensure that safety is never compromised as design progresses through to manufacture and launch.

Once the basic design is determined, the design details can be developed to show the features included in the chosen option. This would include their spatial arrangement (embodiment design, design scheme or general arrangement [GA]). This should show the types of interfaces and the items to be manufactured as well as their appearance.

The outcome of this stage should be that the product is resolved into a framework of modules or components that is now ready to be detailed.

5.6.2 Examining the novelty in the solution

This stage of the design process exists to ensure that any novel technology or applications are theoretically understood and technically proven before significant effort is expended to exploit them. Extra attention should be paid to the more innovative parts of the design where lack of experience makes it more difficult to forecast performance.

It is inadvisable to base a new product design on unproven ideas or technology without verifying the underlying principles. This stage provides the opportunity to validate the proposed solution.

NOTE If there really is nothing novel about the proposed product, this stage can be omitted.

There are benefits in translating design concepts into reality as soon as possible, particularly when ideas, principles or parts of the design need to be tested. It also helps to facilitate decision making when choosing between alternative design solutions. The project manager should arrange for computer simulation, laboratory or experimental work, and prototyping to be carried out to verify that any novel concepts perform as anticipated.

The outcome of this stage is confirmation that novelty incorporated in the new product (where this exists) can operate satisfactorily.

5.6.3 Creating the design

The details of the individual components of the product can now be determined along with their methods for manufacture and delivery. These might include machine and tooling design, production manuals and quality assurance specifications.

The project manager should ensure that the design will be verified by an analysis and testing programme running concurrently with the detail design process.

Where components have a long lead time, either because of manufacturing or purchasing constraints, the detail design process should be completed ahead of other components.

Examples of information received from the detailed design stage:

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) assembly instructions;

f) bills of material/item lists;

g) approved suppliers;

h) preferred components;

i) tooling specifications for components and assemblies;

j) target weights;

k) reliability predictions;

l) instructions for commissioning, maintenance and use, and information leading to end-of-life decisions;

m) product test specifications;

n) test equipment requirements;

o) verification records.

The outcome of this stage should be a detailed design of the product with documentation and guidance on sourcing and manufacture for staff, suppliers, customers and other interested parties.

5.7 The manufacturing phase

5.7.1 Building real and/or virtual prototypes and trial batches

It is often helpful to produce mock-ups, prototypes and other development models at various stages of the design process. These test the function, performance and aesthetic characteristics of the proposed product, and can include the following.

a) Mock-ups of the proposed product, usually in physical form. These are often made during the early stages of design (sometimes referred to as a "looks-like model").

b) Experimental rigs, representative of aspects of the function, but not the form, to test whether a proposed design solution works as intended (sometimes referred to as a "works-like model").

c) Test prototypes that are partially representative of the intended final product can be used to verify the functional characteristics of the design,

and a series of such prototypes might be produced at different stages of the design process to test different aspects of the product (sometimes referred to as a "looks-like, works-like model").

d) Development prototypes are occasionally used to verify the design in terms of its characteristics (e.g. functional performance, ease of assembly, customer acceptability, reliability, maintainability), or to submit to an independent test house for standards pre-compliance or compliance testing.

e) Trial or pre-production batches should be produced to verify manufacturing, inspection and testing processes.

5.7.2 Verifying regulatory compliance

Pre-production prototypes should undergo testing and verification to confirm the performance of the product in all respects.

Depending on the nature of the product and the countries where it will be sold, it might 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.

5.7.3 Manufacturing the product

The choice of manufacturing resources is an important consideration, and a decision should be made as to whether the product will be manufactured using:

a) an organization's existing manufacturing resources;

b) manufacturing resources offered by subcontracting suppliers; or

c) new resources requiring new investment either within the project or by the supplier.

The responsibility for this decision rests at organizational level (see Clause **4**) but might be delegated to the project manager who should ensure the choice of manufacturing resource is agreed.

The project manager is responsible for the smooth handover of the design to production, but usually not responsible for the manufacturing programme itself. However it is likely that manufacturing will require technical support. If queries emerge over design details that cause manufacturing problems, components become unavailable in the necessary timescales, or problems arise with the performance of the product, the project manager should arrange to provide support from the design team to help resolve manufacturing problems. The organization should avoid committing all design team resources to alternative projects before the current commitments are complete and all fundamental manufacturing issues are resolved.

Product delivery should be relatively straightforward if previous stages of the model have been fully processed. However, in the case of large, one-off products, the exact logistics of delivery should be carefully planned and checked to ensure efficient routing and a clear passage to the final destination.

5.7.4 Marketing and selling the product

Despite the design team finishing the bulk of their work before the product selling stage, it will almost certainly be necessary for them to provide technical support during this stage and thereafter, during the product's life.

The project manager should ensure that product information is provided to sales organizations and their personnel to ensure that they are fully conversant with the features and performance of the product.

During the selling and use stage, the opportunity should be taken to gather potentially valuable data concerning users' experiences with the product, in order to ascertain improvements and future product design requirements. The project manager should therefore ensure that good communication links are established with other parties such as:

a) manufacturers and their subcontractors;

b) distributors, dealers and sales organizations;

c) customers and users;

d) post-sales service, support and refurbishing facilities;

e) re-sellers;

f) disposal facilities.

The outcome of this stage is the capability to maintain the product on the market.

5.8 The support and end-of-life phase

5.8.1 Managing design updates

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 can 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 might 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) warranty returns;

i) performance records.

5.8.2 Customer support

It is often prudent to provide some form of after-sales support. As a minimum this might be a consumer helpline provided by a customer services department. More complex products might require a technical helpdesk manned by staff with a more in-depth knowledge of the product.

There might also be a need for support in the form of technicians to replace faulty parts or undertake routine maintenance or servicing. This will almost certainly require the provision and availability of consumable items and spare parts and the employment of personnel who are suitably trained. Such resources can be provided in-house or subcontracted.

If either of the above requirements is foreseeable, the project manager should assume some responsibility for ensuring the necessary resources are provided.

Sales might continue for a long time, perhaps prolonged by used-sales activities. So the after-sales service and spare parts activities should continue for the anticipated life of the product.

5.8.3 End-of-life considerations

Where end-of-life considerations have been made during the design process, an appropriate system should be established to return products into the manufacturing system or appropriate organization.

NOTE When a product line is withdrawn, discontinued or replaced, contractual and legal liabilities and warranties remain in force for products still in use.

5.8.4 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.

Any significant failures under k) should be reported for appropriate action to be taken.

5.9 The evaluation and continual improvement phases

5.9.1 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 customer experience), 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 can be carried out in accordance with independent standards (where such apply) and might, in some cases, be a legal requirement.

The outcome of this stage might 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.

5.9.2 Evaluating the management of the project

Before concluding the project, the project manager should evaluate management of the project and draw up recommendations relevant to future projects.

5.9.3 Evaluating the design process

An evaluation report of the design process should be presented to the organizational level. A review of the progress of design might reveal areas where improvement could be made for the next design project. The evaluation of the design process should examine both company procedures and those that are specific to the project.

The project manager should produce an evaluation report that includes the following:

a) an internal assessment of strengths and weaknesses, comparison with the project proposal, reason for discrepancies, and feedback from the manufacturing functions, customers, service organizations, etc.;

b) an assessment of the adequacy of the project proposal, design brief, and various specifications;

c) identification of those procedures that worked well and those that did not, and of the causes of misunderstanding or delay;

d) proposals for changes for the next project;

e) authorization from management to implement agreed changes. The project manager should consider reporting any ideas that could increase the efficiency of the design management process. These include reducing time-to-market, controlling design and product costs, controlling costs in use, and earned value analysis.

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Useful websites

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The Department for Business, Enterprise & Regulatory Reform (formerly DTI) < http://webarchive.nationalarchives.gov.uk/20090609003228/http://www.berr.gov.uk/> [last viewed 10/9/2015]

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Design Business Association – Trade association for the UK design industry <http://www.dba.org.uk> [last viewed 10/9/2015]

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