

BRITISH STANDARD

Design for manufacture, assembly, disassembly and end-of-life processing (MADE) –

Part 1: General concepts, process and requirements

ICS 01.100.01, 01.110

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Foreword

Publishing information

This part of BS 8887 was published by BSI and came into effect on 31 October 2006. It was prepared by Technical Committee TDW/4, *Technical product specification – Methodology, presentation and verification*, in response to an original proposal from BSI Programme Manager Geoff Gonella. A list of organizations represented on this committee can be obtained on request to its secretary.

Relationship with other publications

The function of BS 8887 is to provide context for the preparation of technical product specifications in accordance with GPS principles. However, it is not the intention that BS 8887 is a “stand-alone” standard since it is part of a triumvirate of TPR (Technical Product Realization) standards comprising BS 8888 and BS 8889. The relationship of these three standards to each other is explained in Annex D.

It is intended that subsequent parts of this British Standard will address specific requirements for various types of engineering manufacture, for example mechanical; hydraulic; electronic; chemical.

It should be noted that BSI does make educational/training aids available in this field and is currently planning a major education/training initiative which, it is expected, will lead to a programme of competency assessment and certification.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is “shall”.

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

This British Standard is introduced at a time of considerable change in the nature and presentation of technical documents prepared as part of technical product specifications. It is structured so as to provide the designer with a framework within which the selection, preparation and presentation of appropriate documentation to facilitate the efficient transfer of the design concept into and beyond the manufacturing environment can be undertaken. It is appropriate to all types of manufacture and has the primary purpose of identifying and specifying the use of ISO Standards relevant to the design for manufacture route.

Support for the design of technical products, by standards, is currently deficient in that there are no British Standards focusing on how the designer ought to set about the task of preparing their conceptualizations for manufacture. The nearest would seem to be the withdrawn PD 6470:1981, *The management of design for economic production*, which is now somewhat dated in terms of its scope and content. The current BS 7000 series deals with the broader concepts of design management and BS 7373-1 and BS 7373-2 address product specification but all stop short of providing for the preparation of the actual documentation for manufacturing, assembly, disassembly and end-of-life processing (MADE).

Technical designers do not just require a broad understanding of those things which influence manufacture, such as materials, the nature and capability of available manufacturing facilities, the implications of out-sourcing, product safety, eco-considerations and the needs of European and International markets. Designers also need to be able to express the design requirements with precision and without ambiguity, in a manner that is understandable and accessible in a broad range of manufacturing situations, possibly remote from the immediate location of the design facility. It is unlikely that this can be achieved through the use of purely National Standards and therefore cognizance of International Standards is essential.

In view of this, and to facilitate the use of such standards, this specification requires the use of BS 8888, *Technical product specification* (TPS). The primary function of BS 8888 is to provide a comprehensive list of International Standards relevant to TPS and BS 8888:2006, Annex A and BS 8888:2006, Annex B identify cross-references, by standard number linking them back to the part of the main text that relates them to appropriate stages of the design definition process and contains the specific requirement for their application.

The complexity of products is generally on the increase, with a higher emphasis on cost control and improved time to market. In addition, today's social model, with the mobility of labour and attendant problems of knowledge and skill retention, brings new pressures for completeness of specification. One result of the simultaneous impact of these phenomena on today's business model, is an increasing need for the development of a specification system ensuring a methodical (rather than intuitive) approach to the preparation of technical product specifications.

This part of BS 8887 addresses the design task, irrespective of whether the designer works for a manufacturer, a design company, or is freelance. It is expected that it will, therefore, be of considerable interest to a wide range of businesses and be applicable to a broad range of product types. Businesses experiencing the need for a more precise approach to design specification, and established designers/design companies who might be seeking a benchmark for design competency might also find this standard of considerable assistance.

It is not the function of this part of BS 8887 or of BS 8888, to teach the designer how to design nor to seek to restrain the creative process. Rather, it provides a methodology for ordering the output of that process in a manner that maximizes the possibility of the most efficient, cost effective transfer of the design concept to realization. It is intended to be beneficial for the designer to take account of the requirements of BS 8887-1 in the formulation of their ideas, but the function of BS 8887-1 in conjunction with that of BS 8888, is to provide for precise, comprehensive, unambiguous specification capable of fully informing manufacturing, assembly, disassembly and end-of-life processing.

There are several stages to the manufacture of a product. In the early years of design, designers traditionally applied the principles of design for manufacture to the production of the individual piece parts which together make up the product. This was the approach adopted by publications such as PD 6470 last published in 1975. Phrases like “design for producability” were used at this time. More recently designers realized this was too limiting and the approach then adopted was that there were two stages to the manufacture of a product; the production of the individual parts followed by their assembly together, hence creating the product. Design for manufacture was then applied to these two stages. Typical of this approach was the work of Boothroyd et al. [1]. Their recommendation was that design for manufacture might be equally applied to the assembly stage as to the production of the individual parts and they coined the term design for manufacture and assembly (DFMA). However, during the last several decades, two major developments have occurred, which mean that design for manufacture needs to be considered beyond these two stages.

Firstly, the importance of product quality and customer satisfaction meant that the customer needed to be included. Hence, designers used phrases like design for the customer (DFC). Secondly, environmental pressures produced new legislation; with the result that end-of-life processing is to be considered at the *ab initio* design stage. This legislation has forced manufacturers to take responsibility for a product when the customer has finished with it.

Thus, to complete the whole life cycle, disassembly stages have to be added, consisting of, not only the actual disassembly of the product, but also the treatment of each and every one of the individual parts through re-cycling, re-use or disposal including the possibility of material separation for materials recovery or disposal purposes.

Environmentalists have coined terms like design for the environment (DFE), design for recycling and design for reprocessing (DFR). Yet others considered that design for the environment ought to pervade the whole life cycle and terms like life cycle design (LCD) or design for the life cycle (DFLC) are used. This approach has been supported by policy initiatives, fiscal incentives and some legislation, which have variously

encouraged or required environment-related elements of product composition, energy consumption and energy sourcing. More recently, the term DFX is used to refer to all these techniques since each is relevant in their own right. It is considered that all the DFX terms are limiting since they each force a focus at a particular point at one stage of design. Furthermore, they represent an acronym rash. A holistic view is taken in this standard and hence, for convenience, the generic term design for manufacture (DFM) is used throughout.

1 Scope

This part of BS 8887 specifies requirements for the preparation, content and structure of design output and the preparation of related technical product documentation for the manufacture, assembly, disassembly and end-of-life processing (MADE) of products. It identifies and describes methodologies and conventions appropriate to the preparation of documentation, in whatever form, intended to transfer a design concept to manufacture, including the determination of required accuracy and tolerances for verification purposes. It also provides guidance on the application of principles and techniques to assist the designer in the preparation of unambiguous instructions, commensurate with the perceived complexity, role and life of the intended product.

In addressing end-of-life requirements, this British Standard extends beyond specification for the manufacture and assembly of products to incorporate recommendations on how best to incorporate into the documentation, guidance on the ultimate reuse, recovery, recycling and disposal of the components and materials used.

NOTE Requirements to modify any design and therefore its specification could arise as a result of experience in manufacture and use but the provision of design improvement occurring subsequent to the issue of the first sealed design brief is outside the scope of this British Standard.

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 8888:2006, *Technical product documentation (TPS) – Specification*

BS EN 1050, *Safety of machinery – Principles for risk assessment*

BS EN 20286-1, *ISO system of limits and fits – Part 1: Bases of tolerances, deviations and fits* [ISO 286-1]

BS EN ISO 1043 (all parts), *Plastics – Symbols and abbreviated terms*

BS EN ISO 11469, *Plastics – Generic identification and marking of plastics products*

BS EN ISO 14040, *Environmental management – Life cycle assessment – Principles and framework*

BS EN ISO 14041, *Environmental management – Life cycle assessment – Goal and scope definition and inventory analysis*
DD ISO/TS 17450-1, *Geometrical product specifications (GPS) – General concepts – Part 1: Model for geometrical specification and verification*
DD ISO/TS 17450-2, *Geometrical product specifications (GPS) – General concepts – Part 2: Basic tenets, specifications, operators and uncertainties*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this British Standard the terms and definitions given in BS 8888 and the following apply.

3.1.1 **manufacture**

production of piece parts

3.1.2 **processing**

transformation of material or component, or materials or components in combination, from one physical or chemical configuration or state to another

3.1.3 **assembly**

bringing together of piece parts in a functional relationship

3.1.4 **demanufacture**

disassembly of the product, and the reuse, reprocessing or disposal of piece parts

3.1.5 **recycle**

action of reprocessing a material, component or piece part which has previously been processed for inclusion in a product

3.1.6 **renewable**

replenishable naturally at source at a rate at least the same as consumption

NOTE This can apply to materials and energy.

3.2 Abbreviations

DFE	Design For the Environment
DFELP	Design For End-of-life Processing
DFLC	Design For the Life Cycle (or LCD: Life Cycle Design)
DFM	Design For Manufacture
DFMA	Design For Manufacture and Assembly
DFR	Design For Recycling (or reprocessing)
DFX	all the “design for” approaches
LCA	Life Cycle Analysis
MADE	Manufacture, Assembly, Disassembly, and End-of-life processing
TPD	Technical Product Document
TPS	Technical Product Specification

4 Design process

For the purposes of this standard, design for manufacture shall be considered to include the following in addition to the fundamental requirements for product use:

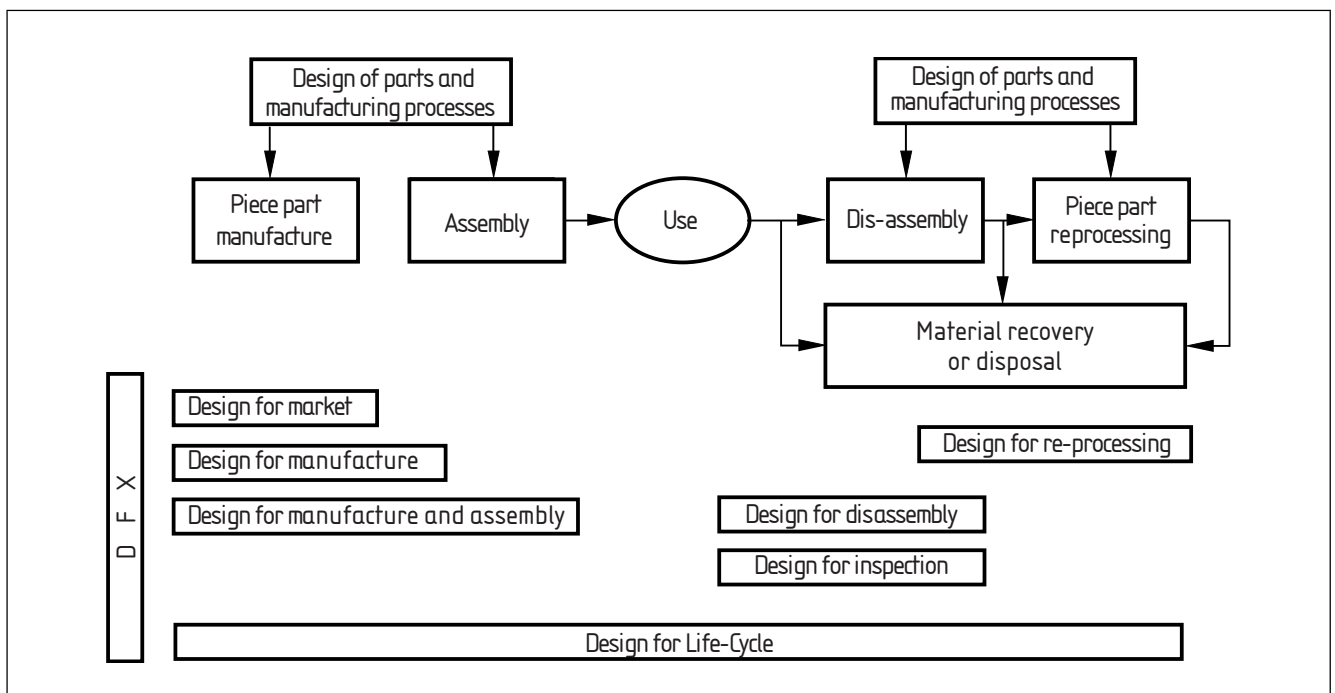
- part production;
- assembly;
- disassembly;
- materials recovery/disposal and part reprocessing.

NOTE 1 It is recommended that PD ISO/TR 14062 is taken into account. Although PD ISO/TR 14062 was drafted for environmental managers rather than designers and engineers, it provides a very useful reference document for users of BS 8887-1.

These design process stages are shown schematically in Figure 1. Design for manufacture considerations shall be applied to each of these five stages.

NOTE 2 The sequence of events implied by the order of the clauses in this British Standard should not be taken as absolute since the process is iterative. In practice many stages are revisited, perhaps many times, throughout the overall activity. This applies particularly to the design improvement element that by its very nature, influences and informs every activity.

Figure 1 The stages in the life of a product and the various DFX terms



5 Design brief

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

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

The design brief shall collate the set of requirements and limits, which identify and define a perceived market need, the satisfaction of which requires specific design input. These are common to all product areas and the design brief shall include the following, which are further expanded in Table 1.

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

Each of the elements identified in Table 1 shall be given positive consideration, even if it is subsequently set aside as having no relevance to the project, since parties involved in the preparation of the brief are advised not to make assumptions about the relevance of particular aspects.

Table 1 Parameters for consideration in the preparation of a design brief

Market need ^{A)}	Technical feasibility	Serviceability ^{A)}	Life cycle ^{A)}
Market sensitivity	Material (<i>suitability and performance</i>)	Level (e.g. module/component) within a product	Materials (<i>minimization, surface area, density, recyclability, recycled content, renewability</i>)
Sales potential	Currently available processes	Ease and practicality of access to relevant level	Manufacturing processes (<i>materials/energy consumption, pollution, toxicity</i>)
Competition	Potentially available processes	Required tools (cost and availability)	Product operation (<i>energy sources and systems [renewable, low carbon], energy consumption</i>)
Opportunities	Health and safety	Health and safety	Life cycle assessment
Aesthetics	Design verification	Skills requirement	Legal constraints
Price ^{A)}	Process conformance testing	Return to use processes	Whole life costs (<i>production, use, end-of-life</i>)
Potential for on-going development	Function verification	Upgradability	Health and safety
Impact on company image	Risk assessment	Spare stock implications	Recovery (materials)
Performance	Milestones ^{A)}		Recycling (materials/energy)
Potential benefits of sale as a function rather than a product			Recovery (energy)
Confidentiality			Reuse
Time scale ^{A)}			Ease and practicality of disassembly
Quantity required			
Inclusive design			

Method of presentation of the final design concept, for approval

^{A)} These items shall appear in every design brief.

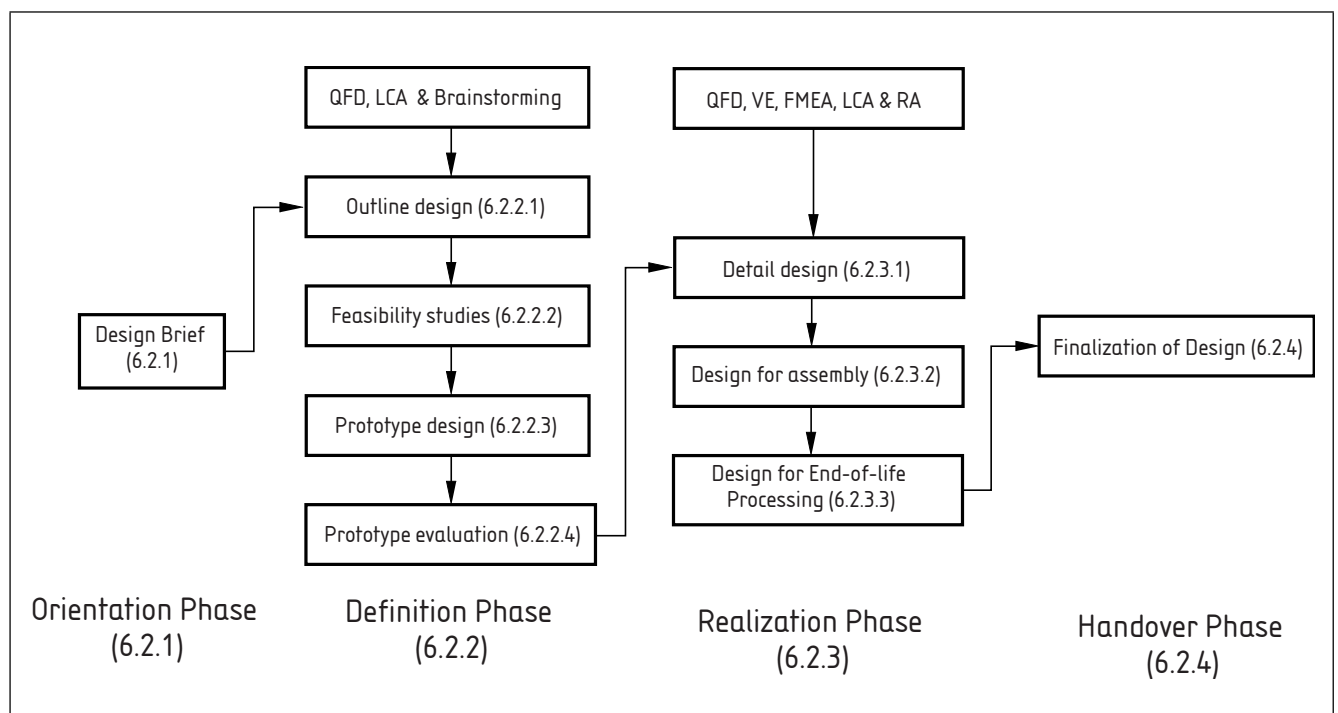
6 Design methodologies

6.1 General

The best practice sequence of events for design shall be in accordance with **6.2** and Figure 2, which set out the totality of possible methodologies/phases that can be beneficially applied throughout the design definition process. Figure 2 represents this best practice sequence graphically and provides cross-reference to the specific techniques that are applicable to any particular phase.

NOTE 1 For any specific entity engaged in design for manufacture the inclusion of any particular phase, as a clearly defined step, is influenced by the circumstances of application and particularly by the size of the entity concerned, the complexity of the design project and the anticipated production run length/volume. However, the whole sequence of events should be conceptually applied in every situation even though particular phases might then be set aside as being inappropriate or merged to simplify their application. The phases for detailed design (6.2.3.1), design for assembly (6.2.3.2) and life cycle consideration (6.2.3.3) are considered to be of sufficient complexity and significance as to require elaboration in Clause 9, Clause 10 and Clause 11 respectively.

Figure 2 Application of specific techniques showing best practice sequence of design methodologies



NOTE 2 There are many established techniques that can assist in the design process and some of these are given in Annex A.

6.2 Best practice sequence of events

6.2.1 Orientation phase (consideration of marketing brief/design brief)

A design project shall be commenced by consideration of the marketing brief, melded into a design brief by a team assembled for the purpose (MADE design team). This team shall contain competent representatives of the critical disciplines which have ownership of the product from design inception to the end of its life. These disciplines shall include, but are not necessarily limited to the following.

- Sales/marketing.
- R&D/design.
- Manufacture.
- Quality assurance.
- Customer service.
- Take-back facilitation.
- Health and safety.
- Environment.

NOTE Representation for more than one discipline may be undertaken by any individual team member provided that their competence in the disciplines represented is confirmed as adequate by the management responsible for the project.

The output of this consideration process shall be a document containing an agreed detailed design brief, in accordance with BS 8888:2006, Clause 5; targets for the various sections of the brief; and an allocation of the work needed to convert the brief into an outline design. The brief shall be forwarded to the management responsible for the project for decision as to continuation.

6.2.2 Definition phase

6.2.2.1 Outline design

During the outline design stage team members shall convert the design brief into an outline design for their allocated sections, taking into account the agreed design targets.

The outline design stage shall conclude with preparation of a set of outline design technical product documents, indicating where the design can be considered hard (relies on re-use of existing designs, or is based on work already tested) or soft (requires validation before proceeding to prototype stage). These technical product documents shall be reviewed by the team for the necessity and sufficiency of feasibility studies.

The output of the outline design stage shall be *either*, a set of outline technical product documents plus an agreed set of feasibility study briefs, with costs and allocation of work required to proceed to first prototype, *or* a conclusion that the design brief cannot be adequately met with current technology at an acceptable cost.

6.2.2.2 Feasibility studies

Team members shall complete agreed studies and prepare reports of the results. From the results of the studies the set of outline design technical product documents shall be completed. The team shall review this set of documents against the design brief and recommend action.

The output of the feasibility study stage shall be *either*, a set of approved outline design technical product documents sufficient to proceed to detailed prototype design conforming to BS 8888:2006, Clause 6, or a conclusion that the design brief cannot be adequately met with current technology at an acceptable cost. Management responsible for the project shall then decide whether to continue with or abandon the project.

6.2.2.3 Prototype design

MADE design team members with relevant competence or their directly nominated alternates shall continue the design work to produce a first working prototype of the product.

The output of the prototype design stage shall be a working prototype either real or virtual, not necessarily physically representative of the final product, and a set of detailed design technical product documents used to construct it, which shall conform to BS 8888:2006, Clause 6 and/or BS 8888:2006, Clause 22 and having specific regard to BS 8888:2006, Clause 19, BS 8888:2006, Clause 20 and BS 8888:2006, Clause 21.

6.2.2.4 Prototype evaluation and feedback

MADE design team members with relevant competence or their directly nominated alternates shall evaluate the prototype and the technical product documents against the design brief and report on work required to completely fulfil that brief.

The output of the prototype evaluation stage shall be a decision by management responsible for the project, as to whether to abandon, re-assess or continue the project. If the decision is made to continue a *sealed design brief* capable of fully informing the remainder of the design process shall be completed.

6.2.3 Realization phase

6.2.3.1 Detail design

When the main design intent has been fully agreed and the sealed design brief issued, a detailed analysis of the possible options for fulfilling its requirements shall be carried out, including determination of any new tooling required.

NOTE See Clause 9 for further information.

6.2.3.2 Lifecycle considerations, including end-of-life processing

Requirements with regard to end-of-life processing shall be prepared in accordance with Clause **11** and Annex C. Statement as to the nature and extent to which lifecycle considerations, including end-of-life processing, have been addressed shall be incorporated in the technical product specification taking account of **13.3**.

*NOTE 1 End-of-life processing is a relatively recent introduction to the design definition process. Manufacturers in certain fields are required to take control of the recovery, disassembly, recycling and disposal for their products at the end of their useful life. See Clause **11** for further information on end-of-life processing.*

NOTE 2 It is recognized that specific action with regard to lifecycle considerations are not required for all products. For example, many end-of-life processing issues are introducible to standard waste recovery/processing streams without special action or following simple separation of components. In requiring a lifecycle considerations statement for compliance with this standard it is accepted that for such products the statement may be to the effect that “no special action with respect to lifecycle environmental impact is considered necessary”.

6.2.3.3 Design for assembly and disassembly

Although much of the proposed expenditure is likely to have been committed, at the end of the detail design phase consideration shall be given to specific requirements for efficient assembly and disassembly of products, in particular to the minimization of the parts count for any given assembly.

*NOTE See Clause **10** for further information.*

6.2.3.4 Risk assessment

Where risk assessment (**A.6**) is undertaken, it shall be in accordance with: BS EN ISO 14040 and BS EN ISO 14041 where there are environmental implications; and BS EN 1050 where there are safety implications.

NOTE Guidance on risk management is also given in BS IEC 62198, and BS 8444-3.

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

Following completion of the manufacturing prototype stage, marketing shall lead the project into the product launch stage, during which all technical product documents shall be reviewed for completeness. Verification of these technical product documents shall be completed during initial manufacture, and shall include checking whether the documents conform to the appropriate sections of BS 8888, particularly BS 8888:2006, Clause **19** and BS 8888:2006, Clause **20** for tolerancing, and BS 8888:2006, Clause **21** for display components. As each technical product document is completed, it shall be deemed to have received final approval, and be transferred to the document controlled store. Once a technical product document has been stored in the document vault the relevant designer shall be released from the project.

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