Design Process

Introduction to design process (**pdf檔案**)
設計流程簡介

1 Engineering Design in Context
1 工程設計的內涵

Our society depends on technology. In recent years, the rapid developments in technology have
provided many benefits, but not without giving rise to a number of associated problems.
我們所處的社會依賴技術. 近年來, 技術的快速發展已經提供許多好處,但也不免帶來一些後續的問題.

When planning future developments, the aim is to increase the benefits and reduce the problems.
Many future options are possible.
當規劃未來的發展時,希望能夠增加好處的部分,而且能儘量減少問題.

For progress to be made, decisions must be taken at many different levels, ranging from broad policy decisions taken by governments, down to detail decisions taken by individuals.
未來有許多可能. 當技術持續進展時,決策必須用在許多不同的層面上,其中大到政府所做施政方針擬定,小至個人所下的瑣碎決策.

Decisions taken at a higher level obviously influence those taken at a lower level, but at whatever level a decision is made it will depend on forecasts and criteria.
上層所做的決策,當然會影響到下層,但是每一個層次所進行的決定,其實都必須依賴"預測"與"評判標準".

It should be remembered that forecasts often turn out to be wrong and that evaluation criteria
depend on values. Values differ, both between cultures and between individuals.
千萬要記得,"預測"有時也會錯誤,而評判標準則必須仰賴數據. 數據有時也會產生差異,不僅因爲文化產生差異,也因爲個人而產生差異.

Selecting the best course of action in any situation is therefore difficult and depends on the information available and the viewpoint of the decision maker.
因此,在各種狀況下想要有最佳作爲,並不容易,且取決於可以取得的資訊與決策者看待問題的觀點.

The fundamental stages in the life of a product are shown in Figure 1.
一項產品最基本的歷程階段,如圖一所示:

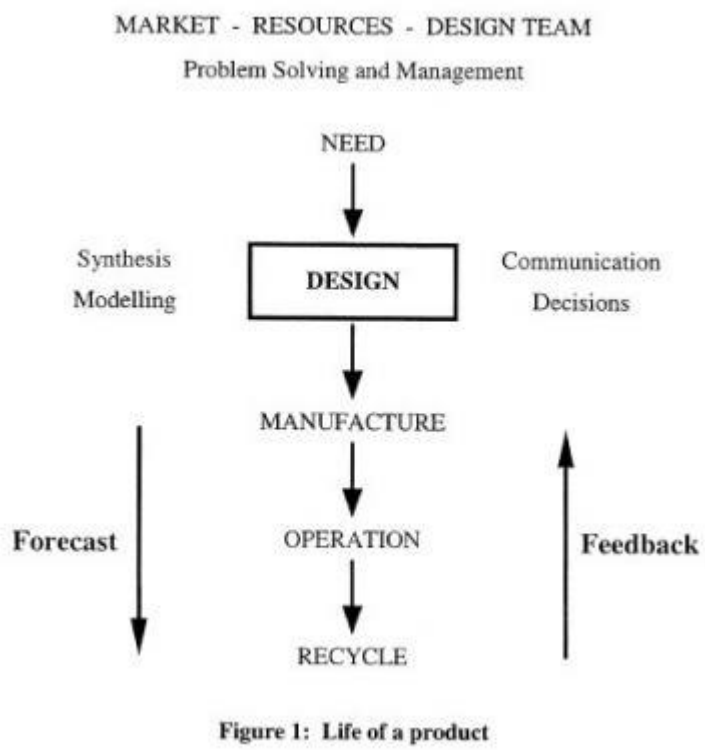

Figure 1: Life of a product

Figure 1: Life of a product
圖一: 產品的歷程

A product proposal, for example a new mountain bike for the leisure market, can result from a
good idea, a new technological development or a carefully researched market need.
一項產品的提案,例如一台專攻休閒市場的新型登山自行車,可以起源於一個好的構想,一項新的技術發展或者是一項精心研究的市場需求.

In order to turn this proposal into a concrete product, a design team will be formed to undertake the complex sequence of activities necessary to define what is to be made.
爲了要將這一份提案,變成一台如假包換的產品,必須要組成一個設計團隊,來執行這項複雜的工作流程,並定義哪些工作必須要分別完成.

This team will have to be provided with sufficient resources, including finance, facilities, tools and information, if the task is to be completed within the required time.
這個團隊必須要擁有充分的資源,其中包括財務,設備,工具與資訊,以使得各階段的工作能夠及時完成.

Progress depends on making decisions and during the design stage the aim is to ensure that the
proposed product will be economical to manufacture, will perform reliably, safely and economically in operation, and will be capable of being recycled at the end of its useful life.
工作的進展依賴決策,並且在設計階段中,目標是在既定的預算中製造出規劃的產品,除了讓產品達到可靠,安全,有效使用,也能在其功能終了時,順利地被回收.

Decisions depend on the quality of the forecasts made during the design process and all design
methods aim to improve the accuracy of these forecasts.
在設計歷程中的各項決策取決於預測的品質,而各種設計方法的目的,都試圖在改善這些預測的準確度.

To make forecasts a design team uses synthesis to generate as many solutions as possible and then modelling to forecast how these solutions would turn out if realised.
爲了進行預測,設計團隊採用合成的方法,儘可能地建立各種可能的設計方案,然後經由模擬,預估真實產品可能的結果.

Only seldom is it possible to get it all "right first time" and a lengthy development programme is often required.
只有非常少數的情況下,能夠一舉得到完全符合現狀的結果,大部分時候,都需要經歷長時間的開發與規劃歷程.

Vast amounts of information, obtained from specialists in many different fields, must be handled
during the design process. Large multidisciplinary teams are often required, introducing many
potential communication problems.
在設計過程中,必須處理不同領域專家們所獲致的大量資訊. 這樣的工作常常需要不同專長的大型團隊,也會產生許多可能的溝通問題.

Continual feedback from all stages of the process provides essential information for improving the product.
經由各階段所產生的連續回饋,可以提供改進產品的重要資訊.

Eventually it will become uneconomic to continue to update an existing product line and manufacture will cease.
當持續更新現有產品線所花費的成品,不再有利可圖時,生產便會停止.

However, market experience and user feedback will stimulate fresh ideas and market needs and the cycle will repeat itself. A typical example is the continuing evolutionary development of bicycles.
然而,市場經驗與用戶回饋則會觸發出新的想法與新的市場需求,屆時產品週期又會重複循環. 典型的例子就是不斷進化的自行車開發案.

In practice product creation is much more complicated than indicated in Figure 1 and products
evolve with time.
其實,產品建構遠比圖一所示,要複雜許多,並且產品也會隨著時間不斷改變.

The central engineering activities of design and manufacture are supported by other key company functions such as marketing, research and development, quality assurance and sales, the relative importance of each depending on the particular company.
最中間的工程設計與製造活動,由其他階段的關鍵公司運作所支撐,諸如,行銷,研究發展,品質保證與銷售. 每一階段的工作重要性則因公司而異.

A general strategy for tackling complex tasks is to break them down into smaller, more manageable problems and to solve each problem in turn. To do this it is useful to have a model
for problem solving and a structure and some guidelines for management.
處理複雜方案的共通法則,是將工作化爲旗下較小且較能控制的方案,並依序解決每一個問題. 建立一個解題的模式,並據以建立管理結構與方案,通常有助於解決這些問題.

Because the design and manufacture processes depend on the type of market considered and the
particular project being tackled, they are difficult to define precisely. However, it is helpful to
have some broad definitions and the following are suggested:
由於設計製造流程取決於市場類別與特殊專案考量,實在很難精確定義. 但是,透過某些廣泛的定義仍有些助益,因此建議如下:

• Engineering design is the process of converting an idea or market need into the detailed information (manufacturing instructions) from which a product or system can be made.

工程設計乃將創意或市場需求轉化爲細部資訊(製造指令),從而使產品或系統能夠據此而順利完成.

• Engineering manufacture is the process of converting detailed information into physical components and assembling those components into a product or system.
工程製造乃將細部資訊轉化爲實體零件,並組立成一項產品或系統.

The aim is to produce the best products, for the lowest cost and in the shortest time. Markets are
seldom static and some of the pressures facing modern designers include:
目標在最短時間,以最低成本,完成最好的產品. 由於市場很少是一成不變,因此現代的設計者所面臨的壓力包括:

• Intense competition. International competition is intensifying, and new products offering improved value to the customer are continually appearing in the market.
競爭不斷強化 - 國際競爭持續強化下,各種功能提升的新產品不斷推出.

This is fuelled by rising customer expectations and leads to shorter lead times as new products are introduced and old ones updated to retain a competitive advantage.
顧客的期望導致全新產品或舊產品的更新版必須在更短的時間內推出,以維繫競爭優勢.

• Changing technology. Technology is changing rapidly with new knowledge, materials and processes becoming available all the time.
科技不斷改進 - 科技快速進展,不斷衍生出新的知識,材料與製程.

• Increasing complexity. Products and systems are tending to become more complex.
複雜度不斷增加 - 產品與系統似乎越來越複雜.

• Greater accountability. There is increasing concern with individual and environmental safety, and a rapid growth of product liability legislation.
議題不斷擴增 - 不僅個人與環境安全的議題不斷增加,與產品最低保障的立法也不斷推出.

The design and manufacture processes must respond to these pressures by having clear and
visible structures for their activities and using the latest techniques. A systematic approach is
recommended.
設計與製造程序必須回應這些壓力,使而利用更清楚且更明確的架構,讓各自的工作都能運用最新的科技. 因此建議採用系統化的方法.

Before describing the fundamentals of the systematic approach, it is useful to discuss briefly two
fundamental activities: problem solving and management.
在說明這些系統化方法的基礎之前,最好先簡要討論兩個基本的內涵:問題解決與管理.

2 PROBLEM SOLVING
2 問題解決

A general strategy for solving a difficult problem is to reduce the overall complexity by splitting
it down into smaller, more manageable sub-problems.
解決困難問題的一般策略,是將具有複雜度的問題,化成幾個比較小,比較容易處理的小議題.

Each sub-problem can then be tackled more or less independently, though the links between them must always be kept in mind.
每一個小議題大可獨立處理,雖然必須要知道各議題之間不免也些關聯.

Finally the individual solutions must be combined to produce an overall solution to the

problem. A
model of problem solving is shown in Figure 2.
最後再將個別的解答,合併成該項問題的整體解. 解決問題的模型如圖二所示:

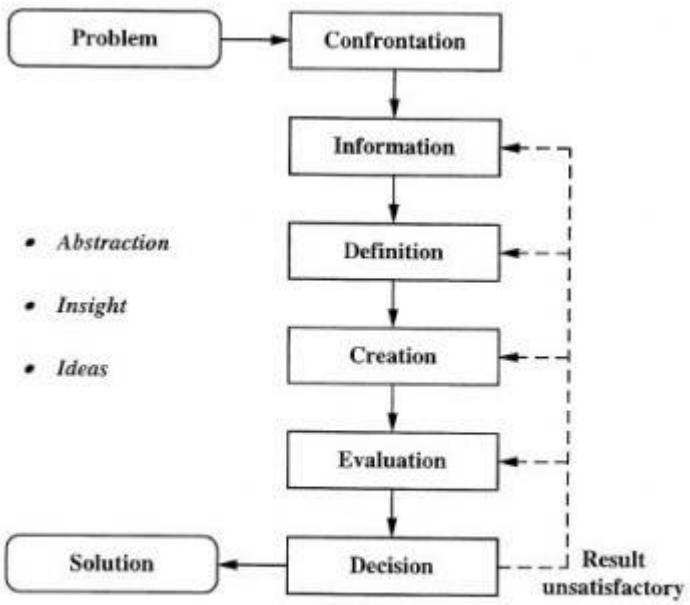

Figure 2: Model of problem solving

Figure 2: Model of problem solving
圖二: 解決問題的模型

A problem must be identified before it can be solved. Once identified it is useful to check that it
really is the correct problem.
問題解決之前,必須要先被提出. 一旦提出問題之後,最好能夠確實查驗,該問題爲"正確"的問題.

It is a waste of time and effort to produce an extremely elegant solution to the wrong problem. Having identified the core problem, it must be confronted, that is not put on one side to be tackled later.
因爲,針對錯誤的問題,提供一連串非常洋灑的解決方案,總是徒勞無功的. 一旦確認了核心問題,就必須要"正面應對".而不是暫時擺一邊,以待他日解決.

This is, in fact, one of the more difficult aspects of problem solving - it is all too easy to give up on a problem before actually getting into it and discovering the possibilities for solutions.
事實上,最難的問題解決面向之一,就是在試圖找出解決方案之前就輕易放過.

The next two stages involve gathering as much information as possible about the problem and then making sure that the problem is clearly defined.
另外兩個階段則是"收集與問題有關的足夠資訊",並且確認問題已經很被定義得"非常清楚".

The process of abstraction can help with these stages. Abstraction is one of a number of techniques available to increase insight into the problem.
抽象化的流程有助於這兩個階段. 抽象化是對問題增加深入見解的技巧之一.

It is from the detailed definition that evaluation criteria are established. It is now necessary to create the widest possible range of solutions.
只有經過仔細的定義,評量標準才能夠加以建立. 這時需要建立最廣泛的可能解答.

At this stage techniques to increase the number of ideas are of particular value.
用來產生許多構想的技術,這時顯得格外有用.

Having generated a wide range of options, these must be evaluated so that a decision can be
made.
也正因爲產出了範圍很廣的可行方案,才能經由評估而最初決策.

If at any stage the result is unsatisfactory, earlier stages will have to be repeated, or the problem abandoned without a solution.
假如上述任何階段的結果,都無法令人滿意,先前的步驟就必須重複操作,或者以無解收場.

Having ideas is an essential part of problem solving and the number of ideas can be increased by:
產生構想是解題的重要步驟,以下方法可以用來增加構想的數目:

• avoiding criticism, that is do not reject apparently silly ideas straight away
迴避批判,切勿直接拒絕乍看之下近似無用的構想.

• introducing some humour, which helps to generate unusual ideas
加入些許幽默,可以產出一些"不實用"的構想.

• using the "group effect", where an idea produced by one member of the group triggers off ideas in the minds of others.
使用"群組效應",利用某一成員所產生的構想,觸發另一成員的心思與構想.

The objective is to undertake the problem solving activity as effectively and as efficiently as possible and to make correct decisions.
目的在使問題解決活動更爲有成效,並且有效率,以理出正確的決策.

Progress in design involves making decisions on the best solutions to a large number of problems, and design is frequently referred to as an "iterative decision-making activity".
設計的進行主要在許多問題的答案中,找出最佳解答. 而設計也常是一件"重複的決策進行活動".

Figure 3 shows the hierarchical nature of decisions and emphasises the fact that all decisions are based on the accuracy of the forecasts made and the quality of the criteria used.
圖三顯示決策的結構特性,並且強調所有決策都是依據"正確的預測"與"高品質的評斷標準".

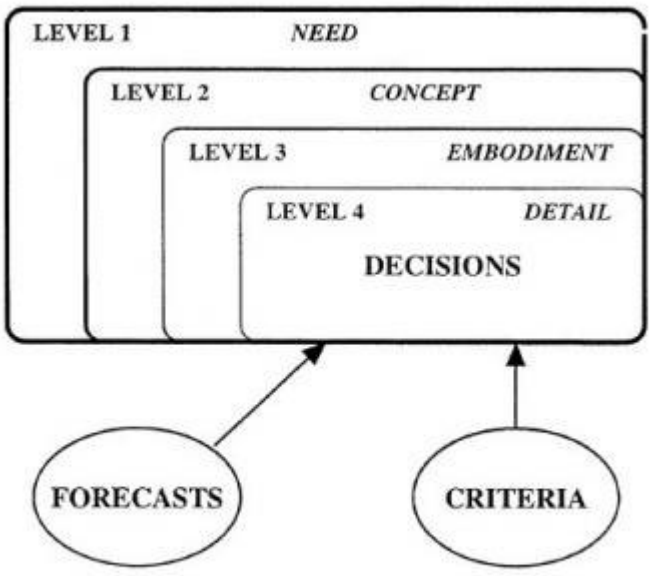

Figure 3: Basis of decisions

Figure 3: Basis of decisions
圖三: 決策的基礎

Design problems are often described as being "open-ended". By this it is meant that they do not
have unique "correct" solutions, though some solutions will clearly be better than others.
設計問題常常被說是"永無止境",主要是因爲,儘管設計方案有好有壞,但並沒有唯一的"正確"答案.

Several solutions must be developed before the best ones can be selected by judging them against the criteria.
最佳方案產生之前,許多其他的方案必須被用來作爲比較.

This is an iterative process involving many feedback loops during which information is updated to improve both the solution and the criteria.
因此才會產生許多具有迴圈的重複流程,期間所產生的資訊則被用來改進"解決方案"與"評斷的標準".

Throughout the problem-solving process it is important to continually look ahead to ensure that
the solutions that are being developed are capable of being realised in practice, that is they can
eventually be embodied.
整個問題解決流程最重要的在於,必須持續事先確認所完成的"方案",在實務中確實可行. 也就是說,必須具體可行.

Many excellent concepts have been let down and consequently failed due to poor embodiment. Useful guidelines to bear in mind when considering the embodiment of solutions are simplicity and clarity.
許多很好的概念最終導致失敗的原因,都是無法被實現. 當考量到方案是否具體可行,必須牢記在心的指導原則爲"簡單"與"清晰".

The simplest design which fulfils the requirements is usually the best, and all functions should be clearly defined and executed.
能以最簡單的設計滿足所有需求的就是最佳設計. 因此各功能要求,必須要能清楚定義並加以執行.

3 MANAGEMENT
3 管理

Design management involves the following activities:
設計管理涵蓋下列活動:

• Setting the objectives
訂定目標

• Planning
進行規劃

• Communicating the plans
爲各種規劃,進行溝通

• Monitoring and controlling the execution of the plans
監控規劃的執行

• Reviewing the outcome.
審視所得的結果

BS 7000, Guide to Managing Product Design, uses these basic activities to structure the Guide

which is based upon the product development model shown in Figure 4.
BS 7000, 產品設計管理導引,使用這些基本的原則來架構這個導引,植基於此的產品開發模型,如圖四所示.

The Guide is split into three main sections, each addressed at a different level of management:
此一導引分爲三個部門,每一部門負責不同層次的管理:

senior management, project managers and design managers. At the end of each main section of the Guide there is a useful checklist of key points.
資深管理,專案經理與設計經理. 在每一個導引的主部門最後,都有一份有用的關鍵要點查驗單.

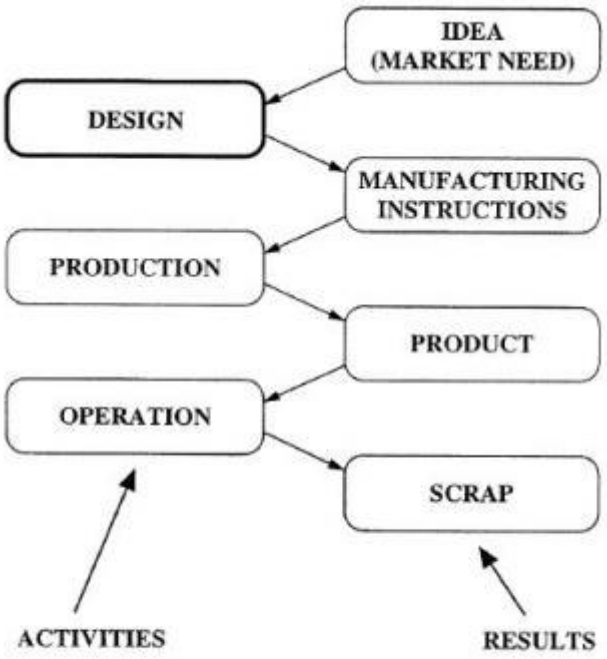

Figure 4: The BS7000 product development cycle
Figure 4: The BS7000 product development cycle
圖四: BS7000 產品開發週期

4 FUNCTIONAL TO PHYSICAL TRANSFORMATION
4 功能到實體的轉換

The central activity of engineering design is the conversion of a set of technical requirements
into a set of manufacturing instructions.
工程設計的中心活動是將一組技術需求轉爲製造指令.

Central to this activity is the transformation from a functional description of the proposed product or system to a physical description, see Figure 5.
這項活動的核心工作則將提案產品或系統的功能描述,轉換爲實體描述. 請參照圖五的說明.

At the beginning of any project, the proposed product is described in terms of a set of functions which it must fulfil.
在任何專案的開端,提案產品以一組必須要完成的功能加以描述.

A mountain bike must, for example, transport the rider over rough terrain as comfortably and safely as possible.
例如,一台登山自行車,一定要能儘量舒適且安全地騎越過崎嶇的地域.

To achieve this a number of technical functions must be achieved including: provide power

transmission, vary gear ratio, provide suspension, provide braking, provide steering, ensure adequate strength, ensure easy maintenance, etc.
爲了達到此類要求,許多技術功能必須要能夠滿足,其中包括: 具有功率傳輸,可變的齒輪比,具有避震器,具有煞車,具有方向控制,確保適當強度,確保簡易維修等功能.

All these must be achieved in such a way that the resulting bike is economical to manufacture and is robust enough to provide a reasonable life, bearing in mind its intended use.
所有功能都必須滿足外,還需要這台自行車可在成本控制下進行製造,在經常使用下,能有足夠強韌的壽命.

The list of functions could be greatly extended, but the key feature is that no mention has been made about how these functions are to be fulfilled - they are essentially solution-neutral.
類似這樣的功能要求可以不斷延伸,但是這些功能的主要特性,在於並沒有提到如何達到這些功能. 這些功能列表,只不過是"方案-中性".

Solutions must be found for all the required functions and these solutions transformed into physical descriptions of what is to be made. Completing this transformations is an extremely complex information processing activity.
必須找到解決方案來滿足所有的功能需求,且這些方案必須轉換爲如何在實務下完成的描述. 這項轉換的完成是一項極端複雜的資訊處理過程.

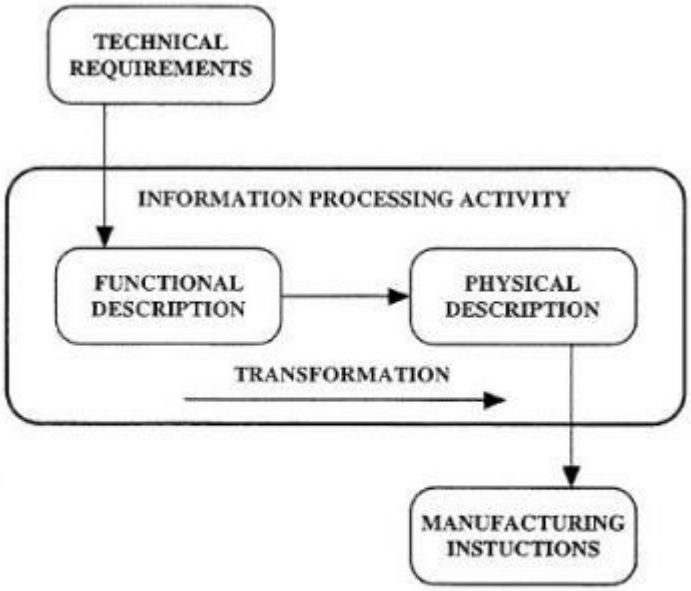

Figure 5: Functional to physical transformation

Figure 5: Functional to physical transformation
圖五: 功能到實體的轉換

All technical systems can be modelled in terms of the flows and conversions of material, energy,
and information (signals).
所有的技術系統都能夠以流程與物料,能量與資訊(訊號)的轉換加以模擬.

This "function" model must be mapped onto the structure of a technical system as shown in Figure 6.
這些功能模型必須對應到技術系統的架構圖,如圖六所示.

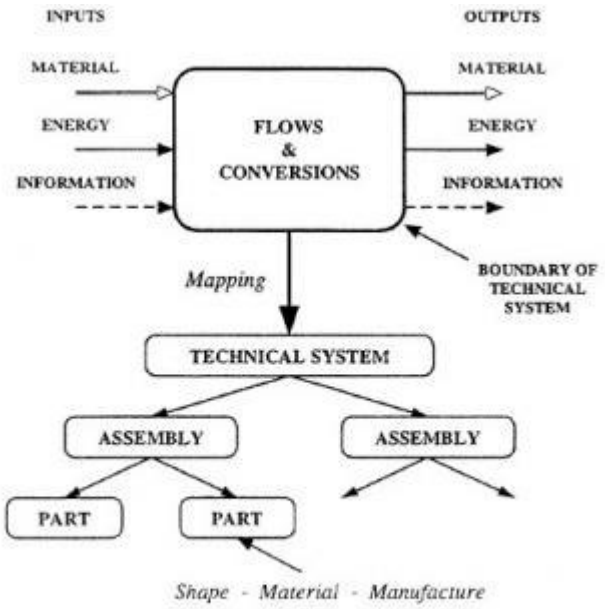

Figure 6: Structure of a technical system (product)

Figure 6: Structure of a technical system (product)
圖六: 技術系統(產品)的架構圖

All technical systems exhibit the same hierarchical structure. The mountain bike represents a
technical system (product) which uses physical effects to handle material, energy and signal
flows.
所有的技術系統展現相同的從屬架構. 登山自行車代表一種技術系統(產品),運用物理方法將物料,能量與訊號流加以處理而成.

The system can be broken down into a number of assemblies, for example frame, handle bars, pedals, brakes, gears, etc. Each assembly can be broken down into individual parts, such as
wheel rim, spoke, spindle, etc.
此一系統可以再細分爲幾個組立,例如,骨架,把手,踏板,煞車,齒盤等. 每一個組立可以再細分爲個別零件,例如,輪圈,鋼幅,主軸等.

For each of these parts, the shape will have to be defined, the appropriate material selected and the optimum method of manufacture chosen.
對每一個零件而言,必須定義其外型,選擇適用的材料,選用最佳的製造方法.

Some parts are purchased as standard components from specialist suppliers, for example ball bearings, roller chain, Bowden cables, etc.
某些零件,以標準零件向專門供應商購買,例如,滾珠軸承,滾子鏈條,Bowden煞車鋼索等.

All specially manufactured parts and bought-in components must be assembled together using the appropriate joining and fastening techniques to build assemblies, which are in turn connected together to build up the final product.
所有必須特別製造的零件與外購零件必須要以適當的結合與固接技術加以組立.最後再組合成爲最終的產品.

5 DESIGN PROCESS
5 設計流程

In line with the general strategy for tackling complex problems, the design process is split

into a
number of main phases, and each phase is then broken down into a number of steps.
與處理複雜問題的通用策略一樣,設計流程也被細分爲幾個主要的階段,而每個階段再被細分爲更細的步驟.

Methods are suggested to help tackle each step.
然後再爲每一個步驟找出解決的方法.

It is important to emphasise that this systematic approach must be applied flexibly and adapted to
suit the particular project being undertaken.
特別值得一提的是,這樣的系統化方法必須能彈性的應用,並隨著不同專案而有所調整.

It is not intended to replace intuition, inventiveness or insight; but rather to support and enhance these qualities by disciplining thinking and helping to focus concentration on important aspects of the problem.
這樣的做法並非要取代直覺,創新或內省;而是希望以有紀律的思考來支撐並強化這些特性,以利於將重心專注在問題的重要面向.

The four main phases of the design process are shown in Figure 7. Note that the input to and
output from this process is consistent with an expansion of the design activity of Figure 4.
設計流程的四個主要面向,如圖七所示. 特別注意這些流程的輸入與輸出,確保與圖四的設計延伸工作一致.

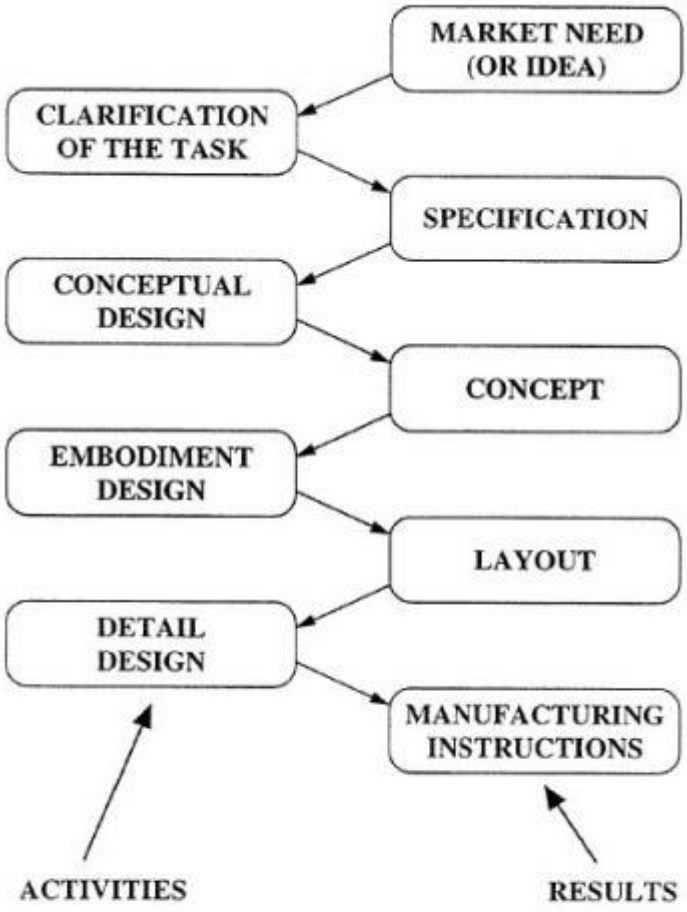

Figure 7: Model of the design process

Figure 7: Model of the design process
圖七: 設計流程的模型

In order to provide an overview, each phase is summarised briefly below. In subsequent sections
of this booklet, the individual steps of Clarification of the Task and Conceptual Design are described in more detail.
爲能提供概略說明,每一階段都簡短摘要如下. 在隨後的章節,個別工作的說明步驟與概略設計將會解說得較爲清楚.

Clarification of the Task. The starting point for the design process is an idea or a market need,
often stated in vague, and sometimes contradictory, terms.
工作的釐清 - 設計流程的起點爲一個意念或市場的需求,常常只是以模糊,時而自相矛盾的術語加以陳述.

Before the subsequent design phases start, it is important to clarify the task by identifying the true requirements and constraints.
在隨後的設計階段之前,釐清該項工作所需的真正需求與約束條件是非常重要的.

The result of this phase is a design specification which is a key working document that should be
continually reviewed and updated as the design develops.
這個階段的結果爲設計規格,也就是一份關鍵的工作文件,在設計開發過程中,必須經常被檢視與更新.

Conceptual Design. In this phase, concepts with the potential of fulfilling the requirements listed in the design specification must be generated.
概念設計 - 在這個階段,必須完成與設計規範中需求列表所對應的可行概念方案.

The overall functional and physical relationships must be considered and combined with preliminary embodiment features. The result of this phase is a concept drawing.
必須考慮全面的功能與實體間的關係,並與基本的實體特稱加以結合. 此階段的結果爲一份概念繪圖.

Embodiment Design. In this phase, the foundations are laid for detail design through a structured development of the concept.
實體設計 - 在這個階段,主要爲概念開展出結構化的細部設計.

In the case of a mechanical product, the result of this phase would be a detailed layout drawing showing the preliminary shapes of all the components, their arrangement and, where appropriate, their relative motions.
以機械產品而言,此階段的結果將會是細部的配置圖,描繪出所有零件的基本外型,其對應關係與可能的相對運動.

Detail Design. Finally, the precise shape, dimensions and tolerances of every component have to
be specified, and the material selections made, or confirmed.
細部設計 - 最後,精確的外型,尺寸與每一零件的公差都必須清楚標示,材料的選用也必須加以確認.

There is a close interrelationship between the shape of a component, its material and the proposed method of its manufacture.
各零件造型,材料與所建議的製造方法有著密切的關聯.

The result of this phase is detailed manufacturing instructions. The detail design phase is no less
important than any of the others. Many excellent concepts have failed in the market due to lack
of attention to detail.
此一階段的結果爲精細的製造指令. 此精細的設計階段,與其它階段同等重要. 許多優秀的概念之所以在市場上以敗北收場,常肇因於缺乏對於細節的專注.

6 CLARIFICATION OF THE TASK

6 工作的釐清

The steps of task clarification are shown in Figure 8.
工作釐清步驟如圖八所示.

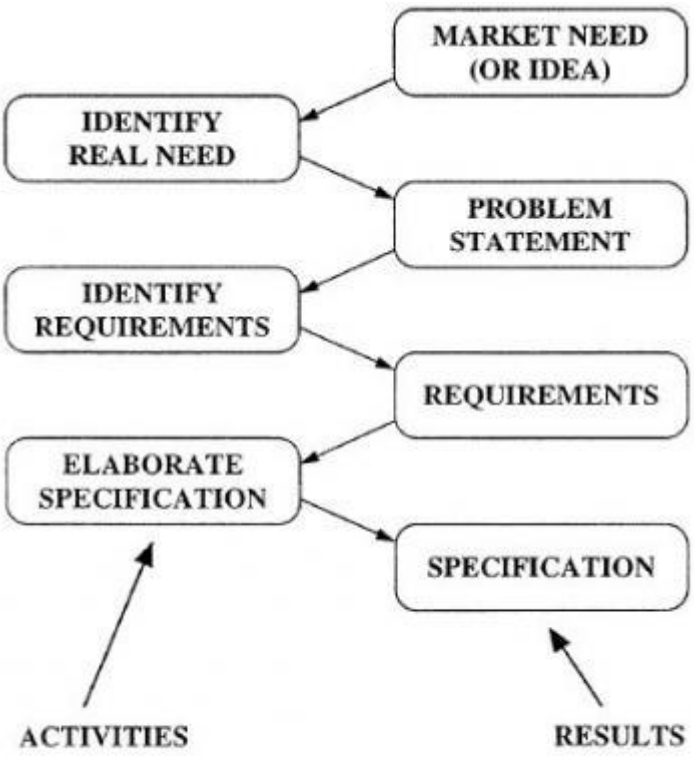

Figure 8: The steps of task clarification

Figure 8: The steps of task clarification
圖八: 工作釐清的步驟

The market need (or idea) is transformed into a specification by identifying the "real need" and
defining a problem statement, refining that statement to identify requirements which are collated in a product specification.
市場需求(或構想)透過"真實需求"的確認與問題說明的定義等兩種方法,轉換爲產品規格,該說明則進而再細化爲,與產品規範密不可分的"必要條件".

6.1 Identify Real Need
6.1 真實需求的確認

To avoid solving the wrong problem, it is wise to spend some time identifying the true needs and
preparing a clear solution-neutral problem statement which avoids any indication of how the
problem should be solved.
爲了避免解決錯誤的問題,花點時間在真實需求的確認,並理出一份清楚的方案-中性問題敘述,確有其必要.這份敘述則必須避免使用任何解題方法的暗示.

A useful technique is to systematically raise the level of abstraction using the following steps:
系統化提升抽象化的層次是個有效的技巧,茲分述如下:

• Eliminate requirements that have no direct bearing on the main functions and essential constraints.

去除與主要功能及必要約束條件沒有直接關聯的需求條件

• Transform quantitative statements into qualitative ones.
將定量描述轉換爲定性描述

• Formulate the problem in solution-neutral terms.
將問題以方案-中性的術語系統化表達

Abstraction broadens the range of possible solutions described by the problem statement by
eliminating unnecessary constraints.
將非必要約束條件去除後的抽象化,能夠擴展問題描述下,可能方案的範圍.

It also encourages the designer to think more about general concepts and less about issues relating to specific solutions.
也能鼓舞設計者思考更多通用的概念,避免將心思花在特定相關的方案上.

As an example, consider the problem statement:
例如,以如下的問題描述爲例:

Design a cylinder-type lawn-mower to cut grass.
設計一台汽缸式,能夠"切'草的割草機

This statement clearly indicates the direction of the solution by suggesting both the type of device
and that the grass must be "cut".
此一描述清楚地表達解決方案的方向,亦即,建議裝置的類別與"切"草的方法.

The size of the search field is thus restricted unnecessarily from the outset. An improved statement, at a higher level of generality, is:
如此,搜尋範圍被非必要的限制所約制. 改進後的描述,以較高的通用層面爲考量,爲:

Devise a means of keeping the grass short.
設計一台能讓草變短的裝置.

This statement defines a broader problem and encourages a wider range of possible solution
concepts.
此一描述定義了較廣泛的問題且能鼓舞出較大範圍的可能解決概念.

6.2 Identify Requirements
6.2 確認需求

Having identified the real problem it is wise to limit the search field by preparing a detailed list of
all the requirements and constraints.
完成真正問題的確認之後,列出一份詳細的需求與約束條件將會有效縮小搜尋的範圍.

These can be listed under the headings of:
可以透過以下的標題加以條列:

• Geometry
幾何外型

• Kinematics
運動學

- Forces
力

- Energy
能量

- Materials
材料

- Signals
訊號

- Safety
安全

- Ergonomics
人因

- Aesthetics
審美

- Economics
經濟

- Manufacture
製造

- Assembly
組合

- Quality Assurance
品質確保

- Transport
運輸

- Operation
操作

- Maintenance
維修

- Timescales
開發時間

- Environment
環境

Where possible use quantified statements. For example, "Weight not to exceed 100 N" is much
better than "Low weight".
至於可能的量化描述,諸如,"重量不超過100N"比"重量輕"好很多.

This appears to contradict the removal of quantitative statements when identifying the real need.
這樣好像與"去除量化描述"的要領有所牴觸.

However, when the real need has been identified such statements are essential to communicate acceptable performance limits for the new product.
但是當真實需求可以找出類似的描述,讓新產品表達出重要的性能時,就可以予以保留.

Not all the requirements can be quantified easily and value judgements will be involved.
並非所有的需求都能簡易量化且附有數值的判定.

For example, it is difficult to quantify factors such as appearance, ease of operation, etc.
例如,要將外觀,操作簡便等予以量化,著實不易.

An ideal solution would meet all the requirements, but this is seldom possible with the resources available and compromises must be made.
一個理想的方案將會滿足所有的需求,但是在可用的資源與取捨下,卻不太容易達成.

To aid selection and evaluation, it is useful to identify each statement as being either a Demand or a Wish.
爲了能輔助選擇與評估,可以將各種描述分類爲"需求"與"期望".

Demand (D) - ideally a requirement which must be fulfilled. If a proposed solution fails to meet a single demand, then it should be rejected.
需求(D) - 理論上,一定要符合的必要條件. 對於所提方案若無法達到需求中的一項,就必須予以剔除.

Wish (W) - ideally a requirement which will improve the value or quality of a solution, ie desirable but not essential. It is useful to indicate the weighting (Wt) of wishes as high (H = 3), medium (M = 2) or low (L = 1) importance.
期望(W) - 理論上,可以提升方案價值或品質的條件,亦即,想要但非必要. 可以將"期望"的等級以比重分爲"高期望(H=3)",中期望(M=2)或低期望(L=1).

Although a relatively simple idea, in practice categorising requirements as either demands or
wishes is not always that easy.
雖然相對簡單的想法,在分類上可以簡單分爲需求或期望,但實際的問題卻不是如此簡單.

It may be a demand that a certain minimum requirement is met, eg for legal reasons, but a wish that the minimum requirement is exceeded by a certain amount, eg for marketing reasons.
當某一最低條件符合時,可以視爲需求,諸如法律考量,但是當超出某一最低條件之後,就成了期望,例如市場考量.

The dividing line can be a little fuzzy - however the concept is valuable as it forces one to think about the status and importance of the various requirements.
之間的分野卻非常模糊 - 至少此一概念對強制設計者在考量許多條件重要性上,還是有其價值.

6.3 Elaborate Specification
6.3 規範開展

The requirements and constraints are best compiled into a comprehensive description, or specification, of the product to be developed.
產品開發時,需求與約束條件的滿足必須要透過"設計規格"界說清楚.

The specification should be clear, correct and as complete as possible.
這些規格必須要清晰,正確,並且儘量完整.

It should list all the problem specific requirements in such a way that the reader is clear about the tasks the product is to perform.
務必要列出所有明確的問題需求,讓讀者可以對於所要設計的產品工作,一目瞭然.

Demands and wishes should be clearly identified along with a keyword to uniquely identify each requirement.
需求與期望也要明確標出,並針對每一個條件,以關鍵字加以說明.

In theory, since a solution must meet all the demands, preliminary selection from several possible
solutions should be based on the demands.
理論上,由於解決方案必須要符合所有的需求,可以根據需求條件,由幾個可能的方案中,進行初步篩選.

A proposed solution that does not meet all the demands should not proceed to the next stage of the design process.
未能達到所有需求的提案,在後一個設計階段中,就不會被提出.

Those solutions that do meet all the demands must, usually after further work, be evaluated and the best selected.
而符合所有條件的解決方案,則持續往下進行,並且擇優選用.

In theory, evaluation at this stage is based on the wishes. The aim is to find the solution with the highest value and quality.
原則上,此一階段的評量,是以期望條件爲準. 目標在找出最高品質的解決方案.

To keep things simple at this stage, the demands in the specification will provide the criteria for a
preliminary selection, and the wishes the criteria for evaluation.
要在這個階段中,讓事情保有簡單的特性,在規格中的需求將會被用來作爲初步選組的標準,而期望條件則作爲
評量的準則.

Preparing a design specification is an extremely important task. However it can be a little tedious.
準備一份設計規格,是非常重要的工作. 雖然會有些繁瑣.

A computer package, called SpecBuilder, has been prepared to assist. This package helps format the specification and provides an on-line tutorial to prompt possible requirements
under the headings listed above.
一套稱爲SpecBuilder的電腦套件,則可用來輔助這樣的工作. 這個套件將會有助於統一規格格式,並提供線上導引,以提示更多如前所述的可能需求.

The package is available on the Design and Project Office (DPO) system. A Users Guide is available in the DPO and the package includes comprehensive on-line help.
這個套件可以在設計與專題系統辦公室取得. 使用說明與線上使用說明,也都可以找到.

The package also generates Evaluation Tables, which are described later.
此一套件也能產生下一章節會提到的評量表.

Figure 9 shows the first sheet of a design specification for a grass cutter project.
圖九顯示的就是割草機專案設計規格的第一頁.

GARDEN EQUIPMENT COMPANY		DESIGN SPECIFICATION Grass Cutter Project	Issued: 11/1/1999 Page: 1
D/W	**Wt**	**REQUIREMENTS**	**Keyword**
		GEOMETRY	
W	M	• Maximum storage size: 600x600x300 mm	Storage
D		• Minimum width of cut: 300 mm	Cut width
W	M	• Adjustable cutting depth: 5 - 50 mm	Cut depth
		KINEMATICS	
W	H	• Easily manoeuvred	Manoeuvre
W	L	• Cutting speed up to 2 m/s	Cut speed
		FORCES	
W	H	• Maximum weight not greater than 100 N	Weight
W	M	• Force to move not greater than 50 N	Move force
W	M	• Withstand fall onto hard surface from 2 m	Robust
		ENERGY	
W	M	• Power requirement - maximum up to 1 kW	Power
W	M	• Power source - electricity	P/source
D		• Maximum noise level not to exceed 85 dB	Noise
		MATERIAL	
W	L	• Suitable for a life expectancy of 5 years	Life
W	L	• Must not corrode within design life	Corrosion
		SIGNALS	
D		• Simple to start/stop	Start/stop
W	L	• Indication when cuttings storage need emptying	Storage
W	L	• Maintenance instructions on the machine	Maint instr
		SAFETY	
D		• Electrical safety to BSI standards	Elec safety
D		• No accessible sharp edges or hot spots	Sharp/hot
D		• Cutting blade protection	Blade prot
W	M	• Automatic electrical cut-out	Auto cut-out
		ERGONOMICS	
D		• Easy to operate and control	Easy operation
W	M	• Simple cutting height adjustment in under 1 min	Cut adjust
W	H	• Pleasant appearance	Appearance
		ECONOMICS	
W	H	• Target selling price not more than £75	Price

Figure 9: Part of a design specification for a grass cutter

Figure 9: Part of a design specification for a grass cutter
圖九: 割草機設計規格的一部分

7 CONCEPTUAL DESIGN
7 概念設計

The steps of conceptual design are shown in Figure 10:
概念設計的步驟如圖十所示:

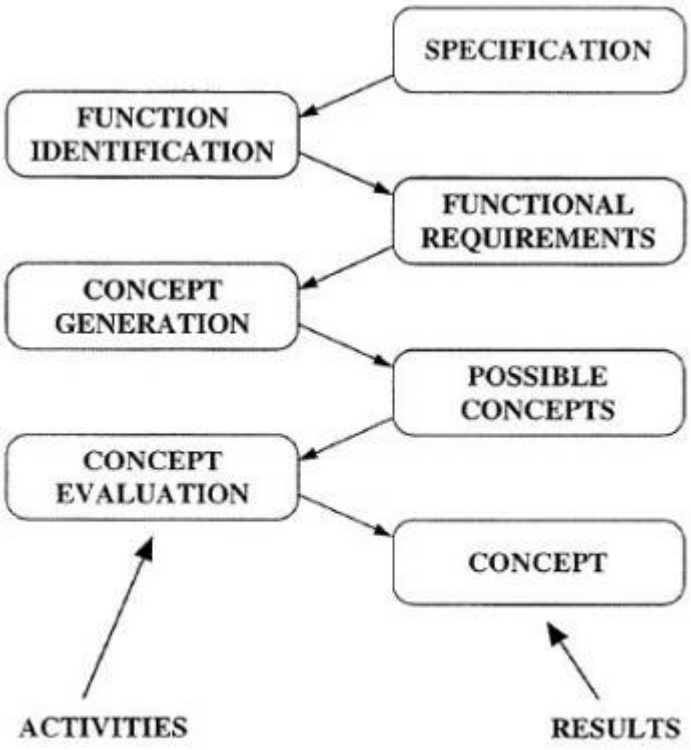

Figure 10: The steps of conceptual design

Figure 10: The steps of conceptual design
圖十,概念設計的步驟

A concept is now developed from the specification by identifying the functional requirements for the product, generating possible concepts and selecting the most promising.
概念爲經由確認產品功能需求後,由規格所衍生. 建立可能的概念並選擇其中最佳.

7.1 Function Identification
7.1 功能確認

All technical devices can be analysed in terms of the flows and conversions of material, energy
and information (signals) which take place within their system boundaries.
所有的科技產品都能夠在系統介面內,透過流與材料,能量與資訊(訊號)的分析加以表達.

The first step is to identify the overall function. The overall function follows directly from the
solution-neutral problem statement. For our grass cutter, the overall function might be:
第一步爲確認大體上的功能. 而大體上的功能則直接延續方案-中立的問題描述. 以上面的割草機來說,大體上的功能可能是:

Shorten grass.
讓草變短.

This overall function, along with inputs and outputs, is shown in Figure 11.
此一大體上的功能,加上輸入與輸出,如圖十一所示:

Figure 11: Overall function

Figure11: Overall function
圖十一: 大體上的產品功能

The overall function can now be broken down into an appropriate number of smaller functions
which indicate the logical and physical relationships between the flows and conversions of material, energy and signals.
這個大體上的功能,在這裡可以分爲幾個適切的小功能,以說明流,材料,能量與訊號間的邏輯與實體關係.

There is generally an identifiable main flow which dominates the situation, plus a number of supporting auxiliary flows.
通常都會有一組可以辨識的關鍵主流程,加上幾個支撐用的輔助流程.

The character of a function is usually indicated by "imperative + object", for example "Adjust settings" or "Convey cuttings".
函式的特性則一般使用"強制動作+物件",例如,"調整設定"或"輸送切除".

The arrangement of functions can be varied to determine the most favourable function structure,
remembering that the solution must eventually be embodied.
這些功能的處理可以多到能夠找出最有利的功能架構,並且最終能被實現的方案.

There are two different types of function structure:
以下爲兩種不同類別的功能結構:

System function structure
系統功能結構

Process function structure
流程功能結構

When preparing a system function structure, the system boundary is drawn around the "device",
for example the grass cutter, and the relevant inputs, outputs and functions defined as shown in
Figure 12.
準備系統功能結構時,系統邊界會繞著"裝置"界定,以割草機爲例,表示相關輸入,輸出與功能的結構,如圖十二所示:

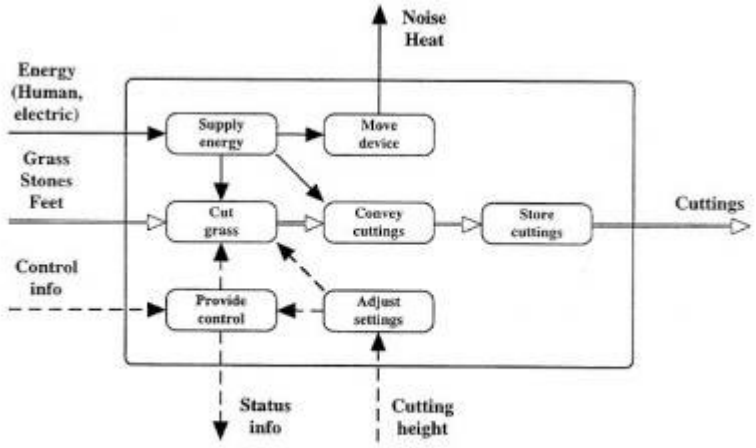

Figure 12: System function structure

Figure 12: System function structure
圖十二: 系統功能結構圖

Many devices are used as part of a process and in this case a process function structure (flowchart) showing a sequence of sub-functions can be illuminating.
許多裝置爲流程的一部分,在這個案例中,流程功能結構(流程圖)可以表示出一系統的子功能.

A process function structure for shortening grass is shown in Figure 13. The important thing is to use the method flexibly so that it provides as much help as possible.
而割草機的流程功能結構,可參考圖十三. 重點是經由彈性運用至能提出有用的內容爲止.

It is possible to produce a very detailed function structure, breaking each function down into
smaller and smaller units.
當然,也能產生出非常細微的功能結構,也就是把每一個功能再細化爲越來越小的單元.

However, the procedure should only be continued so long as it provides valuable insights - to do it purely for its own sake is pointless. A useful guideline is to aim for between 10 and 20 functions.
但是,這樣的步驟,只要能提供有用的見解,就得繼續進行,而不是隨性而爲. 最佳的指導原則是只專注在10到20個功能上.

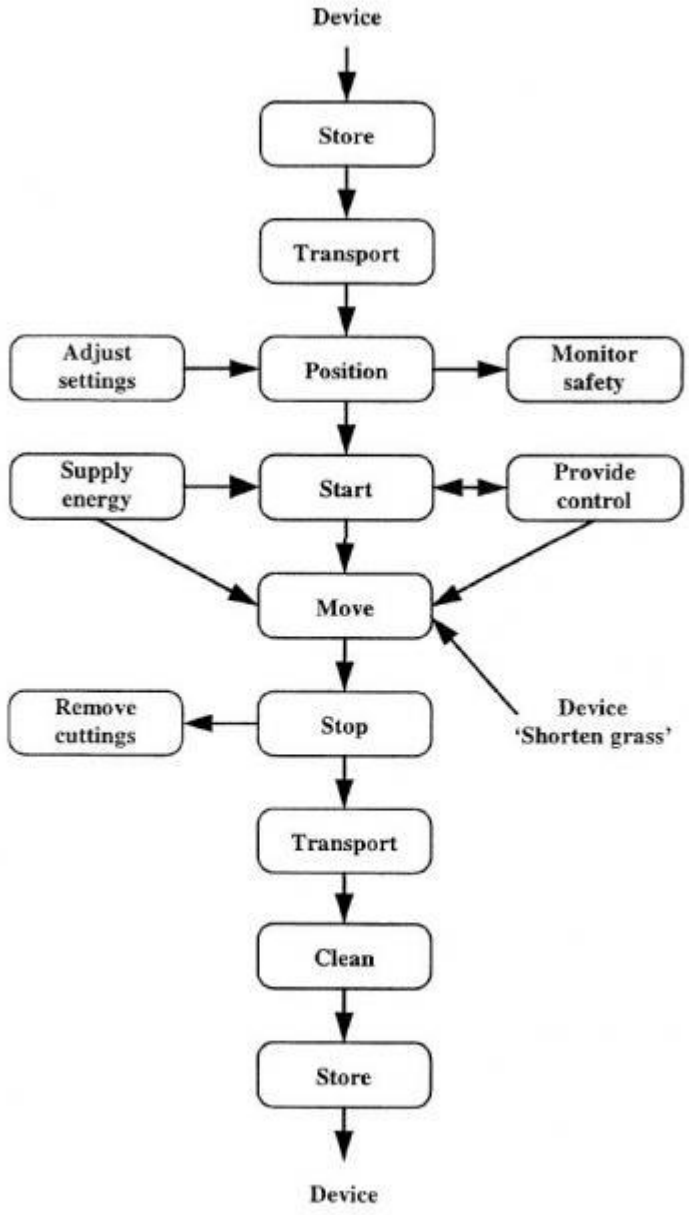

Figure 13: Process function structure

Figure 13: Process function structure
圖十三: 流程功能結構

7.2 Concept Generation
7.2 產生見解

In theory the function structure should be created independently of any particular physical solution. In practice, one always has a tentative solution in mind.
理論上,這些功能結構應該要能針對任何一項實體方案,獨立產生. 但是在操作上,設計者不免有些先入爲主的方案.

Now one or more solution principles must be found for every function.
但是在這裡,每一個功能都必須找到一個或多個方案原則.

At this stage idea generating techniques, such as Brainstorming, can prove valuable. Existing
devices can be analysed and useful ideas can be obtained from the study of natural systems.

這裡所使用見解產生技巧,諸如,腦力激盪公認是有價值的方法. 既有的裝置可以用來分析,而經過自然界系統的研究,也能夠得到有用的見解.

The books by French listed in the Bibliography provide useful examples and insights.
參考資料中,由法國人所寫的書,提供許多有用的範例與見解.

Once solution principles have been found, they can be combined systematically using a table of
options like the one shown in Figure 14.
一旦找到解題原則,可以採用設計選項表,系統化地將原則組合,如圖十四所示.

Selected key functions from the function structure are
listed in the left-hand column.
由功能結構中,選出的關鍵功能列在左邊直欄位. 針對每一種功能的解題原則,則放在橫格欄位.

Solution principles for each function are then identified in the rows. A combination is made up by selecting one solution principle from each row. Obviously, a great number of combinations can easily be generated.
由每一橫格中選擇一種解題原則,就可以得到一種設計組合. 如此,就可以輕易產生許多的組合設計.

Many of these will contain incompatibilities and can therefore be rejected immediately, but the technique usually highlights a useful number of possible combinations which had not been thought of previously.
其中許多帶有不相容條件的設計,將隨即予以剔除. 這樣的技巧,經常會造就出先前沒有想到的有用設計組合.

Again, only pursue the technique so long as it provides valuable insights.
畢竟,這些方法只要能提供有價值的觀點,就可以採用.

Selection criteria for the combinations are based on the demands identified in the design specification.
這些組合取捨的標準,是依據設計規範中所確認的需求.

If the demands have been correctly identified, then any combination of solution principles which fails to meet a single demand must be modified or rejected.
假如這些需求已經過確認,解題方案中,無法滿足某一需求的任一組合,則必須被修改或剔除.

Simple yes/no decisions will suffice. The best time to do this is while creating the combinations, that is do not include any combination which engineering common sense suggests is unlikely to meet a
demand.
簡單的標示'是或不是"的決策應已足夠. 最好當某一組合建立時,就能夠予以標示. 也就是不要納入一開始就明顯與需求不符的任何組合.

As a guideline, select not more that five sensible combinations.
基本的原則是,不要選超過5項切實的組合.

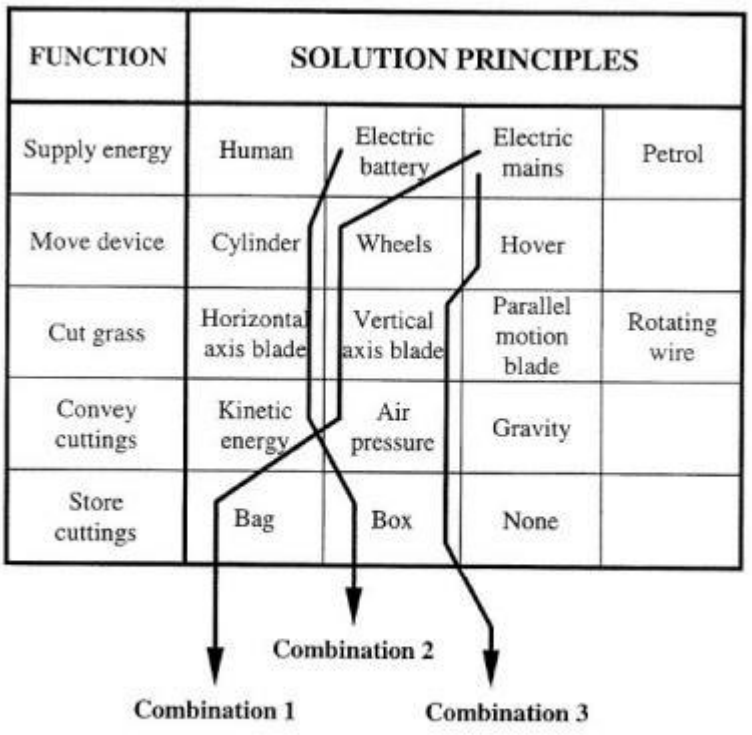

Figure 14: Table of options

Figure 14: Table of options
圖十四,設計選項表

7.3 Concept Evaluation
7.3 概念評估

The selected combinations will need to be firmed up into concepts before they can be evaluated
to determine the best.
所選的設計組合能進一步成爲設計概念之前,必須要經過評估,以找出最佳化設計.

The aim now is to determine which has the most favourable combination of additional features, and will thus provide the maximum competitive advantage. Three products, illustrating concepts based on the combinations selected from the table of options, are shown in Figure 15.
這裡的目標在決定,那一組的設計有最令人滿意的各種特徵組合,並且能提供最大的競爭優勢. 根據以上設計選項表所選出的三種產品概念設計圖,則列在圖十五中.

Before starting a formal evaluation procedure it is worth noting down which concept you consider to be the best and why.
正式啓動評估流程之前,最好先決定那一個概念最好,並寫下理由.

The formal method can then be used to "audit" your intuitive decision and provide new insights.
接著以正式的稽核方法來驗證直覺,看是否會產出新的見解.

If there is a difference between your first "guess" and the result of the procedure, it is illuminating to determine why.
若與先前的看法產生出入,則應闡述其緣由.

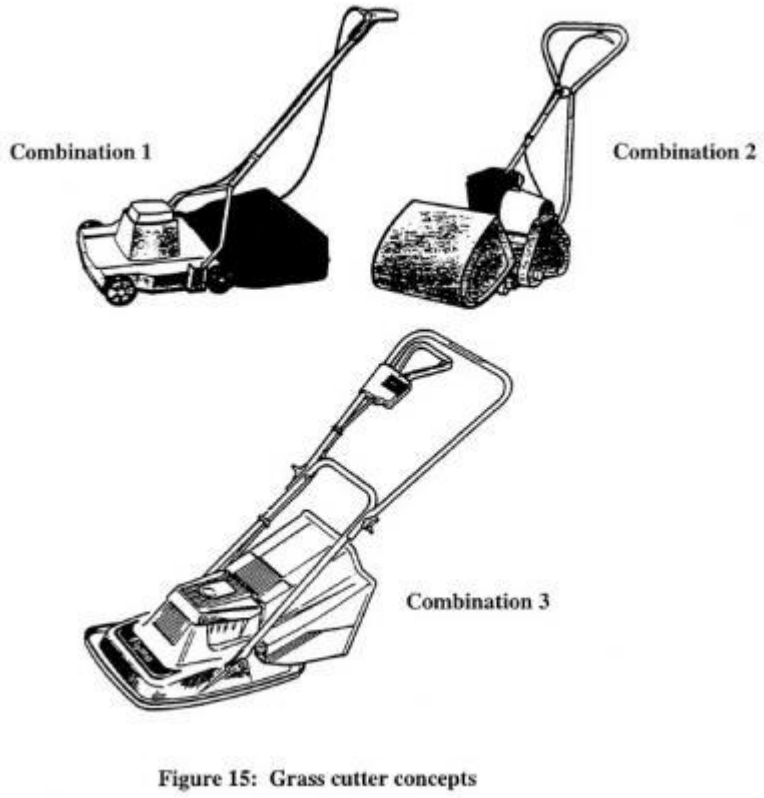

Figure 15: Grass cutter concepts

Figure 15: Grass cutter concepts
圖十五: 除草機概念圖

Evaluation is based on the wishes identified in the design specification.
評估的標準則依據在設計規範中所定下的相關期望.

More than simple yes/no answers are required to determine the relative merits of each concept. To do this each criterion must be weighted to indicate its relative importance.
這時在決定每一項概念的相對優劣,就不能只採用簡單的"是或不是"來標示. 而是對每一項評量標準,都必須以權重來表示其相對重要性.

The wishes can be ranked as being of high, medium or low importance and given numerical weightings of 3, 2 and 1 respectively.
各設計期望可以分別使用3,2,1的數位權重來表示高,中,低等重要等級.

More detailed approaches are possible, leading to a much finer gradation in the weightings, but the
simple approach suggested above is generally adequate, particularly for a preliminary evaluation.
也可以採用更細的權重分佈來加以評量.上述簡便的方法,則用於初步的評量.

The evaluation criteria need to have parameters to characterise them.
評量標準需要透過參數來進行特性描述

Some can be quantified, such as "weight in newtons" or "power in kilowatts", but some will only have a qualitative indication, for example "easy assembly" or "pleasing appearance".
有些可以量化, 例如 "重量幾牛頓" 或 "功率幾千瓦", 而有些則只能有定性指標, 例如, "容易組合" 或 "宜人的外觀".

So that all sorts of different parameters can be "scored" in an evaluation chart some sort of generally applicable value scale must be introduced.
因此所有不同參數的類別可以在評量表中, 依據某種通用值衡量表進行"取分".

It is easiest to do this against some datum, so one concept is selected and the relative value for each criterion judged in turn using the following scale:
以某特定數據進行評比, 會比較容易(進行), 概念是依照下列的衡量表,利用每一準則所選的相對值,進行評比:

The values may now be entered into an evaluation chart, where each value is multiplied by the appropriate weighting to give a weighted value and these are then summed to give an overall
weighted value for each concept relative to the datum.
可以將值輸入評量表中, 每一值都乘上適當的權重, 所得的權重值再加總得到整體的權重值, 然後再進行各概念所對應的數字(比較).

The one with the highest overall value will, generally, be the best.
得到最高的整體(權重)值, 通常就是最好.

An evaluation chart for the grass cutter is shown in Figure 16.
割草機的評量表, 如圖十六所示.

Note that criteria which scored zero for both the wheeled and hover mowers are not shown.
請注意, 輪式與氣墊式割草機, 評量得分爲0者並沒有列出.

In this example, the hover mower is judged to be marginally better than the wheeled mower, both being considerably better than the cylinder mower.
在這個案例中, 氣墊式割草機經過評判, 略比輪式割草機要好, 而兩者都比桶式割草機好很多.

However, the results should be used cautiously bearing in mind the subjective nature of many of the numbers included in the chart. Small differences between the overall values are generally not significant, and even a concept with a high overall value can have worrying weak spots.
但是, 對於結果的引用要特別小心謹慎, 許多表格中的數字所代表的真正意涵. 在整體(權重)值間的小差異通常並不明顯, 況且得到高整體(權重)值的概念, 也可能會有令人憂心的弱點.

		CYLINDER		WHEELS		HOVER	
Criteria	Weighting	Value	Wt val	Value	Wt val	Value	Wt val
Manoeuvre	3	DATUM		+1	+3	+2	+6
Weight	3			+2	+6	+2	+6
Appearance	3			+1	+3	+2	+6
Price	3			+1	+3	0	0
Move force	2			+1	+2	+2	+4
Robust	2			-1	-2	-1	-2
Cut adjust	2			-1	-2	-2	-4
Cut speed	1			+1	+1	+2	+2
Life	1			0	0	-1	-1
		0		+14		+17	

Figure 16: Evaluation chart

Figure 16: Evaluation chart
圖十六: 評量表

The SpecBuilder package will help will automatically select all the wishes from the design specification and set up a template evaluation chart to compare up to five concepts. The Users

Guide explains this in more detail.
規格建立套件有助於由設計規範中, 自動選擇所有的需求, 並建立一個樣式評量表, 最多可比較五項概念. 使用手冊中會有更深入的解說.

The technique does ensure a disciplined approach and does provide a valuable guide to the relative merits of the concepts, but in the final analysis common sense should prevail.
這些技巧確立以制式的方法, 透過有價值的方嚮導引, 得到相對較具內涵(價值)的概念, 但是, 在最終的分析(過程)中, 常識仍然非常需要.

Check the outcome against your first guess and check that the chosen concept meets the demands and high ranking wishes.
將所得結果跟最初的想像進行比較, 然後查驗所選的概念是否滿足需求, 並且獲得高等級的期待.

The selected concept must now be presented in such a way that other people are convinced that it is worth committing to the embodiment design phase - clarity and brevity are essential.
所選概念的表達,則要以透明簡潔的方式,讓其他人得以信服, 此案值得進入細部設計階段.

BIBLIOGRAPHY

參考書目

[1] BS 7000, Guide to Managing Product Design, British Standards Institution, London, 1989.
[2] Invention and Evolution, French, M. J., Cambridge University Press, Cambridge, 1988.
[3] Form, Structure and Mechanism, French, M. J., Macmillan, London, 1992.
[4] The Design of Design, Glegg, G. L., Cambridge University Press, Cambridge, 1969.
[5] The Selection of Design, Glegg, G. L., Cambridge University Press, Cambridge, 1972.
[6] The Science of Design, Glegg, G. L., Cambridge University Press, Cambridge, 1973.
[7] The Development of Design, Glegg, G. L., Cambridge University Press, Cambridge, 1981.
[8] Engineering Design - A Systematic Approach, Pahl, G. and Beitz, W., Springer, 1996.
[9] Product Design and Development, Ulrich, K.T. and Eppinger, S.D., McGraw-Hill, 1995.
[10] Case Studies in Engineering Design, Matthews, C, Arnold, 1998.