SOME STUDIES ON INTEGRATED DESIGN APPROACH FOR PRODUCT LIKE STRETCHER UNDER EXTREME AMBIENT CONDITIONS

Thesis submitted for the degree of Doctor of Philosophy in the Department of
Production and Industrial Engineering
Delhi College of Engineering
University of Delhi

By

PREM CHAND GUPTA

Under the Supervision of

Dr. S. K. Garg
Professor
Department of Mechanical Engineering
Delhi Technological University
(Formerly Delhi College of Engineering)
Bawana Road,Delhi-110042, India

Dr. Sachin Maheshwari
Professor
Manufacturing Processes and
Automation Engineering Division
Netaji Subhas Institute of Technology
Sector-3, Dwarka, Delhi- 110045, India

Department of Production and Industrial Engineering
University of Delhi
Delhi-110007
2012

DECLARATION

This is to certify that the thesis entitled ***"Some Studies on Integrated Design Approach for Product like Stretcher under Extreme Ambient Conditions"*****,** submitted by me to the University of Delhi for the award of the degree of Doctor of Philosophy, is a bonafide record of research work carried out by me under the supervision of Dr. S.K. Garg and Dr. Sachin Maheshwari**.** The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree.

Place: Delhi

Date: 2012

(PREM CHAND GUPTA)

Research Scholar

THESIS CERTIFICATE

This is to certify that the thesis entitled ***"Some Studies on Integrated Design Approach for Product like Stretcher under Extreme Ambient Conditions",*** submitted by Sh. Prem Chand Gupta, to the University of Delhi, for the award of the degree of Doctor of Philosophy, is a bonafide record of his research work carried out by him under our supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree.

Research Guides

(Dr. S. K. Garg)
Professor
Department of Mechanical Engineering
Delhi Technological University
Bawana Road, Delhi

(Dr. Sachin Maheshwari)
Professor and Head
Division of Manufacturing Processes and
Automation Engineering
Netaji Subhas Institute of Technology, Delhi

(***Professor Raj Senani***)
Head of the Department/ Dean FOT
University of Delhi
Delhi1-10007

Place: Delhi

Date: 2012

ACKNOWLEDGEMENT

I wish to express my sincerest, deep gratitude and foremost appreciation to Dr. S.K. Garg and Dr. Sachin Maheshwari my supervisors, for their invaluable advice, guidance, enthusiastic encouragement, feedback and support with patience and kind understanding throughout the period of my study. My heartfelt thanks are extended for their advice and guidance in keeping my progress on time after their busy schedules. They were kind enough to spare their valuable time at the institute as well at their home. They provided all possible support and constructive comments and suggestions for the research work.

I wish to thank Director, Institute of Nuclear Medicines and Allied Sciences-Delhi, Defence Research and Development Organization, Govt. of India, Dr Subash Khushu divisional head and work shop staff for their valuable technical support in fabrication and testing of the prototypes of the stretcher and multipurpose army field cot cum stretcher.

I would like to thanks to the higher officials of Army Medical Corp's, Armed Forces and Allied Forces to provide their necessary inputs and advices as experts user domains. Finally, I wish to thank my family for their support and encouragement throughout my study.

(PREM CHAND GUPTA)

Some Studies on Integrated Design Approach for Product like Stretcher under Extreme Ambient Conditions

Abstract

Product design is a scientific process and it can be engineered as per the customer needs. To develop a successful and customer oriented product, product design model, tools and methodology play important roles as these help the designer to perform all the required design activities in a systematic manner and to eliminate even small design errors at various stages which collectively may cause failure of design. In this research work the IPD approach and few important design tools like computer aided design (CAD), benchmarking, quality function deployment (QFD) and TRIZ (the innovative problem solving method) were studied and a generic product design model and approaches were proposed to design an advance casualty evacuation stretcher for our Armed Forces.

Modern day warfare is highly mechanized and technology oriented, with the result, the casualty figures are likely to increase with every war and conflict. Medical fraternity is geared up to minimize loss of life and limb by providing immediate first aid and speedy evacuation. The casualty evacuation (Casevac) stretcher is a medical device and used to carry casualties or an incapacitated person from the place of incident to medical point. As per Charles et al. (2004) in medical science, it is known fact that the survival rate of patient treated within the golden hour i.e. first hour after serious injury occurs is 80%. At 1.5hr after serious injury without definitive treatment being administered, the chance of survival decreases to 20%. The historic wound and casualty data suggests that more than 90 % of those severely wounded persons die within the first hour of injury unless treated. Therefore, casualty evacuation stretcher forms a very important link in carriage of casualties' right from the forward defended locality (FDL) to rearwards and thus, it is one of the most important requirements of the Armed Forces.

The Armed Forces have to be deployed in difficult terrains, high altitudes and snow bond areas where the load carrying capacity of a soldier reduces up to 70 %; therefore in such conditions casualty evacuation becomes more difficult. From the literature and conducted customer survey reports it is found that there is a strong need of a lightweight, portable, comfortable, safe, strong and cost effective casualty evacuation stretcher to meet the military and civil requirements, specifically suitable for difficult terrains and harsh environments i.e. extreme ambient conditions where the army has to be deployed.

The research efforts have been focused on building up a broad theoretical foundation based on literature review which includes various product design models, tools/techniques like CAD, TRIZ and QFD to develop a systematic integrated product design approach and case studies. Since, in the present era of global marketing, innovation and creativity are becoming more and more important and necessary in product design to win the market as the countries having higher innovation capabilities are economically stronger and advance; therefore, based on the literature review and research work, two approaches were developed.

The first approach is to evaluate the degree of novelty of a design concept at concept development stage to guide the designer to decide either rejection or modification of the concept. The second is the QFD integrated TRIZ" (QIT) approach for improving the design concept by trading off the design attributes in the innovative and structured way. The proposed approaches have been incorporated with the integrated design methodology to develop a generic product design model.

To verify the proposed product design model and proposed approaches, "Light Weight Foldable Stretcher" (LWF-Stretcher) and "Multipurpose Army Field Cot cum Stretcher" (MPAFCS) were designed by applying them. The concept evaluation approach guided the design team to evaluate the novelty of the stretcher and MPAFCS concepts at the initial design stage which led to the innovative and successful product designs. The QIT approach, guided the design team to improve the designs of the stretcher and MPAFCS by trading off the design parameters in the structured manner and to achieve the set target values of the "higher priority-design attributes" required by the customer like lesser weight, higher safety and lower cost.

By incorporating the approaches, approximately 19.375% weight of the stretcher could be reduced. Besides even after adding additional features like, backpack size, patient gripping straps, IV fluid rod, and auto locking joints .The overall weight of the stretcher was still lesser than that of the existing design. Another very useful product developed with the help of the proposed approaches is MPAFCS which can be used by the doctors and surgeons to examine as well to perform the field surgery of the soldiers to save his/her life or limbs.

Besides being used during war or disaster situations MPAFCS can also be used for various civil applications like as transit camp beds, night shelter beds, sleeping beds in metro cities where houses are small, medical beds in primary health centres for carrying and treating patient etc.

Acceptance of the patent and award of design registration by the Indian Patent Office proved the novelty of the products and purchasing of manufacturing licenses of stretcher and MPAFCS by three reputed firms showed the business potential and commercial success of the products. *Therefore it can be said that the proposed integrated product design proposed approaches are very useful and can be applied to design and develop the customer oriented product successfully and to make the nation economically stronger.*

(Prem Chand Gupta)
Research Scholar

TABLE OF CONTENTS

LIST OF FIGURES

Figure No	Description	Page No

Figure No	Description	Page No

LIST OF TABLES

List of Symbols

A	Cross-Sectional Area
B & b	Outer and Inner Size of Square Main Beam Section
E	Young Modulus of Elasticity
Ia	Degree of Novelty and Innovation Type for Design Attribute
Ip	Degree of Novelty and Innovation Type f Design Concept
Ix	Moment of Inertia w.r.t. X-Axis
L	Length
m	Mass
M	Bending Moment of a Beam
MPa	Mega Pascal(Stress)
S	Stiffness
W	Weight /Load
W_D	Design Load
W_{Ri}	Relative Weighted Score
W_{Si}	Absolute Weighted Score
y	Perpendicular Distance Of The Extreme Layer From Neutral Axis
Z	Section Modulus
δ	Deflection
ρ	Density
Σ	Sigma
σ_b	Yield Stress (Bending)

Abbreviations

AHP	Analytic Hierarchy Process
BM	Benchmarking
CAD	Computer Aided Design
Casevac	Casualty Evacuation
CE	Concurrent Engineering
DLT	Dynamic Load Testing
FDL	Forwarded Defended Locality
FEA	Finite Element Analysis
FMEA	Failure Mode Effect Analysis
FOS	Factor of Safety
GII	Global Innovation Index
HOQ	House Of Quality
IMT	Innovation Management Techniques
INCOSE	International Council on Systems Engineering
IPD	Integrated Product Design
LWF	Light Weight Foldable
MIL-STD	Military Standards
PA	Proposed Approach
PHC	Primary Health Center
QFD	Quality Function Deployment
QIT	QFD Integrated TRIZ
MPAFCS	Multi Purpose Army Field Cot cum Stretcher
SUF	Scale Up Factor
TPM	Technical Performance Measures
TRIZ	(Teorija Reshenija Izobretatelskikh Zadach) Theory of Inventive Problem Solving

GLOSSARY

1. Alpha Prototype: It is first prototype and can deliver all the intended functions of a product, since the materials and components used in it are similar to what will be used in actual production.

1. Anthropometry: Anthropometry refers to human body measurement

2. Approach March Load: It includes the combat load plus a pack, sleeping roll, extra clothing, extra rations, and extra ammunition

3. Beta prototype: It is almost complete, but still needs some modification and improvements

4. Canvas sling: Canvas sling is an item of climbing equipment consisting of a sewn loop of webbing that can be wrapped around sections of rock or tied to other pieces of equipment

5. Contradiction: When two different parameters are in conflict with each other results in occurring of a technical contradiction.

6. Dynamic Load : the load which is applied very suddenly and thus cause vibration of the structure or they may change in amplitude as time lapses

7. Dynamic load factor Dynamic load factor: The factor by which the static load has to be multiplied in order to get the equivalent dynamic load under the given dynamic conditions

8. Fighting Load: It is a load to be carried by avoiding detection from enemy with carefully moving is necessary, it consisted of the soldier’s clothing, load-bearing equipment, helmet, weapon, rations, bayonet and ammunition

9. Figure of merit: Design Judging Criteria

10. Medical Device: Medical Device is a product which is used for medical purposes for patients, in diagnosis, therapy or surgery.

11. Prototype: It is the first or original example of something that has been or will be copied or developed

12. Relaxation: It means leaving of the MPAFCS unloaded till it gains constant reading

13. Spreader bar: It stretch the stretcher in lateral direction and keep the stretcher in this position during use.

14. Static load: A static load which remain static without any build up of energy

15. Stretcher: Casualty evacuation stretcher is a framework of two poles with a long piece of canvas slung between them, used for carrying sick, injured, or dead people.

16. Transfer of technology: Design activity will always involve the transfer of ‘know-how’ from one person, or group of persons, to others in the design process.

ABSTRACT

Life is very precious and all possible efforts should be made to save the life of an injured soldier/person in wars and disasters. In this connection, medical assistive devices like casualty evacuation stretcher and medical bed play an important role.

The armed forces have to be deployed in difficult terrains, high altitudes (4200m to 5800m) and snow bond areas where the load carrying capacity of a soldier reduces from 50% to 70 % (West, 1997) under such conditions carrying of casualty is very difficult. It is also known fact that the survival rate of patient treated within the golden hour after serious injury occurs is 80%. At 1.5hr after serious injury without definitive treatment being administered, the chance of survival decreases to 20% (Charles et al. (2004). Therefore medical fraternity is geared up to minimize loss of life and limb by providing immediate first aid and speedy evacuation and the medical devices like stretcher and stretcher cum bed become an important link in this evacuation process.

The existing stretchers are difficult to carry, deploy and store when not in use due to its folding length, heavy weight and manual locking mechanism. The designs do not have the patient gripping straps and other accessories therefore, is unsafe and difficult to carry the patient. The changing war and disaster scenarios in last few years suggest that design of advance multipurpose stretcher for both the military and humanitarian relief requires the innovative solutions. Therefore there is need of designs of the advance casualty evacuation Stretcher and "Stretcher cum Bed" to meet the military and civil requirements. Patented stretcher- designs show the efforts made since last many decades (since 1st world war) but now there is great need to apply the scientific and engineering approaches to design the state of the art designs of the stretcher and stretcher cum bed to fit into the current war and disaster scenarios.

Therefore, the aim of the dissertation was to evolve an IPD based approach with innovation and creative engineering techniques to design the novel products like stretcher specifically suitable to extreme ambient conditions. The research work was initiated with understanding of the terms like product-design, product design models, tools/techniques with their advantages and limitations. Therefore, sequential, concurrent and integrated product design (IPD) approaches and its various tools like

Quality Function Deployment (QFD), Computer Aided Design (CAD) and "Theory of Inventive Problem Solving Method" (TRIZ) have been studied and a generic product design model is proposed.

There is great competition in this era of global marketing and this competition can be faced by applying higher rates of innovation and creativity in product design. As per the report of the global innovation index (GII), "innovation is a dominant factor in the national growth". Since the innovation and creativity in the domain of product design, can play a pivotal role in industrial and national growth, therefore, innovation based tools and techniques are studied and an approach is evolved to evaluate the degree of novelty of a concept at the design stage. An innovative approach is also evolved to improve the design concept in a structured way to develop a customer oriented product.

To depict the effectiveness of the approach, a design problem of casualty Evacuation Stretcher was taken. By incorporating the QFD and TRIZ techniques in the stretcher design process, a considerable reduction in weight (1.3 Kg or 16.25 %) and improved features can be achieved. Even after additional features like patient gripping straps, auto locking hinge joints, built in space for emergency drugs and detachable IV fluid rod, overall weight of the proposed stretcher-design is still lesser than that of existing design. The stretcher is designed ergonomically as per Indian population's anthropometry and Indian terrains.

Since the design of product is found novel therefore the "Design Registration" is awarded and patent has been accepted by the Indian patent office for the product. Two good industries have purchased the production licenses of Light Weight Backpack Stretcher for mass production shows business potential of this product.

To validate the approaches, another very useful product designed with the help of the proposed approaches is MPAFCS which can be used by the doctors and surgeons to examine or even perform the field surgery of the soldiers to save the life or limbs. Besides being used during war or disaster situations the MPAFCS can also be used as night beds, camp beds, medical beds in primary health centers in the rural area and so on. The concept novelty was evaluated from the proposed approach before fabrication of prototype. The concept was found novel and due to its novelty the "Design Registration" has been awarded and its patent also has been accepted by the

Indian patent office. Under DRDO-FICCI ATAC program, the market potential for the MPAFCS was surveyed and transfer of technology was given to a reputed industry through "FICCI", Federation of Indian Chambers of Commerce and Industry which is the largest, oldest and an international apex business organization in India. "Transfer of Technology" of the MPAFCS was given to the industry on May 03, 2011, at New Delhi, (http://www.ficci.com/past-Events). The success of these products indicates that, proposed design model and approaches may be very effective and useful to design and develop the novel and market acceptable products.

CHAPTER 1

INTRODUCTION

All over the world, medical experts are agreed on the concept of "golden hour" (60 minutes) of evacuation in which the maximum lives can be saved. The historic wound and casualty data suggests that more than 90 per cent of those severely wounded die within the first hour of injury unless treated with life support. According to the statement of retired Admiral S.K. Mohanty' (The Hindu, April 6, 2010), who served as a surgeon in Kashmir during the Kargil War, "In war zone situations all trauma patients, must be evacuated to a medical centre within 60 minutes if they are to survive." In this connection, Katoch (Katoch R 2010) adds that in recent Iraq conflicts, one of the reasons for lowest "casualties" of U.S. Force was the rapid evacuation system.

In army field-hospitals or border static hospitals are the first surgical facility and the evacuation from the forwarded defended locality (FDL) to these hospitals can be done by air, ambulance, mules or stretcher bearers and the stretcher becomes an important link in the casualty evacuation chain in any counter-insurgency operation.

1.1 Casualty Evacuation Stretcher:

Modern day warfare is highly mechanized and technology oriented. Modern weapons are more lethal and precise, with the result, the casualty figures are likely to increase with every war and conflict.

Figure 1.1: Stretcher with casualty

Medical fraternity is geared up to minimize loss of life and limb by providing immediate first aid and speedy evacuation. Many a times, timely and fast rescue operation saves the life or limb of a casualty. Therefore, Casualty Evacuation Stretcher form a very important link in carriage of casualties' right from the forward defended locality (FDL) to rearwards and thus, these are one of the most important requirements of armed forces. In addition to being an important component in casualty evacuation in war or in field area, the stretcher form a necessary tool when armed forces are called upon to aid civil authorities during floods, earthquakes or major accidents. The Casualty Evacuation (Casevac) Stretcher is a medical device and used to carry casualties or an incapacitated person from one place to another as shown in figure1.1. The Casevac stretcher is usually moved by two people, one at the head and the other at the feet. The casualty is placed on the stretcher and can be carried or wheeled away. The Casevac stretchers (for simplicity it may be called as stretcher afterwards).

Figure 1.2: Existing single fold stretcher

The armed forces have to be deployed in difficult terrains, high altitudes and snow bond areas where the load carrying capacity of a soldier reduces up to 70 % at a altitude from 4200m to 5800m (West, 1997) since the rate at which humans can perform physical work (power output) depends on the amount of oxygen available to the body, therefore, as the altitude increases maximal oxygen uptake falls human load carrying capacity reduces.

Current U.S. army doctrine recommends 22 kg (or 30% body weight) as “Fighting Load” and 33 kg (or 45% body weight) as “Approach March Load” for the soldiers. The “Fighting Load” is the load to be carried by avoiding detection from enemy with carefully moving is necessary, it consisted of the soldier’s clothing, load-bearing equipment, helmet, weapon, rations, bayonet and ammunition. The “Approach March Load” includes the combat load plus a pack, sleeping roll, extra clothing, extra rations and extra ammunition (Knapik and Reynolds, 2001).

The stretchers which are in use in Indian Armed Forces are sturdy but heavy as shown in figure1.2. In today’s advanced battle scenario, a soldier is required to be lightly clad and heavily armed. The existing stretchers are bulky and heavy; do not fit into the concept of modern day battle. The commonly used stretchers by Indian Armed Forces weigh between 9 kg to 14 kg and single/double folding, resulting in difficulty to carry. The stretcher is commonly made of mild steel or aluminum tubes with a stitched canvas as stretcher sheet on which the patient lies. The canvas is heavy and prone to damage as it absorbs moisture and also allows bacterial, fungal and mould growth, leading to frequent replacement, thereby financial losses.

In the scenarios like war, causality evacuation is one of the important but difficult tasks and it becomes more difficult at hilly terrains, high altitude, and under extreme ambient conditions. Therefore, for the armed forces; there is need of the lightweight, backpack, safe, strong and reliable stretcher suitable to be used under extreme ambient conditions prevailing in India.

The casualty evacuation stretcher is a simple but very important and necessary life supporting product. The concept of the stretcher has been used since many years and has inspired many designers. But there is hardly any indigenous effort to design the stretcher suitable for the extreme ambient conditions, in which Indian armed forces have to be survived.

Today, it is widely accepted that product design engineering plays a vital role in creating product value. It is also a truth that the appropriate tools/technique and methods can be very helpful to solve the problem in an efficient and effective way. Therefore, to design the stretcher, the Integrated Product Design approach with its tools like QFD and TRIZ have been studied and an effort is made to apply the approaches to design a stretcher that suits to Indian conditions and meets the user needs. The brief description of IPD approach is discussed in the following paragraphs.

1.2 Integrated Product Design (IPD):

The challenges faced today required innovative and creative methods of product design and development, business and management in place of old ones. The old paradigm was based upon the theory of centrally controlled and centrally operated and most of the decisions were made at the top level.

According to Dahan and Hauser (2001), in 21st century, the important factors in product developments are customer satisfaction, time-to market, and cost reduction through total quality management, but none is viewed as a guarantee of success. The research challenges of the next decade are those that address product development as an integrated, end-to-end process that requires a detailed understanding and coordination of customers, competition, and internal capabilities.

According to the Tragg and Yuan (1998) IPD is a design methodology that incorporates a systematic way of early integration of all the activities and disciplines that play a crucial part throughout the life cycle of a product. It is the concurrent development of the product and process using cross functional teams that are strategically aligned with the needs of the customer, stakeholders, supply network and the business enterprises to optimize the design, manufacture and support of a system through the applications of technology, product-engineering, quality-tools and utilizing industry best practices. Many MNCs like General Motors, LG Electronics, Fords and Boeing are using IPD in their projects.

It was found from the literature (Benjamin, 2008; Hambali et al.,2009) that to win the market competition and customers’ satisfaction in an optimal way, various product design models, methodologies and tools developed by researchers and academicians are very essential and useful. To apply the product design model in a better way, the Integrated Product Design (IPD) approach is found better than the sequential product design approach. Therefore, the IPD approach and its tools like Quality Function Deployment (QFD), Computer Aided Design (CAD) and the theory of inventive problem solving (TRIZ) have been studied and applied in design of the stretcher and multipurpose army field cot cum stretcher. The brief descriptions of the CAD, QFD and TRIZ are given the following paragraphs.

1.3 Computer Aided Design (CAD):

Computer aided design can be defined as any design activity that involves the effective use of computer to create, modify and document an engineering design (Fusina and David, 2000). CAD method has been used since 1960 by U.S. defence and industries. Indian defence research and development organizations started the application of the CAD since 80's and today; it is being widely used by various Indian industries. In the present scenario, the use of CAD systems for geometrical modeling has been matured. The capabilities of CAD software have been increased and improved over the time. It allows easy, fast and cost effective performance estimation of various alternatives at conceptual and preliminary design stages.

In detail design stage, CAD can refine the design in terms of manufacturability (size, tolerance, and fitment) and can provide more accurate stress-analysis (structural, thermal, magnetic, etc.) outputs. The engineering drawings and bill of materials (BOM) can be generated directly from the 3-D CAD model, which is very useful for cost estimation and product scheduling. The CAD-model can be transferred into CAM model for final realization of physical product. Therefore, CAD is very useful tool in reducing cost, lead-time and improve the quality of the product therefore applied for this research work.

1.4 Quality Function Deployment (QFD):

Dr Yoji Akao first presented the concept and method of QFD, in Japan in 1960 as a method or concept for new product development under the umbrella of Total Quality Control (Chan and Wu, 1998; Zaim 2002; Lin et al., 2004). The introduction of QFD to America and Europe began in 1983 and today, QFD continues to inspire strong interest around the world in the academia and industries. It is being applied in many industries like automobile, electronics, construction and service sectors. It is widely and effectively applied in product design and development process. It is being applied in Indian industries also in which Tata Chemicals TVS-Sunderam, NBC- bearing manufacturer are few ones.

According to the Chan and Wu (1998), the Quality function deployment (QFD) is ‘‘an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production i.e. marketing, planning, product design and engineering, prototype evaluation, production process development, production, sales. QFD is very effective decision making tool which can show the technical strength and weakness of the organization with respect to the competitor's product, degree of technical difficulties in the design concept but it does not suggest how to improve the concept to satisfy the customer needs. To answer how the design can be improved and customer can be satisfied; the technique like TRIZ is studied and applied.

1.5 TRIZ (Teorija Reshenija Izobretatelskikh Zadach):

TRIZ (Theory of Inventive Problem Solving) technique is comparatively new and was not known upto1990 but the 1st paper on TRIZ was published in 1956 in USSR. TRIZ approach can increase the ability of a person to generate creative design solutions. The tougher market competition can be faced by the industries by means of increased rate of innovation and creativity in the products design and development. TRIZ consists of comprehensive collection of techniques and forty guiding principles.

But now its popularity in the US, Japan, Pacific Rim, Western Europe and even in India is growing rapidly. Magazine (Fortune 500) listed the companies which have cited a phenomenal increase in productivity, and they credit TRIZ for the breakthrough ideas and quality solutions to tough engineering problems as fuelling. Fortune 500 is an annual list of the 500 largest industrial corporations in the US and/or other countries, brought out in the Fortune magazine on the basis of sales and gross revenue. This registered trademark is a benchmark of business excellence for any company or organization targets to achieve. India is blessed with a number of Fortune 500 companies which are perfectly in tune with international standards and service level. These companies have been contributing steadily to the GDP of the country and therefore, playing a crucial role in lifting up the economy of India. The Premier Fortune 500 includes the Indian companies and public bodies like ONGC, Indian Oil, Bharti, Reliance Industries, Tata, State Bank of India, Wipro, HCL, etc. In India both the techniques are at infant stage; however some of the MNCs like Hewlett Packard, IBM, Motorola, and Raytheon and Xerox are practising TRIZ whereas academic institutes like IIT Bombay and India Modern TRIZ Academy are making effort to popularising the technique by organising various workshops and seminars.

1.6 Motivation:

My strong motivation factor is the Quotation of Former President of India Dr A.P.J. Abdul Kalam which is "Let my Brain Remove your Pains" Therefore to make the lives of our soldiers safe and comfortable; by using my engineering knowledge and experience through this research work was undertaken. In the present era, there is great revolution in product design and development methodology worldwide in domains like automobile, electronics, chemical, food, plastic and textile but hardly any attention is given towards the design and development of medical devices like stretcher, medical beds and so on. There are certain methods to evaluate the innovation potential of a country or organization based on many indicators like number of patents, scientific-output, creative-output, business- sophistication and market-sophistication and more but there is no method to evaluate the novelty of the product concept. However, the product novelty is very important even to survival in the market in the present era of globalization. Therefore, a gap if felt in this direction motivated me to initiate the research work.

Other motivation factors:

a. Interaction and discussion with higher official of Armed Forces (Director General, Medical Services, Deputy Director General Med Services) pertinent to the problem of Army Medical Corp personnel to evacuate the casualty in the field.
b. Special articles in the known medical journal like Medical Journal Armed Forces and Frontier Medical etc. pertaining to the casualty evacuation problems of soldiers in fields.
c. Visits to the exhibitions like International Medical Technology, Defence Expo where the focus remains on high tech devices and consumables/disposable medical items.

d. Poor attention of Indian industries towards the design and development of medical device like stretcher.
e. Publication of many research papers on product design in various leading international journals like Journal of Engineering. Design, Journal of Science and Technology, Journal of Product Innovation Management, International Journal of Applied Science and Engineering, Journal of Economic and Social Research, European Journal of Operational Research, International Journal of Innovation Management, Journal of Integrated Design and Process Science and various IEEE and international conference on engineering design proceeding.
f. Publications of various papers on Quality Function Deployment and TRIZ in many international journals and books like Engineering of Creativity (Introduction to TRIZ Methodology of Inventive Problem Solving", ISBN 0-8493-2255-3, Dieter-George, "Engineering Design", McGraw Hills, Material Selection in Mechanical Design, 3^{rd} edition, An imprint of Elsevier, Procedure for Design of Products with Consideration to User Interactions, Sweden ISBN 91-7373-265-6, Integrated Product and Process Development Handbook by Department of Defence U.S. which indicate the importance of the product design.

1.7 Aims and Objectives of the Research:

The main objective of the research work is to get insight of Integrated Product Design approach and its tools/ techniques to develop a customer oriented product like stretcher by understanding various pertinent issues and evolving the approaches such as:

1. IPD approach, its important tools and techniques
2. Benefits of IPD approach over the conventional approach in product design
3. Evolve an approach to evaluate the degree of novelty of a design-concept
4. Evolve an approach to improve the design concept in an innovative and structured way to meet the customer requirements for the product
5. Apply the proposed approach to design the advance "casualty evacuation stretcher" suitable to use under the extreme ambient conditions prevailing in India for satisfying the needs of our Armed Forces.

6. Validation of the proposed product design approach by applying it to design similar product like multipurpose army field cot cum stretcher.

1.8 Research Methodology:

In this thesis, the research adopts an Integrated Product Design (IPD) approach, utilizing different kind of sources, methods and theories to satisfy the research objectives. The literature and product survey includes concepts, product development models and existing stretcher designs with their advantages and limitations.

The research efforts have focused on building up a broad theoretical foundation based on literature review, case studies, and various product design tools and techniques like CAD, TRIZ and QFD to build a systematic integrated design approach to address the problems in design of the product like casualty evacuation stretcher to be used under the extreme ambient conditions. The design data was collected through literature review, product reviews (patented and commercial similar products designs), stretcher manufacturer's news-letters. Customers' needs and requirements were collected through structured questionnaires from surveys, group discussions and interviews.

1.9 Outline of the Dissertation:

The thesis is divided into seven chapters and the structure of the dissertation is as follows:

Chapter-1 provides the brief introduction of the casualty evacuation stretcher, existing designs of the stretcher and the needs of the light weight backpack stretcher. It briefly introduces the integrated product design approach and its various tools like CAD, QFD and TRIZ, then it discuss the aims and objectives and research methodology.

Chapter-2 discusses the literature review pertaining to the product design models, methods and tools, then advantages of design models followed by various design approaches like sequential, concurrent and integrated product design. IPD approach is discussed in detail by describing the definitions, principles, advantages and limitations. It also includes brief description of the product "requirement analysis process" and types of the reviews. The chapter deals with Quality Function Deployment (QFD), its history, implementation procedure, structure, advantages and its limitation. It is followed by the innovation in the product design, innovation type, innovation indicators, types of newness and TRIZ, an innovative problem solving tool to improve the design concept.

Chapter-3 describes the literature review pertaining to the designs of the medical stretcher, its types, BIS standards for dimensions, specification of canvas and load bearing capacity of the stretcher which is followed by gap analysis between the user needs and existing designs of the stretcher.

Chapter-4 describes the output of the research work. It discusses the detail description of the proposed design methodology, followed by detail description of proposed design model. It describes the proposed approach to evaluate the degree of novelty of a design concept. Finally it suggests the QFD integrated TRIZ (QIT) approach to improve the design concept to ensure a customer oriented product.

Chapter-5 discusses the design of the "light weight foldable stretcher" by applying the proposed approach. It includes stretcher needs analysis, customer survey details, evaluation of novelty of the stretcher concept, application of QFD to design the stretcher. It describes the detail design procedure of hinge joint and other components like main beam, fabric, spreader bar, locking mechanism etc. It includes various types of tests like bond strength test, shear and fatigue test of metal composites components then static, dynamic load tests and user field trials to verify the stretcher design. Finally it discusses the improvement of the stretcher design by applying the proposed QIT approach. At the end of the chapter there is the summary of advantages gained in the design of the stretcher by applying this proposed IPD.

Chapter-6 describes the design of the multipurpose army field cum stretcher (MPAFCS), which includes the need and requirement analysis of the MPAFCS, details of market survey and the gap analysis, followed by evaluation of the degree of novelty of the MPAFCS concept. It gives elaborated description of the QFD to design the hinge joint other components like frame, main beam, spreader bar, locking mechanism, strip joint and fabric etc of MPAFCS. Further it discusses the static load testing of alpha product then improvement of the concept by applying the proposed QIT approach to eliminate the gaps between the designed and required product attributes. It also discusses the details of the improvement made in the components of the MPAFCS, then the static and dynamic load testing of beta product and final specification of the MPAFCS design.

Chapter-7 discusses the conclusion, which includes the advantages of the proposed approach in the design of stretcher and MPAFCS designs and recommendation and direction for future work.

CHAPTER 2

LITERATURE REVIEW

(PRODUCT DESIGN MODELS, METHODS AND TOOLS)

Introduction:

According to the Ulrich and Eppinger (1995), "A product is something sold by an enterprise to its customers and the product development is the set of activities beginning with the perception of a market opportunity and ending in the production, sale and delivery of a product. Product design and development can be defined as a process of creating a new product effectively, economically and optimally to make the user's life easy and comfortable.

Design refers to the activities involved in deciding the product's mechanical architecture, selection of suitable materials, processes and engineering the various components necessary to make the product work. It also includes the creation of style, look and feel of the product. *Development* refers as a whole of all the activities from identifying a market opportunity, creating a product to appeal the identified market, testing, modifying and refining the product until it is ready for production.

As per Liu (2003), "product development is a creative and interdisciplinary activity that transforms a market opportunity and technological innovation into the successful product". Product development processes should integrate all the major functions within the organization such as strategic planning, marketing, product design, manufacturing and financial planning and budgeting. It also involves interactions with stakeholders. Product design and development is the set of activities starting with the perception of a market opportunity and ending with delivery of a product. Its various components can be defined as under:

2.1 Product:

As on today, the product may include, physical objects, goods/ novel ideas, software or service from which the customer gets direct utility and can satisfy the user needs or wants. It may be tangible or intangible. A tangible product is any physical product that can be touched like a computer, watch, automobile etc. An intangible product is a non-physical product like an insurance policy, research papers and process. As per the Oxford reference dictionary, "Product is an article or substance manufactured for sale". Product can be defined as anything that is produced, whether as a result of generation, growth, labor or thought, the product of the firm, the product of the manufacturer or the products of the brain".

2.2 Design:

Views on the definition of design or what the design can be considered by several researchers, designers and engineers are expressed as:

As per the Finkelstein and Finkelstein (1983), "Design is a creative process which starts from a requirement and defines a system and the methods of its realization or implementation, so as to satisfy the requirement. It is primary human activity and is central to engineering and the applied arts. Chiang et al., (2001), advocates that designs are considered to satisfy some purpose or function. According to Gotri et al., (1998), the engineering design could be regarded as a transformation process from a set of functional specifications and requirements into a complete description of a physical product or system which meets those specifications and requirements. Zeng and Gu (1999) describe the design as an intelligent activity that begins with design requirements and ends with a product description.

Evbuomwan at el., (1996) summarizes the design as the process of establishing requirements, transforming them into performance, specification and functions, which are then mapped and converted into the economical, manufacture-able design solutions within constraints by applying creativity, scientific principles and technical knowledge. Ullman (2003) defines the design process as "The organization and management of people and the information they develop in the evolution of a product."

2.3 Product Design and Development Process:

Ulrich and Eppinger (1995), describe the product development process as the sequence of steps or activities that an enterprise employs to conceive, design and commercialize a product". The design process helps to make sure not to overlook any of important aspects, set the unbiased solutions and enhance the team creativity. Krishnan and Ulrich (2001), view the product development process as a transformation or a translation of a market opportunity into a physical artifact available for sale.

Categories of design process: Based on process the product design can be classified into four categories named as creative design, innovative design, redesign and routine design (Sriram et. al., 1989). When there is no prior plan existing for the solution then it may be called as creative design and key issue in this design process is the transformation of solution from subconscious to the conscious state. Innovative design occurs when the decomposition of the problem is known but the solution for each part has to be synthesized. This design may be original or novel combination of existing components. When design of a product exists and is modified to meet the newly developed requirements, it may be termed as redesign. In routine design the parts and alternatives exist and it finds the appropriate alternatives for each subpart that satisfies the given constraints. The different design processes are shown in figure 2.1.

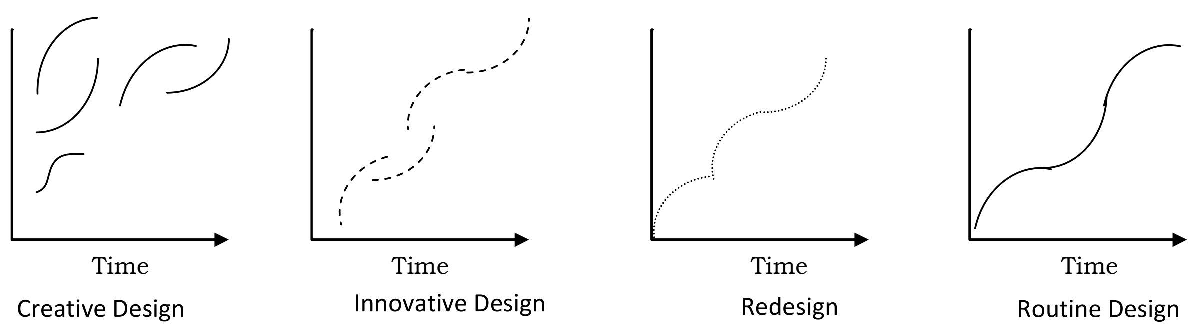


Figure 2.1 Categories of design process (Sriram, 1989)

2.4 Product Design Methods and Models:

It has been known that approximately 80% of manufacturing cost of a product is determined by the design of the product (Mikkola and Skjoett, 2003), therefore, in this research work, product design process is focused and discussed in detail in this chapter. Hubka (1983) defines a design method as any system of methodical rules and directives that aim to determine the designer's manner of proceedings to perform a particular design activity and regulate the collaboration with available technical means. The American Society of Mechanical Engineers ASME (1986) defines the design methodology as a collection of tools and techniques for designers to use while designing and it's prescriptive as it indicates how to design. It is shown by the studies (Cooke et al., 2003; Chakrabarti et al., 2004) that the design engineers have a probability to forget, losing the track of design requirements/specifications or ignorance of requirements during the design. It is also shown that identification and detection of the design error sources in case of introduction of error also become difficult for the designer. Cooke's (2003) studies show that design errors take place due to the sequence of minor design decisions which individually may seem correct but collectively lead to a design error.

Thus, a design methodology is required to assist the designers to make better design decisions that meet design requirements. The aim of the study of the product design and development models is to adapt general statements to the requirements of the mechanical engineering design process and to incorporate the specific working and decision making steps (Kusar et al., 2004).Therefore, the following design models developed by many researchers are discussed here in details to develop generic steps, phases or activities and which can be verified and validated by designing the stretcher and multipurpose army field cot cum stretcher under this research work.

2.4.1 Pugh's product design model "Total Design":

Stuart Pugh is a well recognized and eminent personality in the field of product design; his model is simple and well defining each of the major steps, involved in the development of new products. As per Pugh et al., (1996), "Total Design" is the systematic activity necessary from the identification of the market/user need to selling of the successful product to satisfy that need. It is an activity that encompasses product, process, people and organization. The activities in the total design model include the market analysis (User needs), product design specification, conceptual design, detail design, manufacture and sales as shown in figures 2.2. In the model, first a basic brief is drawn to refine the area of research on customer needs from market study before the literature search. Related patents, books, official and representative literature, statistical data and benchmarking of competing products may be considered as different sources for contents of literature survey to establish the gap analysis and become noticeably better specification than the competitors.

On the basis of product design specification (PDS), subsequent activities are completed, thus acting as the control for total design activity. The model allows iterations in the activities based on emerging of new information. This model recognizes to utilise various design methods or techniques to achieve the efficient and effective design solutions. In this model, the design activities are divided into two branches, one discipline independent which can be applied to any product or technology like modelling, decision making methods, analysis and synthesis techniques and the other branch includes specific discipline dependent techniques and technological knowledge like stress analysis, hydraulic, thermal analysis, electronics and so on. The model figure 2.2, also considers the frame work of planning and organisation i.e. overall product development process frame work.

2.4.2 BS 7000 product design model:

This model commences with feasible study stage followed by conceptual design, embodiment design, detail design and design for manufacture stages with their respective output as design brief, concept drawings, layout drawings, detailed product definitions and manufacturing instructions. The model ends with a post design support stage as shown in figure 2.3

2.4.3 Product design by Baxter:

In the mid 1990's, Mike Baxter revealed his vision of product development, it embodies many similarities to other methodologies but focus more than most on analyzing the opportunity for the idea (Baxter, 1999). The initial step is the selection of product development strategy adopted by the design team; it may include market pull strategy or technology push strategy.

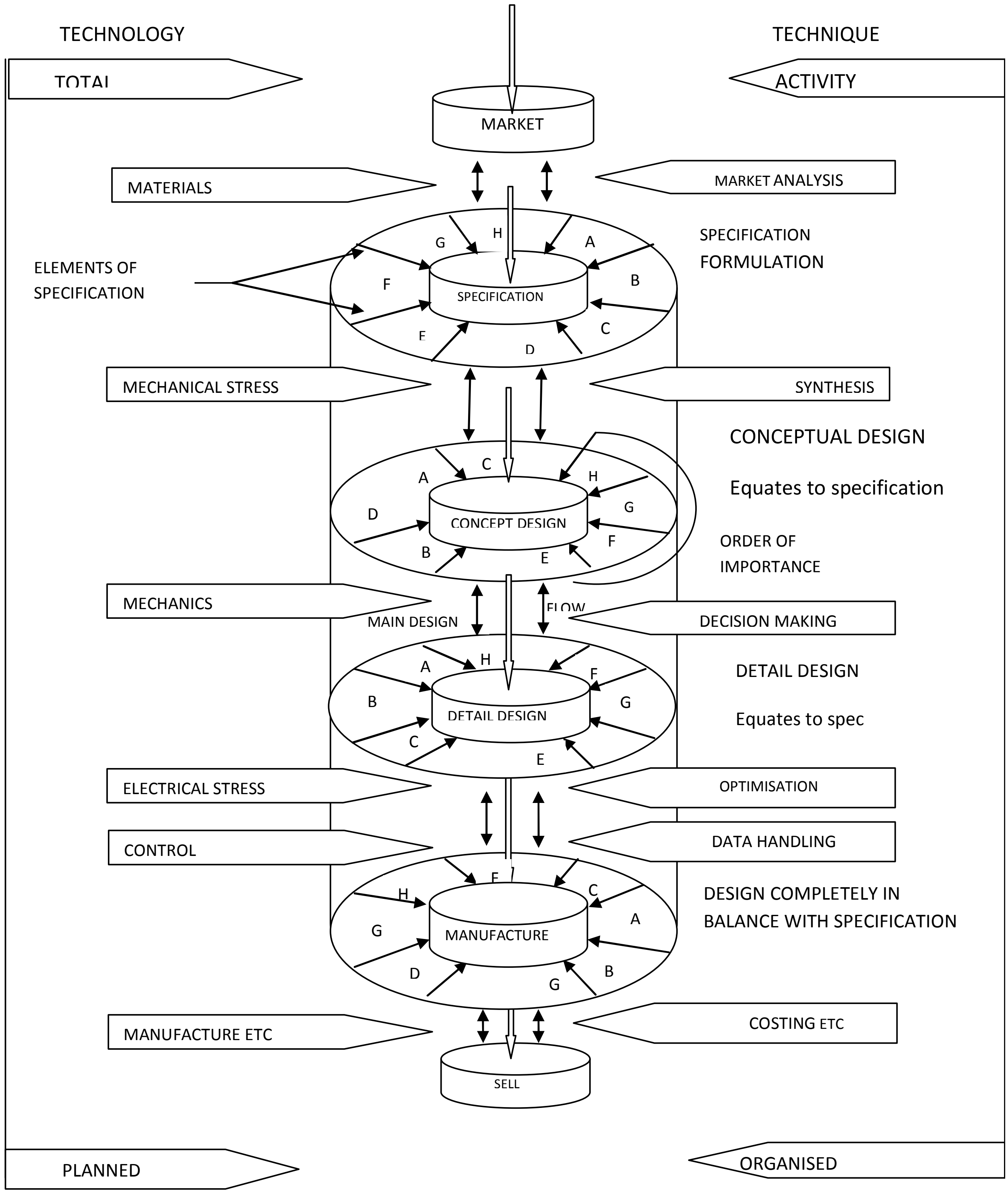


Figure 2.2: Product design model by Stuart Pugh (Pugh, 1996)

Technology push requires just as much research as market pull. The only difference in this case is that a technology is available which has the potential to fulfil a need of the market that is not yet exploited by the competition. One of the important steps of Baxter's methodology is a customer survey to identify the needs of the target market along with a search for technology opportunities and it can be completed by performing competition analysis, benchmarking, technology monitoring and forecasting.

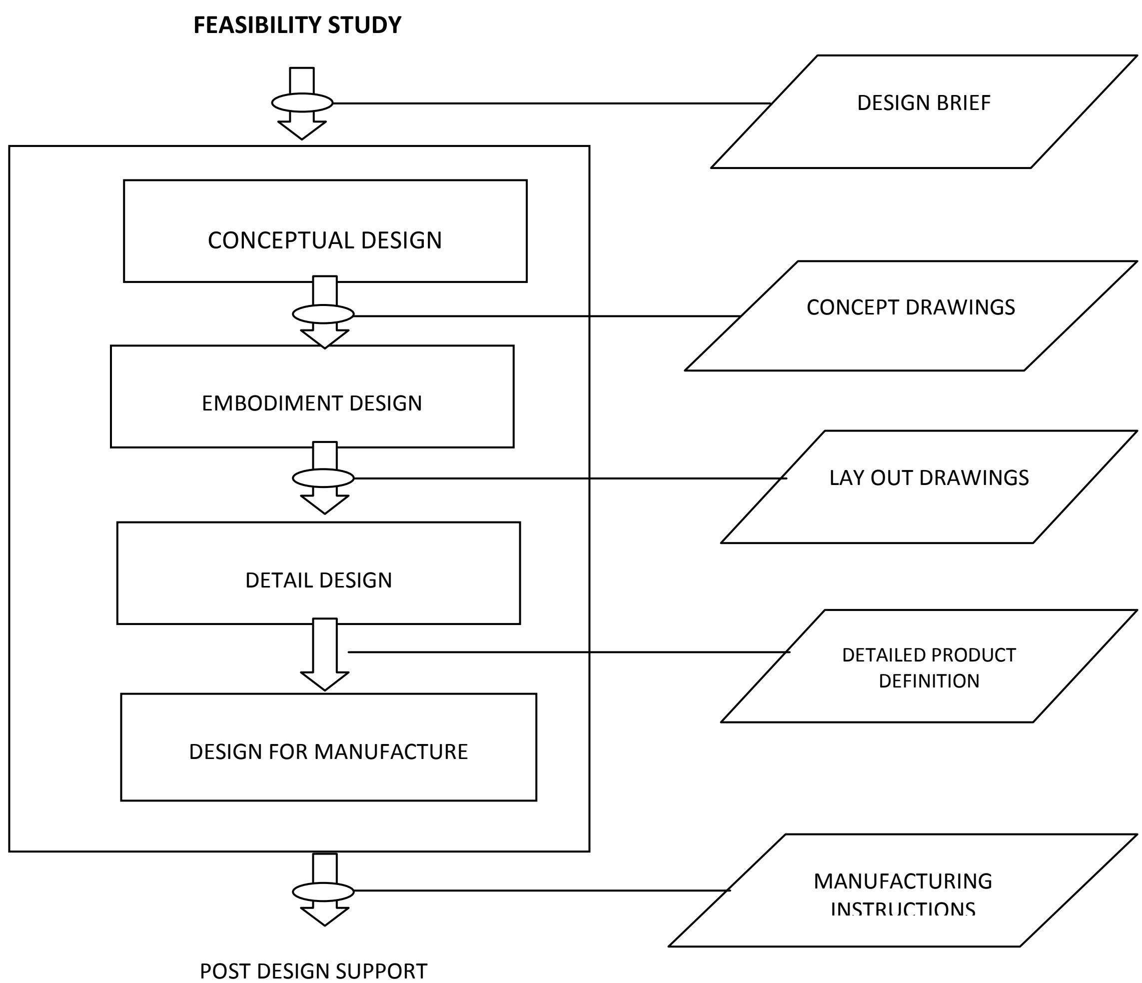


Figure 2.3: BS 7000 design model (BS 7000:2006)

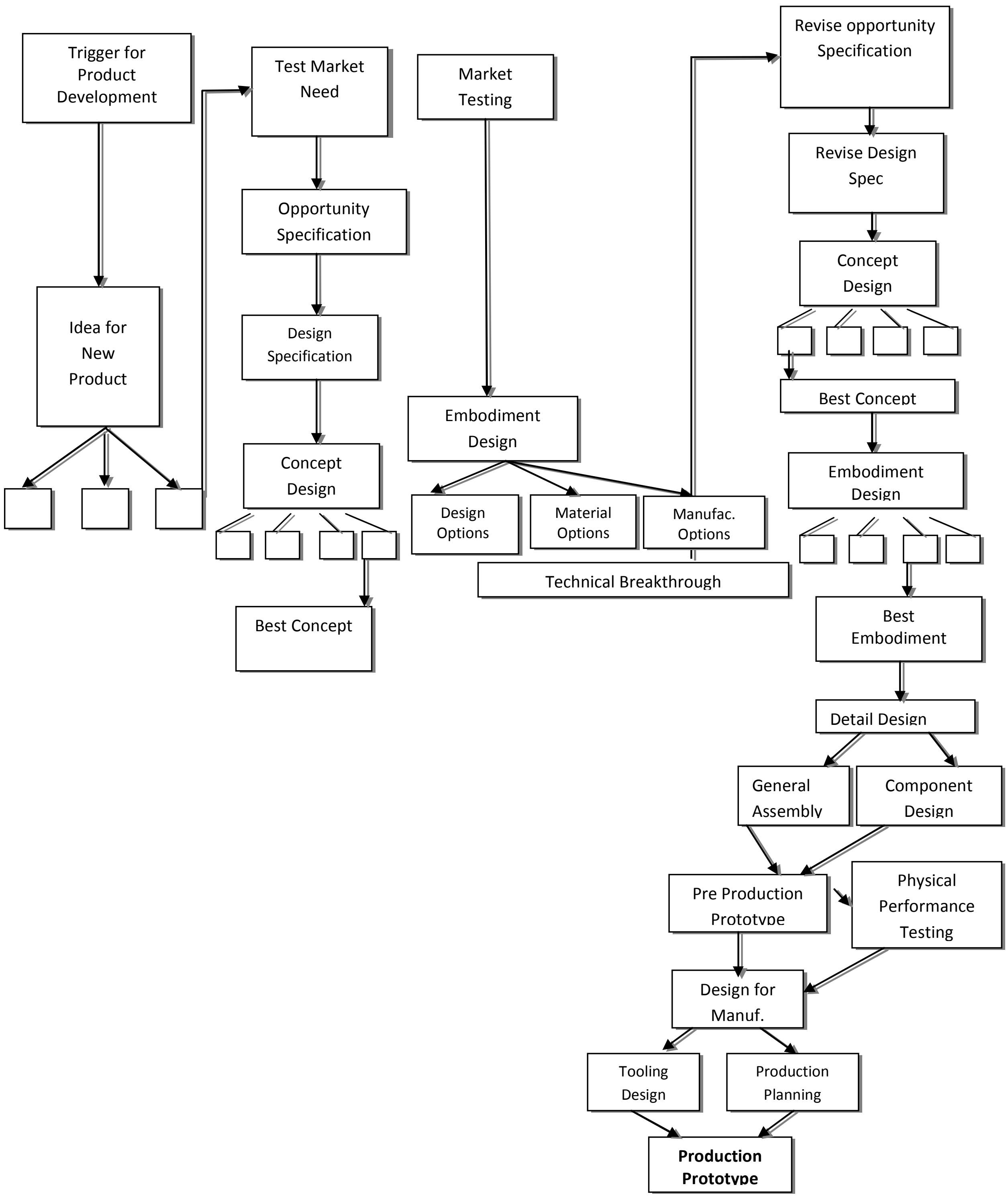


Figure 2.4: Product design model by Baxter (Baxter, 1999)

This analysis provides the information that where the product requires compete the market. Based on the needs expressed by the customers, the company can choose the options to embody new product. The output of this stage is called the opportunity specification as shown in the figure 2.4. When there are a number of product opportunities identified within a market, then it requires a selection process to establish which one(s) is best for the company. To solve such problems, each option should be assessed with respect to the company goals and then put through a systematic opportunity selection scheme to quantitatively justify the decision.

2.4.4 Cagan Jonathan & Vogel Craig product design model:

Cagan and Vogel (2002), the professors of mechanical engineering at Carnegie Mellon University, developed the "User Centred Integrated New Product Development Methodology" which focuses on early stages of product development. The salient feature of this approach is that the behaviour of the customer is observed to identify the new product opportunities.

It is a user-centred approach and uses the Social, Economical and Technological (SET) factors to identify the best product opportunity gap and exploits the targeted market with the product. Identification and understanding of opportunity, conceptualisation and realisation of opportunities are the main phases of this user-centred iNPD approach. It includes all the required design activities in addition to the opportunity analysis. For further clarification on product opportunity, additional information pertaining to the lifestyle, interaction, further task analysis and anthropometric data is also gathered and analysed

According to Cagan and Vogel, to sell the product, it must have some form of value in the eyes of the customer which may be called as "perceived value" and the perceived value may be broken down in seven different attributes which includes, emotion, aesthetics, product identity, impact, ergonomics, core technology and quality. The value of a product opportunity can be identified by investigating the size of a market, the number of competitive products, the quality of competitive products and the cost of product.

2.4.5 Nigel Cross's product design model:

Cross developed a series of steps to design a product as shown in figure 2.5, the steps of interest are: clarifying objectives, establishing functions, setting requirements and determining characteristics. In this approach, the problem is defined and formulated keeping in view the objectives to find the required solution. "The Objective Tree" (graphically represents all of the tasks that a product needs to accomplish) method is used to clarify the objectives. According to Cross the objectives may be customer requirements, user needs or product purpose (product features). Each objective is then ranked into sets of "higher-level" meaning more important and "lower-level" objectives meaning lesser important to the user (Cross, 1994).

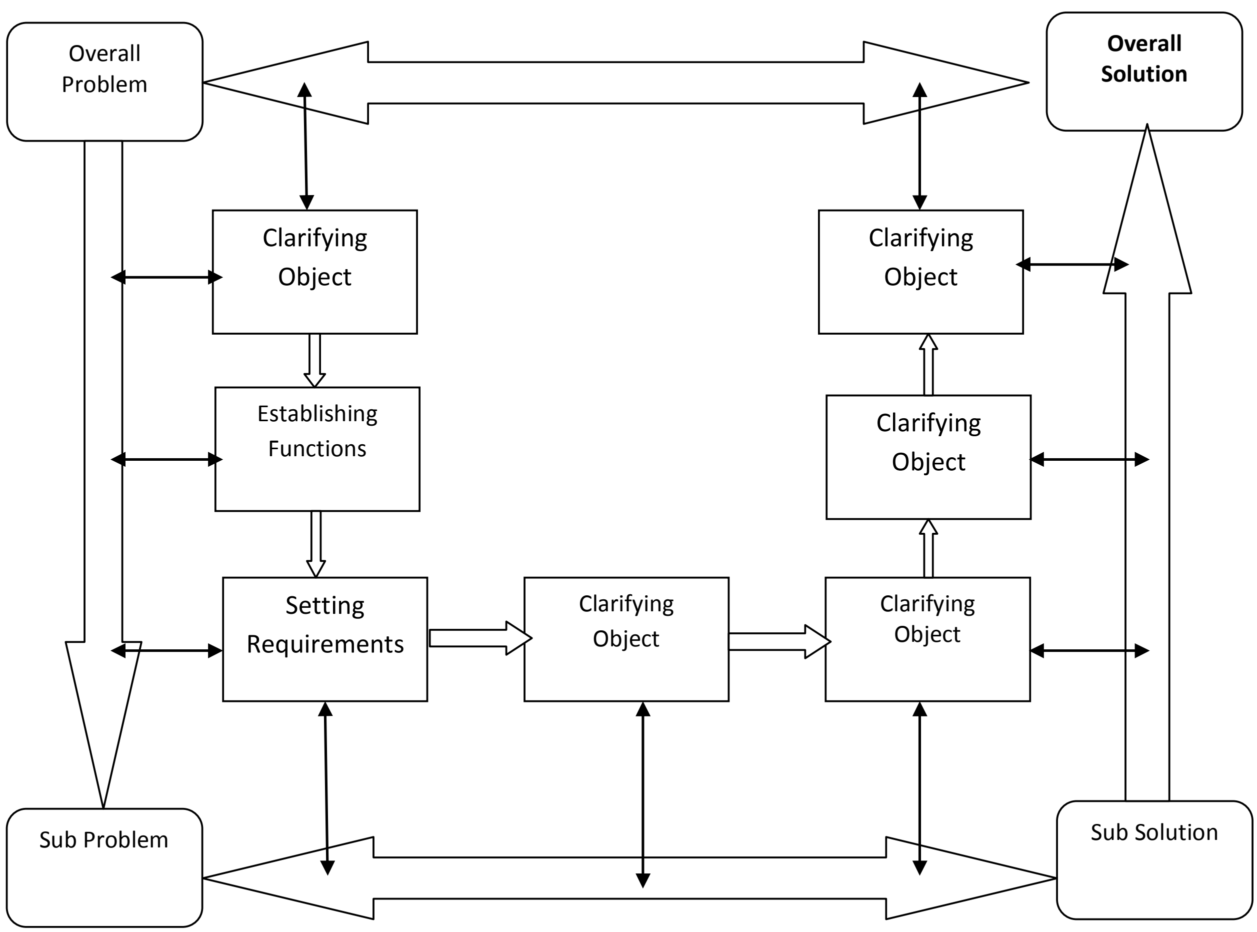


Figure 2.5: Engineering design model by Cross (Cross, 1994)

2.4.6 Product design model by Marpless:

In this model, the design process is commenced with statement of problem to be solved. This is represented by the starting nodes in the Marpless tree. From this node, sub problems are derived that must be solved before finding a solution to the main problem.

This is an iterative process, theorising solutions, delineating these solutions and modification. In the tree the final solution is the sum of the solutions a(21211), a(22211), a(22221) and a(232). In the figure 2.6, a vertical line denotes the problem while slanting line denotes the solution. The model suggested by Marples consists of three principal phases as synthesis, evaluation and decision (Evbuomwan et al., 1996). At synthesis phase, possible solutions of the design problem are searched and examined. At evaluation phase, the viable solutions are evaluated against certain criteria and followed by final decision.

2.4.7 Ulrich and Eppinger's product design model:

Karl Ulrich, the professor of engineering and system design and Steven Eppinger professor of management at MIT, combined their knowledge of engineering and management to develop a comprehensive product design methodology including marketing, design/engineering and manufacturing into the process as shown in figure 2.7.

In Ulrich and Eppinger's model, the first step is to create a mission statement by identifying opportunities, locating product opportunities and focus on gathering information.

All the opportunities found are then placed into a database and this database is then sorted with regard to the company's abilities by using a specific series of factors such as technology, user-centred approach with technical cost, customer focus and imitative products. The database can be used as a catalogue to be reviewed and used in subsequent stages of product design and innovation. Each of the factors listed help in ranking the opportunities to allow the selection of the best opportunity for the company. The target market definition can now be mapped out based on the nature of the opportunity, competition and requirements for that market.

Point of Problem Formulation

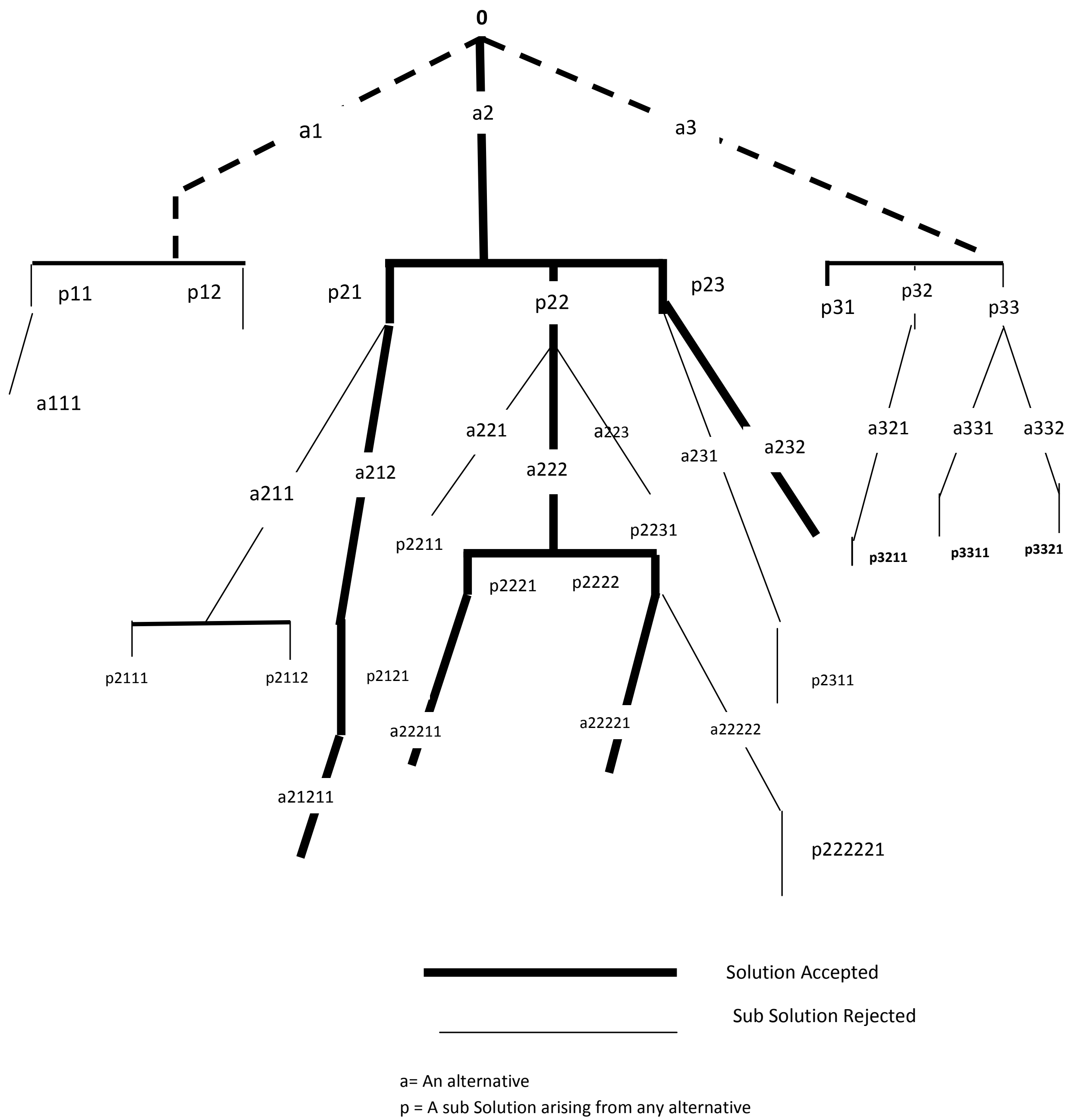


Figure 2.6: Design model by Marpless (Evbuomwan et al., 1996)

The data gathered till this stage (the opportunity data and the product segment) can then be used to generate the mission statement of the opportunity. Target market and customer needs are then investigated and identified by using the mission statement as a road map.

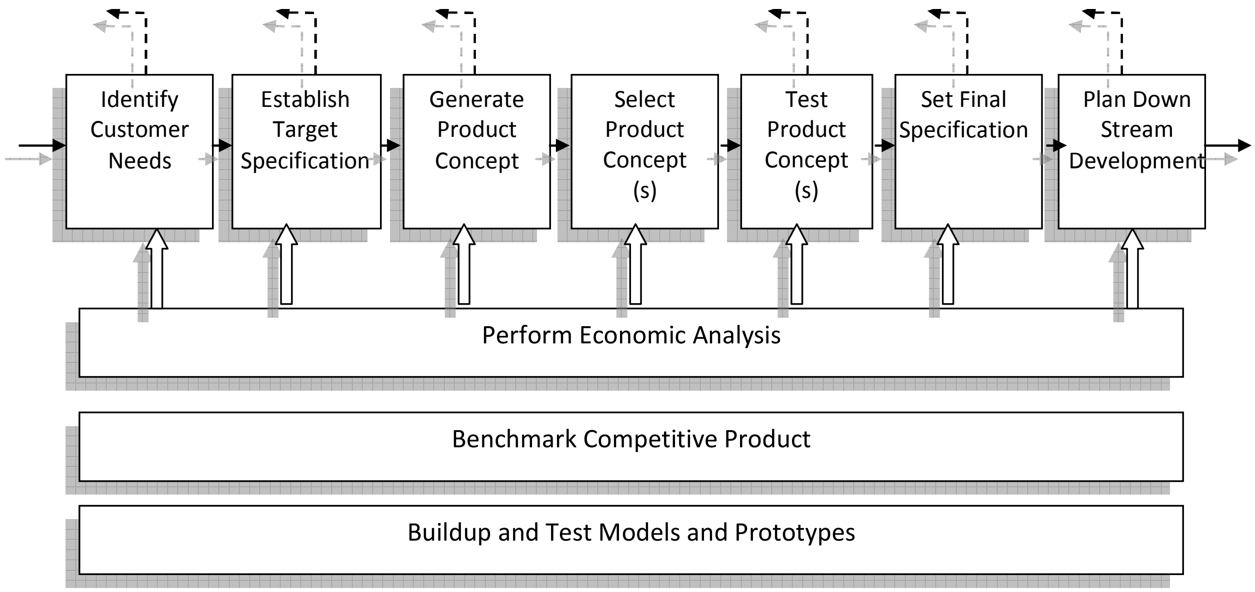


Figure 2.7: Ulrich and Eppinger's product design model (Ulrich and Eppinger, 2003)

Ulrich and Eppinger recommend for gathering "raw data" straight from customers through interviews, focus groups and observations of customers interacting with competing products. The designer must seek customer statements regarding the opportunity. The statements can be recorded and interpreted by the design team.

The interpretation of customer statements are grouped according to the similarity of the needs and subsequently rank the groups against one another based on their importance to create a hierarchical list of the customer needs. A survey can then be generated to assess quantitatively the relative importance of the needs from the customers' point of view.

2.4.8 Product design model by French:

French's model (French, 1971) starts with needs as in other models and feedback system improves the system where as required, the model is depicted in figure 2.8.

It consists of following phases/activities of design process:

1. Problem analysis: In this phase the needs are identified so that these can be fulfilled as precisely as possible.
2. Conceptual design: Broad solutions in the form of schemes have to be generated followed by evaluation and selection of the suitable concepts.
3. During the embodiment phase, the schemes generated in the previous phase are worked out in greater details.
4. In detailing phase, the generated solutions/schemes are specified with finer details.

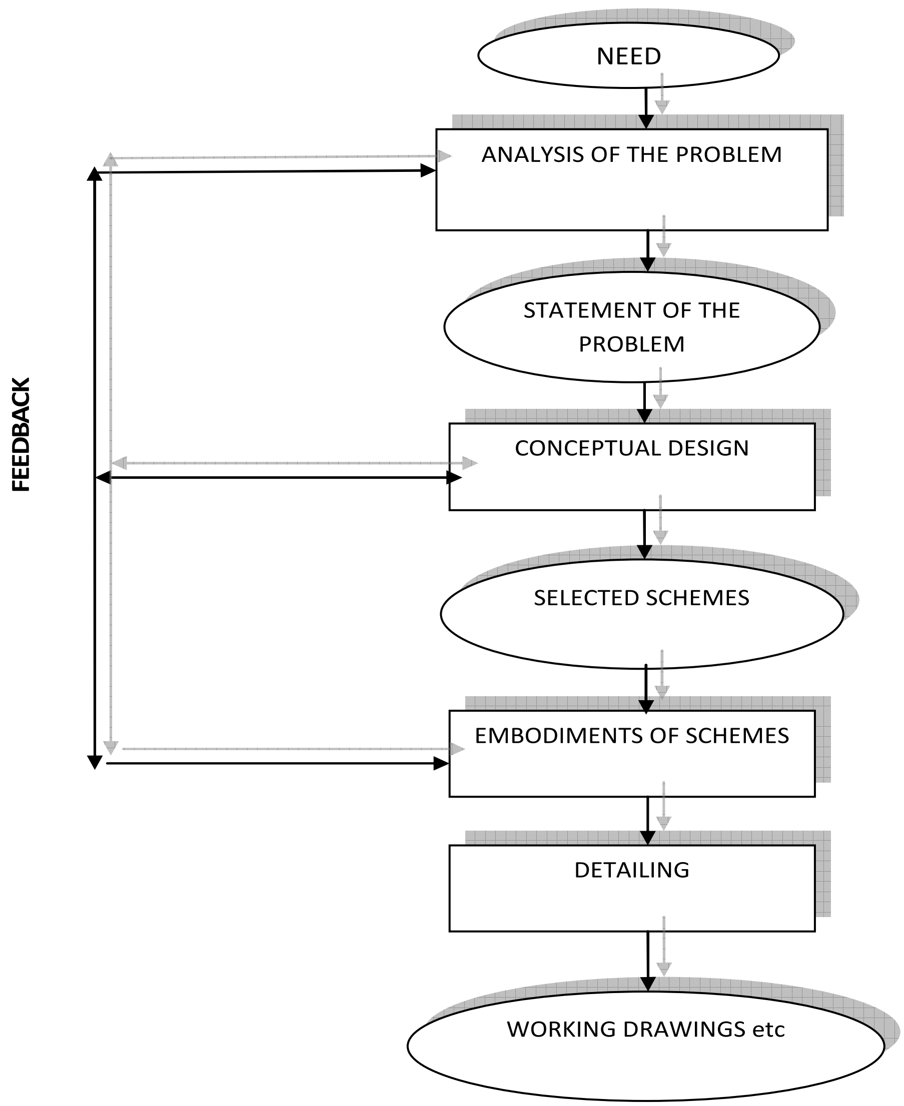


Figure 2.8: Design model by French (French, 1971)

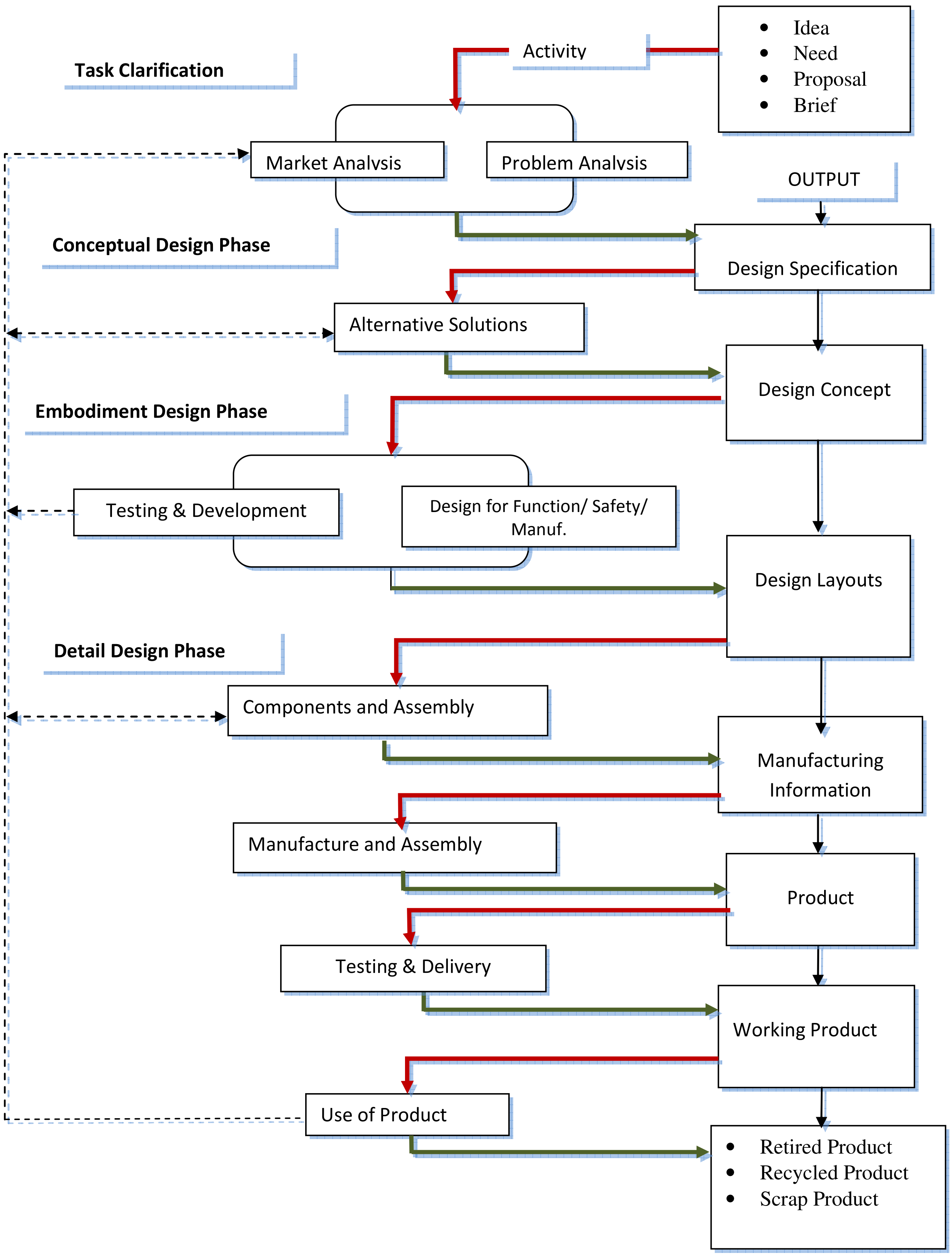


Figure 2.9: Product design by Hales and Gooch (Hales and Gooch, 2004)

2.4.9 Product design by Hales and Gooch:

Hales and Gooch (2004), offer a methodology that combines design and management into a single process. In Hales and Gooch approach a clear statement of the problem is the initiation point as shown in the figure 2.9. To evaluate the proposed solutions, requirement and constraints are set. Undesirable factors in a particular situation are identified and considered to be solved if there is improvement in the situation and is acceptable to all the stakeholders. In this method, customer demands are treated as higher priority than customer wishes, which creates a hierarchy of the customer needs. Subsequently the product specifications are generated based on these demands and needs.

2.4.10 Pahl and Beitz's product design model:

During the mid 1980's, Pahl and Beitz (1995) introduced their reasonably comprehensive model of product design. Although they did not follow the exact sequence of actions as Pugh, but their methodology still follows the basic process. Pahl and Beitz's methodology represents their model in four main phases which are: Task clarification, conceptual design, embodiment design and the detail design.

The task clarification involves the collection of information about the problem under consideration. Conceptual phase involves the establishment of function structures, the search for suitable solution principles and their combination into concept variants. At the embodiment design phase, for the product, layout and forms are considered in accordance with the technical and economical factors. In the detail design phase, individual parts are specified for arrangement, form, dimensions, surface-finish, tolerances and materials specifications keeping in view the technical and economical feasibilities.

Pahl and Beitz make it clear that their method might require an iterative process to achieve the best possible results that leads the designer into creating a layout for the solution. The model follows a market positional methodology, meaning that the method's first step is to investigate the socio-economic factors of a market and compare them with the company's product design and development potential. Through the results gathered, the design team can systematically search for new product ideas that are compatible with the company's development team and manufacturing capabilities.

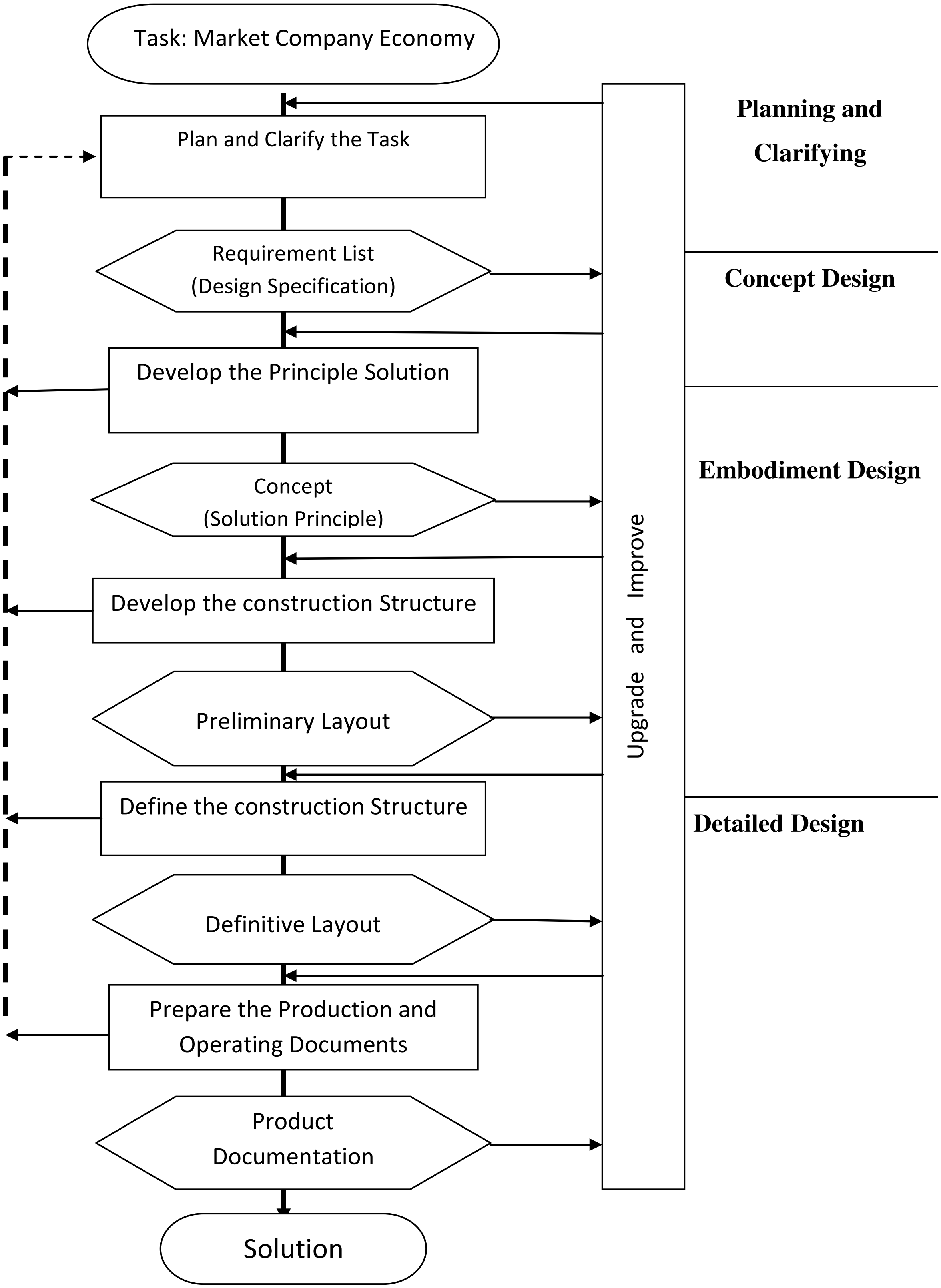


Figure 2.10: Product Design Model by Pahl and Beitz (Pahl and Beitz, 1995)

A series of ideas can then be generated to satisfy a gap in the market. Each idea has to be weighed against a series of criteria in order to select the better ideas for further development. As shown in figure 2.10, the model shows the entire life cycle of the product. It is based on an elaborate analysis of the fundamentals of technical systems, the fundamentals of systematic approach and general problems solving processes.

2.5 Summary of the Product Design Models:

All the models shown in this chapter, describe various phases and activities that design team can follow as per the organizational strategy and market needs. Though all of them are valid and have shown their potential for success, some are more complicated than others and require more expertise in the field of product design. Summary of these product design models studied is shown in table 2.1. It shows that all the models initiate the process with customer needs and indicate the importance of customer. Task clarification and design specification activities are followed by concept generation and are almost similar activities in the models however the nomenclature used are different. Baxter, Pugh, Hales and Gooch described the activities in more detail. Crick and Ulrich & Eppinger's models discuss the importance of Innovation and creativity, which shows the importance of innovation and creativities in product design since long back however now it has become the need of the time. In this thesis, customer voice, innovations and creativity are taken as important considerations along with the necessary product design tools to achieve the required goals.

2.6 Advantages of the Product Design Model:

Design models have the potential to improve designers' performance by providing structure to their actions and thoughts. Designing is a highly challenging task and due to globalization, new technologies and societal changes, the problems encountered by the designers are becoming more complex and companies are facing a greater risk of failure. Product design model and methods guide the designers to perform all the required design activities and in eliminating the sources of even small errors to avoid the problems which may appear at later stage of design. Thus, structural procedures and design activities support the designers to overcome these uncertainties and help the designer in every stage. The design activities may include:

1. Clarification of the objectives (Establishing of the user requirements, product functions and constraints identification)
2. Concept development(Establishes design specification and generate solutions)
3. Preliminary design (Establish model and its analysis. Testing and evaluation design)
4. Detail design (Refine and optimized design product and process)
5. Prototype/ Pilot/ Demonstration
6. Product launch/Productivity/ Delivery
7. Maintenance and support

Table 2.1: Summary of the reviewed design models

Model/Reference	Salient Features
Pugh's Model "Total Design" (Pugh at el., 1996)	• The design process flow from market (User needs) to sale. • Advocate the necessity to utilise various design tools and techniques • Design technique includes (1) discipline independent which can be applied to any product or technology e g decision making, modelling and analysis approach. • Discipline Depended and technological knowledge like structural stress analysis, thermodynamic analysis electronics etc. • It considered overall/total product development process from technological, technical and organisation issues
Pahl and Beitz's Design Model (1995)	• Has four main phases: Task clarification, conceptual design, embodiment design and the detail design. • Investigate the socio-economic factors of a market and compare them with the company's product design and development potential
B.S.7000 Design Model (BS-7000, 2006)	• It commences with feasible study stage followed by conceptual, embodiment, detail and manufacture design stages with their respective output. • The model is drives from Pahl and Beitz's model
Hales and Gooch Model (2004)	• Customer demands are treated as higher priority than customer wishes • Subsequently product specifications are generated based on these demands and needs.

Krick Model (Evbuomwan et al., 1996).	• Five stages model as problem formulation, problem analysis, search, decision and specification. • Generation of alternative solutions by performing enquiry, **invention** and research.
Nigel Cross's Model (1994)	• The Objective Tree" (graphically represents all of the tasks that a product needs to accomplish) • Method is used to clarify the objectives(customer requirements/product features)
Baxter's Model (1999)	• Focuses on analyzing the opportunity for the idea as well technology opportunities • Splits product design into two different sections named as product planning and product design • product opportunity meant by confirmation of the product with the commercial [sic] viability and consistency with the company's product development strategy
Cagan and Vogel (2002)	• User Centred Integrated New Product Development Methodology. • Customer- behaviour is observed to identify the new product opportunities. • Uses Social, Economy, and Technology (SET) factors to identify the best product opportunity gap • Exploits the targeted market with the product. perceived value (e.g., emotion, aesthetics, product identity, impact, ergonomics, core technology, quality)
Ulrich and Eppinger's product design model (2003)	• User Centred Approach with technical engineering data • Identify opportunities by focusing on gathering information, locating product opportunity • All of the opportunities found are placed into a database to review and use in subsequent stages of product **innovation.** • Combine Marketing, design & manufacturing

2.7 Generic Steps in Product Design Process:

From the product design models as discussed above, the generic steps in a product design process may be as summarized under:

1. Specify the requirements provided by the customers and generate initial design specifications
2. Generate alternative design-concepts that must satisfy the customer needs
3. Build, validate and simulate virtual model of each design concept
4. Select the best design by doing a trade off analysis. Update the customer requirements based on experience with the model
5. Build and test the prototype of the product as per product specification
6. Update the customer requirements based on experience with the prototype and develop the final design specification of the product
7. Build and test a preproduction version of the system and validate the manufacturing process
8. Update the manufacturer requirements based on experience with the production analysis

The entire product design experts agreed that for any successful product design process, gathering of customer needs, product requirement analysis, product design specification and various design reviews are very important activities, therefore, these issues are described in the following paragraphs.

2.8 Product Design Requirement Discovering and Writing Process*:*

The process of developing and specifying product requirements is often referred as "Requirements- Analysis". The requirement for any two devices or products may not be similar but there is a uniform and identifiable process for logical discovering of the requirements. Many researchers (Bahill 2006 and Grady) suggest the models to discover and write the design requirements for a product as shown in figures 2.11 and 2.12. It is designer's responsibility to work with the customer and to develop a complete "picture" of the problem and its scope. It has a number of activities and important issues as discussed in the following paragraphs:

a) *Customer needs*:

The product design must begin with a complete understanding of the customer's needs.

The necessary information required to initiate the design comes from preliminary studies and specific customer requests. Usually the customer is not aware of the details of what is needed. Design engineers have to enter the customer's environment, discover the details, and explain them. Discussion with customer's customer and the supplier's supplier can also be useful.

b) Discover the problem:

Based on the problem statement, write the product/system requirements and it is important to ask why each requirement is needed. This activity is frequently referred to as mission analysis. The terms used in the needs identification process must have the same meaning for everyone involved in the product development chain and the most common five steps-process to identify customer needs are:

1. Gather raw data from customers by conducting interviews in focus groups. Observe customer's environment/watch the use of an existing product by the customers or perform a task for which a product is intended.
2. Interpret the raw data in terms of customer needs.
3. Arrange the needs into a hierarchy of primary, secondary and (if necessary) tertiary needs.
4. Establish the relative importance of the needs.
5. Outcome should be ensured that it is consistent with the knowledge and intuition.

c) State the problem:

The design team must identify the functions that the product should meets. The product requirements can be determined by analyzing the customer needs, requirements and objectives. It includes operating environments for the product, people and measures of effectiveness. It is a key link in establishing achievable requirements that satisfy needs (Martin, J., 1996). According to the IEEE technical document on requirements, the requirements are derived from customers' expectations, project constraints, external constraints and higher level system requirements. Since requirement analysis is an important and critical step and to ensure the identification of correct requirement it should be refined till all possible measurable parameters have been defined, hence it is a parallel and iterative process as shown in figure 2.12.

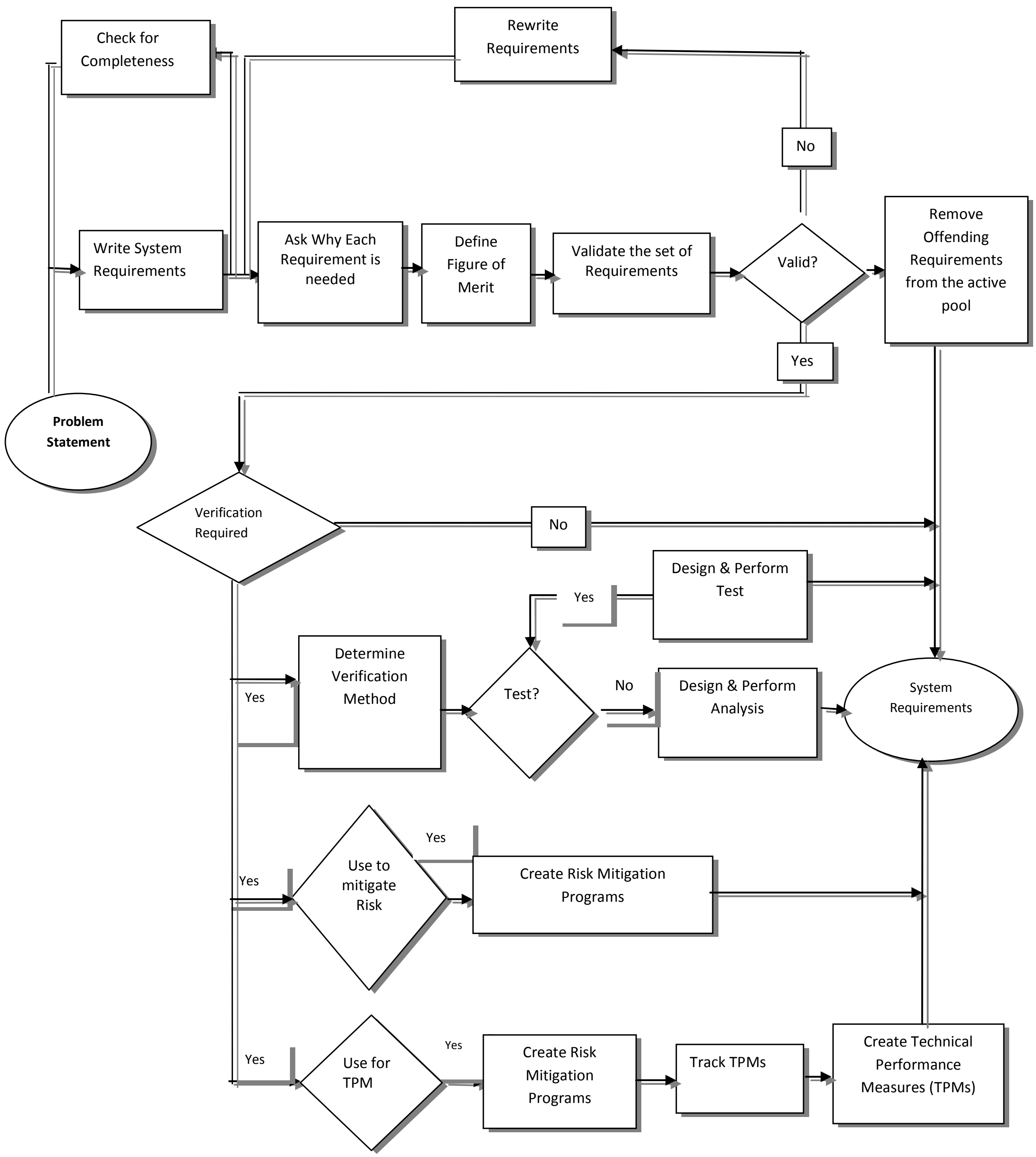


Figure 2.11: Product design requirement writing process (Bahill and Dean, 2009).

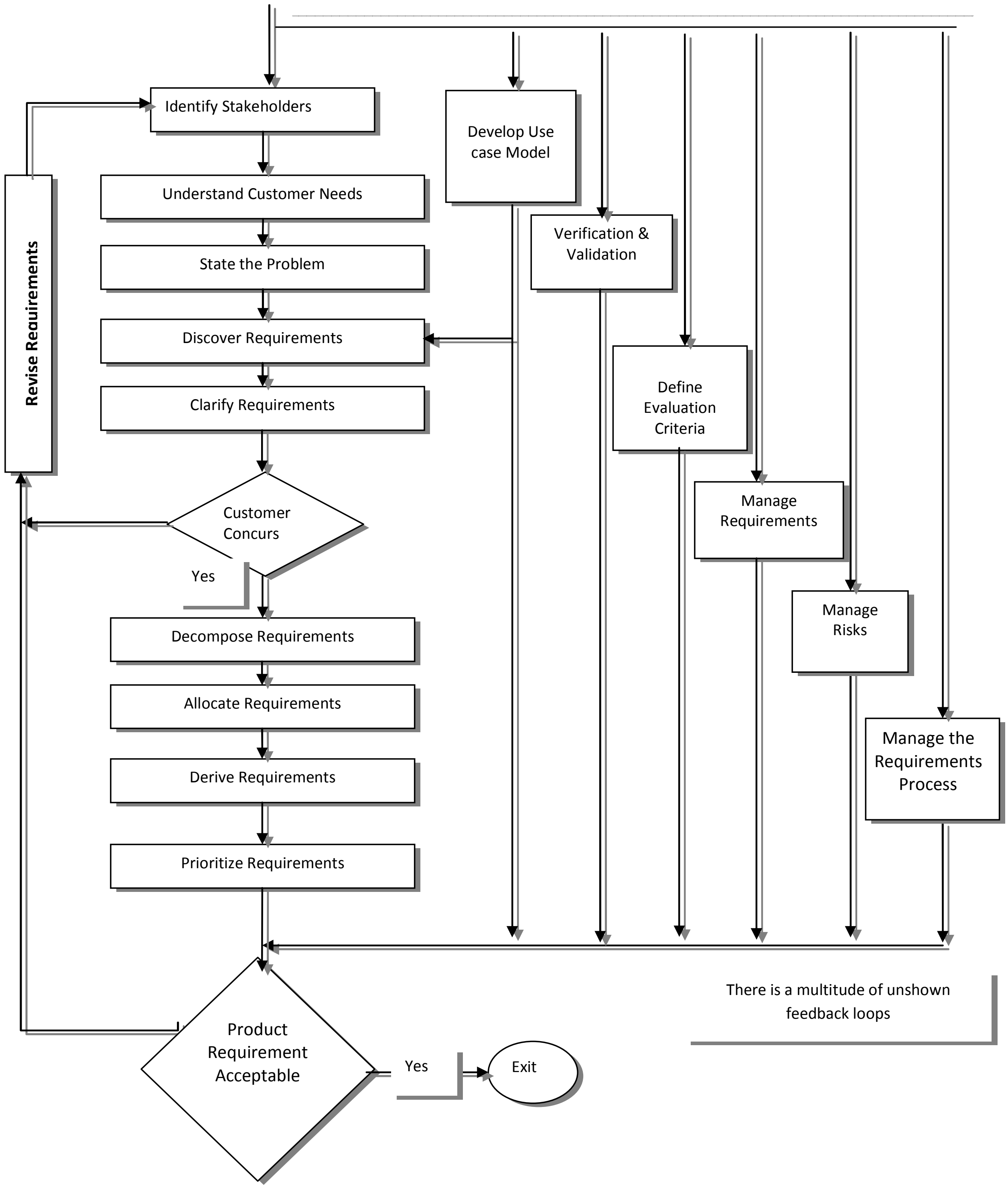


Figure 2.12: Requirements discovery process (Grady, 1995)

First product requirements should be looked then the proposed product functions. Re-examine the requirements and again re-examine the functions and the process should be iterated till a satisfactory level of solution achieved. It will help to reduce the number of requirements and find out the real needs. After filtration of needs, define the figure of merit (FOM), discuss the requirements with customer to get it validated.

d) Consultation with the customer:

Customer must be consulted to ensure that the requirements are correct and complete. The design team and the customer should identify which requirements can be used as trade-off requirements. The customer should be satisfied that if these requirements are met, then the product will do what it really needs to do. This should be done in formal reviews with the results documented and distributed to appropriate parties. All parties must agree to a way of measuring system performance to ensure that the system does what the customer wants it to do.

e) Define performance and figures of merit:

Figures of merit are the criteria on which the different designs can be "judged" the product performance. Each figure of merit must have a fully described unit of measurement such as load bearing capacity in kilograms, folded volume in m^3 and so on. The value of a figure of merit describes how effectively a preference requirement has been met.

f) Validate the product customer requirements:

Ensuring that the needs given by the customers are consistent, real world solutions that can be built and tested to satisfy the customer's needs is known as requirement validation. During the validation it should be ensured that each requirement is technically feasible and fit within budget, schedule and other constraints. If designer finds that the customer has requested a perpetual-motion machine, the project should be stopped.

g) Product design verification:

A critical element of the requirements development process is describing the tests, analysis or data that will be used to prove compliance of the final product with its requirements.

Each test must explicitly link to a specific requirement; this will help to expose un-testable requirements. The testing specifications should explain procedures and conditions of testing of the product with output values. The process frequently uncovers overlooked requirements. Verification means building the right product to ensure that the product does what it is supposed to do. It determines the correctness of an end product, compliance of the system with the customer's needs, and completeness of the system. It also guarantees the consistency of the product at the end of each phase, with itself and with the previous prototypes. It can help to identify the gap between the requirement and actual performance of the product design.

h) Specification preparation:

Specification may be called as a document that contains the mission statement, technical requirements, verification criteria, functional decomposition and interface definitions. When invoked by a contract, it is legally enforceable and contractually binding.

i) Define technical performance measures:

Technical performance measures (TPMs) or metrics are used to track the progress of the design and manufacturing process. These are the measurements that are made during the design and manufacturing process to evaluate the likelihood of satisfying the system requirements. Not all requirements have TPMs, just the most important ones. In the beginning of the design and manufacturing process, the prototypes will not meet the TPM goals. Therefore the TPM values are only required to be within a tolerance band. It is hoped that as the design and manufacturing process progresses the TPM values of the prototypes and preproduction units will come closer and closer to the goals.

2.9 Review of the Requirements:

The product requirements must be reviewed with the customer repeatedly and minimum at the end of the every phase i.e. modeling, testing and prototyping and pre production phase as shown in figure 2.13. The objective of these reviews is to find missing requirements, ensure meeting of the specified requirements and verification of customer satisfaction (Bahill, et al., 1996). Additional objectives include assessing the maturity of the development effort, recommendation to proceeding for the next phase of design and committing additional resources. These reviews should be formal and the results/ conclusions of the reviews should be documented.

a) Product requirements review (PRR):

During PRR, the product development team understands the mission and the system requirements. It confirms that the system requirements are sufficient to meet mission objectives. It ensures that the performance and cost figures of merit are realistic, and that the verification plan is adequate.

b) Preliminary design review (PDR):

It demonstrates that the preliminary design meets all the requirements with acceptable risk, tools for the product development and verification has been identified. "Work Breakdown Structure" examination is completed; therefore full-scale engineering design can begin after this review.

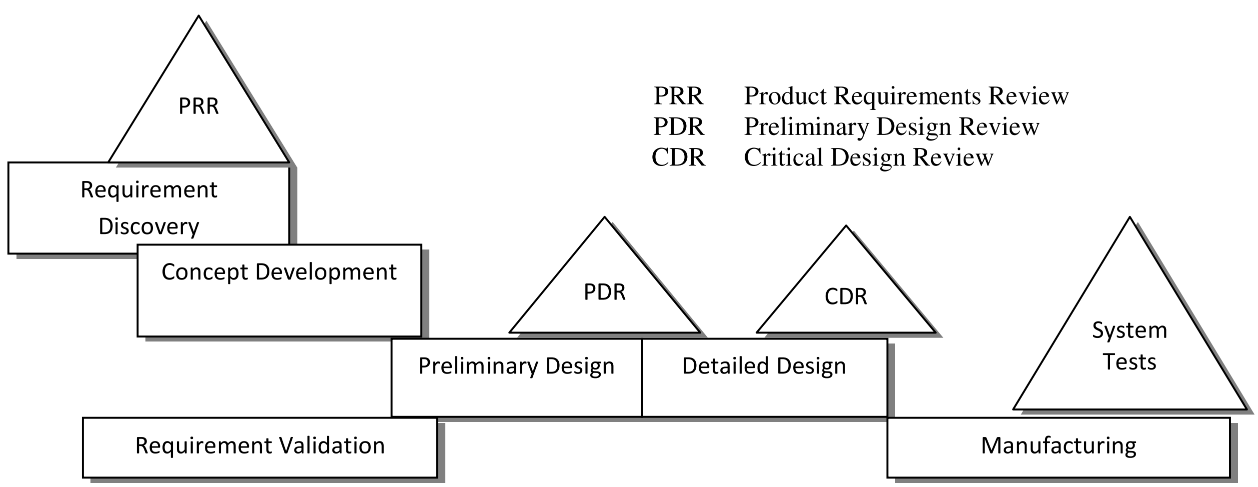


Figure 2.13: Stages and timing of major reviews (Bahill et al., 1997)

c) Critical design review (CDR):

It helps in verifying that the design is meeting the specified requirements and examines the design in full detail to ensure the resolution of the technical problems and design anomalies. It checks the “technical performance measures” and ensures that the design maturity justifies the decision of manufacturing commencement.

2.10 Characteristics of Good Requirements:

A requirement is a necessary attribute of a product to be designed. The designer cannot design the product if a magnitude is not given for each attribute. For a successful product, requirements must be quantitative and testable. Requirements should be written in terms of quantitative values and the attributes should be testable and verifiable. Necessary and sufficient conditions that product must have to meet in order to be acceptable product and expressed with shall and must. The product requirements may be divided into the following categories:

a) Mandatory requirements:

When mandatory requirements have been identified, designer should propose alternative candidate designs, all of which satisfy the mandatory requirements. Preference requirements are then evaluated to determine the “best” designs.

b) Preference requirements:

Preference requirement are the requirements those would make the customer happier and are often expressed with *should* and *want.* The requirements should be evaluated with a multi-criteria decision technique because none of the feasible alternatives is likely to optimize all the criteria, and there will be trade-offs between these requirements.

2.11 Product Design Methodologies:

Beitz (1994) states that design methodology is used for knowledge about practical steps and rules for the development and design of technical systems, based on the findings of design science and of practical experience in various applications. It includes the study of principles, practices and procedures of design. Its preliminary focus is to develop a deep and practical understanding of the design process and how this process can be modified, made more effective, transparent and can be managed to achieve sustainable design outcomes. Design methodology involves a number of considerations.

Hein (1994) defines design methodology not in itself a method but rather a body of knowledge related to methodical and systematic techniques. There are various design methodologies/principles like sequential product development, Dynamic product development, User centered product development, Concurrent product development and Integrated product development. In the dynamic product development method, Ottoson (2002) advocates for the real time feedback (immediate and qualitative information) which facilitates better control and effective guidance in design process. Basically, there is only two different methodologies/principles to design the product called as sequential engineering (SE) and concurrent engineering (CE).

Since few researchers and hand books (Vajna, 1998; INCOSE Handbook, 1998) consider slight difference in IPD and Concurrent like when CE teams are extended with experts in marketing —and eventually also extended with other people—CE is commonly called *Integrated Product Development (IPD).* Some of US companies also adopted the terminology as Integrated Product Development (IPD). The concurrent engineering was developed and practiced by U.S. Aerospace since the days of Sputnik. These three design methodologies are of interest and described in details in the following paragraphs.

2.12 Types of Product Design Methodologies:

Three types of product design methodologies are considered and described as under:

a) Sequential Engineering
b) Concurrent Engineering
c) Integrated Product Development Engineering

a) Sequential Engineering (SE):

In the *sequential engineering*, resources are focused on designing a product that will meet the customer's need. After the design and evaluation of its manufacturability, the design is evaluated for its assembling and then for supportability or maintainability. The problems induced with manufacturability or supportability is referred to the design engineers for resolution. In SE after completion of the first activity satisfactorily and with this output, next activity is initiated as shown in figure 2.14. In the SE approach the output of the first activity becomes the input for next activity and the changes pull the design-activity back to the previous design stage. In this model, efficiency and control is considered activity based rather than process based, but having low levels of risk in both incremental and breakthrough products.

The process is repeated until a satisfactory output in the form of product, results from the last activity is achieved. As per Roos (2001), in the sequential engineering, various steps from design to manufacturing are considered as an isolated problem. The limitations of the SE are that if some problems arise during product design process, it may cause redesigning of the product and this redesigning activity will increase development time and cost of the product.

Therefore, this traditional model of Sequential Engineering is not suitable for today's industrial pressures where cost, quality and time are far more demanding than ever before. Due to the globalization, delivery time and cost have now been recognized as the determining performance parameter and become critical requirement for developing new products. In the sequential engineering environment, function oriented tools are used rather than process based and generally there is no protocol for the transfer of information between the different tools employed. However the Sequential Engineering has certain advantages such as low levels of risk in both incremental and breakthrough products, as each stage are completed before hand-over to the next but time, cost and design quality are adversely affected in this model.

b) Concurrent Engineering (CE):

According to Koufteros et al., (2001), concurrent engineering is the extent to which product and process designs are generated simultaneously in the early stages of the product development process. To overcome the limitations and drawback as discussed above (paragraph 2.12-a) of Sequential Engineering, Concurrent Engineering is developed and practiced worldwide by many companies like Boeing commercial Airplane Group for Boeing 777, John Deere & Company, AT &T for electronic switching system, Mercury Computer system Inc, Hewlett- Packard, Cisco Systems, ITEK Optical Systems and Rover.

It has several benefits like fast concept to market time, higher product quality, lesser cost and greater customer satisfaction. Figure 2.15, shows the design steps in the concurrent engineering. In CE, the product design, manufacturing, assembling and maintenance processes are considered simultaneously when product is being designed. In it, there is overlapping and more interaction between the activities of a design process. It requires higher coordination through the other aspect of product development such as product definitions, organizational context and teaming. Comparison between the SE and CE approach are shown in figure 2.16.

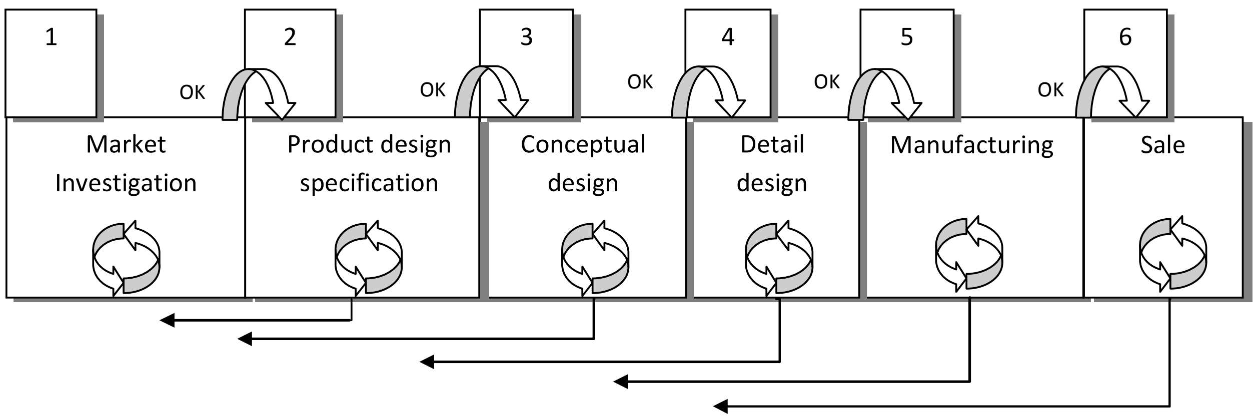


Figure 2.14: Sequential product development engineering (Hambali et al., 2009)

c) Integrated Product Design (IPD):

According to Rainey (2005), integrated product design involves marrying the technical aspects of the product with the design- related needs and expectations. It includes selecting technologies and the technical functions, and determining the product configuration based on the requirements of the entire enterprise. It examines the elements of the creative activities performed to translate the conceptual aspects into a definitive product/market form. The challenges being faced today in product design requires innovative and creative methods of product design, business and management in place of old ones. The old paradigm was based upon the theory of centrally controlled and centrally operated and most of the decisions were made at the top level. In the 21^{st} the customer should be satisfied by delivering quality products which meet their needs by integrating peoples, process, tools and technology.

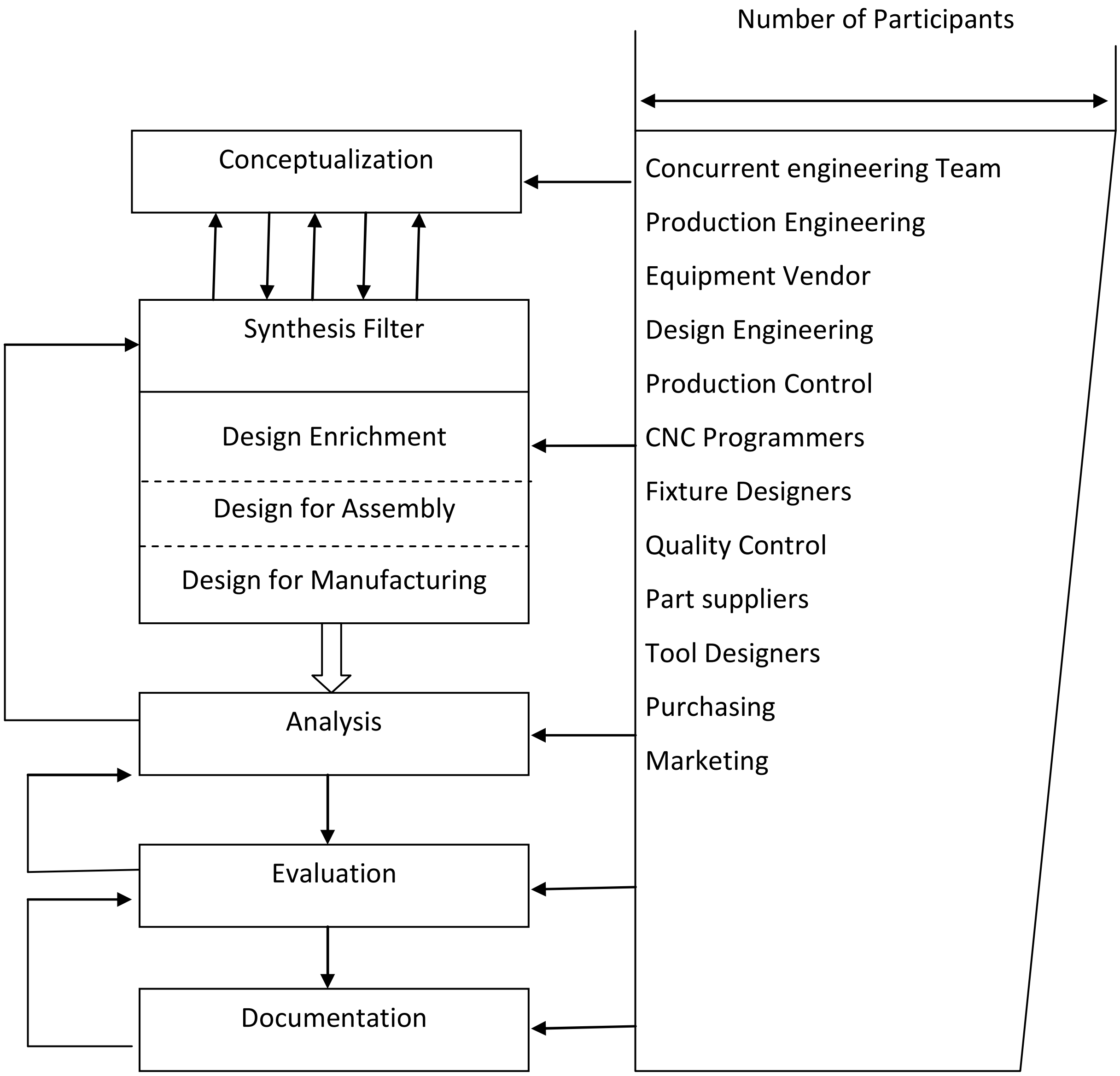


Figure 2.15: Integrated product development engineering

For a multidisciplinary product, a target oriented team and IPD approach is the key to this paradigm shift. Figure 2.17, shows the evolution of product development from era of industrialization to era of globalization and indicate the IPD is the need of the time.

Difference between CE and IPD approaches:

According to U.S. Department of Defence, CE is a systematic approach to the integrated concurrent design of product and its related processes including manufacturing and support whereas IPD implies the continuous integration of entire product team, including engineering, manufacturing, test and support throughout the product life cycle (INCOSE System Engineering Handbook, 1998).

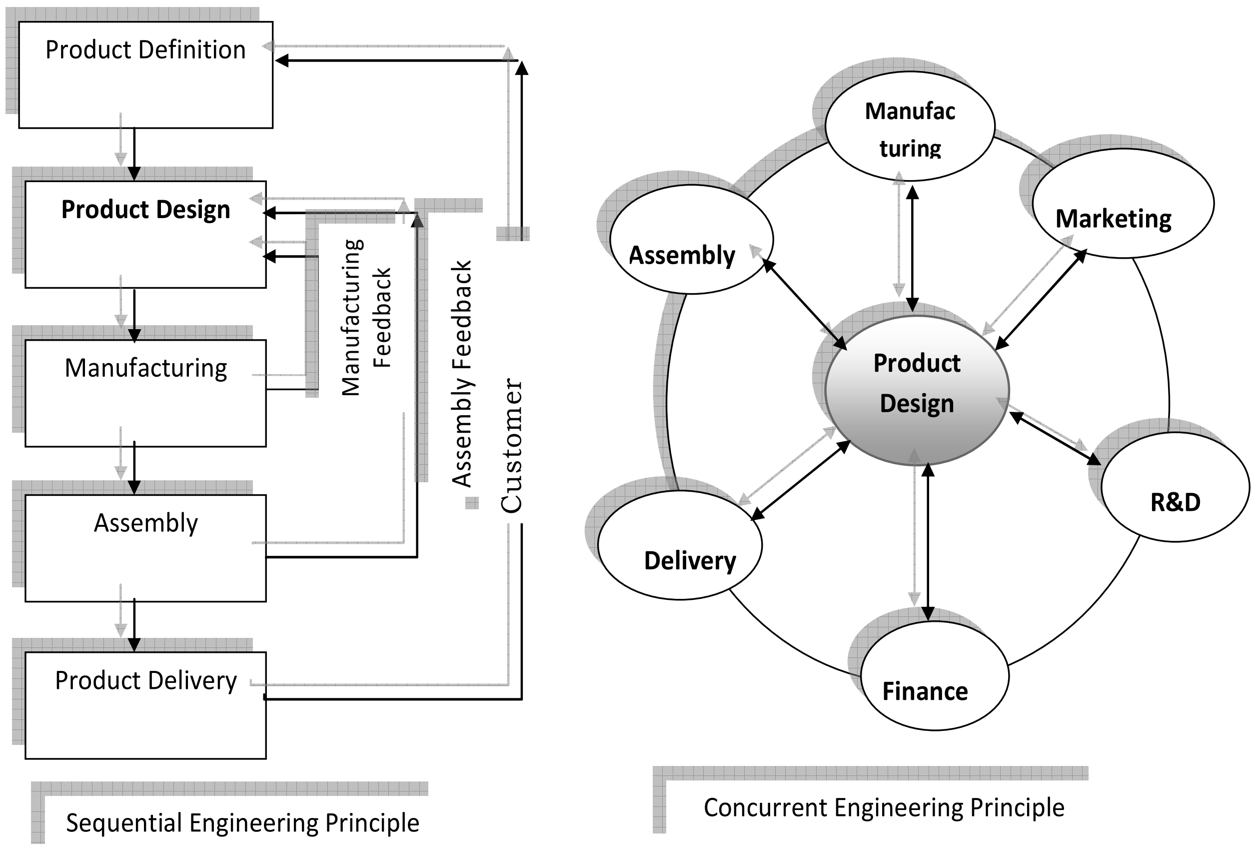


Figure 2.16: Comparison between sequential and concurrent engineering principles

2.13 Definitions, Needs and Advantages of IPD:

a) IPD definitions:

Integrated Product Development is a design methodology that incorporates a systematic approach to the early integration and concurrent application of all the disciplines that play a crucial part throughout the life cycle of a system. The various definition of IPD is given as under:

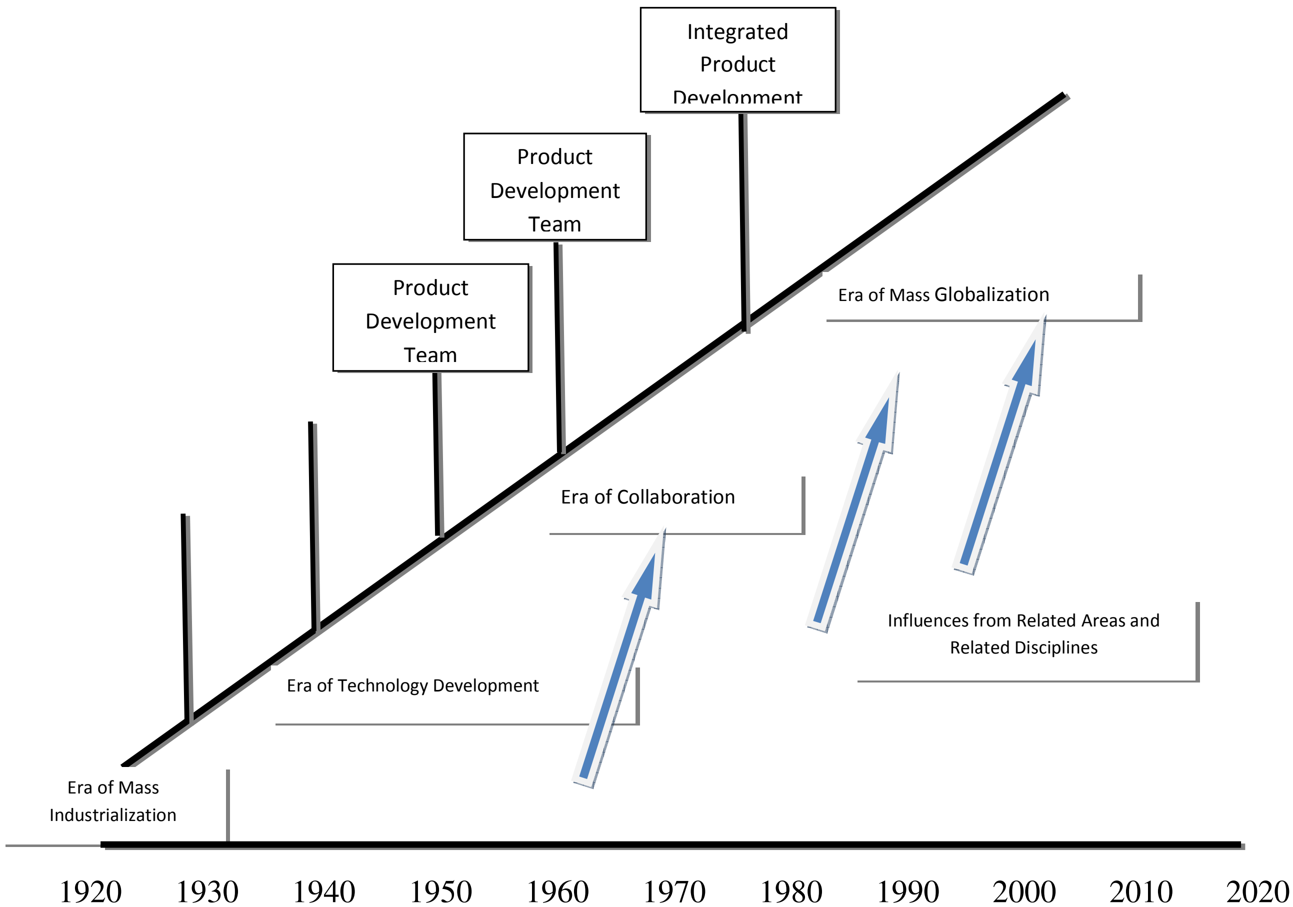


Figure 2.17: Evolution of product development from era of industrialization to era of globalization (Robert et al., 2000)

1. This process seeks to use multi-disciplinary teams to optimize the design, manufacture and support of a system through the application of quality and system engineering tools and utilizing industry best practices.

2. The definition of IPD reflects the idea of blending disciplines early in product development. Integrated product development is a holistic approach to overcome the problems that arise in product development. It is a methodology that contains methods of problem solving, organizational methods of optimizing interpersonal processes and technical methods for the direct improvement of products.

3. It is based on concurrent but goes beyond it with regard to the integration level. In the scope of integrated product development the designers, assembly planners and production planners, as well as the persons responsible for quality or testing not only consult themselves while they are working simultaneously on their tasks, but exchange interconnected intermediate results in a continuous interplay (Wagner and White, 1995).

4. The process indicates, in the broadest sense, the overlapping, interacting, and iterative nature of all the aspects of the product realization process. The method is a continuous process whereby a product's cost, performance and features, value, and time-to-market lead to a company's increased profitability and market share (Lindmann et al., 2001).

5. Integrated Product Development is the concurrent development of new products and processes using cross functional teams that are strategically aligned with the needs of customers, stakeholders, supply networks and the business enterprise (Tragg and Yuan,1998)

6. Integrated Product Development is a process where both upstream (e.g. functional requirements, styling and cosmetic features, and packaging) and downstream (e.g. Manufacturing considerations, testing and disposal) requirements of a products are handled concurrently with its geometry construction (Boyle et al., 2006).

b) Needs of IPD:

To face the present challenges, industries require new methods of product design, development, business and management in place of the old ones. The old paradigm was based upon the theory of centrally controlled and centrally executed operations and most of the decisions were made at the top. 21st Century corporate has discovered that:

i. Satisfy customers by delivering quality products which meet their needs

ii. Increase timely integrated decisions by evolving to centrally controlled and de-centrally executed operations *iii.* Change focus by integrating people, processes, tools and technology into multidiscipline product oriented teams.

c) Advantages of IPD:

Researchers (Laurent 1998 and Droge et al., 2000) found that by applying IPD, the product development time, engineering changes, rework, field failure rate and cost of quality can be reduced more than 50%, and this results in the increase of customer satisfaction which is the ultimate benefit of IPD approach. The few of the main benefits of IPD include:

1. Improved communication between the marketing, engineering and manufacturing services result in sharing the same objectives results in reducing the design time, risks and increases product quality.
2. Ease of management.
3. Clear focus on risk.
4. Enabling corporate agility by supporting coordinated, integrated management at multiple levels and functions of a corporation.
5. Distributing management of day-to-day project make the individuals responsible for the work, allowing individual members to make decisions about their own work within the top-down guidelines and constraints of the project
6. Accepting project plans in varying states of detail depending on the phase of development—one section of the project schedule may be fully detailed while a later stage may have only a few high-level activities defined—allowing teams to be adaptive and responsive to changing requirements and risks
7. Better understanding of customer needs
8. Work force happy

d) Principles of IPD:

IPD is based on the integrated design, manufacturing and support processes. The design of the product and the process must be integrated to assure an optimum approach to manufacture and support the product. According to James (1993), Robert et al. (1997)

and Happe (2001), the essential principles of integrated product design can be summarized as follows:

1. Understand the customer and their requirements
2. Integration of research, product development and process investments with an overall business strategy
3. Use Product Development Teams to facilitate early involvement
4. Designing, manufacturing and support processes should be in parallel
5. Involvement of suppliers early in the development process
6. Use of digital product models to capture and maintain a more complete and consistent representation of the design
7. Integration of CAE, CAD and CAM tools to improve effectiveness and reduce design cycle time
8. Simulation of the product performance and manufacturing processes electronically to reduce costly design/build/test iterations
9. Use of quality engineering and reliability techniques to develop a more robust product and process design
10. Create an efficient and streamlined development approach to reduce cost and design cycle time
11. Improve the design process continuously.

e) IPD tools and techniques:

In the IPD approach, all the activities in the product design and development process are integrated and run in parallel with the information and the feedback when needed. Various IPD tools are applied in the product design and development activities and contribute to reduce the time, cost and improve the product quality, durability and enhance the customer satisfaction by fulfilment of customer's needs. Tools and techniques make the process easy, accurate and quick, therefore many tools and techniques like CAD, AHP, FMEA, QFD, VA, DEM, DFA, TRIZ, benchmarking etc are developed by researchers for product-design and practice in many industries to improve the product's qualities. QFD (Quality Function Deployments) and TRIZ (Theory of Innovative problem solving technique) are the most important tools in product design and have been used in the present work and described in detail in the following paragraph.

2.14 Quality Function Deployment (QFD):

In recent years, due to high demands from customers and rapid technological advancement, product development has become very complicated, and it is very difficult to maintain initial customer requirements throughout the product development life cycle. Basically it is mandatory to control manufacturing product quality according to required product design quality. For this purpose, QFD (Quality Function Deployment) was first developed by Mizuno and Akao in the 1960s in Japan.

The seed of the QFD was rapid growth of endless new product development in Japan. People started to recognize the importance of design quality, but they did not know how to achieve it. The manufacturer were using quality control process charts but in new product development preparation of the quality control process charts at manufacturing site were not convenient.

To achieve the customer satisfaction into the product, Professor Mizuno and Akao developed quality assurance (QA) method with an aim to fix the problem before it is manufactured. In 1966, the fishbone diagram was used by Kiyotaka Oshiumi of Bridgestone Tire in Japan to identify the customer requirements and to identify the design substitute quality characteristics and process factors needed to control and measure it. At the same time, Katsuyoshi Ishihara introduced the Value Engineering principles used to describe how a product and its components work. He expanded this to describe business functions necessary to assure the quality of the design process itself.

Merged with these new ideas, QFD eventually became the comprehensive quality design system for both product and business process. The introduction of QFD to America and Europe began in 1983. Today, QFD continues to inspire strong interest around the world in the academia and industries. Countries that have held national and international QFD Symposium to this day include the U.S. Japan, Sweden, Germany, Australia, Brazil, and

Turkey. QFD has been developed over past 40 years through industrial practices and has been interpreted in different ways. According to the Cristiano (2000), QFD plays a very different role in U.S. companies versus Japanese companies, in terms of improving teambuilding and decision making in the organization.

QFD was originally defined as a step-wise procedure to systematically deploy product development processes or functions which contribute to achieve the required quality. However, many of the industrial applications of QFD focus on the first step of the deployment which maps product functional requirements voice of customers (VOC) into product structure and product components. In this case, it is called as Quality Deployment (QD).

To perform comprehensively a whole QFD process, it requires a lot of effort which gives significant positive result and such result has been recognized by many industrial applications, particularly automotive industry where it is very important to capture customer requirements in the beginning of the long range product development. The well acceptable benefits of QFD recognized by industrial applications are rational set up of required product quality, avoidance of later stage quality problems, transfer of product quality requirements to downstream processes, easy comparison with competitors' strength and weakness, accumulation of vast amount of product quality information, etc. Practical steps of QFD process may be different, depending on the types of products. Generic steps are summarized as follows:

1. Quality Deployment: Mapping of VOC into measurable product quality characteristics, product structure and then product components.
2. Technology Deployment: Mapping of product structure and components into technology items and manufacturing processes.
3. Cost Deployment: Enumeration of cost items according to technology deployment.
4. Reliability Deployment: FMEA (Failure Mode and Effect Analysis) based on the results of the previous three steps.

2.14.1 Applications of Quality Function Deployment (QFD):

Originally the QFD was developed to collect and analyze the voice of customer, to develop the higher quality products to meet the customer needs. The primary functions of QFD were product development, quality management and customer needs analysis. With the success of QFD technique, it has been widely applied in various fields like product planning, management, manufacturing, building construction and education research. But it is widely and effectively applied in product design and development process (Tragg and Yuan, 1998) and discussed as under:

Application of QFD in product design and development:

QFD can be defined as an overall concept that provides a means of translating customer requirements into the appropriate technical requirements at each stage of product development and production (i.e. marketing, planning, product-design, engineering prototype evaluation, production process development, production sales etc.). Product design and development is one of the important field in which the QFD is being applied worldwide since last many decades. The segment of products may be from automobile, mechanical, electronic e.g. digital camera design and even agriculture and food product (Zaim and Sevkli, 2002; Lin, et al., 2004), consumable like hair shampoo. QFD is a visual connective process that helps "design and development team" to focus on the needs of the customers throughout the total development cycle. It provides the means for translating customer needs into appropriate technical requirements for each stage of a product/process development life-cycle (Bouchereau and Rowlands, 2000).

According to the Chan and Wu (1998), the Quality function deployment (QFD) is ''an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production i.e. marketing strategies, planning, product design and engineering, prototype evaluation, production process development, production, sales.

Incentives of QFD include significant reduction in product development time and cost by addressing customer and engineers concerns during front end studies. It contributes in determining and prioritizing critical items where quality technology and engineering effort should be applied. It also helps in taking decision which pertains to the identification of conflicting design requirements and tradeoffs and works as a planning mechanism.

Many Japanese, American, and European companies have adopted QFD for service/product development. A recent large-scale study on global manufacturing indicates that QFD is among the ten action programs that received the most attention and the top ten programs that had the greatest pay-offs (Chan and Wu, 1998). It is clear from the study of Cristiano et al.,(2010) that one of the primary reasons companies in both the U.S. and Japan were motivated to use QFD was because there was a desire for better designs.

***2.14.2 Enhanced or four phase's quality function deployment*:**

The most widely used QFD model for product development is that developed by the American Supplier Institute named as Enhanced Quality Function Development (Cohen, 1995; Mehrjerdi 2010). It involves four linked matrices used for product specification, component specification, manufacturing process capability specification and production rules specification. Each new matrix takes information from the preceding matrix as its starting point as shown in figure 2.18.

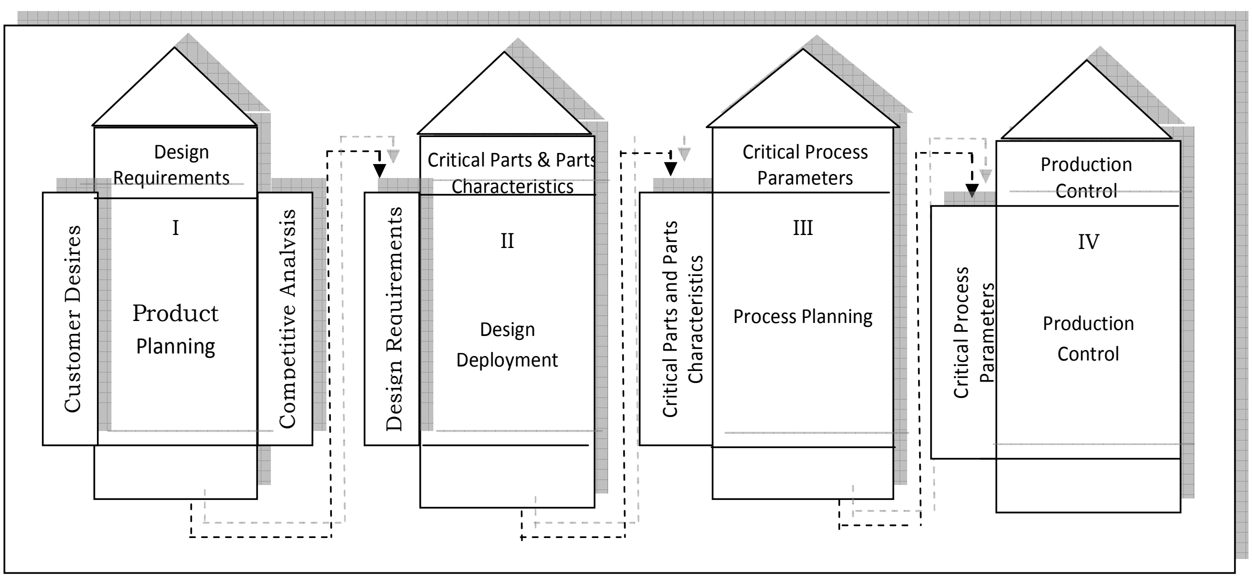


Figure 2.18: Four phases of traditional QFD (Cohen, 1995)

In this approach, the Pugh Concept Selection process is applied for selecting highest scoring concepts in the product planning and design phases. For decision making various tools techniques like benchmarking, failure mode and effect analysis (FMEA) and value engineering can be applied to fill the respective matrices of the house of quality. QFD utilizes a series of matrices, referred to as the House of Quality (HOQ), to translate the voice of the customer through product design and development. There are four phases of the process: Phase 1-Product Planning, Phase 2-Design Deployment, Phase 3-Process Planning and last but not least is the Phase 4-Production Control.

The QFD provides a direct link from phase to phase. The four key elements of each QFD are what (customer needs), how (company measures), relationship (between what and how), and how much (target value). The company measures (how) of one phase become needs (Whats) of the next phase. From the customer demand the product specifications are identified and how each specified parameter can be achieved optimally is decided by the design team and these possible means are filled in the technical specification (Hows) room. The engineering characteristics should be in measurable terms that directly affect the customer perceptions.

2.14.3 QFD structure:

The matrices in QFD fit together to form house-shaped diagram and owing to its shape it is normally known as the “house of quality". The structure of QFD is shown in figure 2.19. The QFD matrices help the design team in setting the targets which are most important in the customer point of view. It also indicates that how these targets can be achieved technically. The ranking of the competitors' products can also be performed by technical and customer benchmarking. The QFD chart is a multifunctional tool that can be used throughout the organization. It shows the customer’s voice and competitor’s strength/weakness and it can guide the designers and managers for new ideas, whereas the summary of basic data of the product can be helpful to the engineers for product design. It has eight rooms in it and each room is described as under:

1) *Customer requirements (Whats):*

The QFD starts with the customer needs /excepts/ requirements and is referred as "Whats". The customer requirements are gathered, analyzed and filled in the room named as Customer requirements (What)

2) Identify engineering characteristics (Hows):

From the customer demand the product specifications are identified and how each specified parameter can be achieved optimally is decided by the design team and these possible means are filled in the technical specification (Hows) room. The engineering characteristics should be in measurable terms that directly affect customer perceptions.

3) Relate the customer attributes to the engineering characteristics:

The best current practice is to use the digits as 9, 3, 1 and 0 in the cells of the relationship matrix to quantify the relationship between the engineering characteristic and the customer needs. (Cells that are left blank are considered as 0 or more precisely, insignificant relationship) 5, 3, 1 and 0 can be used as relationship between the engineering characteristic and the customer needs.

Many teams use graphical symbols in the cells, such as thin hollow circles, thick hollow circles and solid circles. In making calculations these have numbers, such as 9, 3, and 1, or 5, 3 and 1, assigned to them. Many experts of QFD (Besterfield et al., 2001; Lager, 2005) used the symbols for relationships, a double circle, for a strong relationship, a single circle, for a moderate relationship, and a triangle for a weak relationship and for calculation purpose the corresponding score of the above symbols may be 9, 3 and 1 correspondingly.

4) Technical competitive assessment:

To identify the market opportunity or threatening, the design team must first know where they stand relative to competitors. The strength and weakness of the competitive products are gathered and filled in the competitor's products room. This stage is also where alternatives are evaluated.

*5) Develop an interrelationship matrix between "Hows"***:**

The top triangle attached to the technical descriptor, shows interrelationships between the *Hows*. The roof correlation matrix serves to identify the qualitative correlations between the various engineering characteristics (*Hows*) and is accomplished by use of the relationships symbols. These correlations may be either positive or negative and may range from weak to strong. The symbols used for relationships, a solid circle (+9), for a strong relationship, a circle (+3), for a moderate relationship, a cross (-3) for a negative relationship and an asterisk (-9) for a strong negative relationship.

The symbols describe the direction of the correlation i.e. strong positive interrelationship would be perfectly positive correlation, and allow the QFD team to indentify that these technical descriptors supports one another. A strong negative interrelationship would be a nearly perfect negative correlation and indicates the conflicts in the technical descriptors. The conflicting technical descriptors are extremely important, because these are the results of conflicting customer requirements and required to be traded off otherwise may lead to unfulfilled of customer requirements, engineering changes and increase product cost. These trade-offs can be considered based upon company priorities, competitive strategies etc. In particular, this segment of the house of quality -enables the team involved in the process to note how one engineering change may affect other characteristics (Raper et al., 2000).

*6) Customer competitor assessment***:**

The customer competitor assessment contains an appraisal whereas organization stands relative to its major competitors in terms of each customer requirement. It is constructed by assigning ratings for each customer requirement from 1 (worst) to 5 (best).

This assessment helps the design team to assess the strength and weakness of the competitors and study the process and technology which are giving advantages to the competitors.

*7) Develop prioritized customer requirement***:**

The prioritized customer requirement is a block of columns corresponding to each customer requirement in the QFD on the right side of the competitive assessment as shown in figure

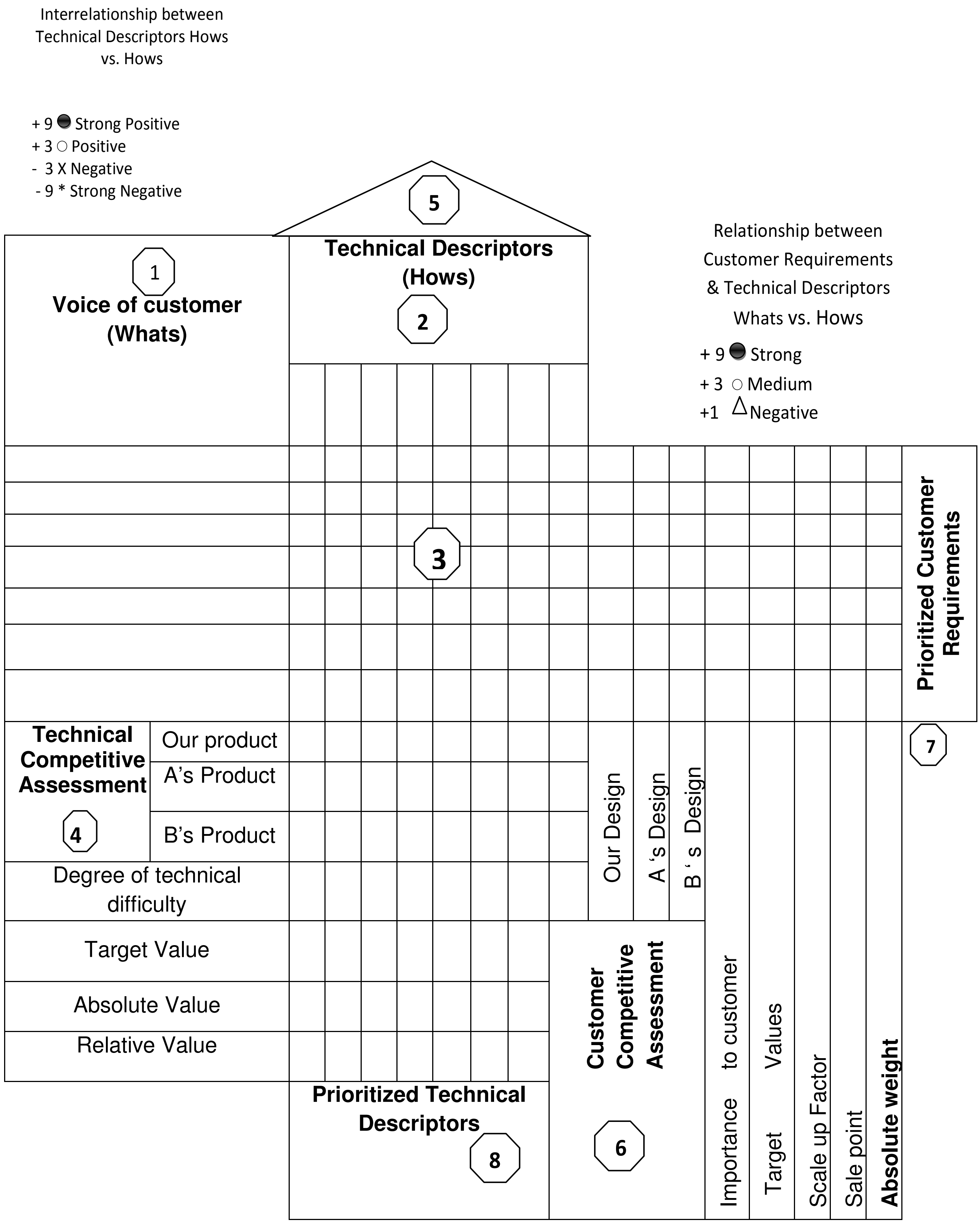


Figure 2.19: Structure of the QFD (Besterfield et. al., 2001)

2.19. It contains the column of importance to customer, target value, scale up factor, sale point and absolute weight and brief description of the each term are as under:

a) Importance to customer: The QFD team rank each customer requirement assigning a rating 1 (for least important) and 10 (most important).

b) Target value: The target value column indicates the team, where the product needs improvement with respect to the competitors, where the product is better and where at-par.

c) Scale up factor: The scale up factor is the ratio of the target value to the product rating given in the customer competitive assessment. Higher Scale up Factor indicates that more efforts are required to make the product customer oriented.

d) Sale point: The sale point is determined by identifying the customer requirement that will help in sales of the product. The customer requirements which can help to sell the product can be given higher value by the "marketing/ sales team". The sale point with higher value indicates to the designer to focus the attention on that requirement.

8) Develop prioritized technical descriptor:

The prioritized technical descriptors may contain target values, technical difficulty, Absolute weight and Relative weight. The QFD team identifies technical descriptors (engineering solutions) to meet the customer requirements. The brief descriptions of the elements of the technical descriptors are as under:

a) Target values:-This is an objective measure of the product that defines values that must be met to achieve the technical descriptor and it is indicator to meet the product specification and customer requirement. The target value can be given in terms of specification values such as max weight –kg, strength—MPa, energy consumption -watt and so on and product must be designed closer to these targeted values.

b) Technical difficulty: It is an assessment of technical capability required to meet the technical descriptor based on the technical know-how and infrastructure of the organization. It helps to evaluate and improve the required capability. The degree of technical difficulty is determined by rating each technical descriptor from 1 (least difficult) to 10 (most difficult) (Besterfield et al 2001).

c) Weighted Score: The last two rows of technical descriptor are the absolute weight and relative weight. The absolute weight of the j^{th} row for the technical descriptor can be calculated by using the equation number (2.1)

$$a_j = \sum_{i=1}^{n} R_{ij} \times C_{ij} \text{----------(2.1)}$$

Where a_j= Row vector of absolute weights for the technical descriptor (j= 1----m)

R_{ij}= weight assigned to the relationship matrix (i= 1-----n, j = 1---m)

Ci= column vector of importance to customer for the customer requirements (i= 1--n)

m= number of technical descriptor

n= number of customer requirements

2.15 Innovative and Creative Design:

To meet the user needs in the competitive era of global market the manufacturing-technology, real time information technology and specialized market strategy are playing important role. But one of the most important factor which is becoming highly significant and the key success factor is innovative and creative design methodology. “Creativity is defined as the production of new ideas that are fit for a particular business purpose” (DTI Economics, 2005).

2.15.1 *Definition of innovation*:

As per the American Heritage Dictionary, (2000), the term ‘innovation’ came from the Latin word ‘novus’, which means ‘new’ and is derived into the verb ‘in+ novare’ that covers the meaning ‘to make new’. Therefore, the word innovation stands for introducing something new’ first time. According to the study of Leonard and Barton (1999), “Innovation is the end result of a creative activity and ‘creativity’ is a process of developing and expressing novel ideas that are likely to be useful", further "innovation is the embodiment, combination and/or synthesis of knowledge in novel, relevant, valued new products, processes or services. According to Amabile and Conti, (1996) innovation can be defined as the successful implementation of creative ideas within an organization. In this view, creativity by individuals and teams is a starting point for innovation; the first is necessary but not sufficient condition for the second.

Innovation and creativity is becoming very important issue in the era of globalization and it is being a thought worldwide that it is going to be a competitive edge in future business. According to the study, conducting on global innovation index for 132 countries by confederation of Indian Industry in 2009-2010, the overall ranking of India is 56th in Global Innovation Index (GII). Table 2.2, shows the GII innovation index for few other countries and it can be concluded from the study, that higher innovation ranked countries are stronger in world level business.

Table 2.2: Ranking of India in global innovation index (GII) 2009-2010 out of 132 countries (Overall ranking)

S No	**Country**	**Rank**
1.	Iceland	1
2.	China	3
3.	Singapore	7
4.	Japan	13
5.	Korea	20
6.	India	56

There are many inputs and output indicators on which the innovation index of a country is calculated. The input indicators are human capacity (e.g. investment in education, innovation potentials and quality education institutes), general and information and communication technologies (ICT) infrastructure, business sophistication (e.g. innovation environment in firms, innovation ecosystem, and openness to foreign and domestic competition), market sophistication and institutions (e.g. political and regulatory environments, condition for business provided by govt.). The output indicators include scientific output (e.g. patents, knowledge creation, knowledge application, exports and employments) Creative output and well being. Table 2.3; show the ranking of India at global level based on various innovation indicators.

2.15.2 ***Needs of innovation:***

The knowledge in all its forms plays a crucial role in economic growth of any country, organization and firm. Individuals, firms or nations with more knowledge have better economic position. It is observed that innovation plays a central role within the knowledge-based economy. According to the OSLO Manual, at the macro-level, there is evidence that innovation is the dominant factor in national economic growth and international patterns of trade.

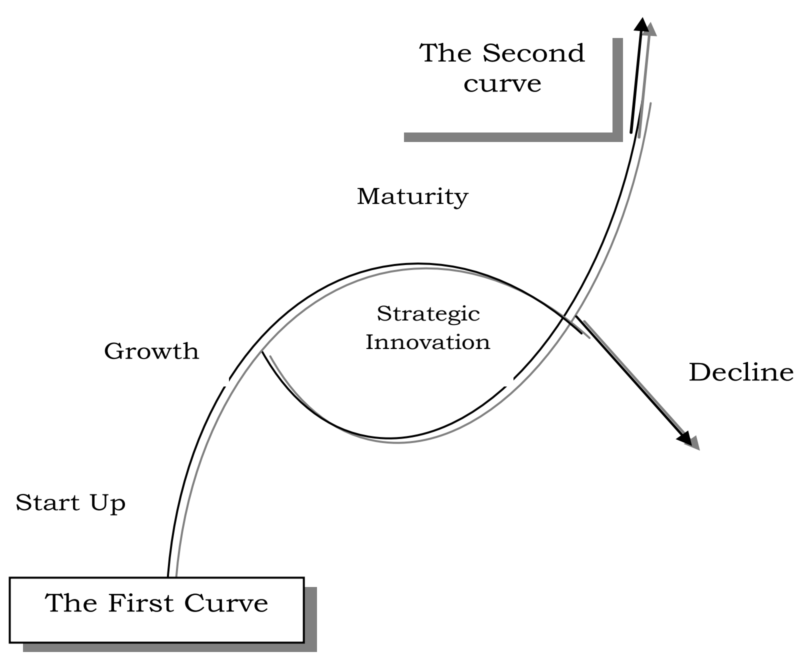


Figure 2.20: Model of innovation (Kuhn and Marsick, 2005)

Economic objectives include replacement of phase out products and extend product range within and outside the main product field of the firm and innovation model suggests that at maturity level of product sale innovation is required to the firm for sustainability and growth as shown in figure 2.20.The innovation can help in improving product quality, reducing product cost by cutting material, energy and reducing production lead time.

Table 2.3: Various indicators of innovations and ranking of India 2009-2010 at global level based on GII Report

Innovation Indicators	**Rank**
Scientific Output	70
Creative output and Well being	78
Business Sophistication	41
Market Sophistication	32
ICT and Uptakes of Infrastructure	108
Human capacity	38
Institutions	73

2.15.3 ***Types and sources of innovation:***

There are two types of innovation named as technological and business innovation. Technological innovation can be sub-categorized as radical and incremental in the product and process innovation. Business innovation based on the first introduction of the innovation to the firm, national and international market. Sources of innovation may be internal and external. Internal sources include in-house research and development, local market, whereas external sources may be competitors, customers, consultancy firms, patents professional conferences, international trade fairs, exhibitions, pertaining journals, government academic and research institutes and according to Bogers, (2010) users are the important source of innovation (intermediate and end users). In traditional innovation models, the needed information is generated on the user site, while the solution information resides with the producer who used to search for information on user needs to incorporate this into the new or existing products development.

2.15.4 Innovation management techniques:

As per Hidalgo and Albovs, (2008) innovation does not always mean employing the very latest cutting-edge technology. On the contrary, it is less a question of technology and more a way of thinking and finding creative solutions within the company. In this context, innovation management techniques (IMTs) can be seen as a range of tools, techniques and methodologies that help companies to adapt to circumstances and meet market challenges in a systematic way. Few important techniques are named here:

a) Creativity Development Techniques: Brainstorming, Lateral Thinking, Camper Method, Mind Mapping and TRIZ
b) Process Improvement Techniques: Benchmarking, Workflow, Business-Process Re-engineering and Just in Time.
c) Design Management Tools: CAD Systems, Rapid Prototyping, Usability Approaches, and Value Analysis
d) Interface Management Approaches: Concurrent Engineering, Marketing Interface Management.
e) Market Intelligence Techniques: Technology Watch, Patents Analysis, Business-Intelligence, Customer Relationship Management and so on.

2.15.5 Degree of novelty of innovation:

The degree of novelty of the innovation can be defined using a number of technical variables, or in terms of technical variable, product innovation. The brief descriptions of these terms are given as under:

1) Technical variables based novelty/innovativeness:

It is very important type of innovation since it is the result of research and development in the field of product design by using new functions, *new materials* and/or *manufacturing process*. According to the OSLO Manual the degree of novelty of innovation pertaining to the product and process includes; use of new materials; use of new intermediate products; new functional parts; use of radically new technology and fundamental new functions (fundamental new products). For the process innovation; the points may be new production techniques and new organizational features (introduction of new technologies).

2) Product innovation:

Product innovation is the introduction of a product or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components, materials, incorporated software, user friendliness or other functional characteristics. There may be various forces for product innovation but the main forces are market and technological as shown in figure 2.21. The product may be radical or incremental innovative and their characteristics are described in following paragraphs.

a) Radical vs. incremental based product innovations:

A technologically new product or radical innovative product is a product whose technological characteristics or intended uses differ significantly from those of previously produced products. Such innovations can be based on combining existing technologies in new uses or can be derived from the use of new knowledge. Example of the technologically new product may include 1st microprocessors and video cassette recorders, using radically new technologies since as the product had not existed before.

b) Newness based product innovations:

The product novelty/innovativeness based on whether it is new to the customer, new to the firm, new to the industry in the country or to the operating market of the firm; and new to the world. The newness of a product can be measured by the first time improvement in the product design.

2.15.6 Innovation indicators:

Many Researchers (Rejean et al. 2008; Cordero, 1991; Gray and Eunsang, 1989) have discussed various indicators to evaluate the innovations for a country/ organization. The indicators include number of patents, budget for R&D, number of employees in the firm and number of creative or high technological institutes. Table 2.3 shows few of them and ranking of India, but there is lack of methods and innovation indicators to measure degree of newness of the design concepts. Garcia and Calantone, (2002) discuss the business and business skill newness. Blair Kingsland (2007) suggests the method for calculating the "Innovation Value Index" and Mark and Martin (2010) discuss about the degree of novelty of an enterprise.
From the new product and new service development projects in many companies, Griffin and Hauser's (1993) showed that the levels of changes or improvements of product can be measured relative to its predecessor product and considered as product newness.

The various innovation indicators such as technology novelty, project complexity, technical functionality (product unit-cost and time-to-market and quality) of the product are estimated in the beginning of the project and after completion of project. The improvements in the levels of indicators are measure as degree of novelties. Griffin, (1997) suggests that product complexity is measured by the number of product functions embodied in the product (e.g. a shampoo with conditioner has *two* functions).

Tatikonda and Stephen, (2000) state that firms have low objectives novelty, when they are accustomed to facing similar project objectives across a series of product development projects. For example some defense firms have great experience in developing high technical performance, high unit-cost products. As these firms shift to different (e.g., consumer) markets, they must now aim to achieve lower unit-cost objectives for their products. Hence, the low unit-cost objective is highly novel to the firm.

2.15.7 Degree of newness of the innovation:

Innovativeness is most frequently used as a measure of the degree of newness of an innovation. Garcia and Calantone, (2002) discuss various types of newness. They also suggest the types of discontinuity and related type of innovation as depicted in table 2.4. But when the firm changes its objectives first time, is a case of *high* objectives novelty. Spectrum of newness as per BS 7000-1:1999 are categorized based on business, product technology and management skill and shown in figure 2.22. Justel et al., (2007) discussed the evaluation and selection of the innovative product concepts but the degree of novelty of the product concepts is decided by the design team which is not discussed and may be subjective.

Table 2.4: Discontinuities and innovation types (Justel et al., 2007)

Discontinuities				**Innovation Type**		
Macro marketing Discontinuing	Macro Technology Discontinuing	Micro marketing Discontinuing	Micro Technology Discontinuing	Radical Innovation	Really New Innovation	Incremental Innovation
1	1	1	1	1	0	0
1	0	1	0	0	1	0
0	1	0	1	0	1	0
1	0	1	1	0	1	0
0	1	1	1	0	1	0
0	0	1	1	0	0	1
0	0	1	0	0	0	1
0	0	0	1	0	0	1

There is a lot of literature and studies on the measurement of innovation at national and Organization level but hardly any to measure the degree of novelty of the product concept which is very important to an efficient front end study of the product development activity

2.16 Degree of Novelty of a Design Concept:

According to the Griffin, (1997) the degree of novelty of the product concept is the improvement in the targeted parameters relative to the existing product or new product development; it can be measured as the difference between the initial set targets and achieved targets in respect of customers and organizational aspects.

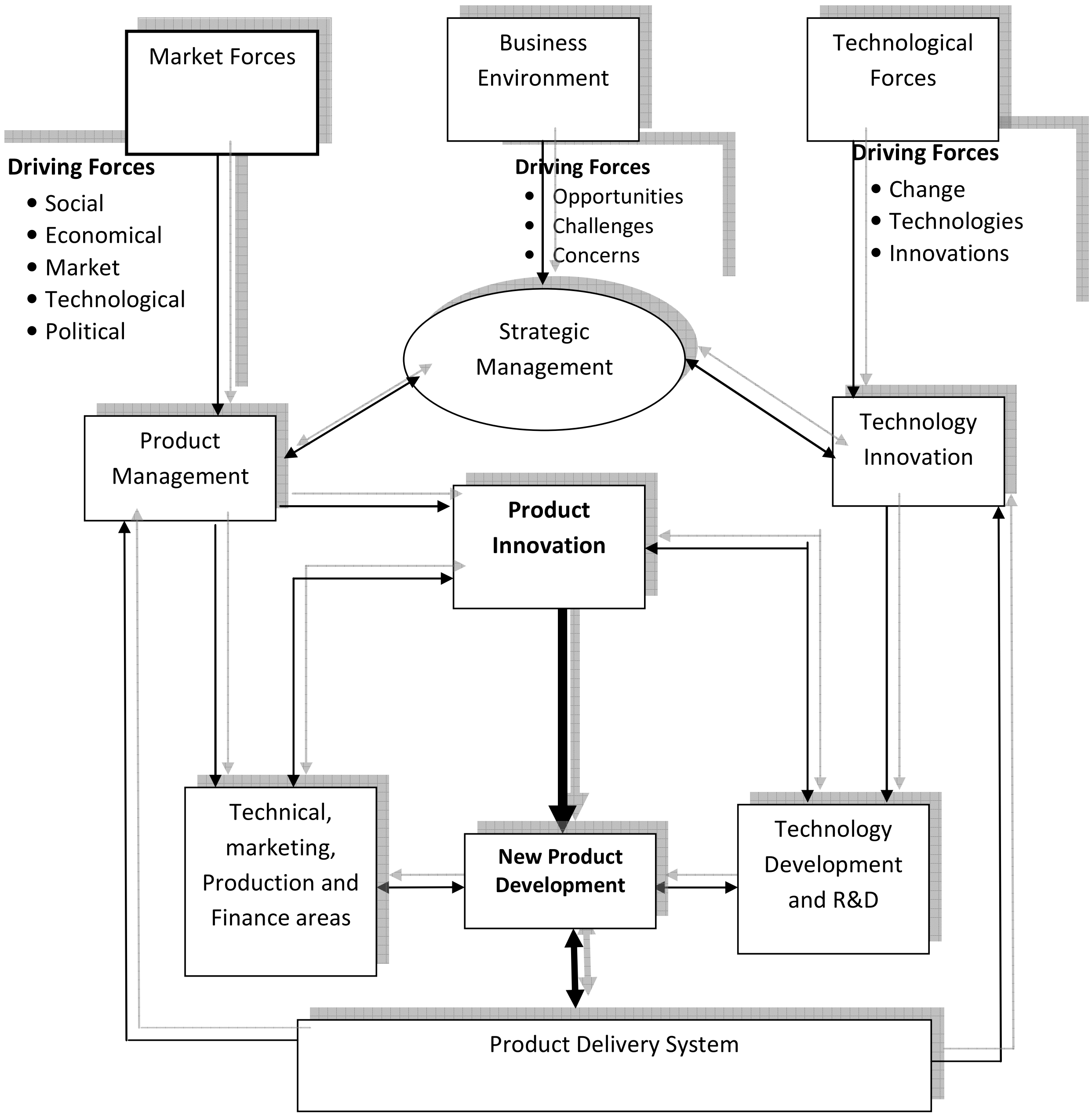


Figure 2.21: Simplified model of the primary elements of product innovation (Rainey, 2005)

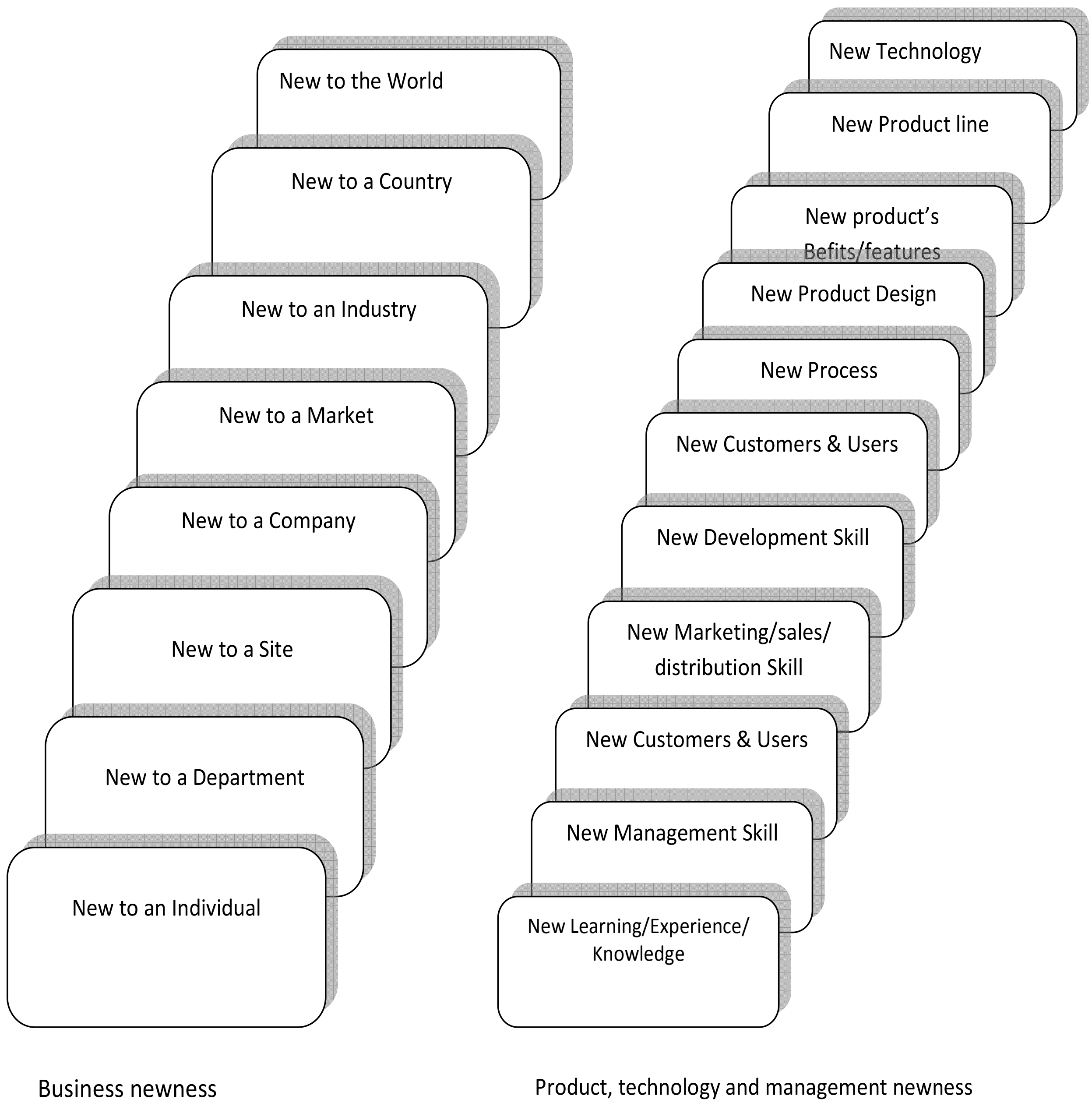


Figure 2.22: Spectrum of newness for business, product, technology and management (BS 7000)

The innovative product concepts should be evaluated based on product objectives/requirements, the product objectives include the parameters such as product performance, product unit-cost and product time-to-market. Product performance includes the technical functionality, quality, and reliability of the product. The properties of the new or changed product or service and the origin of the new or changed product/service and the degree of complexity distinguished are given as:

a) *High degree of innovation:* If the newly developed product consisting of a larger number of parts and components, often coming from different disciplines (e.g. a weather satellite or an aero plane)
b) *Medium degree of innovation:* If the developed unit is consisting of a smaller number of parts and components (e.g. a laser printer, a textiles machine)
c) *Low degree of innovation: A* single innovation e.g. an improved brake for a bike, can fall in this category

2.17 Innovative and Creative Design Techniques TRIZ:

TRIZ (Teorija Reshenija Izobretatelskikh Zadach), the theory of inventive problem solving approach can increase the ability of a person to generate creative design solutions. The tougher market competition can be faced by the industries due to increasing rate of innovation and creativity in the products design and development. TRIZ consists of comprehensive collection of techniques and forty guiding principles. The five guiding principles for creativity in TRIZ are:

a) Contradiction
b) Functionality
c) Ideality
d) Resources
e) Space, time and Interface

a) Contradiction:

When two different parameters are in conflict with each other, it results in occurring of a technical contradiction. It was observed by the TRIZ researcher that with trade off method approach usually conventional solutions are found but by resolving contradiction innovative solutions can be found. In TRIZ, there is a systematic method to identify the contradiction and ways to resolve them. The technique used for this purpose is contradiction matrix.

b) Functionality:

Every system exists to perform useful function. Harmful functions are also generated by the system components and further the component which does not contribute the useful function is considered as harmful. Contradiction happens when harmful functions appear with the useful functions.

c) Ideality:

The ideality of a system is defined as its sum of useful functions over the sum of harmful functions. Concept of ideality helps the designer the direction for improving the system and helps for out of the box thinking solutions.

d) Resources:

Identification and utilization of anything that is available in and around the system to deliver the function to counter a harmful function or to resolve a contradiction. With this way the designer becomes more creative while identifying improvement ideas.

e) Space time and interface:

Importance of thinking about a problem and identifying the solution from all angles is emphasized in TRIZ approach. The generic steps used in problem solving are:

- Analyze the problem and identify opportunities for improvements
- Generate idea for solutions
- Evaluate ideas and develop solution concept

***2.17.1Contradiction matrix and inventive principles*:**

A technical contradiction is a situation in which efforts to improve some technical parameters of a system result in deterioration of other technical parameters like a structure while becoming sturdy becomes heavier. Altshuller the founder of TRIZ analyzed more than 40,000 patents and identified 1250 types of contradictions.

These contradictions are grouped into a matrix of 39x39 engineering parameters. The forty inventive principles were compiled to resolve these contradictions. However these 40 principles provide most promising directions for searching the ideas to overcome the contradictions, not the direct solutions. Figure 2.23 shows a small portion of such matrix.

2.17.2 Benefits of TRIZ:

1. Better and more innovative solutions
2. Save money and time by reducing trial and error solutions.
3. It is based on science instead of psychology
4. Repeatable problem solving process, based on fixed algorithm
5. Allows deriving knowledge from other fields
6. Allows finding markets to your solutions outside traditional fields
7. TRIZ attempts to circumvent the many mediocre solutions to problems and get directly to the best solution faster
8. Bring the ratio of attempted innovation and innovation made closer to 100%

Conclusion:

Product design is a very scientific process and it can be engineered as per the customer needs. To develop a successful and customer oriented products, a design model plays an important role as it helps the designer to perform all the required design activities in a systematic manner and eliminating even the small design errors, since these small errors occurring at various stages get collected and may cause failure of design. The application of the product design tools and techniques used to apply for the design activities can enhance the effectiveness and efficiency of the design process and lead to a competitive product. The application of the suitable product design approach can result in saving of time and cost with higher quality, profit and customer satisfaction. Therefore in the research work the proposed IPD approach with the tools like CAD, benchmarking, QFD and TRIZ were studied in this chapter. The innovation and creativity is becoming more and more necessary in product design in the present era of global marketing. As per the literature, product design innovation means the improvement in the new product w.r.t. the previous one.

	A	B	F	G	H	I	J	K
1		Worsening Feature → Improving Feature ↓	Length of stationary object	Area of moving object	Area of stationary object	Volume of moving object	Volume of stationary object	Speed
2			4	5	6	7	8	9
3	1	Weight of moving object	-	29, 17, 38, 34	-	29, 2, 40, 28	-	2, 8, 15, 38
4	2	Weight of stationary object	10, 1, 29, 35	-	35, 30, 13, 2	-	5, 35, 14, 2	-
5	3	Length of moving object	-	15, 17, 4	-	7, 17, 4, 35	-	13, 4, 8
6	4	Length of stationary object	+	-	17, 7, 10, 40	-	35, 8, 2,14	-
7	5	Area of moving object	-	+	-	7, 14, 17, 4		29, 30, 4, 34

Figure 2.23: TRIZ contradiction matrix

Therefore in this chapter various related issues like product innovativeness, innovation indicators, types of innovations and details of Innovative and Creative Design Techniques TRIZ and its benefits have been discussed.

CHAPTER 3

STRETCHER DESIGNS REVIEW

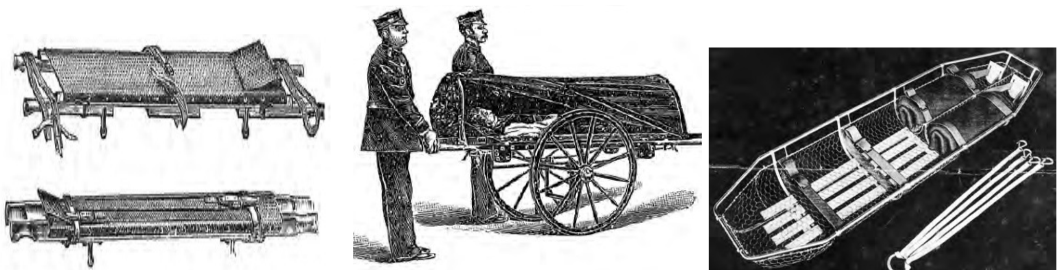
Introduction

To transfer the knowledge of existing products design to new product to be developed, literature study is very important and essential because it not only gives design concepts but also gives an insight of their advantages, limitations and enlightens the designer's thinking towards innovative concepts generation. The development time, cost and resources can be saved by reviewing the related literature and product at initial design stages.

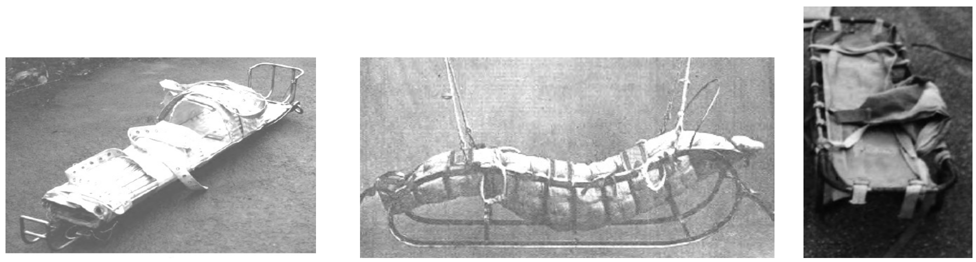
3.1 History of the Stretcher:

In 1899, Sir John Furley supported the design of the Furley stretcher and the Ashford litter which was a basic stretcher with canvas cover and wheels. It came in use during 1st World war. The Furley stretcher was established as foundation for the development of the stretcher. In 1905, Charles Stokes invented the Stroke stretcher and got it patented in 1906 and it could be used as a stretcher and splint. In 1906, Neil Roberson the fleet surgeon developed a stretcher (Neil Roberson stretcher) evolved to overcome the problems specific of confined space rescue and it gave good services during the 1st and 2nd world war and still in use. In 1914, Kirker developed the "Kirker Ambulance Sleigh" Specially adapted for use on board ships for mines injury persons. Dr Donald Gordon Duff developed the Duff stretcher during the 1950s and 1960 and few were taken on the British Everest expatiation in 1953. Then in 1961 the Perche- Piguillem stretcher came into existence and it was adapted for winch rescue. In 1967 peter Bell developed the hood style head cages as per Thomas stretcher's dimensions.

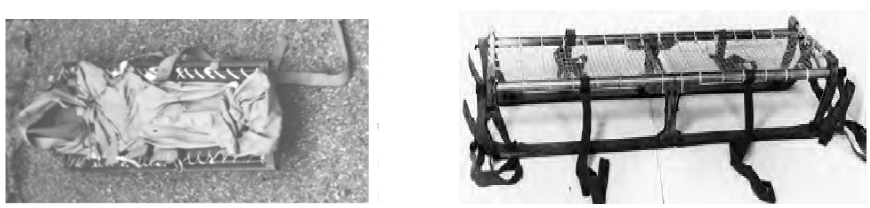
There were various version of Bell stretcher e.g. Mark 1 to 3 and made from stainless steel tubes and fitted with folding handles were introduced in the year of 1972. There was an introduction of Superlite, the one piece aluminum stretcher provided with 70 mm runner and four leg lift harness in 1979. Afterward in 1995 Peter Bell constructed new Thomas style stretcher. Figures (3.1 a – 3.1j) show the various designs of the stretcher.



a) The Furley stretcher and Ashford litter b) Stroke stretcher



c) Neil Roberson stretcher d) Kirker Ambulance Sleigh e) Duff Stretcher



f) Perche Piguillem Stretcher g) Peter Bell stretcher

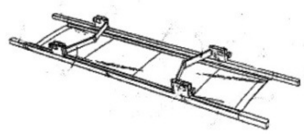
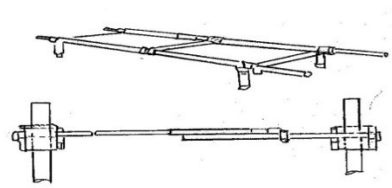
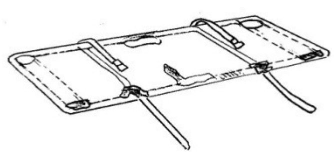
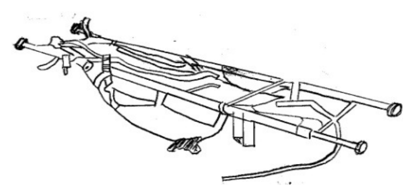
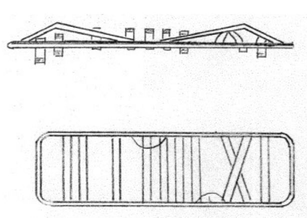
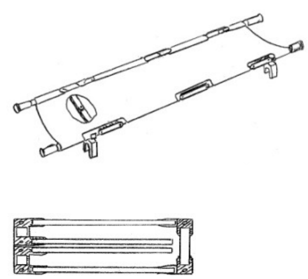
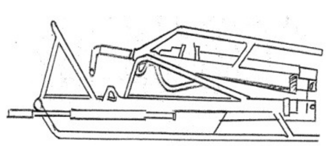
h) Bell -Mark1 Bell-Mark2 Bell- Mark-3stretchers i)Superlite stretcher j)Thomas stretcher

Figure 3.1: Various designs of the stretcher

3.2 Stretcher Designs Review:

The stretcher is being used since early 19th century by mountaineers besides the military application. John Niles Robertson developed a stretcher in year 1906 and many designs were followed (Frontier Medical 2010).There are many companies worldwide which are manufacturing the stretcher. Designs of the stretcher depend upon many factors such as nature of casualty, evacuation methods, climate/terrains and mode of transport.

Table 3.1: Summary of patented stretcher designs

Single Fold Stretcher Design		**Multi Fold Stretcher Design**	
1) Single Lateral Fold Stretcher		1) Collapsible Stretcher	
2) U-Shaped Frame Foldable Stretcher		2) Collapsible Stretcher	
3) Battens Stretcher		3) Compact Foldable stretcher	
4) Floating Stretcher			

Therefore an effort is made to study the various designs of the stretcher to understand the frame design, folding mechanism, stretcher lifting mechanisms, material and various dimensions in addition to their advantages and limitations. The product review is divided mainly into two categories as under:

3.2.1 Patented stretcher designs

3.2.2 Commercially available Stretchers

3.2.1 *Patented stretcher designs*:

Since long back (1899) the efforts were given to design the stretchers and filing their patents and also got patented. Few of the patented designs as shown in table 3.1, were selected to study their advantages and limitations. The foldable stretcher can be divided into two main categories as single fold and double fold stretchers.

3.2.1.1 Single fold stretcher designs:

Single fold stretchers or normal stretchers are the simplest type of the stretcher. They are made of two poles with a cloth stretched between the poles. These can be folded either in lateral or longitudinal direction and the description of few designs of single fold stretcher is given as under:

1) *Single lateral fold stretcher*:

The single fold Stretcher design comprises two longitudinal profiles (3- Main beam) between which a stretcher sheet/fabric (2- fabric) is stretched, main beam being provided with brackets (5-runner) between which spreader bar (4- spreader bars sub assembly) are provided for transversal stiffening), the runners being provided with through openings (7, 8) for insertion of leg and support members securable by the aid of clamping screws.

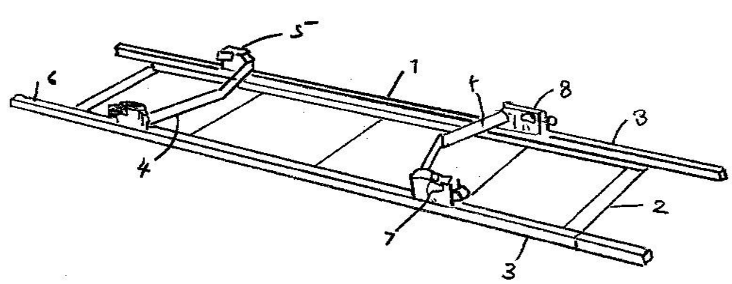


Figure 3.2: Single lateral fold stretcher

The self weight of the normal Stretcher is around 14 kg and folded length is approximately 1.2 meter. One such Stretcher is shown in figure 3.2

2) *U-Shaped frame foldable stretcher :*

This design of foldable stretcher includes a pair of U-shaped frame members hinged and connected together to permit folding of the stretcher as shown in figure 3.3.

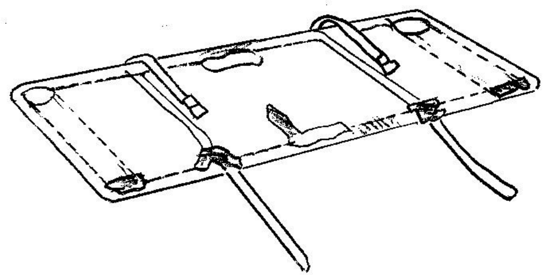
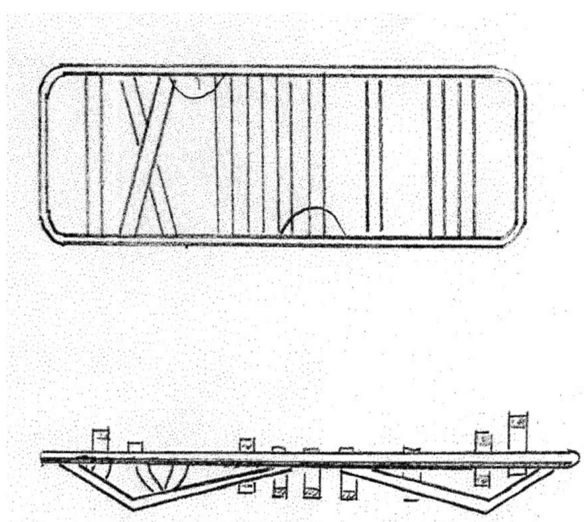


Figure 3.3: U-Shaped frame foldable stretcher

A flexible support panel is secured to the U-shaped frame sections and is provided with recesses or cutouts adjacent the corners and hinge connections of the stretcher to facilitate carrying thereof.

3) Battens stretcher:

The *Battens* stretcher comprises a frame having side members (main beams) supported above ground level, as by legs, and flexible battens each having a series of holes at one end so that a batten may be slid under a body without disturbing the posture and one of the holes engaged with a spigot on one side member.



ERROR: stackunderflow
OFFENDING COMMAND: ~

STACK:

Appendix "A"

Paper Publications, Patents and Transfer of Technology

A. Paper Publications:

1. Evaluation and Selection Methodology for an Innovative Product Design Concepts. *International Journal of Engineering Science and Technology (IJEST) ISSN : 0975-5462 Vol. 3 No. 4 Apr 2011 pp3553 - 3561*

2. Design and Selection of Hinge Joint Concepts for Casualty Evacuation Backpack Stretcher Using IPD Tools like QFD. *International Journal of Engineering Science and Technology (IJEST) Vol. 4 No1, 200-222 ISSN : 0975-5462*

B. Design Registration and patent of Light Weight Foldable Stretcher:

1. Design Registration vide Certificate No202863 dated 20 Jan 2006
2. Patent application accepted vide no1616/DEL/2006

C. Transfer of Technology of the LWF Stretcher:

1. M/s, Artificial Limbs Manufacturing Corporation, (Govt. of India Undertaking), Kanpur.
2. M/s Anjani Technoplast Ltd Noida.

D. Design Registration and patent of Army Field Cot (Stretcher cum Bed):

1. Certificate of Registration of Design vide No219428 dated 23 Oct 2008
2. Patent application accepted vide no 953/DEL/2008

E. Transfer of Technology of Stretcher cum Bed:

M/s Yorco Sale P Ltd Delhi

Central Asia (CE) certification

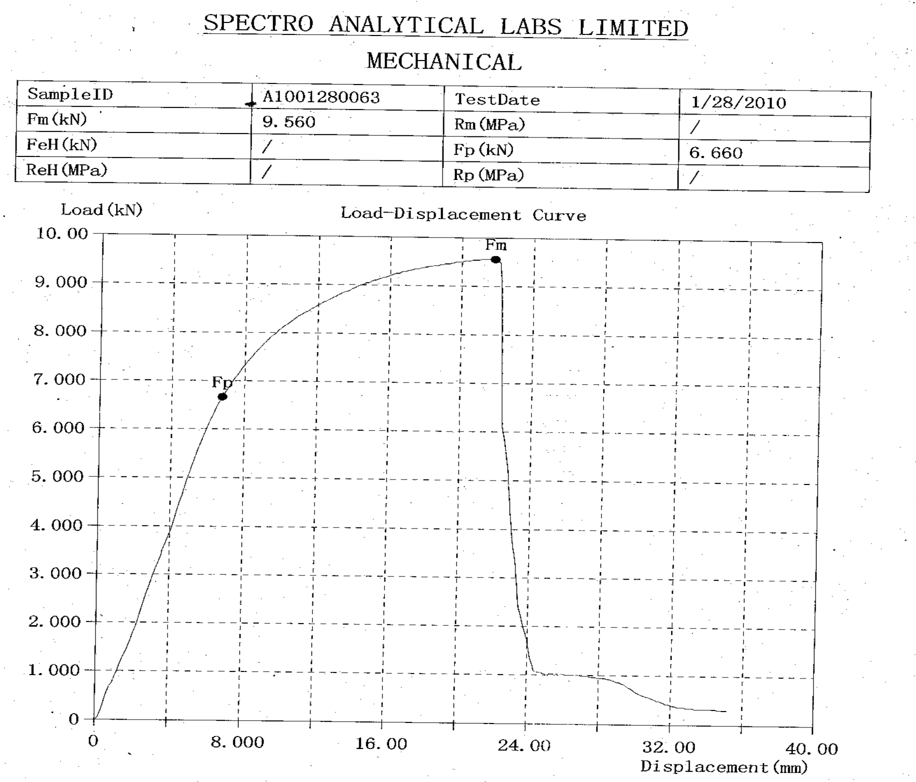
Feature to Improve \ Undesired Result (Conflict)		1 Weight of moving object	2 Weight of stationary object	3 Length of moving object	4 Length of stationary object	5 Area of moving object	6 Area of stationary object	7 Volume of moving object	8 Volume of stationary object	9 Speed	10 Force	11 Tension, pressure	12 Shape	13 Stability of object
1	Weight of moving object			15, 8, 29, 34		29, 17, 38, 34		29, 2, 40, 28		2, 8, 15, 38	8, 10, 18, 37	10, 36, 37, 40	10, 14, 35, 40	1, 35, 19, 39
2	Weight of stationary object				10, 1, 29, 35		35, 30, 13, 2		5, 35, 14, 2		8, 10, 19, 35	13, 29, 10, 18	13, 10, 29, 14	26, 39, 1, 40
3	Length of moving object	8, 15, 29, 34				15, 17, 4		7, 17, 4, 35		13, 4, 8	17, 10, 4	1, 8, 35	1, 8, 10, 29	1, 8, 15, 34
4	Length of stationary object		35, 28, 40, 29				17, 7, 10, 40		35, 8, 2, 14		28, 10	1, 14, 35	13, 14, 15, 7	39, 37, 35
14	Strength	1, 8, 40, 15	40, 26, 27, 1	1, 15, 8, 35	15, 14, 28, 26	3, 34, 40, 29	9, 40, 28	10, 15, 14, 7	9, 14, 17, 15	8, 13, 26, 14	10, 18, 3, 14	10, 3, 18, 40	10, 30, 35, 40	13, 17, 35
15	Durability of moving object	19, 5, 34, 31		2, 19, 9		3, 17, 19		10, 2, 19, 30		3, 35, 5	19, 2, 16	19, 3, 27	14, 26, 28, 25	13, 3, 35
16	Durability of stationary object		6, 27, 19, 16		1, 10, 35				35, 34, 38					39, 3, 35, 23
17	Temperature	36, 22, 6, 38	22, 35, 32	15, 19, 9	15, 19, 9	3, 35, 39, 18	35, 38	34, 39, 40, 18	35, 6, 4	2, 28, 36, 30	35, 10, 3, 21	35, 39, 19, 2	14, 22, 19, 32	1, 35, 32
18	Brightness	19, 1, 32	2, 35, 32			19, 32, 26								
19	Energy spent by moving object	12, 18, 28, 31		12, 28		15, 19, 25		35, 13, 18		8, 15, 35	16, 26, 21, 2	23, 14, 25	12, 2, 29	19, 13, 17, 24
20	Energy spent by stationary object		19, 9, 6, 27								36, 37			27, 4, 29, 19

Figure A-1: TRIZ contradiction matrix

Table A-1: TRIZ's 40 inventive principles

1. Segmentation	21. Rushing through
2. Extraction	22. Convert harm into benefits
3. Local conditions	23. Feedback
4. Asymmetry	24. Mediator
5. Consolidation	25. Self-service
6. Universality	26. Copying
7. Nesting	27. Disposable object
8. Anti-weight	28.Replacement of a mechanical system
9. Prior counteraction	29.Pneumatic or hydraulic construction
10. Prior action	30. Flexible 'shells' or thin films
11. Cushion in advance	31. Porous material
12. Equipotentiality	32. Change the color
13. Inversion	33. Homogeneity
14. Spheroidality	34. Rejecting or regenerating parts
15. Dynamicity	35.Transforming the physical/chemical state
16. Partial or excessive action	36. Phase transition
17. Shift to a new dimension	37. Thermal expansion
18. Mechanical vibration	38. Strengthen oxidation
19Periodic Action	39 inert atmosphere

20Continuity of Useful action	40 composite materials



SPECTRO ANALYTICAL LABS LIMITED

MECHANICAL

SampleID	A1001280063	TestDate	1/28/2010
Fm (kN)	9.560	Rm (MPa)	/
FeH (kN)	/	Fp (kN)	6.660
ReH (MPa)	/	Rp (MPa)	/

Figure A-2: Graph of main beam hinge joint bending load test sample -No 1

SPECTRO ANALYTICAL LABS LIMITED

MECHANICAL

SampleID	A1001280065	TestDate	1/28/2010
Fm (kN)	8. 200	Rm (MPa)	/
FeH (kN)	/	Fp (kN)	5. 680
ReH (MPa)	/	Rp (MPa)	/

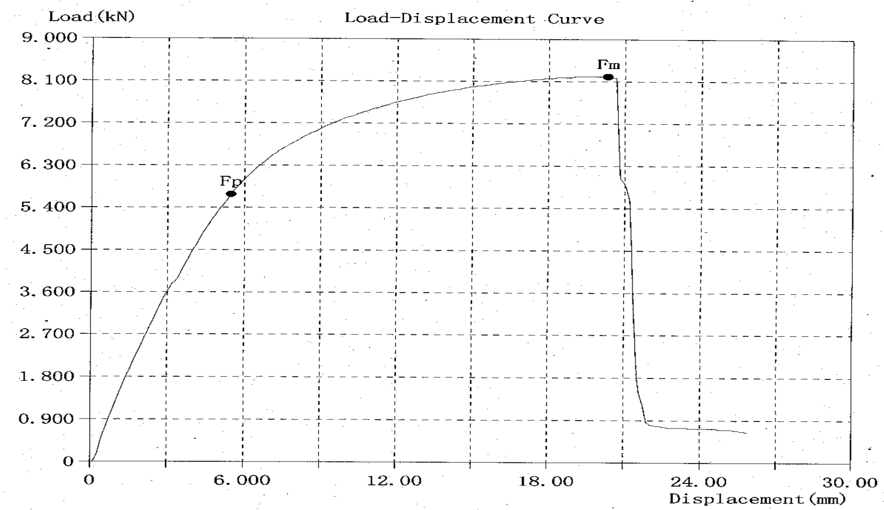
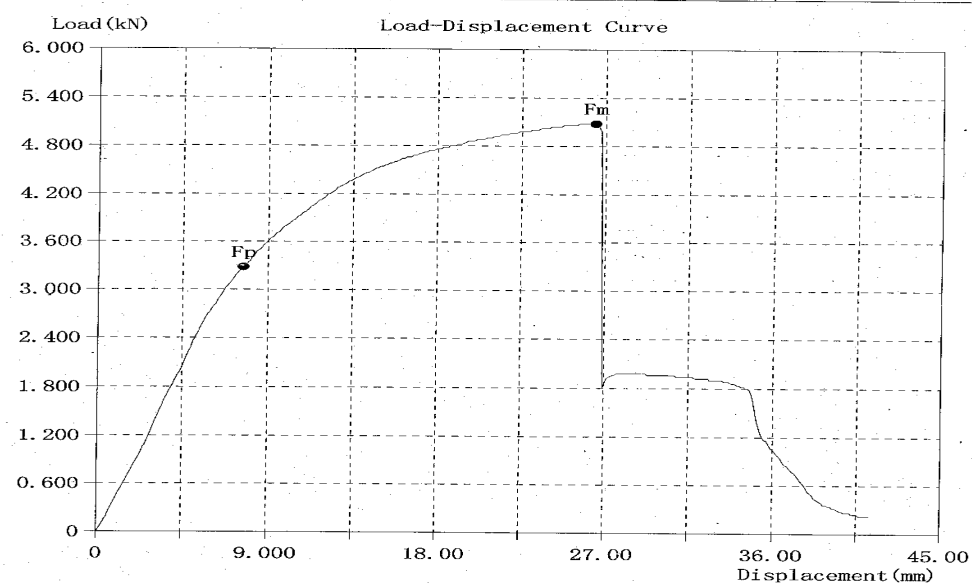


Figure A-3: Graph of main beam hinge joint bending load test sample-No2

SPECTRO ANALYTICAL LABS LIMITED

MECHANICAL

SampleID	A1001280066	TestDate	1/28/2010
Fm (kN)	5. 080	Rm (MPa)	/
FeH (kN)	/	Fp (kN)	3. 280
ReH (MPa)	/	Rp (MPa)	/



SPECTRO ANALYTICAL LABS LIMITED

MECHANICAL

SampleID	A1001280064	TestDate	1/28/2010
Fm (kN)	9. 360	Rm (MPa)	/
FeH (kN)	/	Fp (kN)	6. 580
ReH (MPa)	/	Rp (MPa)	/

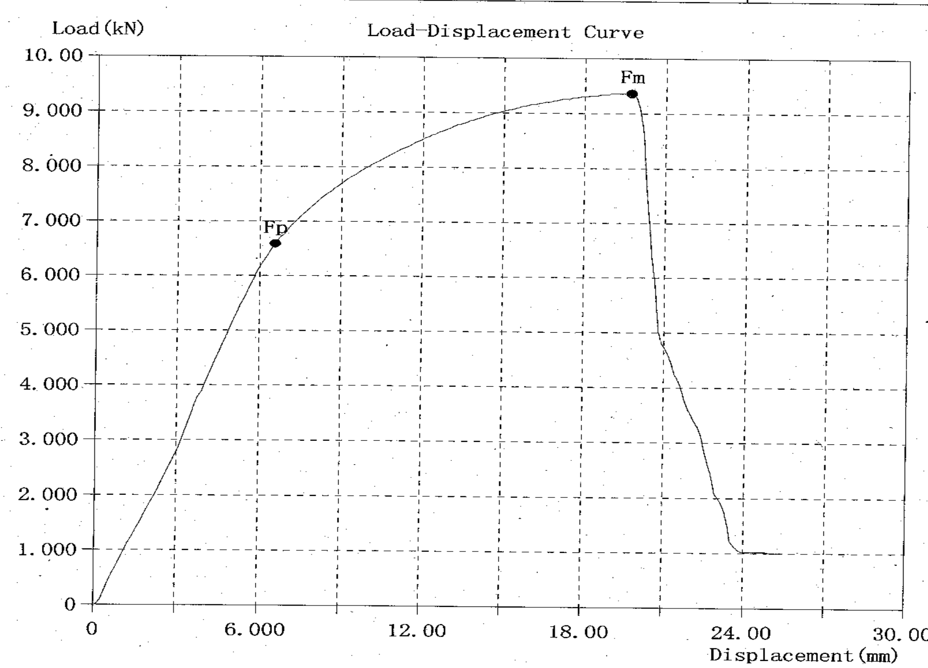


Figure A-4: Graph of main beam hinge joint bending load test sample-No 3

SPECTRO ANALYTICAL LABS LIMITED

MECHANICAL

SampleID	A1001280067	TestDate	1/28/2010
Fm (kN)	5. 280	Rm (MPa)	/
FeH (kN)	/	Fp (kN)	3. 400
ReH (MPa)	/	Rp (MPa)	/

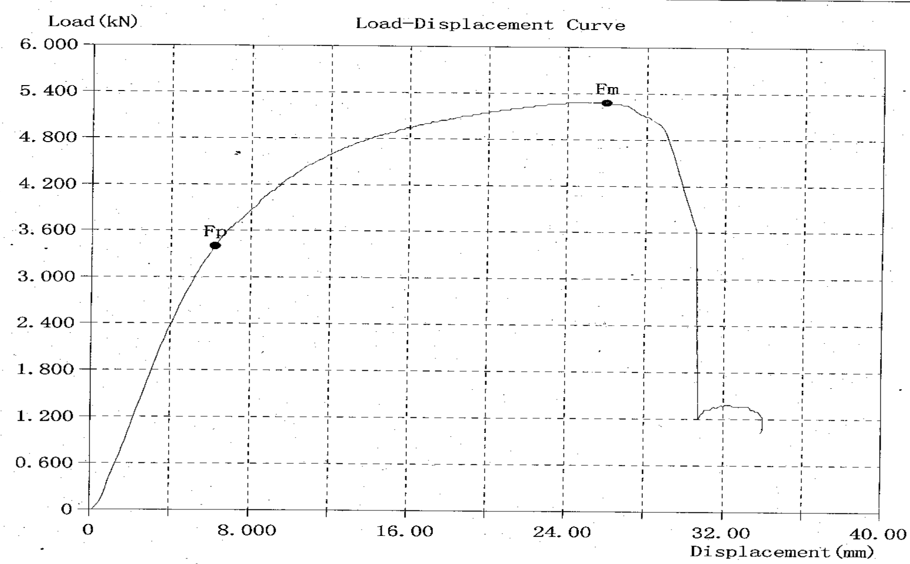


Figure A-5: Graph of spreader bar hinge joint bending load test sample- No1 and 2

SPECTRO ANALYTICAL LABS LIMITED

MECHANICAL

SampleID	A1001280068	TestDate	1/28/2010
Fm (kN)	5. 140	Rm (MPa)	/
FeH (kN)	/	Fp (kN)	3. 320
ReH (MPa)	/	Rp (MPa)	/

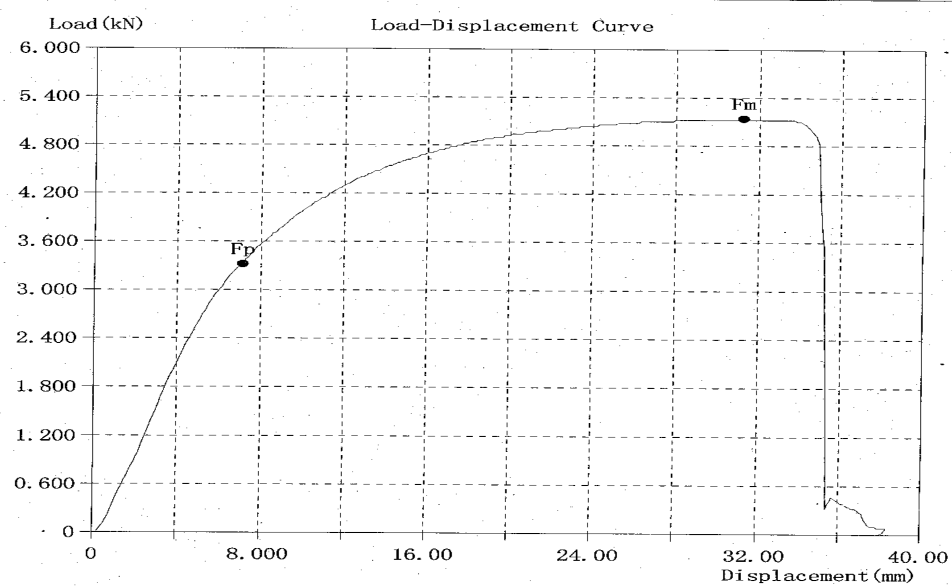


Figure A-6: Graph of spreader bar hinge joint bending load test sample- N-3

Table A-2: Details of patented design hinge joint

S. No.	Name, Paten No. and Date	Applications
1	Invisible hinge joint Pat no.,697628 May16,1912	It is used for the frames of wall beds & has good straining action.
2	Ball bearing hinge,1738015,Dec.14,1923	It is the anti- friction joint
3	Friction hinge joint,1956040,Feb.5,1932	Capable to work under high-tension conditions.
4	Indexing hinge,2635281,March.14,1950	Avoiding interference with intended swinging movement of the swinging frame.
5	Hinge joint for stretcher,3025866, March.20,1962	Used in stretchers but deform easily.
6	Adjustable joint for cots chairs, 3304107, Aug.6, 1962	This joint has locking good mechanism.
7	Lockable hinge joint,3849834,Nov.26,1974	It is rotatable hinge joint capable of being locked in one pre-determined position.
8	Foldable casualty carrier, 3886606, June3, 1975	It is used in the stretcher for carrying the patient can work for long time without deformation.
9	Collapsible Child Pen With improved hinge joint,4069524,Jan.24,1978	It is used for the child pen in which child can sleep, play.
10	Locking hinge joint,4226549,0ct.7,1980	It is simple & inexpensive positively acting bock for hinge joint.
11	Hinge joint,4218809,Aug.26,1980	Have high mobility transverse & parallel about the rotational axis.
12	Profiled hinge joint,4315345,Feb.16,1982	It can bear more load without bending.
13	Hinge, particularly for seats adjustable back, 4453767,Jun.12,1984	In this joint eccentricity of the eccentric can be changed for easy adjustment.

14	Hinge assembly with over center latch 4532674,Aug.6,1985	It transmits the drive force from one arm to another & has locking mechanism.
15	Universal hinge type joint, 4594816 Jun.17, 1986	It has variety of angular position & cost effective.
16	Hinge joint for seats for automotive-vehicle, 4708392, Nov.24,1987	It reduces the friction, which opposes rotation motion
17	Hinge seal,4709121,Nov.24,1987	Used in piano to prevent passage of electromagnetic energy.
18	Helmet visor with locking hinge assemble 4718127,Jan.12,1988	It does not loose & can retain in any position.
19	Hinge joint,4756055,Jun.12,1988	Prevent unauthorized opening of a closure element.
20	Hinge joint for tubular rail & post members 4767232,Aug.30,1988	Good adjustment at different angular position.
21	Hinge for a center fold play yard, 4934025, 7-1990	Easy fold/unfold.
22	Hinge joint,4958643,Sep. 25,1990	It is used for orthopedic brace & do not bend.
23	Knuckle joint,4929113,May.29,1990	Has good structural stability.
24	Lockable articulating joint, 5217315, Jun 8,1993	Easily locked in upward, downward and lateral directions.
25	Hinge joint for frame,373720 Sep.17,1996	Used in roll able cart & can bear more load.
26	Tilt hinge, 6038739,March.21,2000	Capable of obtaining greater frictional torque despite of small size & has stopping mechanism.

Table A-3: Experimental values of the “Dynamic Load Factor” with a drop height of 150mm

Static Load (N)	**Dynamic Load**	**1st Trail**	**2nd Trial**	**3rd Trail**	**4th Trail**	**Average Dynamic Factor**
		Dynamic Load Factor				
100	263	2.63	2.52	2.3	2.5	2.48
200	488	2.44	2.32	2.44	2.5	2.42
300	732	2.44	2.50	2.40	2.44	2.44
400	977	2.49	2.45	2.53	2.45	2.48
450	1200	2.66	2.66	2.44	2.48	2.56

Appendix "B"

No ERIP/IP/0803001/M/01

Tele: 23007351
Fax : 23017582

MINISTRY OF DEFENCE
Defence Research & Dev Organisation
Dte of ER & IPR, IPR Group
Room No. 348, B-Wing,
DRDO Bhawan, Rajaji Marg,
New Delhi – 110 105.

Dated the 12 Mar 2010

The Director,
INMAS,
Delhi – 110 052.

Subject: GRANT OF DESIGN REGISTRATION

A design registration has been granted by the Indian Patent Office on the following article developed by your institute:-

"Foldable Cot."

2. The following have been named as the inventors for the above mentioned design:

(i) Prem Chand Gupta
(ii) Narendar Kumar

3. A copy of the Design document no. 219428 received from the Indian Patent office is enclosed. A copy of the document may please be given to the concerned inventors for their record/retention.

(AVINASH KUMAR)
Jt. Director (IPR)

ORIGINAL

No. 8551

सत्यमेव जयते

GOVERNMENT OF INDIA
THE PATENT OFFICE
CERTIFICATE OF REGISTRATION OF DESIGN

Design No. 219428
Date 23RD OCT. 2008
Reciprocity date*
Country

Certified that the Design of which a copy is annexed hereto has been registered as of the number and date given above in class 06-01 in respect of the application of such design to "FOLDABLE COT" in the name of

DIRECTOR GENERAL DEFENCE RESEARCH & DEVELOPMENT ORGANISATION MINISTRY OF DEFENCE, GOVERNMENT OF INDIA, ROOM NO. 348, B-WING, DRDO BHAWAN, RAJAJI MARG, NEW DELHI-110105, INDIA, AN INDIAN ORGANISATION.

in pursuance of and subject to the provisions of the Designs Act, 2000 and the Designs Rules, 2001.

Controller General of Patents, ~~Designs~~ and Trade Marks

*The reciprocity date (if any) which has been allowed and the name of the country.
Copyright in the design will subsist for ten years from the date of Registration, and may under the terms of the Act and Rules, be extended for a further period of five years.
This Certificate is not for use in legal proceedings or for obtaining registration abroad.

DR. I. BANERJEE,
L. S. DAVAR & CO.
32, RADHA MADHAB DUTTA GARDEN LANE,
KOLKATA-700010.

Date of issue
11TH FEB. 2010.

Institute of Nuclear Medicine & Allied Sciences
31 MAR 2010
Brig. S.K. Mazumdar Road, Delhi-110054

No ERIP/IP/0701081/M/01

Tele: 23007351
Fax : 23017582

MINISTRY OF DEFENCE
Defence Research & Dev Organisation
Dte of ER & IPR, IPR Group
Room No. 348, B-Wing,
DRDO Bhawan, Rajaji Marg,
New Delhi – 110 011.

Dated the 16 Jun 2008

The Director,
INMAS,
Delhi – 110 054.

Subject: FILING OF PATENT APPLICATION

A patent application on the following invention made by O/o CCR&D ACE & NS and your institute, has been filed with Indian Patent Office, New Delhi :-

"Lightweight Foldable Cot."

2. The following have been named as the inventors for the above mentioned invention:

Inventors from INMAS, Delhi
i) Prem Chand Gupta
ii) Narendar Kumar
iii) Subash Khushu
Inventor from O/o CCR&D ACE & NS, New Delhi
iv) Mayank Dwivedi

3. The above application has been accorded 953/DEL/2008 as application number.

4. A copy of this letter may please be given to the concerned scientists for their record/retention.

(AVINASH KUMAR)
Jt. Director (IPR)

Copy to : O/o CCR&D (ACE & NS) - For info.

19 JUN 2008

भारतीय गैर न्यायिक
भारत INDIA
रु. 500 FIVE HUNDRED RUPEES
पाँच सौ रुपये Rs. 500
INDIA NON JUDICIAL

दिल्ली DELHI 355549

Memorandum of Understanding (MOU)
Between
Institute of Nuclear Medicine & Allied Sciences (INMAS), New Delhi, India
Defence Research & Development Organisation (DRDO)
Ministry of Defence, Government of India
&
Yorco Sales Pvt. Ltd., New Delhi,
For
Transfer of Technology (TOT)
for
MULTI-PURPOSE FOLDABLE ARMY FIELD COT (MPAFC)

This Memorandum of Understanding is entered into on the day of May in the year 2011 (Two Thousand Eleven)

BETWEEN

The President of the Republic of India, acting through and represented by the **Director, INMAS, New Delhi, India, a constituent laboratory of the Defence Research and Development Organisation, Ministry of Defence, Government of India** (Hereinafter referred to as **DRDO**, which expression shall whenever the context so requires or admits,

1

Annexure -1: Design registration, patent certificate and transfer technology MOU of MPAFCS

No ERIP/IP/0503004/M/01

Tele: 23007351
Fax : 23017582

MINISTRY OF DEFENCE
Defence Research & Dev Organisation
Dte of ER & IPR, IPR Group
Room No. 348, B-Wing,
DRDO Bhawan, Rajaji Marg,
New Delhi – 110 011.

Dated the 13 Nov 2006

The Director,
INMAS,
Delhi – 110 054.

Subject: DESIGN REGISTRATION

A design registration on the following design developed by Dr William

ORIGINAL

No. 1914

सत्यमेव जयते

GOVERNMENT OF INDIA
THE PATENT OFFICE
CERTIFICATE OF REGISTRATION OF DESIGN

Design No. 202863
20 JANUARY 2006

No ERIP/IP/0501050/M/01

Tele: 23007351
Fax : 23017582

MINISTRY OF DEFENCE
Defence Research & Dev Organisation
Dte of ER & IPR, IPR Group
Room No. 348, B-Wing,
DRDO Bhawan, Rajaji Marg,
New Delhi – 110 011.

Dated the 26 Sep 2006

The Director,
INMAS,
Delhi – 110 054.

Subject: FILING OF PATENT APPLICATION

A patent application on the following invention made by Dr William Selvamurthy, CCR&D (LS & HR), O/o CCR&D MNS & DS and your institute, has been filed with Indian Patent Office, New Delhi :-

"A collapsible and portable stretcher with auto locking system."

2. The following have been named as the inventors for the above mentioned invention:

Inventors from INMAS, Delhi
i) Prem Chand Gupta
ii) Gaurav Khoshoo
iii) Turaga Ravindranath

Inventor from office of CCR&D MNS & DS, DRDO HQrs
iv) Mayank Dwivedi

3. The above application has been accorded 1616/DEL/2006 as application number.

4. A copy of this letter may please be given to the concerned scientists for their record/retention.

(AVINASH KUMAR)
Jt. Director (IPR)

Copy to : ~~SO to CCR&D (LS & HR)~~ – For info.

4 OCT 2006

Copy: Sh. P.C. Gupta Sci–C – For info pl.

100Rs.

COMMERCIALLY CONFIDENTIAL

MEMORANDUM OF UNDERSTANDING

BETWEEN

DEFENCE RESEARCH AND DEVELOPMENT ORGANISATION
MINISTRY OF DEFENCE, GOVERNMENT OF INDIA

AND

ARTIFICAL LIMB MANUFACTURING CORPORATION OF INDIA
MINISTRY OF SOCIAL JUSTICE & EMPOWERMENT,
GOVERNMENT OF INDIA, KANPUR

FOR
TRANSFER OF TECHNOLOGY FOR FABRICATION
OF LIGHT WEIGHT FOLDABLE STRETCHER

This Memorandum of Understanding is entered into on the Twenty First day of June in the year two thousand and four between the President of India, acting through and represented by the Director, Institute of Nuclear Medicine and Allied Sciences (hereinafter referred to as INMAS), a constituent laboratory of the Defence Research

1

Annexure -2: Design registration, patent certificate and transfer of technology MOU of Light Weight Backpack Foldable Stretcher

Rt. Hon Dr Liam Fox Secretary of State for Defence UK, Health Min Govt of India Dr Romdass, showing interest in the Stretcher

Sh. Satpal Maharaj – MP and Chairman Defence Standing Committee, Scientific Advisor to Defence Minister Govt of India, General Commanding Officer Northern Command (Army) and Director of hospital device O/o DG MS Army taking interest in stretcher and stretcher Bed

Annexure -3: Demonstration of the Stretcher and SCB prototypes to the Higher Officials & Transfer of Technology Ceremony of the SCB