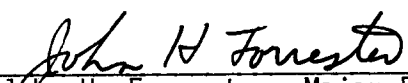
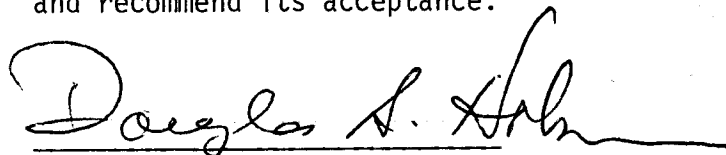


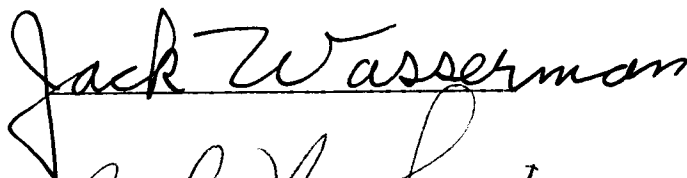
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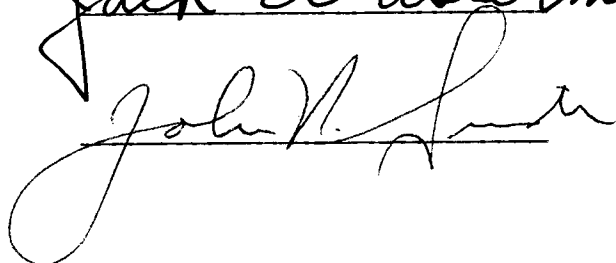
I am submitting herewith a thesis written by Katharine M. Hunter entitled "A Systematic Approach to Rehabilitation Engineering Design Problems." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Engineering Science.


John H. Forrester, Major Professor

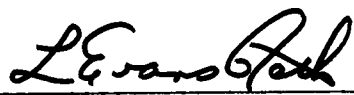
We have read this thesis
and recommend its acceptance:







Accepted for the Council:


Vice Chancellor
Graduate Studies and Research

4

A SYSTEMATIC APPROACH TO REHABILITATION ENGINEERING
DESIGN PROBLEMS

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Katharine M. Hunter
June 1980

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ABSTRACT

The purpose of this thesis is to provide a systematic approach for rehabilitation team members to follow in solving rehabilitation engineering design problems. Since the rehabilitation team is interdisciplinary, it is important for all members to be familiar with the design process. The fundamental phases of the design process are discussed and illustrated with examples.

The first step in the design process is to identify and formulate the problem; this also includes a needs assessment of the user population. Rehabilitation engineering problems have psychological, social, physiological as well as technical aspects and therefore the whole rehabilitation team must be involved in problem definition. Once the problem has been defined a literature review is undertaken to determine the current state of the art; a list of sources of rehabilitation information is included to aid in this phase.

When a literature review does not provide an immediate solution to the problem, creative and innovative ideas must be generated to solve the problem. Four methods of idea generation are discussed and illustrated. Once a variety of ideas have been generated it is then necessary to determine the optimum combination of ideas. This phase involves analysis and synthesis. Models are tested by using the technical and medical tools of analysis and diagnosis to determine the optimum combination of ideas that will solve the problem. Planning and control must be implemented throughout the whole project, and techniques such as CPM, PERT, and accounting procedures may be used.

Evaluation of the project begins with the initial needs assessment and is carried out as an integral part of the whole project, so that ultimately a design is produced that is attractive for manufacturers to manufacture. In rehabilitation engineering design problems, there must be careful attention: to government regulations, detail and high engineering standards to produce both efficient and effective designs that prevent liability due to negligence.

It is recommended that recognition of the particular needs and concerns to the consumer and their interaction with the device must be applied to all aspects of the design process, and the rehabilitation professionals and consumers should work together throughout the whole design process to produce acceptable solutions to rehabilitation design problems.

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INTRODUCTION

The objectives of rehabilitation engineering are to enhance the lives of the physically disabled through clinical involvement in a total approach to rehabilitation combining medicine, engineering, and related science and technology (8). Rehabilitation engineering is not well delineated, but rather broad based and draws on many "purer" disciplines and techniques, integrating the relevant aspects of each discipline to achieve a solution to a problem. The process of arriving at a solution often involves the following steps: assessment of the disability, determination of assistive equipment specifications, evaluation of the feasibility of using an available system or device or modifying it for the specific application, and determination of when a new system or device should be developed (4).

In problems where an assistive device is not readily apparent and available, it is often necessary for the various members of the rehabilitation team to work together to reach a suitable solution. These efforts are greatly facilitated by following a systematic approach to rehabilitation engineering problems by which the team members representing the various disciplines may progress toward an effective problem solution.

The purpose of this thesis is to provide a systematic approach for rehabilitation professionals to follow as they strive to solve rehabilitation engineering design problems. The suggested procedures build upon engineering design principles with emphasis upon their particular application to the interdisciplinary problems of rehabilitation engineering. Thus, it is hoped that this thesis will provide useful

information for the engineer who has recently entered the rehabilitation field, as well as other members of the rehabilitation team who generally will not have had any formal experience using the engineering design process. By having all members of the rehabilitation team familiar with the design process, the team should be better equipped to reach, in the most efficient manner, realistic solutions to the interdisciplinary problems encountered.

The main phases in an engineering design project are: definition and formulation of the problem, literature review, generation of ideas, construction of models, analysis, and presentation of a solution. These phases are shown schematically in Figure 1 and are discussed in detail in the chapters which follow. Within this basic framework the designer must continually evaluate, document, plan and control, and consider economics and product liability throughout the process. This aspect of the process is illustrated in the central core of Figure 1.

In the following chapters, the basic phases of the design process as indicated in Figure 1 are discussed with respect to their application in the field of rehabilitation engineering. A feeder for use by the severely handicapped is used as an illustration of the phases of the design process. Initially it had been proposed to design and construct a feeder for use by children with severe cerebral palsy. The initial design phase entailed definition and formulation of the problem, a literature review, a study of the current state of the art, a needs assessment and establishment of design criteria. Concurrent with the completion of the initial design phase was the Second Annual Interagency Conference on Rehabilitation Engineering (ICRE), held in Atlanta at the

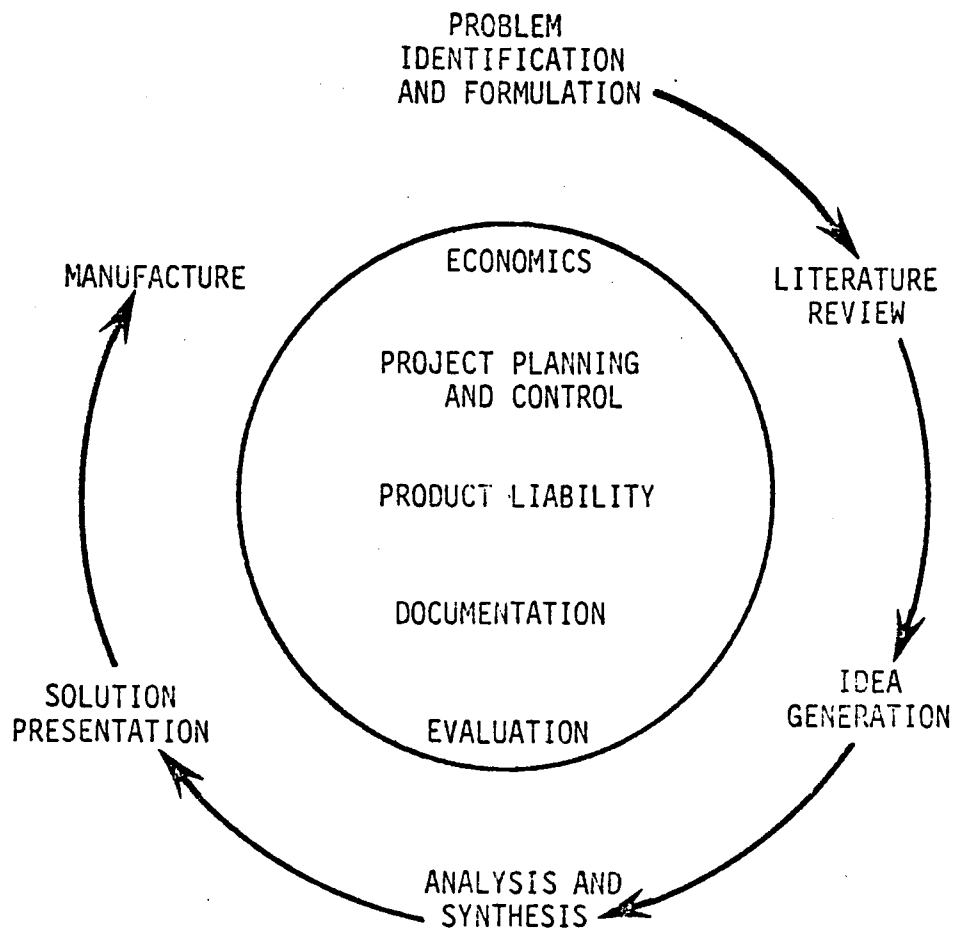


Figure 1. A Fundamental Design Process

end of August 1979. At the conference the Winsford Feeder was introduced and demonstrated. This feeder, which had not been documented or mentioned in the literature prior to the conference, satisfied the criteria of the initial design phase. The needs assessment had shown that the market for feeders of the sophistication demanded by individuals with severe cerebral palsy (C.P.) was of the order of two thousand in the United States. Thus, it was decided not to begin the detailed design phase. To illustrate the design process, appropriate examples are taken from our initial design phase and that of others who developed the Winsford feeder.

CHAPTER 1

PROBLEM IDENTIFICATION AND FORMULATION

The first step in the systematic approach is to identify and formulate the problem correctly. The difficulty is to determine the real problem. The rehabilitation team must determine what is the cause of the problem and what is merely a manifestation of the problem, the generality or specificity of the problem, the components of the problem, the available information about the problem, and the resources available to solve the problem. The team members must be able to ask the right questions and communicate with a broad spectrum of individuals including the patient, his family, health professionals, and scientists to obtain the background information that is necessary to correctly formulate the problem. The consumer, wherever possible, must be included in the problem definition and formulation phase because the consumer often has insight into the problem that no other members of the rehabilitation team have.

In rehabilitation engineering problems the team is often faced with psychosocial and social aspects of the problem in addition to the physiological and technical problems. Thus it is important that these aspects be considered as the problem is defined; this again emphasizes the need to have the entire rehabilitation team familiar with the design process.

Feeder Example

The feeder example of problem identification and formulation is split into the physiological and social problem and the technical problem of feeding. The physiological and social problem presents the feeding difficulties of the consumer, which together with the technical problem present the constraints to the designer. The experience of hand feeding children with cerebral palsy and a literature review contributed to the physiological and social problem formulation. Discussions held with therapists, teachers, and engineers in Memphis contributed to the technical problem formulation.

The Physiological and Social Problem

Many people with neuromuscular disabilities have difficulty eating. Eating is a nutritional necessity, but the process of eating is a very important social activity. Perhaps it is less obvious that the ability to feed ourselves presentably is one of the basic skills that society demands of us in order to be socially acceptable. Unfortunately the physically handicapped are often judged more severely on social habits than able-bodied people. For the adult who may have developed a disability, self-feeding may bring a feeling of independence and greater self confidence. For the child who is born with a disability, the learning of correct feeding patterns is necessary for the development of more complex skills.

The feeding difficulties experienced by handicapped children are variable. They may have structural deformities such as cleft lip or

cleft palate, narrow or inadequate nasal passages and neurological disorders such as exaggerated bite reflex, oversensitive gag, little head control, poor posture, poor muscle tone and muscle imbalance. Disabilities which can result in feeding problems include hemiplegia, rheumatoid and osteo arthritis, Parkinsonism and multiple sclerosis. For disease and trauma patients, the social and psychological effects of being a dependent feeder may cause additional problems associated with feeding such as frustration, embarrassment, anger, and exclusion.

There are many benefits for the patient's family and/or institution when a dependent feeder becomes an independent feeder. The obvious benefits are that the patients can decide what, how much, and when they want to eat. Additionally the family or institutional staff member can be relieved of the time consuming task of feeding, which may reduce expenses for care and/or permit a family to sit down at the same time for a meal together. Independent feeding is often an early motivation for the rehabilitation of spinal cord injured patients. When a patient becomes an independent feeder he may not mind going out in public, so he is then free to join in social events outside the home or institution.

Technical Problem

From an engineering viewpoint the design of a feeder is a mass transfer and materials handling problem. There is food on the plate that needs to be selected and transferred to the mouth without spillage. The food varies in consistency, texture and temperature. The handicapped patients vary in degree of involvement, motor control and muscle

tone. They also vary in physical size, deformity, and psychological motivation. The engineering solution needs to provide efficient and effective mass transfer from the feeder to the patient. The technical problem of mass transfer for such a diverse range of variables requires that certain preliminary limitations be imposed on the problem. Thus it is assumed that the food will be pre-cut and transferred in bite-size pieces, and that certain foods will not be considered practical.

The design process involves looking at the various components of the problem, which are listed below.

- Size: The feeder must be small enough to fit on any wheelchair tray and must be portable.
- Materials: The feeder parts that are exposed must be completely washable, non-toxic, and meet all F.D.A. regulations.
- Weight: The feeder must be light enough to be completely portable for use at school, home, institution or at a restaurant.
- Appearance: The feeder must be cosmetically attractive, compact, and the type of device one could "take out to dinner."
- Operation: The feeder must permit the user to select the food, transfer the food from the plate to the spoon, lift the spoon to the desired (adjustable) height, and let the user select the speed of eating.
- Interface: The controller of the feeder must be compatible with the user's activation sites, and also must have several optional interfaces to accommodate various types of disabilities.

- Cost: The feeder must be competitive in price to most commercial feeders (between \$500 and \$800).
- Power Supply: The feeder should use rechargeable D.C. batteries.
- Safety: The feeder must be safe to use even if the user has a seizure. There should be consideration of possible misuse of the feeder and negligence in design.

The feeder should permit the use of standard plates, spoons, or a cerebral palsy feeding spatula, so that it can be easily integrated into an institutional setting where there may be more than one user per feeder. The feeder should be symmetric to interface with users who are right or left biased.

Needs Assessment

As part of the problem identification and formulation process, it is often necessary to determine the magnitude of a particular problem in terms of numbers of persons involved in order to determine an appropriate action to be taken. Thus a "needs assessment" should be incorporated into the identification and formulation phase.

In Memphis, an estimate of the maximum number of potential users of a feeder for the severely handicapped is ten out of a population of one and half million. If the total population of the United States is two hundred and twenty-two million, an estimate of the total number of devices that would be needed by individuals who could not use any other feeder would be approximately two thousand.

Even if the estimate is increased to include users of other feeders who might choose to switch to this particular feeder, the numbers are still small in manufacturing terms. Therefore a decision about the future of the Memphis project was required. The alternatives were: (i) to continue the design project and attempt to catch up to the development stage of the Winsford Feeder and produce a competitive device for a small market, (ii) to stop the Memphis project and use the preliminary design information as a background for evaluating and suggesting modifications to adapt the Winsford Feeder for use by individuals with cerebral palsy thus producing an immediate solution to the problem. The evaluation would serve as a field test for the prototype to determine the necessary pre-manufacture modifications.

After deliberations with those concerned with the project it was decided to stop design work on the Memphis feeder project and to evaluate the Winsford Feeder.

CHAPTER II

LITERATURE REVIEW

Rehabilitation Information Sources

The second step in the systematic approach is a literature review. Once the problem has been formulated it is necessary to determine if a similar problem has been described previously, and if so, if the existing solution is applicable to the present problem. Many problems may be of the type where it is important to determine the current "state of the art." Since rehabilitation engineering is such a new field, most of the existing indexes are not cross-referenced in a usable manner, and are consequently very inefficient to use. In addition many of the problem solutions have not been documented and published in a manner that is readily retrievable. However, a large amount of information has been published and often can be found in one or more of the sources listed in Appendix A. Additional information can be obtained from commercial catalogs such as Maddack, Abbey Medical, and Fred Sammons.

It is sometimes difficult to retrieve information from the sources listed in Appendix A. For example many investigators have found the MEDLARS indexing and cross-referencing difficult to use for most rehabilitation engineering problems involving the development of devices, since MEDLARS key words are not adapted for technical information retrieval. It is hoped to centralize and organize the spectrum of information sources with the establishment of the National Institute

for Handicapped Research (NIHR). It has been recommended that in the near future a toll-free number be available to enable rehabilitation professionals and consumers to reach the correct information source immediately. This and other recommendations that resulted from the workshop on information retrieval and dissemination held as part of the Second Annual Interagency Conference on Rehabilitation Engineering are included in Appendix B.

Feeder Example

The initial literature review for the feeder project was done on MEDLAR; however it did not yield any information on feeding devices but did provide a list of citations on the physiological problems of feeding (previously discussed in Chapter I). Letters were then written to Easter Seal, United Cerebral Palsy, ICTA, Veterans Administration, and the National Rehabilitation Information Center (NARIC). All the agencies responded but most of them referred to the other agencies listed for information! Some information was received on feeding devices, utensils, and techniques, including feeders for use by quadriplegics. No information was received on devices that would solve the particular feeding problems of a severely involved individual with cerebral palsy.

The most useful information was obtained by consulting commercial catalogs for sources of information on current solutions. Four commercially available feeders were identified: (i) Automatic Feeding Device, distributed by J. A. Preston Corporation, (ii) Beeson Automaddack FeederTM, distributed by Maddack Inc, and Abbey Medical,

(iii) The Cerebral Palsy Feeder distributed by Fred Sammons and Abbey Medical, and (iv) the Two Step Eater, distributed by Abbey Medical. Although these feeders have positive attributes none of them satisfied the design criteria previously formulated for this investigation. The problems encountered with all these commercial feeders can be summarized as follows: no effective mechanism for transferring the food from the plate to the spoon, poor height adjustment for varying table heights, limited adaptability to variable activation sites, cosmetically unattractive.

Many automatic feeders have been developed to the prototype stage, but have not been made commercially available. These feeder projects have been undertaken by the Veterans Administration, universities, and research institutions. However, very little information has been published on these prototypes. Some of the V. A. feeders are Moorewood, Vapo #2, Adaptive Therapeutic Spoon, Syndor, and Angele Feeders. These feeders do not satisfy the criteria of the present problem by either their size, weight, complexity, cosmetic appearance, or treatment of the food prior to presentation to the consumer.

CHAPTER III

GENERATION OF IDEAS

The solution of rehabilitation engineering problems involves the application of medical and engineering principles, a knowledge of bio-compatible and engineering materials, low volume manufacturing techniques, and economics. Rehabilitation problems require creative and innovative ideas; and many attempts have been made to develop procedures for generating these ideas. Before deriving some of these procedures, creativity and innovation will be discussed from a design engineer's point of view.

Creativity is the origination of a concept in response to a human need, whereas innovation is the application of logic, experience or artistry to discover a new, novel or unusual idea. Creativity requires innovation but also a peculiar insight and a vivid imagination. Conditions that stimulate creative thinking are related to an individual's state of mind; these include an inquiring and questioning mind, ability to concentrate and communicate, ability to accept conflict and tension without becoming frustrated and an ability to consider each new idea. Personal qualities that lead to creativity include intellectual curiosity, acute powers of observation, sensitivity to recognize that problems exist, directed imagination, initiative, originality, memory, ability to analyze and synthesize, intellectual integrity, ability to think in analogies and images, intuition, patience, determination, and persistence. There are also conditions that depress creative thinking.

Such as limited scope of basic knowledge, failure to look at all the conditions of a problem, preconception, prejudgement, failure to investigate the obvious and trivial, failure to grasp the real problem, emotional barriers and social and cultural restraints.

"Creative" rehabilitation engineering is often innovation, where existing devices and tools find new applications. The creative aspects may be in arriving at a particular diagnosis and subsequent problem formulation. Some common procedures for generating creative and innovative ideas include the following: checklists and attribute lists, systematic search for design parameters, brainstorming, and synetics. These four methods are discussed below.

Checklist and Attribute Lists

This method deals with the improvement of existing solutions. Checklists provide a simple method to originate a number of new ideas in a short amount of time by using prepared lists of questions such as:

1. In what ways can the ideas be improved in quality, performance, and appearance?
2. To what other uses can the solution be put, for example, can it be enlarged or modified to meet the demands of the general public?
3. Can another solution be substituted or combined with another idea?
4. What are the solutions' advantages and can these be improved? What are the disadvantages and can they be overcome?

5. What is the technical base of the idea and are there other technical bases that might work equally well?

Attribute listing or value analysis is a technique of idea generation to improve existing solutions. Value analysis is based on the assumption that most ideas are merely extensions or combinations of previously recognized observations. Attribute listing involves:

- (a) Listing the key elements or parts of the solution.
- (b) Listing the main features, functions or significant attributes of a solution and each of its key elements or parts.
- (c) Systematically modifying, changing, or eliminating each feature, quality, or attribute so that the original purpose is better satisfied or a new need is fulfilled.

Feeder Example

Since the techniques of using checklists and attribute listing deal with improving existing solutions, the Winsford Feeder will be used as the prototype to be evaluated.

Checklists

1. The Winsford Feeder can be improved in appearance by modifying the housing. A plastic housing with rounded edges and handles would decrease the weight and be easier to carry.
2. The feeder is so effective that it is suitable for severe cases, thereby also satisfying the needs of those less severe. However, therapists do not like to over prescribe

aids because the patients will become overly dependent; therefore a sophisticated feeder should only be recommended for severely involved individuals.

3. The Winsford Feeder should be used as a feeder for individuals with severe cerebral palsy.
4. The advantage of the Winsford Feeder is that it uses an active transfer mechanism to push the food from the plate onto the spoon. The lever arm is sufficiently flexible so that if it is touched by mistake it will bend. The liquid bracket could be replaced with a counter balanced container bracket to reduce the chance of spillage; also provision for placement of the bracket on either side would overcome the asymmetry of the feeder. During evaluation the scraper should be carefully examined and possibly replaced by a rubber spatula or scoop.
5. The technical bases of the feeder in terms of the control, transfer, and delivery are respectively, electrical, pusher mechanism, and lever/hoist mechanism. This combination of bases appears to provide an effective solution to the problem and matches those arrived at in the preliminary investigation of this problem.

Attribute Listing

Plate

Main Features: The use of a standard plate is very advantageous, since it makes the device more portable and easier to integrate

into the home, institution, or restaurant environment. No modifications required.

Plate Rotation Mechanism

Main features: The rotation device which uses three spindles is simple, versatile and highly effective. It is powered by a separate motor. No modifications required.

Spoon

Main features: Any standard spoon can be used, also a cerebral palsy feeding spatula can be substituted for the spoon. No modifications required.

Spoon Attachment Mechanism

Main features: The spoon is simply inserted and screwed in place.

Modifications: The screw could present some difficulty but could be replaced by an off-centered cam lock-down device.

Liquid Container Attachment:

Main features: The bracket slides onto the front of the housing. The size of the bracket limits the diameter and the position of the container.

Modifications: The attachment is asymmetric and for some individuals this is a problem. There should be optional right or left placement for the bracket. A complete redesign of the liquid holder is needed so that it appears as an integral part of the device.

Food Transfer Mechanism

Main features: The best attribute of this feeder is the food transfer device. The scraper swings from the edge of the plate and pushes the food from the plate onto the spoon. The scraper is stainless steel, which in combination with some foods is noisy.

Modifications: The stainless steel scraper could be replaced by a high density polyethylene scraper that is easily cleaned and would likely provide quieter operation.

Delivery Mechanism

Main features: The food lever device has five inches of height adjustment. The safety feature of the mechanism is that if the lever should touch the face it either moves out of place or the lifting device stops and is reactivated when the interference has been eliminated. No modifications required.

Power Requirements

Main features: The feeder uses a six volt rechargeable battery that operates for twenty-one meals between charges and only requires eight hours to recharge. No modifications required.

Control

Main features: The feeder is controlled by a chin switch although many other types of control devices can be substituted. The feeding cycle begins when a switch is activated; the pusher swings from the edge of the plate and pushes the food onto the spoon. The spoon is then automatically lifted to mouth level.

Upon reactivation of the switch the spoon is returned to the plate for refilling. The plate is rotated by moving the switch in the opposite direction in order to place more food in front of the pusher. By holding the start switch closed, the spoon will not rise and the pusher may be used two or more times to fill the spoon. The plate may be rotated any amount at anytime regardless of the position of the spoon. Should the spoon touch the users face it will only exert a small force before the lifting arm stops. The lifting arm will automatically re-engage the next time the start switch is used. No modifications required.

The Appearance

Main features: The outside dimensions of the feeder are twelve by eighteen inches, and it weighs eighteen pounds. The housing is sheet metal with a baked enamel finish. Modifications: the housing material could be replaced with a durable plastic which allows for a more attractive appearance and possibly a weight reduction.

The Cost

Main feature: The retail price of the Winsford Feeder is listed at just under eight hundred dollars.

Modifications: The cost could be reduced by possibly replacing one of the three motors with a linkage system. Any modifications to save on the overall cost must be carefully evaluated because of the interaction of all the components of the system.

Systematic Search of Design Parameters

A systematic search considers all the possible combinations of given conditions or design parameters. The success of this technique depends upon the identification of the significant parameters that affect the design. The steps in the search are as follows:

1. The description should be general so that it will not exclude possible solutions.
2. Select the major independent variable conditions required to describe the characteristics and functions of the problem.
3. List the alternative methods that satisfy each of the independent variable conditions selected.
4. Establish a matrix with each independent variable represented by one axis of a rectangular array. When more than three conditions are shown the display can be presented as parallel columns.
5. The results can also be shown as a list of all the possible combinations.

Feeder Example

1. The Problem Statement: A feeder for the Severly Handicapped
2. Independent Variable Conditions:
(a) control, (b) transfer, (c) delivery.
3. Methods of satisfying each condition:
(a) Types of controls: electrical, mechanical, pneumatic, fluidic.

- (b) Types of transfer: scoop-bucket, push-scrape, pull-suck, screw, jaws-pinchers.
 - (c) Types of delivery: pulley, lever-hoist, tape-coil, worm gear, piston, telescopic tube.
4. The Matrix: See Figure 2 which shows a matrix of the design parameters.
 5. Combinations:

A sample of some of the possible computer listed combinations is shown in Figure 3. Some combinations that are less obvious will present themselves. The use of the computer is very useful when there are a large number of parameters.

Brainstorming

The term brainstorming was coined by A. F. Osborn, in Applied Imagination (6) to describe an organized group effort aimed at solving problems. The objective of brainstorming is to stimulate ideas and not to generate a complete solution to a given problem. The technique involves compiling all the ideas that a group can generate while deferring any judgement on their worth. This is accomplished by releasing the imagination of all the participants from restraints such as fear, conformity and judgement, and providing a method to improve and combine ideas the moment an idea has been expressed. Group brainstorming is used to supplement but not replace the process of individual idea production and works well for finding a large volume of alternative solutions or novel design approaches. This technique is not recommended

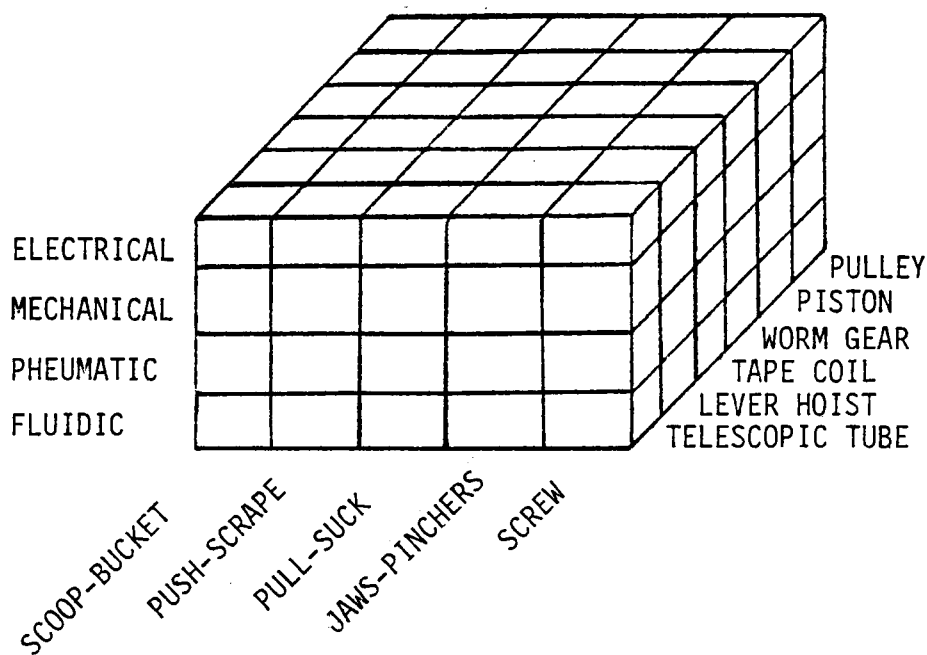


Figure 2: The matrix for the Feeder Example.

ELECTRICAL	SCREW	TAPE-COIL
ELECTRICAL	SCREW	WORM GEAR
ELECTRICAL	SCREW	PISTON
ELECTRICAL	SCREW	TELESCOPIC TUBE
ELECTRICAL	JAWS-PINCHERS	PULLEY
ELECTRICAL	JAWS-PINCHERS	LEVER-HOIST
ELECTRICAL	JAWS-PINCHERS	TAPE-COIL
ELECTRICAL	JAWS-PINCHERS	WORM GEAR
ELECTRICAL	JAWS-PINCHERS	PISTON
ELECTRICAL	JAWS-PINCHERS	TELESCOPIC TUBE
MECHANICAL	SCOP-BUCKET	PULLEY
MECHANICAL	SCOP-BUCKET	LEVER-HOIST
MECHANICAL	SCOP-BUCKET	TAPE-COIL
MECHANICAL	SCOP-BUCKET	WORM GEAR
MECHANICAL	SCOP-BUCKET	PISTON
MECHANICAL	SCOP-BUCKET	TELESCOPIC TUBE
MECHANICAL	PUSH-SCRAPE	PULLEY
MECHANICAL	PUSH-SCRAPE	LEVER-HOIST
MECHANICAL	PUSH-SCRAPE	TAPE-COIL
MECHANICAL	PUSH-SCRAPE	WORM GEAR
MECHANICAL	PUSH-SCRAPE	PISTON

Figure 3: A sample of combinations of parameters for the Feeder Example.

for problem solutions that are vast, complex, vague, controversial or judgement dependent. Usually there is a chairman and a recorder. Approximately a day before the session the chairman should give the participants a clear, concise problem statement to ensure that the ideas are directed toward a common target. Prior to the session the chairman should state the following rules of brainstorming:

1. All ideas that come to mind are to be recorded. No idea should be stifled. Use of a blackboard and tape recorder is encouraged.
2. Suggested ideas must not be criticized or evaluated. Judgements must be withheld until after the session because many ideas are inhibited due to fear of ridicule or criticism.
3. Combine, modify, alter or add to ideas as they are suggested. Participants should attempt to improve on other ideas as well as contribute their own. Modifying a previously suggested idea will often lead to other entirely new ideas.
4. A large quantity of ideas should be generated. Research has shown that when a brainstorming session produces more ideas it will also produce higher quality ideas.

The chairman must keep all evaluation and judgement out of the meeting so that a spirit of enthusiasm will permeate the meeting. The environment should be free and informal. Each participant should come to the session with a list of the ideas that he has generated. These lists of ideas help to get the meeting started. A typical session

should last from a half to one hour. The recorder keeps an account of all the ideas presented and after the session lists them according to their type. Group members often add to the accumulated list for up to a day after the session. Later the entire list should be rigorously evaluated, preferably by a different panel of participants.

The make up of the team is important. There should be six to twelve individuals of similar age and position. It has been suggested that a team should include a few capable individuals who are not very familiar with the particular topic under discussion. Those who are concerned with evaluation and judgement usually make poor team members. A brainstorming team for rehabilitation engineering problems should be made up of consumers, and their families, therapists, doctors, nurses, teachers, social workers and engineers.

FEEDER EXAMPLE

A brainstorming session held at the University of Tennessee Rehabilitation Engineering Center produced the following list of ideas for feeding methods and materials handling.

Feeding Methods:

infiltration	spoon	swallow	suck
absorption	retractible tape	scoop	bite
imbibition	ant eater	slurp	lap
alligator	goose neck	snake	chew
venus fly trap	frog's tongue	conveyor	drink
lamprey	lick		

Materials Handling:

conveyor	telescopic tube	backbone	suck
mobius loop	conduit	bucket	trains
wind up spring	vacuum	scrapers	hoist
lifting tong	wormgear	spatula	pulleys
containers	magnets	gondolas	troughs

Synetics

Synetics has been developed by William J. J. Gordon (5). This technique attempts to bring about a solution to a problem by drawing unrelated ideas together and forcing them to complement one another. The synetics participant tries to imagine himself as the personality of the inanimate object, for example, "How would I react if I were that crutch?" The key to this technique is the leader's ability to make the team members "forcefit" or combine unrelated ideas into a new and useful solution. He urges the members to understand the problems and explore their broad aspects. The problems are viewed from various analogous situations. Synetics uses various psychological states that are involved in creative acts, and usually draws the team members from diverse fields of learning so that the group spans many areas of knowledge. It is important that the members are imaginative but not necessarily experienced since a novice approaches a problem with fewer preconceived ideas and thus is not bound by mental restriction. The team must include at least one expert in the particular problem area. The expert, using his technical knowledge, can fill in the facts and is often the "devils advocate" since he points out the weaknesses of an

idea. In rehabilitation engineering problems there is a psychological advantage for a potential consumer to be involved in both the brainstorming and synetics sessions. In this way he is actively participating and contributing in the creative aspects of a solution to a problem and ultimately has much more concern for the success of the project. All synetics sessions are recorded for future reference.

Feeder Example

The pusher mechanism will be used to show how the synetic approach to idea generation can be used. An example of the pusher mechanism is a ships steering mechanism. The helmsman directs the tiller which in turn directs the rudder which pushes the water and steers the ship. The "feelings" of the rudder and pusher are similar; they are both subordinate, directed, and in short a master-slave situation. The rudder mechanism is made to "force fit" the pusher mechanism and by using a ships steering mechanism as a source of ideas, the pusher mechanism design of the feeder will evolve.

CHAPTER IV

ANALYSIS AND SYNTHESIS

Once a rehabilitation engineering problem has been identified, formulated, and researched, and ideas have been generated, the task then becomes one of selecting the "optimum" combination of ideas to solve the problem. This very difficult part of the design process is called "synthesis" and must take into consideration medical, social, psychological and economic aspects of the problem in addition to the technical aspects in order to bring all parts of the problem together such that they complement one another to comprise an effective solution. Here again the necessity for a broadbased team approach is apparent. Interwoven with the synthesis aspect of design is the analysis of the various components so that each can be optimized with regard to the total design.

The tools of engineering analysis can be divided into several categories such as mathematical tools (mathematics, statistics, and metallurgy), and physical tools (dynamics, solid mechanics, fluid mechanics, electricity, thermodynamics, and vibrations). Often, the design could be improved with some analysis, such as stress-strain analysis in the critical areas of the design. Too often designers rely on the assumption that "If it is big enough it will be strong enough."

The rehabilitation professional also has the medical tools of diagnosis, as previously discussed in Chapter I, which in combination with the engineering tools of analysis help to define, analyze, and

rehabilitation problems. For rehabilitation engineering problems bio-compatibility and toxicology analysis is important and must be routinely carried out to comply with Food and Drug Administration (F.D.A.) requirements for rehabilitation engineering applications. The analysis that is performed must be correctly documented for F.D.A. inspection.

Models

The human mind only can think effectively about simple problems and small bits of information; therefore it is necessary to break down complicated problems into simple problems that can be solved independently and integrated into a final solution. Models are often simplified or idealized versions of complex systems. A model may represent a system as a whole or an action of some part of the system. The function of a model is to make visualization, mathematical analysis, or testing more practical.

The validity of the solution depends upon the assumptions made in forming the model and the accuracy by which the model represents the real system. Experimentation, evaluation, and model refinement are necessary to test the usefulness and accuracy of a model. The "art" of making a model consists of selecting the most appropriate degree of simplification and assessing the importance of the effects that have been neglected. In rehabilitation engineering it is extremely difficult to find models for the total system because of the man-machine interface element and the difficulty of modelling the human operator. Some types of models which are useful in rehabilitation engineering problems are listed below.

1. Scale and Breadboard Models

Scale models are used for visualization, experimentation and to predict the behavior of a prototype in many types of problems. They are also useful in designing complex plants and systems where a three dimensional layout is important. Breadboard models were initially used by electrical engineers to examine and test electrical circuits. These models can also be used for hydraulic, fluidic or pneumatic circuits. The assumption behind breadboard models is that the physical layout of the components has a negligible influence on the overall performance of the circuit.

2. Mathematical Models

A mathematical model or algorithm can be built to examine the behavior of a system. A mathematical model is often analyzed by using a computer. The variables which represent constraints or design factors can be changed so that the behavior of the system can be analyzed subject to these constraints. It is important to realize that the accuracy of the mathematical model depends upon the assumptions on which the model is based. A rudimentary mathematical model is the spring mass system.

3. Charts and Graphs

Charts and graphs are used to illustrate the results of analysis. These illustrations become models when they are used to study and predict the behavior of the system.

4. Diagrams

Diagrams are pictorial representations of models. The general types of diagrams are block, flow, circuit, and free body. In block diagrams the components are drawn as blocks and the connecting lines

between the blocks indicate the flow of information. A flow diagram is similar to a block diagram; the blocks represent unit operations and the lines represent the flow from one operation to another.

For example the feeding cycle of a feeder is represented as a flow diagram. The blocks represent the actions of the feeder, and the lines represent a flow of information to and from a decision point.

Figure 4 illustrates the feeding cycle of the feeder as a flow diagram.

Circuit diagrams are used to model in electrical or symbolic language various phenomena including electrical, and fluid circuits. For the analysis of forces a "freebody" diagram is drawn, where all the restraints or supports are removed from the diagram of the object and are replaced by reaction forces, moments or couples. Freebody diagrams are an essential part in the study of mechanical systems.

5. Analog Models

Analog models are used to study analogous situations. An analog model must provide a descriptive picture and action that corresponds to the actual system. It should be mathematically similar to the prototype, since it is the mathematical models and not the actual systems that behave alike. Examples of analogous models are electrical circuits which are used to model springmass, fluid, or chemical systems.

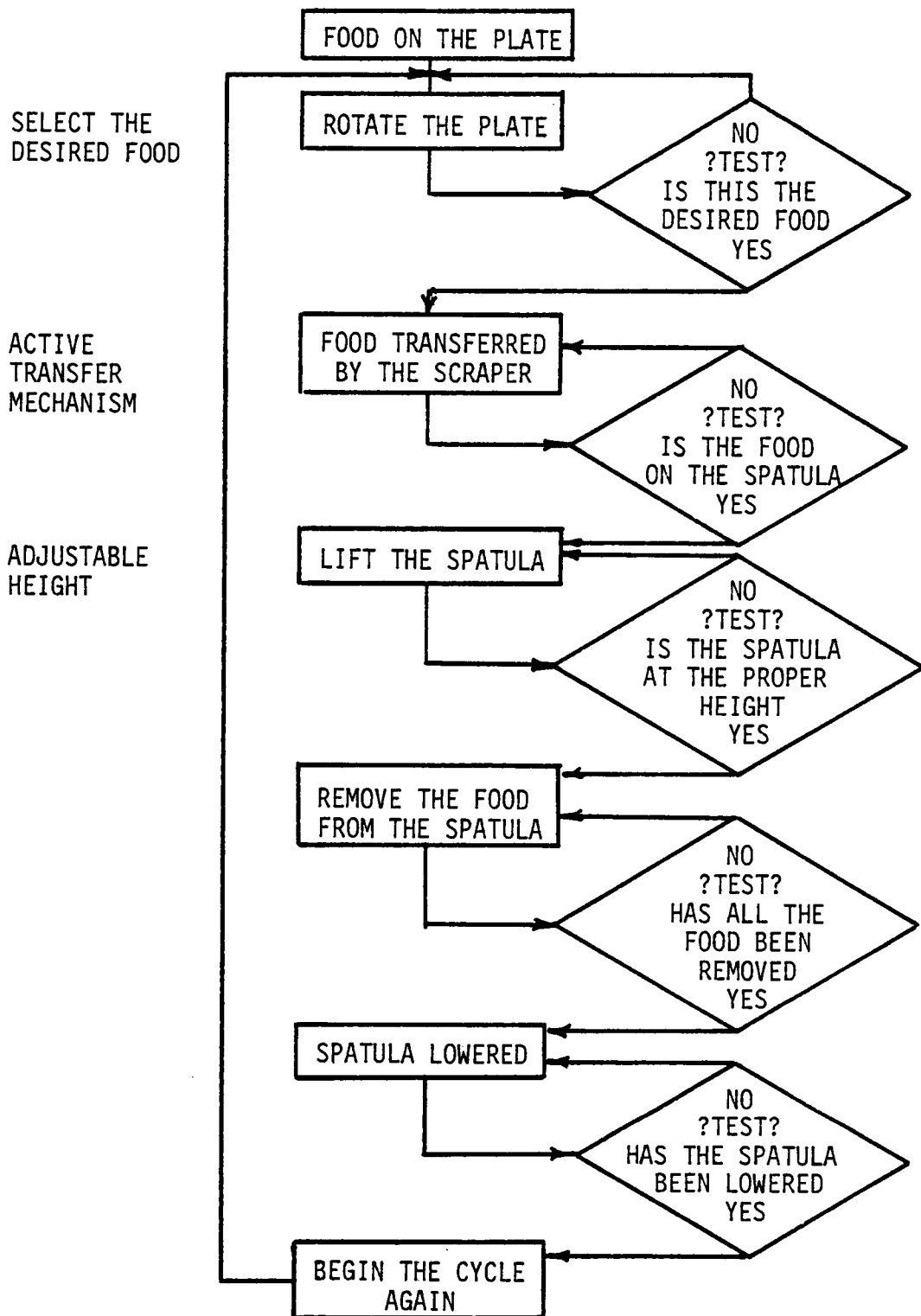


Figure 4. A Flow Diagram of the Feeding Cycle

Feeder Example

An analysis of the effects of a force on the bowl of the spoon of the feeder illustrates many aspects of models. The force is shown to have two components: one part is due to the weight of the food in the bowl and a second is due to a force which might be applied by the user or by the plate (it would be negative if applied by the plate). The assumptions made in the analysis are discussed in the next section. The free-body diagram (Figure 5) shows the resultant force and moment at the spoon attachment. Using the equations of equilibrium and material properties, equations can be developed which predict the maximum deflection and maximum stresses in the spoon. These equations could then be used to determine the cross sectional geometry and the properties of the material to be selected.

Free Body Diagram of the Spoon

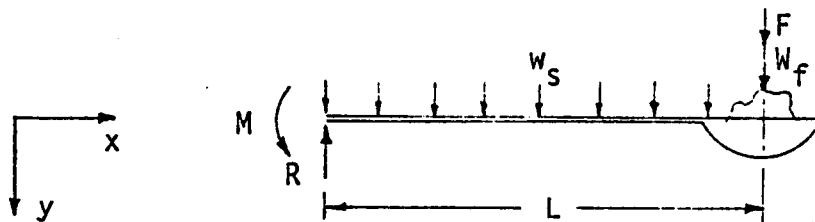


Figure 5. A Free Body Diagram of the Spoon

w_s : weight of the spoon per unit length

w_f : weight of food in the bowl of the spoon

F : Applied force

R : Resultant (shear) force at the attachment

M : Resultant moment at attachment

$$\Sigma F_y = 0 = R - W_f - F - w_s L \quad \rightarrow \quad R = W_f + F + w_s L \quad (1)$$

$$M = \frac{w_s (L-x)^2}{2} + (W_f + F)(L-x) \quad (2)$$

Mechanics of Materials

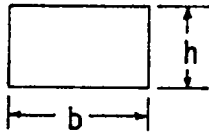
Assume that the elastic modulus E and the moment of inertia I are constant with x . From beam theory $M=EI(d^2y/dx^2)$. By integrating twice and using the boundary conditions for a clamped beam ($dy/dx = 0$) and ($y = 0$) at ($x = 0$) the following equation for the deflection of the beam is obtained:

$$y = \frac{1}{EI} \left[\frac{w_s}{24} [6L^2x^2 + x^4 - 4Lx^3] + \frac{(W_f + F)(3Lx^2 - x^3)}{6} \right]$$

At $x=L$ and $w_s L = W_s$ the deflection at the tip of the spoon is:

$$y = \frac{L^3}{EI} \left[\frac{W_s}{8} + \frac{W_f + F}{3} \right]$$

It is noted that the above equation can be used to obtain the deflection y of the bowl in terms of the length and weight of the spoon, the force on the end of the spoon, the geometry of the cross section of the handle, and the elastic modulus (a material property) of the spoon. It is now assumed that the cross section of the handle of the spoon is a rectangle as shown below. It can be shown that the maximum stresses at any position x along the spoon are given by the following equation (7):



$$A = bh$$

Maximum bending stress

$$\sigma = \frac{6}{Ah} \left(\frac{w_s}{2} (L-x)^2 + (W_f + F)(L-x) \right)$$

Maximum transverse shear stress

$$\tau = \frac{3}{2A} (w_s (L-x) + W_f + F)$$

Principal stresses

$$\sigma_{1,2} = \frac{3}{Ah} \left(\frac{w_s}{2} (L-x)^2 + (W_f + F)(L-x) \right) \pm \sqrt{\left(\frac{3}{Ah} \left(\frac{w_s(L-x)^2}{2} + (W_f + F)(L-x) \right) \right)^2 + \left(\frac{3}{2A} (w_s(L-x) + W_f + F) \right)^2}$$

Maximum shear stress

$$\tau_{\max} = \sqrt{\left(\frac{3}{Ah} \left(\frac{w_s(L-x)^2}{2} + (W_f + F)(L-x) \right) \right)^2 + \left(\frac{3}{2A} (w_s(L-x) + W_f + F) \right)^2}$$

The largest values of the normal and shear stresses occur at the point where the spoon is fixed to the feeder arm (at $x=0$) and are obtained from the above expressions.

Maximum bending stress

$$\sigma_{\max} = \frac{6}{Ah} L \left(\frac{w_s}{2} + W_f + F \right)$$

Maximum shear stress

$$\tau_{\max} = \frac{3}{2A} (W_s + W_f + F)$$

Principal stress

$$\sigma_{12} = \frac{3L}{Ah} \left(\frac{W_s}{2} + W_f + F \right) \pm \sqrt{\left(\frac{3L}{Ah} \left(\frac{W_s}{2} + W_f + F \right) \right)^2 + \left(\frac{3}{2A} (W_s + W_f + F) \right)^2}$$

$$\tau_{\max} = \sqrt{\left(\frac{3L}{Ah} \left(\frac{W_s}{2} + W_f + F \right) \right)^2 + \left(\frac{3}{2A} (W_s + W_f + F) \right)^2}$$

The designer could use the above equations, particularly the last two, to determine the maximum stresses expected in terms of some specified loading conditions and geometry of the cross section of the spoon. A material could then be selected which would safely withstand these stresses. It may be desirable to specify a particular material and the expected loads, and then use the equations to design the cross-section of the spoon in order to keep all the stresses safely below the critical values for the particular material.

It is admitted that in the problem considered the designer may not feel it is necessary to go through the above analysis in order to design the spoon for the feeder; indeed it is expedient to use "off the shelf" items whenever they satisfy the needs of the design. However if the spoon was a "new device" with which we had no previous experience, then an analysis could save many days of experimental "trial and error" research to determine an acceptable design solution.

Additional analyses could be made on the spoon including those related to forced and free vibration. If desired, the spring-mass system and electrical analyses could be used to study the behavior of a vibrating spoon. The results of the analyses would be used to ensure that the natural frequency of the spoon did not approach that of any imposed oscillating force in order to avoid problems or resonance. These are standard engineering analyses.

Assumptions

Assumptions determine the difference between the model and reality and are introduced to simplify a problem. A basis for simplifying any problem is to reduce the number of unknowns and therefore the number of equations required for solution. All assumptions must be scrutinized and tested; therefore all the assumptions must be clearly stated.

Feeder Example

Assumptions are made to simplify and solve the model example. The application of the solution of the model to reality is only as valid as the assumptions that were made to link the model to reality. The first simplification is to restrict the frame of reference to just the spoon and the attachment. In the free body diagram the density per unit length of spoon is assumed to be uniformly distributed. The weight of food and the bowl of the spoon are lumped weights acting on the centerline through the center of gravity of the bowl of the spoon. The assumptions were made to obtain a one dimensional solution for the vertical shear force and the bending reaction at the attachment.

For the stress analysis calculations the spoon is assumed to be a fixed-end beam with a distributed load and a lumped load acting at the end of the beam. The assumptions of beam theory were then applied and used to solve for the deflection. Deflection is also important in determining the stiffness and the internal forces and strains in a statically indeterminate beam. In determining the deflection a constant (EI) was assumed that is only valid for constant cross section and elastic modulus; where the cross section varies the equations become very complex and (I) must be defined in terms of (x) in order to integrate the equations.

Pure bending and shear were assumed in the stress analysis. The flexural formula of beam theory (M_y/I) assumes that plane sections normal to the axis of the spoon remain plane as the spoon is bent. Throughout the whole analysis the elastic flexural formula was applied which also assumes that stress is linearly proportional to strain (Hooke's Law). This assumption is not valid if certain plastic materials are used.

Testing

Testing is a very important part of model evaluation. Experiments are necessary to test partial as well as complete systems. The assumptions that link reality and the model must be tested to determine their validity. The "hardware" of the model must be inspected and the materials used in prototype construction must be acceptance tested. In all tests it is necessary to document the test conditions, procedures, and results. Four types of tests that are useful in rehabilitation

engineering design problems are discussed below:

1. Performance testing shows how a particular design will behave, and if the assumptions made in the analysis are valid. Performance testing is carried out during the entire design process.
2. Quality assurance tests are used to test that the materials used in the construction of assemblies meet the specifications of the design. A designer may account for material variation by designing for the weakest material or specifying quality assurance test procedures. Sub-assemblies or component parts that go into a prototype should be tested prior to insertion into the assembly. For example, in the feeder it is necessary to test the small motors used to rotate the plate, lift the spoon, and move the scraper.
3. Life endurance and safety tests are tests that indicate the life expectancy of a product in service and the sort of punishment that it can take before failure. Usually these tests are accelerated with respect to time, for example by increasing the applied loads, varying the cycle frequency or increasing the severity of the environment. The accelerated test results are used to predict the life expectancy of the material. Under some operating conditions the material may be subjected to combined loading such as a combination of axial compression and transverse vibration, as well as temperature and pressure effects. These loads are not additive and must be analyzed by applying theories

of failure. A designer must be aware of these effects and account for them in the design. He may use a factor of safety which is a ratio between the failure and the design load of the material. It must be determined if there are critical aspects of the design which should not fail under normal or even abnormal operating conditions. In applications where human life is at risk, the factor of safety must be such that no variation in workmanship, materials, or design could make the part unsafe and cause failure under normal operating loads.

4. Human acceptance tests are tests that determine if the design is acceptable. Designers must be concerned with the interaction of their design with people. They must be concerned about the physical, mental, and emotional needs and limitations of the human operator, and how these will affect his performance. A new design must be tested by the people who will use the device. Psychologists and/or human factors engineers can aid in the design of these tests. For rehabilitation engineering problems careful attention must be paid to the human operator. The tolerance level is much lower for handicapped individuals than able-bodied individuals. A design must be acceptable as well as satisfying the technical and economic constraints.

CHAPTER V

PROJECT PLANNING, CONTROL AND ECONOMICS

There are two standard engineering procedures for project planning and control: the critical path method (CPM) for deterministic projects and the project evaluation and review techniques (PERT) for probabilistic projects. Both these procedures: (i) introduce objectivity into planning and control, (ii) are easy to apply (iii) reduce the complexity of the planning process and (iv) provide a means of evaluation and control of activity during execution of the project. Details on the theory and worked examples of these two methods (CPM and PERT) are included in Appendix C. CPM is applied when only one time estimate is made for each project activity. A critical path is a sequence of events from project start to finish for which there is no slack time. In PERT, three time estimates are made for each project activity (earliest, most probable, and latest). The advantage of PERT is that it permits chance in the scheduling since it uses random number variation. The accuracy of these two systems lies in the accuracy of the time estimates. These methods permit control of the project, especially those activities which are critical. CPM and PERT project control techniques provide a feasible approach to planning subsequent evaluation and management of a project. All the calculations are made before an activity is executed. The calculated probability gives a good estimate of the feasibility of a project or suggests revisions that are required. Other parameters such as cost can be substituted for time in the calculations.

Most of the rehabilitation engineering research and development is sponsored by grants. The economics are therefore different than in the commercial world, where success is measured by profit, but the basic budgeting procedures are still the same. Projects can run into trouble if they are not administered properly. Correct budgeting procedures must be followed and proper ongoing evaluation is necessary throughout the entire project and not just at "budget time."

In the design process the model should be studied to determine that it can be economically manufactured and marketed. Careful market analysis, consumer demand analysis, and cost analysis must be done as part of the initial feasibility study. In rehabilitation engineering low production volume and specificity of design determine the economics.

The budget is a very important part of any design project. A list of line items which might appear on a project budget are shown in Figure 6.

SALARIES

Professional (Engineers, Therapists, Teachers)

Clerical (for documentation and information retrieval)

Technical (machinists, electronic, plastics, carpentry)

Consultants (Physicians, Experts)

Evaluators (internal/external)

Legal (patents, liability)

Casual Labor (miscellaneous)

OVERHEAD

Equipment and Machines

Data Processing

Data Management

Telephones

Postage

Supplies

Printing

Maintenance

Rent

Utilities

MISCELLANEOUS

Documentation
(of procedures and results)

Information Dissemination

BENEFITS

Social Security

Unemployment Insurance

Retirement

Hospitalization

Liability Insurance

MATERIALS

Prototype Construction

Test Equipment

Test Samples

EXPENSES

Travel

Staff Development

Conferences

INDIRECT COSTS

Figure 6: Budget Line items for a Project

CHAPTER VI

PRODUCT LIABILITY

Liability is an important facet of professional responsibility. Liability insurance is becoming a very important overhead expense for many professionals. The legal responsibility of a professional is to exhibit reasonable care and competence. Historically a professional could not be held liable or sued for negligence. Recently there have been an increasing number of liability cases where a professional is being sued for negligence.

A rehabilitation engineering designer is caught in two places: he can be held liable for lack of reasonable care or competence. and also he can be held liable for negligence of design. If a design is shown to be unreasonably dangerous the whole project is in jeopardy since the effects of negligence in defective design are much more far reaching than the effects of negligence in defective manufacture. A whole company can go bankrupt as a result of one defective design.

A designer, under tort, is responsible for any injuries which are a consequence of his design. The designer must not only design for the intended use but also for all foreseeable and unforeseeable uses of the product. A rehabilitation engineering designer at one time was protected from liability since the product was prescribed by the physician and therefore the liability was transferred from the rehabilitation engineer to the physician. Recent developments in the law of product liability and several judicial cases show that the designer can no longer rely on the protection of the prescription of

the physician and therefore the designer must be more responsible for his design.

A consumer who is testing a new experimental device usually signs a release form, the same sort that is signed on admission to a hospital. Judicial decisions have shown that in negligence the form has no value for the defendant (designer). The release merely means that the plaintiff (consumer) is aware that there is risk involved, but it does not relieve the designer or physician of liability due to negligence. Attention to liability must be made during all the phases of the design process. The added expenses incurred for expert and legal consultation are accounted for as line items on the budget.

CHAPTER VII

EVALUATION

Evaluation is a very important and vital aspect of the design process. The dynamic aspects of evaluation throughout the whole design process as envisioned by Levy (8) are shown in Figure 7. There are six stages within the design process where evaluation needs to occur:

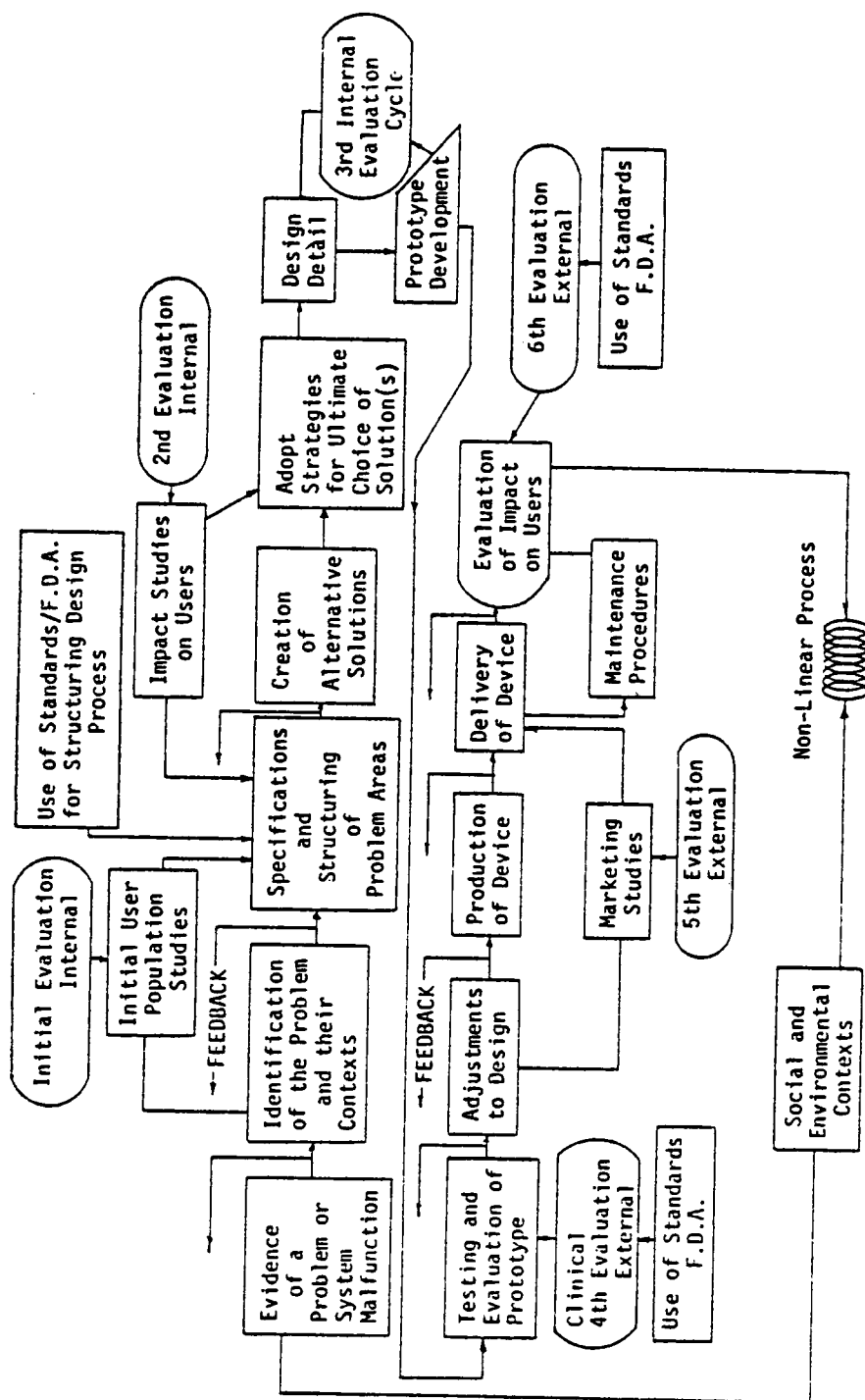
- (i) Initial user population studies, a comprehensive assessment of specified client needs (and estimate the initial market potential),
- (ii) Impact studies of the device on users (internal clinical evaluation),
- (iii) prototype design development (internal technical evaluation)
- (iv) testing and evaluation of prototype with regard to user impact and industrial potential (external field testing) (v) marketing studies (external market research analysis) and (vi) evaluation of impact on users over a long period of time (external field evaluation).

The most important aspect of evaluation is to ask the correct questions; therefore the evaluation questionnaire design is critical. The design of an evaluation questionnaire follows a similar procedure to the engineering design process. Figure 8 illustrates the steps for developing an evaluation questionnaire. The evaluation questionnaire for the Winsford Feeder has been designed as an example of the process and is shown in Appendix D.

FEEDER EXAMPLE

Step 1. Problem Review

The definition of the problem must be analyzed to determine if it has clearly delineated the problem.



- | | |
|---------|----------------------------------|
| Step 1. | PROBLEM REVIEW |
| Step 2. | EVALUATION PARAMETERS |
| Step 3. | FORMULATE EVALUATION APPROACH |
| Step 4. | SPECIFY EVALUATION QUESTIONS |
| Step 5. | SPECIFY DATA BASE |
| Step 6. | SPECIFY DATA ANALYSIS TECHNIQUES |

Figure 8. Steps for Developing an Evaluation

The Problem: To evaluate the Winsford Feeder as a viable and potentially commercial solution to the problem of feeding individuals with severe cerebral palsy.

- Step 2. The parameters of the evaluation must be defined; this will include who is going to use the information generated by the evaluation and the type of information that they will require. For the Winsford Feeder the developers of the feeder require field test information about the device prior to manufacture and the University of Tennessee Rehabilitation Engineering Center requires modification information of the feeder for use by the severely involved individuals with cerebral palsy.
- Step 3. Formulate the approach to the evaluation. This is accomplished by reviewing the information requirements and synthesizing the purpose of the evaluation. For example, in evaluating the Winsford Feeder the information required by the developers concerns the ease of manufacture. The purpose of the evaluation is to determine the design modifications that are required prior to manufacture, if the device is to be used by cerebral palsied individuals, to analyze the effectiveness of the feeder, and to suggest modifications that could make the device more attractive to manufacturers.
- Step 4. The most important step in establishing an evaluation questionnaire are the evaluation questions. The

evaluation is only as effective as the questions it asks and the information it retrieves. For the feeder example the questions are based on how effectively the design criteria is satisfied for each particular user. The users have individual characteristics, these are noted in the user profile sections of the questionnaire.

Step 5. The data base is the central source of feedback and evaluation information about the project. For the Winsford Feeder the most likely data base will be the University of Tennessee Rehabilitation Engineering Center and the Winsford Feeder developers. The selected population of users will include cerebral palsy children with varying degrees of involvement and spinal cord injured patients. The evaluators will be teachers, parents, patients, therapists, engineers, and other resource personnel.

Step 6. The collected data is analyzed qualitatively or quantitatively by various techniques. In large scale evaluations the computer is used in which case the questionnaire should be designed for digitization. The Winsford Feeder evaluation is small and is therefore qualitative.

CHAPTER VIII

Group Dynamics

In rehabilitation engineering design problems it is necessary for the rehabilitation team to work together to reach a suitable solution. These efforts are facilitated by following a systematic approach to design by which the team members representing the various disciplines may progress toward an effective problem solution.

For rehabilitation engineering problems there is another dimension to the systematic approach to design, namely personal interaction or group dynamics. The rehabilitation team is often made up of therapists, nurses, physicians, teachers, parents, social workers, psychologists and engineers. The team members assume certain "roles" as a result of professional stereotyping and labeling and consequently there are certain expectations and pre-judgements of the contributions of the team members are made. For example, the role of a physician is not the same as that of an engineer. In general the physician presents the medical-surgical aspect, while the engineer presents the technical aspect of the problem.

It is important for the team members to have reasonable expectations of the "roles" each can assume and the contributions which can be made to the problem definition/solution. For example an engineer may unrealistically expect a physician or a therapist to be able to describe a disability in quantitative terms, or a medically trained person may expect an engineer to provide answers to a broad range of non-trivial

technical problems. Thus it is important for the team members to have knowledge of and respect for each others area of expertise in order to maintain a cooperative relationship. It is suggested that the team members initially discuss their background, roles and scope they see for themselves as well as those of others on the team. These roles may change for different problems, and open lines of communication are essential in order to minimize hard feelings which can develop when one member sees another member over stepping his "boundary," or not carrying out his share of the work.

The team members need to realize that not all the members will be working on the problem at the same time. Thus a knowledge of the chronological steps to a problem solution can facilitate cooperation among team members. For example, initially the problem may involve the physicians and nurses and later on involve the family, therapists, and engineers.

There is often an innate hierarchy within the rehabilitation team (which may be real or imagined by one or more team members). The hierarchy may produce domination and subordination complexes, which should be minimized in order to avoid an adverse effect on the contributions made by the various team members. The interaction of each team member is determined by the particular personality and the atmosphere produced by all the personalities. The protocol of a team depends upon the personality and context of the team as a whole. The protocol or ground-rules, which all members should be aware of, determine how the team members will interact. It is the interaction

of the team members and their ability to communicate and share resources which will determine the success of the systematic approach to design.

CHAPTER IX

SUMMARY AND CONCLUSIONS

The rehabilitation team will be better equipped to solve the interdisciplinary design problems of rehabilitation if each team member is familiar with the design process. This process begins with the definition and formulation of the problem and requires understanding of the physiological, psychological, social, and technical aspects of the problem. Often, the contribution of the patient is very important in defining the problem.

The literature review determines the current state of the art or the existence of a possible commercial solution but due to the broad spectrum of sources of information this is often difficult. However the dissemination of rehabilitation information will improve as a result of the recent establishment of NIHR and the use of computers in information exchange.

The application of established techniques of idea generation in rehabilitation engineering produce innovative designs. To determine the optimum combination of ideas it is helpful to create models by making assumptions, applying methods of analysis, and testing. To reduce the risk of liability due to negligence careful attention must be made to engineering standards, and government regulations. The designer should be aware that the release forms offer very little protection from liability due to negligence; therefore he should use accepted practices to investigate and document all his research.

Techniques such as CPM and PERT are introduced for project planning and control. Proper accounting procedures should be applied so that proper budgeting control of the project can be maintained or modified.

Evaluation is an integral part of the design process, beginning with an initial needs assessment and carried on through the manufacturing phase until an evaluation has been made of the impact of the design (device) on the user.

Cooperation among members of the rehabilitation team is very important for obtaining solutions to rehabilitation engineering design problems. Therefore there should be consideration to the personal interaction of all the team members.

The particular needs and concerns of the potential consumers and their interaction with the products of rehabilitation engineering design should be recognized and applied to all aspects of the design process.

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APPENDIXES

APPENDIX A

LIST OF SOURCES FOR REHABILITATION ENGINEERING INFORMATION

National Library of Medicine (NLM)
8600 Rockville Pike
Bethesda, MD 20014
301/656-4000

NLM's extensive collection is made accessible through a computer-based storage and retrieval system, the Medical Literature Analysis and Retrieval System (MEDLARS). MEDLINE (MEDLARS On-Line) terminals are available in approximately 800 medical libraries across the U.S.

National Technical Information Service (NTIS)
5285 Port Royal Rd.
Springfield, VA 22161
703/557-4650

NTIS was established to simplify public access to government publications and data files. The more than one million titles are in the areas of science, technology, engineering, business, economics, library and information sciences, social and behavioral science. Weekly Government Abstracts are issued in twenty-six areas including: Biomedical Technology, and Human Factors Engineering, Medicine and Biology. The bibliographic data base which contains all current abstracts is available through NTIS search which can be accessed through Lockheed and Systems Development Corp.

Smithsonian Science Information Exchange (SSIE)
Room 300
1730 M. Street, N. W.
Washington, D. C. 20036
202/381-4211

SSIE collects, indexes, stores and disseminates prepublication descriptions of ongoing and recently completed research projects in all fields of life and physical sciences. Over thirteen hundred supporting organizations contribute to the file including federal, state, and local governments, non-profit organizations, foundations, colleges and universities. Eighty percent of the file covers federally sponsored research extra-and intramural.

Searches are custom tailored by SSIE. The data base is also accessible through Systems Development Corporation.

Veterans Administration Rehabilitative Engineering Reference
Collection
Office of Technology Transfer (OTT)
252 Seventh Avenue
New York, NY 10001
212/620-6659
Lily Hom Information Specialist

OTT has a reference collection that was begun more than twenty-five years ago by the Research and Development Division of the VA Prosthetics and Sensory Aids Service, Department of Medicine and Surgery, which in 1973 became the Research Center for Prosthetics, from which the OTT evolved.

The collection comprises twenty-five hundred books, one hundred and thirty five periodicals, nine hundred technical reports to the VA or other agencies, twelve and a half thousand reprints and copies of papers, seven thousand patents and some audio-visual materials.

The reference collection is available for use by professionals in the medical and allied health and engineering field.

Veterans Administration
Marketing Center
Hines, IL 60141
312/681-6829

Publishes a quarterly: Evaluation of New Products which includes devices, aids, equipment. Plans are underway to put this information on computer so that it can be retrieved on demand. Also an FRP has been published for development of an Information Collection and Retrieval System composed of current products, aids, devices and related handicapped information. The first product would be a directory of current products, aids and devices.

National Aeronautics and Space Administration
Technology Utilization Office
600 Independence Avenue, SW
Washington, DC 20546
202/755-2420

To promote technology transfer within the nations' industrial complex NASA operates a network of seven Industrial Application Centers which provide access to ten million documents, the world's largest repository of technical data. The Industrial Application Centers are located at universities.

In the biomedical field, NASA has just published: Technologies for the Handicapped and Aged.

Rehabilitation Service Administration (RSA)
RSA Research Information System (1955-1971)
v. i-4 Abstracts; v. I, II Index
(A very limited number of sets of abstracts is in the office of Research Utilization, and can be made available. The two index volumes are not available. If you need access contact NARIC).

National Rehabilitation Information Center (NARIC)
8th and Varnum Streets, NE
The Catholic University of America
Washington, DC 20064
202/635-5826

Receives, stores, catalogues, makes retrievable all research reports and A-V materials produced by RSA grants and support. including those in the area of rehabilitation engineering. Has physical copies on hand and will reproduce on demand. NARIC also provides access to other computerized data bases (including MEDLINE)

IMPART
Texas Rehabilitation Commission
Carol J. Whitcraft, Ph.D.
Frederick O. Bohls, Ph.D.
Texas Rehabilitation Commission
118 East Riverside Drive
Austin, TX 78704
512/447-0367

IMPART stands for Innovative Matching of Problems to Available Rehabilitation Technology. IMPART receives rehabilitation problems and searches for individualized solutions. Rehabilitation engineers examine the problems and may use computerized research files to solve them.

Information Exchange Program
Arkansas Rehabilitation Research and Training Center
University of Arkansas and Arkansas Rehabilitation Services
346 North West Avenue
Fayette, Arkansas 72701

Publishes Research Directory of the Rehabilitation Research and Training Centers Publication and Audiovisual Aids Directory of the Rehabilitation and Training Centers and Informer, a monthly training directory of the Rehabilitation Research and Training Centers.

Trace Research and Development Center for the Severely Communicatively Handicapped
1500 Highland Avenue, Room 314
Madison, WI 53707
608/262-6966

Has a master chart and listing of non-vocal communication aids and has an annotated bibliography of communication aids.

Dr. John Eulenberg
International Action Group for Communication Enhancement
Artificial Language Laboratory
Computer Science Department,
Michigan State University,
East Lansing, MI 48824

Publishes Communication Outlook which focuses on Communication Aids and Techniques in cooperation with the Trace Center for the Severely Communicatively Handicapped, makes technical reports available.

Sensory Aids Foundation
399 Sherman Avenue, Suite 4
Palo Alto, CA 94306
415/329-0430

Specializes in sensory aids to assist blind or partially blind persons with employment.

Adaptive Systems Corporation
1650 So. Amphlett Blvd., Suite 317
San Mateo, CA 94402

Provides and Information System for Adaptive and Rehabilitation Equipment (ISARE) which provides a list of six hundred items and two hundred manufacturers, plans to be made available on time sharing basis by fall 1979.

Accent of Information
Gillum Road and High Drive
PO Box 700
Bloomington, IL 61701
309/378-2961

Computer based information on equipment, input from manufacturers, some feedback from users.

Rehabilitation International Information Service
432 Park Avenue South
New York, NY 10016

Rehabilitation International provides quarterly mailings of selected publications on specialized aspects of Rehabilitation throughout the world.

National Easter Seal Society
2023 West Ogden Avenue
Chicago, Ill 60612

The National Easter Seal Society has many publications and also an information center.

United Cerebral Palsy Association Inc.
66 East 34th Street
New York, NY 10016

The United Cerebral Palsy center has many publications and provides information on request.

Disabled Living Foundation: Aids Center (DLF)
346 Kensington High Street,
London, W14 8NS. England

The DLF provides full information on the availability, manufacturers and prices of adaptive equipment and devices displayed at its aid center.

ICTA Information Center
Fack, S-161
25 Bromma 1, Sweden

ICTA (International Committee on Technical Aids, Housing and Transportation) publishes information sheets on new technical aids, their availability price and manufacturer, also it publishes a quarterly newsletter "ICTA Inform"

Green Pages
PO Box 1586
Winter Park,
Florida 32790

Green Pages is a directory of products and services for the physically disabled.

APPENDIX B

TECHNICAL WORKSHOP VI INFORMATION RETRIEVAL AND DISSEMINATION REPORT

Leader: Dr. James Reswick

Purpose :

To stimulate discussion of information needs in the field of rehabilitation engineering, and to document the discussion in such a way as to contribute to the NIHR five year planning process.

Objective:

To formulate recommendations with respect to the following two prospective activities of the Institute, as specified in the Federal Register Vol.44, No. 82:

To facilitate access to, and collection of information concerning developments and use of, rehabilitation procedures, methods, and devices for handicapped people to live more independently and to participate in family and community life, including activities related to education, vocations and avocations.

To increase and disseminate the scientific and technological information presently available in the field of comprehensive habilitation and rehabilitation, and to provide a comprehensive information service for handicapped individuals.

Problem Addressed:

The workshop addressed the issues of availability, access and dissemination of rehabilitation engineering information in the public and private sectors.

The primary concern was with the problem that, while an extensive amount of information is created in the area of rehabilitation engineering, current means of identifying and accessing that information

are disjointed and not comprehensive or efficient.

The participants' diversity of position and experience contributed to the definition of what information resources are available and what gaps exist in both the existence of and accessibility to information.

Recommendations:

1. The documentation required by federally funded rehabilitation engineering research and development projects should be more substantial and emphasize practical detail to a greater degree than the currently required abstracts. The documentation of research procedures and results should be submitted to an appropriate information system that provides for an input and retrieval mechanism which is readily accessible to the public and private sectors. The allocation of funds for this function should be a standard line item in project budgets.
2. The Institute should require any new federally funded information system in rehabilitation engineering to solicit and either include or reference available product evaluation information.
3. Since product information is not presently available from any central source, the Institute should develop, in cooperation with other agencies, a comprehensive network utilizing to the greatest extent possible existing sources and programs.
4. There should be no restriction on eligibility for accessing the national information network. Disabled individuals should be provided information in accordance with their ability to pay.
5. The Institute should take an initiative in the innovative distribution of references to basic sources of rehabilitation engineering information through novel channels and mechanisms.
6. Current information retrieval systems should review their index structures with a view to refining and augmenting them for improving accessibility to existing rehabilitation engineering information. The Institute should identify systems to comply with this recommendation by determining the rehabilitation engineering content of current information resources through review by appropriate experts.

7. The Institute should prepare and disseminate to rehabilitation practitioners a concise list of sources of rehabilitation engineering information, as an interim mechanism to be available until the national information network has been created.
8. The Institute should encourage schools which train rehabilitation professionals to include information skills in their curricula.
9. The Institute should have an "800" telephone number to:
 - a) refer consumers to organizations and rehabilitation professionals;
 - b) provide sources of and/or product information;
 - c) provide information about the status of current research efforts.

The patterns of use of this service should be recorded and analyzed for feedback into the rehabilitation engineering research community as an indicator of consumer/ professional needs. The information resources employed to provide these services should be shared with other information providers.

Cost:

More specific and detailed plans are required for realistic costs to be associated with the above recommendations.

Development of Equipment Index for Information Network

Need:

Several factors justify the need for a universal and comprehensive indexing system for rehabilitation equipment and services. These include the exponential growth of the data base and the demand for effective service delivery. Cost effectiveness of service delivery will depend of the speed and precision with which information can be accessed, as well as the comprehensiveness of that information. Recognizing the interdisciplinary nature of this field, a suitable indexing system would make the data base available to all users through the use of a thesaurus of familiar terminology.

Rehabilitation equipment indexing and directory systems presently in use were discussed. It was decided in the group that none of these systems completely met the needs of the users.

Recommendations:

1. The users of the system were identified as follows: Service Delivery, Information centers, Third Party Payers, Planners and Producers. Consensus opinion was that this system would be developed for users with a background or training with rehabilitation equipment.
2. To provide universal access, the methodology of the system should be oriented to key words from one(or a combination) of the following categories 1)Devices, 2)Problems,3)Services, 4) Geography. The data fields should be made multiply selectable providing precise selection to the needs of the user.
3. The format for the system should be two dimensionally expandable in precision and scope. Different output formats are required as options to maximize the usefulness of the data for individual users. These are as follows: 1) Digital format for telecommunications, 2) Custom printout of data searches for special needs, 3) Pictorial representations of devices and applications.
4. Priority of immediate efforts, or the first stage, must be to develop an indexing structure with a corresponding thesaurus. Efforts at data collection should begin with commercially available devices, and evaluation of these devices.
5. Custom devices and modifications should receive second priority in indexing, along with individual referral contracts and services.
6. Other considerations to be included at a later time include the following: documented solutions of special problems, failures at attempts to solve special problems, agencies, organizations, third party payers, clinics, educational programs, and other services including vocational and recreational.
7. The system should be pilot tested using one narrow field of data. It is suggested that communication aids for the non-verbal could be a good testing subject since the TRACE project has already developed the data base for this field.

8. The design of a suitable indexing system, or directory, must be a cooperative effort by users and information specialists. It is recommended that an interdisciplinary committee be assigned the tasks of defining and developing the actual format to be used, the thesaurus and the working model.
9. The committee would determine the costs and needs of implementing this working model as a pilot project within the California Service Delivery Research Project. This committee would also be responsible for identifying the cost estimates of this project, and recommendations for the next stage of efforts.
10. There is perceived to be some urgency to develop an indexing system, or directory, of rehabilitation equipment as there are several information indexing systems in early and advanced stages of planning. It is recommended that a committee be chosen as soon as possible to develop the first stages of planning this system, with the working model of non-verbal communication aids completed within nine to ten months.

Cost:

Budget for a five person committee for three meetings, and costs of project is estimated at \$10,000.00 .

APPENDIX C

CRITICAL PATH METHOD AND PROJECT EVALUATION AND REVIEW TECHNIQUE THEORY AND EXAMPLES

Critical Path Method (CPM) [10]

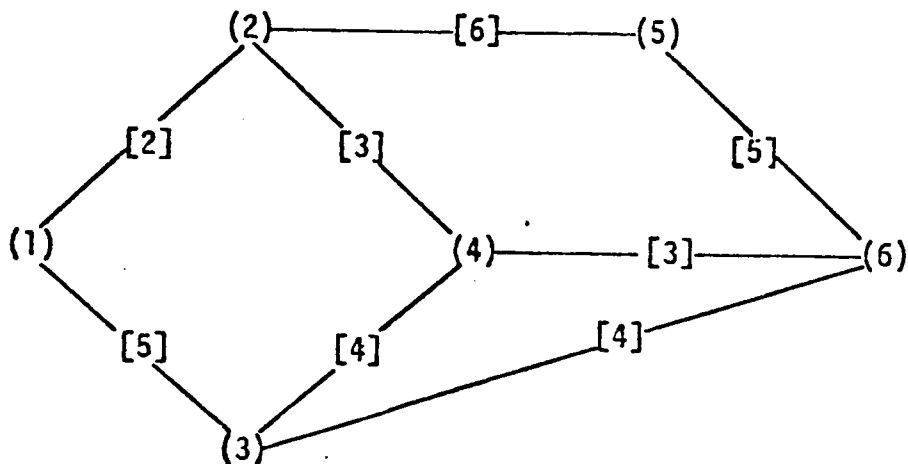
The rules for using CPM are as follows:

1. Each activity is defined by the two events which start and finish it.
2. The physical nature of a project defines the ordering of events, and the time difference between the start and finish of an activity is called the activity time.
3. The start event for a certain activity succeeds all end events of the preceding activities.

The CPM is best shown by a network, where the nodes represent events and the arcs represent activities. The direction of time flow is from start to finish. Associated with each activity is an estimate of the expected completion time (Y). Two times are associated with each event: (TE) is the earliest time an event can occur for a given project start, and (TL) is the latest an event can occur for a given project finish. (See Figure C-1).

Certain relationships evolve:

$$TE_i = \begin{cases} \text{Project start } TE_0 & i=0 \\ \text{Max } (TE_{i-1} + Y_{i-1,i}) & 0 \leq i \leq n \end{cases}$$
$$TL_i = \begin{cases} \text{Min } (TL_{i+1} - Y_{i,i+1}) & 0 \leq i < n \\ \text{Project finish} & i=n \end{cases}$$



Time (y_{ij})	Activity start end event (i) (j)		Earliest Starting Time (TE_i)	Latest Starting Time ($TL_j - y_{ij}$)	Earliest Completion Time ($TE_i + y_{ij}$)	Latest Completion Time (TL_j)	Maximum Available Time ($TL_j - TE_i$)	Activity Slack Time ($TL_j - TE_i - y_{ij}$)
2	1	2	0	0	2	2	2	0
5	1	3	0	1	5	6	6	1
3	2	4	2	7	5	10	8	5
6	2	5	2	2	8	8	6	0
4	3	4	5	6	9	10	5	1
4	3	6	5	9	9	13	8	4
3	4	6	9	10	12	13	4	1
5	5	6	8	8	13	13	5	0

The above analysis shows that the Critical Path for this example is: 1-2-5-6.

These events represent those events where there is no slack time.

Figure C-1: Critical Path Method

Therefore the maximum amount of time available is project finish less project start, and the slack time is $(TL_{i+1} - TE_i - Y_{i,i+1})$. The slack time represents the amount of latitude available in scheduling an activity. If the slack time is zero then the project is critical and then there is no sequencing decision. In CPM it can be shown that there is a connected chain of critical activities from project start to finish: the critical path. See Figure C-1 for a worked example of the critical path method.

PROJECT EVALUATION AND REVIEW TECHNIQUE (PERT)

Both (CPM) and (PERT) use an event and activity network. In (CPM) only one time estimate was made, while in (PERT) three time estimates are made. Y is a random variable with a beta distribution which ranges from: a (probable earliest completion time) to b (probable latest completion time) and m (most probable completion time). The advantage of (PERT) is that it provides a method of using random number variation which inherently allows for chance in scheduling calculations. The key to (PERT), is estimating the times, this is based on knowledge and experience. Note that for a beta distribution the mean and variance are:

$$\text{Mean } t_e = (a + 4m + b)/6 \text{ and the variance } \sigma^2 = [(b-a)/6]^2$$

In the (PERT) analysis :

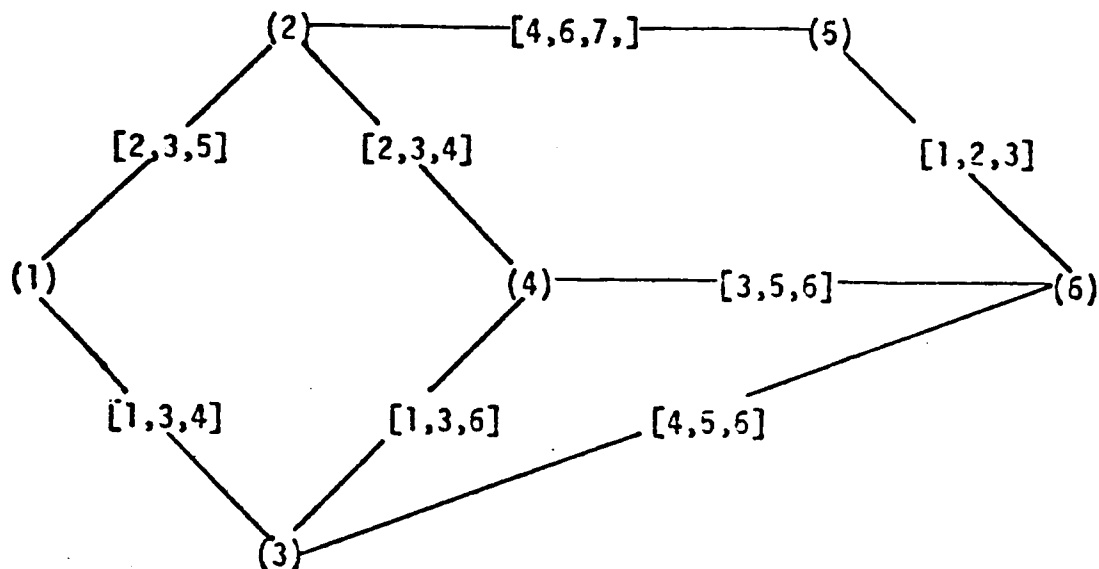
1. List each event from the last to the first
2. List the previous event from the last to the first.
3. List earliest, most probable and latest completion times.
4. Calculate expected value mean t_e for each activity.
5. Calculate the variance σ^2 for each activity.
6. Calculate the earliest expected time for an event by adding the mean t_e of each activity to a cumulative total of expected times through the proceeding event staying on the same path from start to finish. When more than one activity leads to an event the activity whose expected time gives a maximum value up to that event is chosen as the expected value for that event.
7. Calculate the latest time for each event by fixing the earliest time of the end event as its latest time then the latest time for all preceding events are obtained by subtracting the expected activity time from the latest for the succeeding event, staying on the same path and working from the finish to the start. When there is more than one activity leading from an event, the minimum value through the event is selected.
8. Calculate the slack time by subtracting the earliest expected time from the latest time (TL-TE). The probability of meeting the schedule time is calculated as follows:

$$\frac{\text{Schedule time} - \text{Earliest expected time}}{\text{Standard deviation of sum of activity time}} = \frac{\text{Area under the Normal Curve}}{}$$

$$= \frac{TS - TE}{\sqrt{\text{sum of variables}}}$$

The acceptable probability range is between 25% and 60%. Less than 25% indicates that with the given resources the project cannot be completed on time. Values greater than 60% indicate that the available resources are being wasted.

For rehabilitation engineering design projects the arcs represent the phases of the design process and the nodes represent the start and finish of these phases or strategic points in the design process. Figure C-2 shows an example of the project evaluation and review technique.



Activity	Event	Previous Event	Completion Times			Mean t_e $a+4m+b/5$	Variance s^2 $[(b-a)/5]^2$	Expected Times		Slack Time TL-TE
			Earliest a	Probable m	Latest b			Earliest TE	Latest TL	
1	6	5	1	2	3	2.00	0.111	11.00	12.33	1.33
2	6	4	3	5	6	4.83	0.250	12.33	12.33	0.00
3	6	3	4	5	6	5.00	0.111	7.83	12.33	4.50
4	5	2	4	6	7	5.83	0.250	9.00	10.33	1.33
5	4	3	1	3	6	3.17	0.694	6.00	7.50	1.50
6	4	2	2	3	4	4.33	0.111	7.50	7.50	0.00
7	3	1	1	3	4	2.83	0.250	2.83	4.33	1.50
8	2	1	2	3	5	3.17	0.250	3.17	4.50	1.33

The (PERT) network analysis shows that the "critical path" is 1-2-4-6. If the Scheduled time (TS) is 12.50 then the probability of meeting the scheduled time is: $\frac{TS - TE}{\sqrt{\text{Sum of Variances}}} = \frac{12.50 - 12.33}{\sqrt{0.25 + 0.11 + 0.25}} = 0.21$

From the tables for the Normal Curve 0.21=58%. The probability falls in the normal range.

Figure C-2: Project Evaluation and Review Technique.

APPENDIX D

EVALUATION QUESTIONNAIRE FOR THE WINSFORD FEEDER

USER PROFILE

Name of User: _____ Sex: _____

Address of User: _____

_____ Telephone: _____

Birth Date of User: _____ Age: _____

Parent's Name: _____

Address: _____

_____ Telephone: _____

Name of Evaluator: _____

Address of Evaluator: _____

_____ Telephone: _____

Agency of Evaluator: _____

Date of Evaluation: _____

CLINICAL DIAGNOSIS

A. Spinal Cord Injury (level) _____

B. Muscular Dystrophy (type) _____

C. Cerebral Palsy (type) _____

D. Polio _____

E. Spina Bifida (level) _____

F. Other _____

NEUROMOTOR EVALUATION

Developmental Motor Age: Years _____ Months _____

Test Instrument used: Gessell _____ Milani-Comaretti _____ Other _____

Muscle Tone: Hypertonicity _____ Hypotonicity _____

Symmetrical _____ Asymmetrical _____

PRIMITIVE REFLEX PATTERN:

	Present	may/may not be Present	Never Present
Asymmetrical Tonic Neck Reflex			
Symmetrical Tonic Neck Reflex			
Positive Supporting Reaction			
Tonic Labyrinth Prone			
Tonic Labyrinth Supine			

HEAD CONTROL

Excellent(maintain without support, indefinitely) _____

Good (maintain with minimal support 3minutes-1 hour) _____

Fair (15 seconds-3 minutes) _____

Poor (needs full support) _____

Effects of head control on tone (describe effect) _____

PATTERN OF ARM/HAND USE

	LEFT	RIGHT
Dominated by Flexion		
Dominated by Extension		
Dominated by A.T.N.R.		
Fluctuating Tone		
Dominance: not established		

ORAL MECHANISM: (Describe in Detail)

Lips_____

Tongue_____

Jaw_____

MOTOR SKILLS SCREENING FOR SWITCH OPERATION

	Is able to initiate movement		Is able to control movement	
	YES	NO	YES	NO
Fingers on Left Hand				
Fingers on Right Hand				
Left Hand				
Right Hand				
Left Shoulder Placement				
Right Shoulder Placement				
Left Leg Placement				
Right Leg Placement				
Left Foot Placement				
Right Foot Placement				
Head Rotation				
Head Flexion				
Head-Side Flexion				
Head Extension				
Vertical Eye Motions				
Horizontal Eye Motions				
Chin Placement Left				
Chin Placement Right				

What is the preferred Motor Control?

Fingers_____Hand_____Head_____Eye_____

Chin_____Knee_____Foot_____Leg_____

PART II DEVICE PROFILE

SIZE

	small	good	large	Comments
Overall				
Plate				
Spoon				
(C.P.Spatula)				
Scraper				
Liquid Container Bracket				
Controller(Interface)				

SHAPE

	too long	too wide	too high	Comments
Overall				
Plate				
Spoon				
(C.P.Spatula)				
Scraper				
Liquid Container Bracket				
Controller(Interface)				

MATERIALS

	Adequate	Recommendations
Overall		
Plate		
Spoon		
(C.P.Spatula)		
Scraper		
Liquid Container Bracket		
Controller(Interface)		

WEIGHT

	light	good	heavy	Comments
Overall				
Plate				
Spoon				
(C.P.Spatula)				
Scraper				
Liquid Container Bracket				
Controller(interface)				

APPEARANCE:(Comment on the cosmetic and functional appearance)

How important is SYMMETRY of the liquid container placement?

Comment on the Operation and performance of the following parts:
(please be specific)

Food Scraper_____

Plate Rotation_____

Spoon Lift_____

Height Adjustment_____

SPILLAGE

How often does it occur during the meal?_____

What sort of foods spill the most?_____

When does spillage occur?(at the start or end of the meal)_____

Can the user control spillage with practice?_____

How serious is the problem?_____

Does it embarrass the user?_____

BATTERY

What is the average recharge time?_____

How many meals are there between recharging periods?_____

How long is an average mealtime?_____

CONTROL(please indicate the type of interface controller you are using)

Speed (slow, fast, what times in the cycle need changing?)

Scraper_____

Plate Rotation_____

Lift Lever_____

How well does the interface adapt to the user?_____

Does the interface function according to expectations?_____

What are the expectations?_____

What was the initial learning time?_____

What modifications (if any) need to be made to the interface?_____

LIQUID CONTAINER BRACKET

Comment on the placement(right or left side?)_____

Comment on the size_____

Suggest modifications_____

Major design changes_____

OPERATIONS

How easy is it to remove the components for cleaning?_____

How easy is it to clean the components?_____

How safe do you regard the device?_____

Are there any obvious safety hazards?_____

Is it too noisy?_____

How effective is the feeder?_____

Does the food get too cold before feeding is completed?_____

Is the liquid container easy to use?_____

Is the feeder portable?_____

Do the benefits (for the user, family and/or institution) justify
the price (\$750) of the feeder?_____

User Comments:_____

Evaluators Comments:_____

VITA

Katharine Mary Hunter, was born in Victoria British Columbia, Canada on November 28, 1955. She attended Norfolk House School in Victoria 1960-1962, and Crofton House School in Vancouver from September 1963 to June 1973. She entered the University of British Columbia in September 1973 and she received a Bachelors of Applied Science in Mechanical Engineering in May 1978. In September 1978 she entered the University of Tennessee at Knoxville where she held a teaching assistantship in the Department of Engineering Science and Mechanics and a research assistantship at the Rehabilitation Engineering Center in Memphis. She received a Masters of Science degree in Engineering Science (Rehabilitation Engineering Option) in March, 1980.

She is a doctoral student at the University of Toronto in the Department of Mechanical Engineering.

The author is a member of the American Society of Mechanical Engineers, the Canadian Medical and Biological Engineering Society and the Rehabilitation Engineering Society of North America (RESNA). She is also an Engineer-in-Training with the Professional Engineering Association of British Columbia.