CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

SELECTION OF A MATERIAL HANDLING SYSTEM
FOR OLIVE VIEW MEDICAL CENTER;

A Comparative Analysis Between an Automated
and a Manual System

A graduate project submitted in partial satisfaction of
the requirements for the degree of Master of Science in
Health Services Administration

by

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The graduate project of Joel Michael Bergenfeld is approved

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LIST OF TERMS

1. Centralized Materials Management

The combining of all supply functions into one unitary department under the control of one department head.

2. Clean Core

That portion of the central core of the hospital which functions as a sterile and clean logistics area for all supplies.

3. D.S.C.C.

The Decentralized Supply and Care Center is a supply storage area located near the patient's bedside for the immediate and anticipated needs of the patient. It also functions as a work area for other nursing needs.

4. Life-Cycle Costs

The actual inflation adjusted expenses anticipated for a given capital investment.

5. Material (Supply) Distribution System

The process by which supplies and equipment are received, stored, sorted, and delivered to the area of use. A network of supply function arranged to meet the needs of the facility.

6. Materials Handling Systems

The transportation mode by which supplies and equipment are transported to the area of use.

7. Soiled Core

That portion of the central core of the hospital which functions as a contaminated logistics area for trash, linen, and soiled instruments.
8. **S.P.D.**

The Supply Processing and Distribution Center is that area at the base of the hospital core from which all hospital supplies originate and processing functions performed.
ABSTRACT

SELECTION OF A MATERIAL HANDLING SYSTEM FOR OLIVE VIEW MEDICAL CENTER

by

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In February of 1971, Olive View Medical Center was destroyed by an earthquake. Planning for the construction of a new facility began almost immediately following the establishment of a temporary hospital. A major conflict related to the initial planning centered around developing a supply distribution system which could support a maximum level of patient care, yet be economical. Once a supply system was selected a second problem centered around the selection of a materials handling system which could provide the transportation mode for the distribution system. After a careful review of the literature and many meetings with architects and hospital personnel, a supply system was selected for the Olive View Medical facility. Thus, a twenty-year life cycle cost comparison between a fully automated and a manual material handling system was undertaken as the basis for selection for the new hospital.
A time and motion study was made of the manual cart exchange system used at the Tarzana Medical Center. Concurrently, the number of anticipated supply trips for the new hospital was estimated. Using the data from the Tarzana study an average time per trip was determined. Deductively, the total estimated material handling time for the new facility was projected. Thus, this resulted in 3.54 F.T.E.'s or current labor cost of $27,600 annually.

Using the above data, a life-cycle cost analysis was studied between the automated and manual systems using an inflation factor of 8 per cent. Results of this study clearly favored the manual system which was less than one-third of the actual true cost of the automated system. However, a comparison of these results to one undertaken by the Controller General of the United States showed that the results would vary with increasing inflation rates. In view of these findings, and in order to provide maximum labor savings with a minimal capital outlay, a semi-automated system was suggested for consideration. An automated vertical dumbwaiter would reduce transportation time between floors, provide substantial labor savings, yet require only a minimal initial outlay of capital.
Such a system could prove beneficial to the patients in faster, more direct care, as well as lower costs on his bill.
1. **INTRODUCTION**

In planning an acute medical facility, one must determine beforehand what method of distribution is required to provide for a maximum level of patient care. Once a distribution system is agreed upon, the architect designing the facility should include physical structures needed to accommodate this system in their construction program and final plans. If the facility is constructed prior to these considerations, the adaptive nature of the distribution system could be impractical, ineffective, and inefficient. Therefore, the structure should be built around a material delivery plan with careful consideration given to the backup handling system.

Any supply system should include all of the following elements: central sterile supplies; sterile processing; linens; food services; and disposal removal. A structure which cannot provide for all of these services creates administrative chaos, additional labor costs, non-nursing activities by the nursing staff, and most important interferes with the provision of a maximum level of patient care. Henceforth, an emergency cardiac patient cannot afford the luxury of precious moments needed to
secure the required supplies. Nor can the other patients afford the lost nursing time when it is spent securing supplies on an as needed basis. The key to any successful system is to keep the nurse at the bedside. It must provide the necessary materials at the right place, at the right time, in the right amount. Therefore, each system must be planned before the facility is built. Ideally, the architects will design the building around our patient care needs and not force us to compromise these needs to accommodate existing plans.

Once a distribution system is agreed upon, we must take a second great step and determine the mechanics of the system. This should include staffing patterns, and scheduling of deliveries and collections. In considering how we move supplies from point A to point B, the supply handling and distribution activity should be programmed to effectively minimize nursing time and available space.  

1Beginning in 1966 the JCAH recognized the necessity to raise and strengthen the standards from their present level of minimum essential to the level of optimal achievable and to assume their suitability to the modern state of the art.  

2Section III of the JCAH Accreditation Manual for Hospitals addresses itself to these needs and
establishes new priorities and principles relating to central service activities. The principle on which this standard is based is, "a clean, safe, environment shall be provided and maintained within the hospital.... It shall be effectively organized, directed and staffed by qualified personnel."

The magnitude of this study is to, firstly, design and recommend a material distribution system for the new Olive View Medical Center, and secondly, to compare and analyze a fully manual system and a fully automated system. Included in this analysis will be a brief discussion of the various automated systems available. The selection form among these alternatives will be based on: 1) capital cost considerations, 2) realized labor savings, 3) increased level of patient care, and 4) special considerations related to the new Olive View itself. It is the scope of this study to determine what we want (a detailed material distribution system), and who is to do it (what material handling system will get the job done).

The methodology for this study is quite simple. A subjective review of interviews and surveys from both nursing and patient central service department (PCS) administration, will provide the information required for a
system desired. These must be reviewed objectively from both an architectural and administrative planning level.

Hence, special considerations have to be made for a public facility in view of total health care delivery. Once the delivery system is acceptable, then an objective study of alternative handling systems will be made. The system selected will be that system which from a capital cost analysis appears to be the most economical over a twenty year life span. Special considerations will be given to labor savings, maintenance costs, operating costs, capital equipment costs, and practical considerations such as space, traffic, and public acceptability.

This study will include a brief review of this available literature and a discussion on the nature of the general problem of material handling. Although this is not an experimental project, it is a very common problem in planning a new hospital. I propose this study to be used as a practical guide to others who may face a similar planning problem in the future. A discussion of the alternatives will also create new areas for future studies and perhaps possible experimental situations which can be objectively analyzed.
2. HISTORICAL AND LITERARY REVIEW

MATERIAL DISTRIBUTION SYSTEMS

The basic functions of all efficient material handling systems are supply, processing, and distribution of material required to sustain a maximum level of patient care. The supply system is "a loose collaboration of various hospital functions and equipment which must be coordinated to place supplies in premeditation of need at the patient's bedside; at the floor nursing center; and at designated points in the therapeutic system. Henceforth, it must also encompass facilities for returning, for processing, and for distributing various materials and equipment that have been used in patient care."\(^5\)

The general nature of this system is related to those materials used in direct patient care and excludes those processing functions related to housekeeping care. Thus, inclusive in the system design will be, general storage, bulk storage, processing functions related to patient care, sterile processing, central supply, linens, and the pharmacy. Within this system all functions are allied, and all but one are susceptible to a single
control. The exception is the sensitive area of the pharmacy, which remains under the undisputed control of the pharmacist, from the point of receiving in the building, to the point at which the nurse takes over.

One might ask the obvious question, "Why all of this current concern about hospital efficiency?" The answer lies in the dramatic increases in hospital costs within the last twenty years. A study by Gordon Friesen, discovered some startling statistics. In 1946, the per patient day expenses in a non-federal, short term, general hospital was $9.39. At the end of 1964, this expense had risen to $41.58, an increase of 342 per cent. However, during this same period the consumer price index rose only 57 per cent. In 1964 alone, there was a 6.9 per cent increase in the per patient day expense in these hospitals over the preceding year compared with 2 per cent increase in the consumer price index. Now, ten years later, 1974, the California Hospital Council reports the average daily room and board rate to be $85.00 per day, and an average daily patient day to be $74.00 nationally. This represents an increase of over 144 per cent where the consumer price index for this very same period rose only 39 per cent. These statistics have raised a new problem that all
hospital administrators must deal with. "What can we do to stem this tide of rising expenses; at the same time maintaining optimal care for the people of this country?"

Gordon Friesen has suggested as a possible solution, the freeing of skilled hospital personnel (nurses, technicians, and others) to perform only those skills for which they were trained. In his study he discovered that 50 per cent of skilled nursing time is expended in non-nursing functions. According to a recent government study, labor costs which account for two-thirds of hospital operating costs, are the most important factor in rising hospital operational expenses. Thus increased productivity is essential, if the highly inflationary cost of hospital care is to be controlled. Since the hospitals must compete with industry for employees, hospitals must receive the maximum economic benefit (productivity) from each employee. Recently George Otte, assistant vice-president of AMSCO Systems noted that hospitals are inherently inefficient as compared to private industry. He attributes this difference to automation and greater planning as it relates to material distribution. In his estimation, it takes three hospital employees today to perform the function of just one person in industry performing a comparable function. Hence, "Every effort is being expanded to
improve the direct patient care area of the hospital through innovations in medical and surgical techniques, skills, services and products." Similar innovations are currently needed in the hospital service areas. He concludes that, "such areas can be streamlined, made more efficient and brought under control from a cost standpoint." 10

The Friesen study concluded that the per patient day expenses can be reduced in four ways. Firstly, by the functional design of the hospital building, secondly, by automation of tasks (primarily those involving information systems, supply functions, and communications), thirdly, by better utilization of physical resources, and finally, with a program of continuous inservice education to upgrade the skills of all employees, and application of the classical elements of management to every area of hospital operation.

Historically, problems of this nature have generated a new field of technology. 12 Materials Management consists of planning, directing, controlling, and coordinating all those activities concerned with material and inventory requirements from the point of their inception to the point of their use. 13 The objectives of
material management must be based on the overall objectives of the organization. Material management must operate effectively, i.e., provide the user the materials he needs, in the quantity, quality, and time needed. Additionally, it must operate efficiently, i.e., provide needed material at a minimum ultimate cost so that the total organization can provide service to the customer at a minimum cost. Hospital organizations provide a natural setting for the application of this concept. All too often the material flow involved in the operation of a storeroom, pharmacy, central supply service, and dietary service operate in an uncoordinated manner. The centralization under an integrated material management system of the material activities involved in each of these areas may offer substantial economies. Several hospitals have recently adopted the material management concept, in whole or in part, and others might profitably investigate its applicability to their particular situation. In summary, material management provides the organizational responsibility to 1) determine requirements for material, and 2) procure, store and disperse material on time within allowable costs. It is therefore, "the logistics function of the hospital providing time and place utility, time
utility by storage, and place utility by transportation." Supply handling and distribution is an essential element in today's hospital environment which is constantly under pressure from governmental regulation to provide a maximum level of patient care as it relates to shared responsibility for medical malpractice, and the consumeristic attitudes of modern day patients.

Hospital supply needs are constantly changing to accommodate the demands of new techniques, procedures, people, and to improve efficiency. Thus, many departments are switching from individual order (or requisition) to exchange cart systems for nursing unit supplies. Others have initiated messenger (or courier) services; some are moving into automated material handling; and a few have already adopted computer based inventory control and charge systems. Nearly all report some sort of work simplification. Industrial engineering or other efficiency studies of departmental functions have been or are being conducted. In larger hospitals and departments especially, central service supervisors are not unfamiliar with modern management methods. Their departments have or are in the process of developing written goals or objectives for the department, policy manuals, inservice training programs for personnel, and systematic practices aimed at achieving
adequate communication and good interdepartmental relations.

16 The Controller General of the United States in his report on a study of health facilities construction costs also realized the importance of material handling to the total efficiency of a hospital. He summarized that "in hospitals there are increasing requirements for efficient methods of transporting material and supplies, which are vital to the economic operations of the institution." Hospitals have two basic transportation needs. One is the movement of bulk material and supplies, including dietary items, linens, medical supplies, equipment, medication, and waste. The second type of transportation need is the movement of non-bulk items, including medical records, pharmaceuticals, "stat" (emergency) orders, laboratory specimens, X-rays, and the transportation of patient records. The study undertaken was a cost comparison between the various automated and semi-automated material handling systems with existing or modified manual systems. According to the architects they contacted, material handling systems were usually evaluated only on the basis of initial costs because of funding limitations. Often such an evaluation results in the use of manual material handling systems without an evaluation of the
life cycle operating advantages of an automated or a semi-automated system. The Controller General's study was aimed at determining whether on a life cycle cost basis a degree of automation or total automation would be more economical than a manual distribution method. For purposes of our study we classified material handling systems into three general categories: manual, semi-automated, and automated.

The data they used were obtained from thirty-six hospitals ranging in size from 115 to over 500 beds. Data from twenty-five of these hospitals were used to establish life cycle costs of the manual material handling systems, seven for the semi-automated systems, and four hospitals for the fully automated systems. Additional data were collected from the various manufacturers on their systems to round out the required data. Since the configuration of the hospital may be a key factor in determining which system is cost justifiable, this study was geared to a typical general hospital (medical-surgical) ranging from 100 to 200 bed, four-story buildings; 200 to 300 bed, five-story buildings, etc. He concluded "all cost elements of alternative material handling systems showed that initial costs of the semi-automated and automated systems were greater than those of a manual material handling
However, two of the four semi-automated systems analyzed indicated a potential for reduced life cycle costs. The other two semi-automated systems, and the two automated systems, had higher life cycle costs than the manual systems. These life cycle costs when evaluated at several life spans at various inflation and discount rates showed that the relationship of the manual and semi-automated material handling alternatives were sensitive to changes in this rate. The additional savings related to the handling of non-bulk items has not been dealt with properly in this study.

17 In a similar study, M. R. Shellenberg, concluded that the best system would be an automated system using automated carts on a monorail with overhead tows. In the Shellenberg study however, capital costs were not the critical criteria but rather organization and time saving to provide more patient care. 18 These results were supported by Bruce Komiske, who favored a conveyor system under similar circumstances. 19 Gerald Delon, investigating this problem area for the American Institute for Engineers, in a report in May 1971, concluded that there was no single best distribution system to fit all hospitals. Choice of a cost effective system seemed to
be a function of size, design, patient mixture, and technology. These results seem to support my hypothesis that a material distribution system has to precede the selection of the material handling system. We must first establish how we will provide services, secondly, how we will support this service with maximum efficiency and minimum cost.

One must consider all of the possible alternatives as they relate specifically to his facility in order to make the right selection from among the alternatives available. One must consider the physical requirements of the facility, the economic or cost considerations for supporting a system in the budget, and finally the adaptability of the system to change and growth.

HOSPITAL SUPPLY SYSTEMS

In reviewing the systems now being used in hospitals, there appear to be three basic models. All others are either a combination of these or some derivative.

1. **REPLENISHMENT SYSTEM**

   A replenishment system has a standard storage and purchasing department which fills special orders, requisitions and central supply rooms to a given quota. This quota is usually fixed by the nursing staff, and is based
upon maximal levels of supplies in the utilization areas at all times. While this system is practical in a very small hospital, it is very inefficient in a medium to large facility. It requires a large area for storage near the patient care areas, and multiple nursing personnel to be sure these supplies are at the bedside when needed. Another disadvantage is that it requires additional nursing time away from the patient in order to pick up these supplies at some central location, thereby increasing the non-nursing duties. Inventory costs and controls become prohibitive under these circumstances because it becomes very difficult to step down or budget individual supply items to the patient or the unit. Hence, one finds increased hoarding of supplies and pilferage from employees.

While in the past most hospitals operated using this system, increased demands, the growth of disposables, and new technological advances in equipment, have made this old system inefficient. Thus, many departments are switching from individual order or requisition to exchange cart systems for nursing unit supplies. (Examples of this system can be found at Mid Valley Hospital, Tarzana Medical Center, and Torrance Memorial Hospital.)

2. CENTRAL DISTRIBUTION SYSTEM

This system is the centralization of all processing,
distribution, and supply functions of a hospital into one department. "Visualize, if you will, a system where the central point is a dispatch center, from which every single item of supply and equipment (except meals) moves into the channels of use, either on a programmed basis, on an as needed basis, or on an emergency basis, according to the needs of the individual nursing floor or department." Hence, a central dispatch center for all processed stores emanating at one point and providing all support supplies from linens to I.V. solutions. Included as a part of this central dispatch area are processed stores, laundry, pharmacy, bulk stores, decontamination and processing areas.

The primary advantage for this arrangement is to allow the coordination of similar services and the implementation of advanced management and organizational principles to a hospital setting. The emerging of the materials manager developed into a position with both the authority and the responsibility to provide efficient materials support to the hospital. The functional divisions under the materials manager provide the following services. Supplies are assembled and held as either individual items or as a cart complement, on shelves by the processing stores. These are programmed for distribution
to the various departments. The decontamination center washes and sterilizes all reusable supplies and equipment. Central processing assembles trays, packs, and all other reusable supplies and equipment received from decontamination and processed to the ready to use form. All processed supplies are sterilized and held in the processed store areas until used.

What are the principal advantages of centralization? A pooling of supplies by all users which eliminates duplication of paperwork and handling. It stimulates maximum efficiency in space utilization and reduces personnel time and expenses. "Circulation between supply functions is 'internal' and totally separate from other hospital traffic elements." Centralization allows a tighter control on internal supply and processing movement as well as internal supply. Physical relationships between all S.P.D. sectors allow maximum internal reallocation of space with major shifts in purchasing and inventory procedures (i.e., the increased use of disposables will decrease the space required for reprocessing, but increase the bulk storage space required, etc.)

The disadvantages of a totally centralized S.P.D. system are few. The autonomous nature of formerly key departments within the hospital and competition between
the former department heads could cause poor employee relations. This problem could be overcome by careful restraining, inservice education, and by making all employees part of a new department rather than absorbed by another existing one. A totally centralized system will only work with a top level materials manager who is capable of coordinating all of its activities and providing leadership where once there was chaos.

3. **TOTAL SUPPLY BY AN EXCHANGE CART SYSTEM**

23 The exchange cart system or the "Friesen System" was developed by Gordon Friesen who recognized a need to provide supplies at the patient's bedside when they were needed. Using mobile carts, the requisitions of individual supplies and equipment had been eliminated. The objectives of the cart system are: to provide the nursing units with a total supply system, whereby the right supply will be in the right place at the right time; to relieve the nursing staff from non-nursing duties such as inventory, requisition, recording, delivery, and processing of supplies; to effect a practical system of inventory control; and to place full responsibility in the material management department for the functions of supply, processing and distribution.
Using the exchange cart system, carts are assigned to each nursing unit in place of a supply closet. Some carts serve as storage units on the nursing floors while others are being refilled to the proper inventory level in the supply areas. Periodically, the carts are rotated between the nursing units and the supply areas for systematic replacement of deplenished supplies. Usually, supplementing the exchange cart system are special wall cabinets known as nurse servers, which are set into the wall of a patient's room. The nurse server has doors on the corridor and room side of the wall permitting daily delivery into the nurse server of a day's complement of linen, general and sterile supplies that are adapted to the needs of each individual patient. From the room side, the nurse may reach items for patient care without leaving the room, while all restocking can be done from the corridors, thereby reducing traffic in the rooms. The pharmacy may also use these locked cabinets to deliver the prescribed drugs in efficient procedures of rounds. Complementing the exchange cart and nurse server system is a nurse call system (communications) which allows the patient to communicate with the floor clerk without additional travel time. A secondary intercom near the nurse server allows the nurse to call either the floor supply
clerk (core-girl) or the central supply dispatcher for required supplies.

Supply technicians from central distribution replace the entire carts in the clean logistics area (holding area or clean core) once every twenty-four hours. The carts to be restocked enter the logistics center where they are cleaned and restocked to a given level. Sequentially, the cart is restored to its quota and moved to a dispatch point, whereupon it is ready for distribution to the unit the next morning.

Pre-programmed supplies for individual patients are also delivered to the clean side of the nurse server. All other supply items are available from a central dispatch center in the central supply department for speedy delivery. This may be accomplished either manually by means of an automatic ejector conveyor or some other form of automatic cart transport system. It has been suggested by Gordon Friesen that, "Prepricing of chargeable items in the processed stores ensures their proper charging to the patient and reduces clerical work for professional personnel."24 A system of this magnitude creates a method for a continuous inventory of all supplies and equipment used by the hospital.
Soiled supplies can be transported similarly. All soiled supplies are accumulated by cart in a soiled logistics area (soiled holding or soiled core) where they are moved to a decontamination center for disposal or reprocessing. Likewise, in the nursing units the soiled side of the nurse server retains all of the soiled matter and waste used by the individual patient. There is no necessity to leave the room to dispose of soiled supplies. The regular housekeeping staff cleans the nurse server at regular scheduled intervals.

Individual patient components are transported to the unit floors during slack periods (usually in the evening hours) when traffic is very low, and the nurse servers are replenished accordingly. The exchange carts can be exchanged once daily (between 7:30 and 9:00 A.M.). The actual time required for the replenishment and exchange cycle will vary according to the number of beds, types of services available, and material handling system used.

Charles E. Howsley, an associate administrator at St. Anthony's Hospital, Columbus, Ohio, which utilizes a complete exchange cart system, notes some interesting complementary advantages of this system. "Because cart size is sufficient for the medical and surgical supplies, all other storage, including cabinets, cupboards, drawers,
and so forth, have been 'programmed out' of the nursing units, saving hundreds of thousands of dollars in the initial construction costs of the new building. It also resulted in better control and utilization, eliminating the practice of hoarding expensive supplies in every nook and cranny of the unit. The cupboards and cabinets of the nursing units in the older building were removed and replaced by the total mobile supply cart." As a result of centralization of all S.P.D. functions, less total space for storage and a greater efficiency for storage space was possible in the bulk storage areas.

MATERIAL HANDLING SYSTEMS

Material handling is the modus operandi by which materials of any defined nature are transported between two or more points. A material transit system may be either manual, semi-automated, or fully automated. In hospitals there are increasing requirements for efficient transportation of equipment and supplies which are vital to the economic operation of the hospital. Hospital economists are currently evaluating automated systems as a means of combating increasing labor costs for material handling personnel.

THE MANUAL SYSTEM

A manual system is one by which supplies are hand
carried or transported in manually pushed carts, with vertical transportation restricted to dumbwaiters or elevators. 26 The manual system is generally operated in two ways. In the first method, carts are loaded in supply areas and vertically transported by dumbwaiter or elevator to the nursing units where materials and supplies on the cart are used to replenish supply closets. 27 The second method, "the exchange cart system" or "The Gordon Friesen Method" uses the carts in place of the supply closet. Periodically, the carts are rotated between the nursing units and supply areas for systematic replacement of inventory supplies. The manual system is quite flexible. Maintenance is simple, and it requires a very low capital commitment. Since most of the carts and personnel can be used for a variety of different material handling tasks, the manual system has the greatest amount of flexibility. Most of the carts, with the exception of certain specialized carts (i.e., dietary carts) are relatively inexpensive and easily maintained.

The major disadvantage of manual systems are their high operating costs. These high costs are attributable to the increasingly high cost of labor. Large numbers of personnel are required on a twenty-four hour basis to transport the quantities of diverse materials necessary to
support a hospital. Secondly, the manual system runs the risk of contamination resulting from the transportation of supplies and other materials through public corridors and elevators. Finally, manual systems have been criticized for their inability to provide emergency supplies in the minimum possible time. However, this could be viewed as a problem in the supply distribution system and not attributable strictly to a material handling system.

**THE SEMI-AUTOMATED SYSTEM**

A semi-automated system is one which when combined with a manual system reduces only a part, but not the total operating cost attributable to labor, since it merely assists or reduces the manual system rather than replaces it. The flexibility and low capital outlay makes this system very attractive for use in hospitals. Of the many material handling systems available on the market today, only three are suitable to be used in conjunction with a manual system and these are: 1) self-propelled carriers, 2) conveyors, and 3) pneumatic tube systems.

1. **SELF-PROPELLED CARRIER SYSTEM**

The self-propelled carrier system consists of a series of small cars which run both horizontally and vertically along tracks installed either visibly or in the interstitial space. Destinations for each car are
determined by means of a selector device located on each car. This system is extremely flexible and can be modified by manipulation of the track. Cars are available in two sizes with a capacity of one-half cubic foot (11 pounds) and one cubic foot (20 pounds). The relative small size of the cars limits the volume of bulk supplies this system can accommodate, thus, most of its effectiveness is in the transportation of non-bulk supplies and small bulk deliveries. The approximate speed of this system is 100 feet per minute. 28 An example of this system is the "Mosler Telelift System" manufactured by Mosler Airmatic Systems Division, Wayne, New Jersey.

2a. STANDARD CONVEYOR SYSTEM

Conveyor systems are available in almost every shape and size for the transportation of material and supplies. Conveyor carts or containers range in carrying capacities from 1.7 cubic feet up to nine cubic feet. The larger conveyor containers are capable of handling the bulk requirements for linens, supplies, and waste removal. Smaller systems are more appropriate for medical records and non-bulk items of that magnitude and size. Conveyor systems are capable of handling from eight to eighteen 1.7 cubic foot containers per minute at speeds of about 15 to 120 feet per minute.
2b. SELECTIVE VERTICAL CONVEYOR SYSTEM

A selective vertical conveyor is a continuous chain conveyor on which mounted cars are connected at specific intervals. A container is placed in a mounted car and transported to a given station. The conveyor loads and unloads containers automatically. It is capable of serving all floors of any facility on the average of between eight and twelve times per minute, receiving and discharging loads continuously, automatically, and simultaneously at any number of floor stations. This system provides basic vertical transportation, however, it may be coupled with horizontal conveyors and branch lifts to provide a complete distribution system.

The carrier tub comes in three sizes ranging from 16 inches by 11 5/8 inches by 9 13/16 inches deep, to 20 inches by 16 inches by 4 1/2 inches deep. Each tub has an equal weight capacity of forty pounds per load. Cars are made of fiber glass and are easily sanitized. When only a vertical transportation system is required the select vertical transportation system is generally efficient and relatively inexpensive as compared to a completely automated system. However, the complementary horizontal conveyors and lifts lead into great expense as well as high maintenance costs.
The mechanics of the select vertical system consist of a drive unit at the top floor, a take up section at the lowest floor, and a carrying chain laid between. On the carrying chain are mounted cars connected at intervals and a pendant from a pin which is integral to the chain. Loading occurs on the top side of the chain while unloading on the down side. Stations may consist of either a loading unit, unloading unit, or both. The automatic delivery of materials is accomplished through the use of expensive coding gears called escort coding.

The encodement is accomplished by polarizing metal strips embedded in the tub itself, rather than by using mechanical fingers on the vertical cars. This type of magnetic encoding is accurate only if the reader and encoded strips come within close proximity to each other and the tub is almost perfectly aligned. Variance of this alone will cause inaccurate reading and misdirection of the load. Horizontal coordination is usually accomplished using "traffic cops," which work off of an electric eye and a shuttle arm. This type of encoding control has been criticized as a major disadvantage to the system.

A common example of this system is one produced by Guilbert Inc., which is marketed as "Cargomaster/Conveyor." This system may be observed in operation at
the Torrance Memorial Hospital, Torrance, California.

2c. AUTOMATIC DUMBWA T E R SYSTEM

The automatic dumbwaiter is a very small elevator. When it is loaded with a cart, an attendant selects its destination where it is ejected automatically. The dumbwaiter either returns to its point of origin or waits for another "call." A system of this kind offers many exciting advantages to material handling. It has a capacity for large sizes and weights and a very low cost per floor. The Mosler Telelift System can travel 100 feet per minute carrying a net load of 20,000 pounds to a single station in one hour. Hence, this is quiet and requires very little maintenance. It is flexible to hospital growth and can be adapted for special procedures (i.e., a dumbwaiter to the operating room direct, to deliver case carts with complete materials required for each operation.) A similar system could be used to return the used and soiled materials from the operating room to a decontamination area for processing.

3. PNEUMATIC TUBE SYSTEM

The pneumatic tube system is one of the most common and oldest transportation systems used within hospitals to date. In this system carriers are moved through tubes by air pressure. A tube system may be
manual, semi-automated, automatic, and centrally or
decently controlled. The most common size pneumatic
carrier used in hospitals is four inches by seven inches.
This is currently the largest available with automatic
distribution. However, the capacities of this system are
limited to six to eight pounds and 200 cubic inches.
Materials travel at an average rate of twenty-five feet
per second. If the system is fully automated, it is
possible to send carriers between any two stations.

The prime advantages of a pneumatic tube system
are speed and demand delivery of items, and the semi-
automated and automated systems result in considerable
labor savings. The major disadvantage of such a system
is its susceptibility to misuse (sabotage), and general
maintenance problems. Many systems now in use attribute
many of the maintenance problems to poor design (i.e.,
turn radius are too small) and suggest that these problems
can virtually be eliminated by careful programmed
planning.

Many larger systems are used to transport soiled
linens and trash to a processing area or collection point.
When these systems are combined with vertical gravity
chutes, the pneumatic systems drive the trash and soiled
linens horizontally to a collection container. A second
method would be to utilize a complete pneumatic system to transport soiled linens and trash from multiple depository points to one or more collection points. Usually, one tube carries both trash and linen with the final destination determined by a switch at each entry point.

The pneumatic tube system is an excellent method for transporting non-bulk items, such as medical records, X-rays, laboratory samples, etc. However, because of its limited capacity it is inefficient to accommodate bulk transportation. Examples of pneumatic systems can be found at the Tarzana Medical Center, Tarzana, California, and in most hospitals across the country.

The semi-automated system in review can reduce operating costs substantially through long term labor savings. It is extremely flexible to a hospital's needs and growth potential. It may be coordinated to complement a manual system to provide a complete distribution system without an extremely high initial capital outlay. Special systems can be obtained to handle special jobs and occupy a minimal degree of space. The initial cost of the semi-automated system is considerably higher than a manual system. The semi-automated system must be considered independently for each facility and measured against labor savings and increased patient care.
THE AUTOMATED SYSTEM

An automated system is one in which all materials are mechanically transported with minimum manual assistance possible. A review of the literature and an investigation of the field revealed three systems functioning in hospitals. For the purposes of this study, these systems will be referred to as: 1) battery powered carts, 2) self-powered monorails, and 3) chain-driven monorails. A discussion of all three follows below.

1. BATTERY POWERED CARTS OR SELF-PROPELLED CARTS

This system uses battery powered, unmanned carts which are guided by electronic tape embedded into the corridor floors and elevators. Furthermore, by using special elevators they can be dispatched anywhere in the hospital. The carts are stainless steel and completely enclose the material transported. When the cart arrives at its destination it can be manually controlled by using a power control handle. The cost of each cart is approximately the same as the purchase of a new mid-priced automobile. However, very little or no structural changes are required to implement the system. It does however require a large area for cart storage, recharging of batteries, washing, and sanitizing the carts.
This system is best suited for the transportation of bulk items because of its capacity of up to 32 cubic feet or 1,000 pounds. It travels at an average speed of 90 feet per minute horizontally, and between 50 and 300 feet per minute vertically. At the completion of a single cycle, the carts are returned to a processing area with a load of soiled linens or trash. The contents are emptied and processed while the cart is automatically sterilized ready to begin a new cycle.

The battery powered cart system is manufactured by Jervis B. Webb Company for the American Sterilizer Company, using the trade name of "AMSCAR". An example of this system can be found at St. Alphonsus Hospital, Boise, Idaho.

2. **SELF-PROPELLED MONORAIL**

The self-propelled or tractor driven overhead monorail system works on the same general ideas as the street trolley. The system consists of a network of tracks running vertically and horizontally between the various departments and nursing units of the hospital. A transporter, which is a suspended carrier tub, is attached to this monorail. The transporter collects, transports, and delivers these containers throughout the hospital, using leveling devices to keep the containers
The containers have a capacity of 16 cubic feet (220 pounds), and can move at a speed of 100 feet per minute vertically and 200 feet per minute horizontally. Each container can be detached at the point of use and equipped with casters for easy manual movement. Soiled linens and trash can be returned to the decontamination areas using the very same system. Containers are processed through a cleaning route before being returned to the clean materials system again. The mechanics of this system require a great deal of space for cart storage, rails, switches, and a special floor. Structural considerations must be planned into the facility, such as a tunnel and shaft ways, as well as an area for container sterilization.

It is estimated that the cost of this system should be approximately ten per cent of the total cost of the hospital, increasing then the initial capital investment considerably. However, the manufacturer of the equipment will generally offer a prospective client a
computerized simulation and study of his traffic patterns for a modest cost, to be applied against the purchase price of the equipment. 35 The most common system available to the hospital market is the "Cyberail" system, manufactured by the Sybron Corporation. The maintenance cost estimations for the self-propelled monorail system is considerably more expensive than any other automatic or manual transportation system. Combined with the high initial outlay for the system one must view the labor savings with some concern. An example of this system can be found at the Lutheran Hospital and Medical Center, Wheat Ridge, Colorado.

3. CHAIN-DRIVEN MONORAIL OR POWER AND FREE MONORAIL

The power and free overhead chain conveyor is enclosed in a monorail which works in conjunction with a gravity rail. In certain parts of the system a power driven chain provides the motive force to move carts along the rail, while in other parts of the system the force of gravity or the impetus from a powered section is all that propels the cart.

36 The power and free overhead conveyor system utilizes two tracks. A continuous chain driven trolley and a free track are used. The power track contains a
trolley wheel assembly that is pulled along by the chain, while the free track contains a freely moving trolley wheel assembly. A carrier from which a cart is suspended is mounted in the free track. Thus, both tracks are mounted closely so that the drive dogs on the chain of the power track engage a crossarm on the carrier suspended from the free track. The entire load moves at the speed of the power chain. The carrier, however, stays in the free track at all times. A system of this nature is extremely versatile since the carriers operate independently. Individual carriers can be moved to selected locations and can be freed for storage and processing. All movements can be controlled by operators or through movement selection devices located on each carrier. The selectors permit the dispatch of a cart from any one station on the system to any other station. Furthermore, the cart moves horizontally along the monorail system to a special elevator and is vertically transported to the proper level where it is automatically ejected. Carts used in this system are standard size hospital carts (51x22x56 inches), which have a capacity of 12 to 33 cubic feet or 200 to 250 pounds. Carts can travel at a speed of 50 feet per minute horizontally and 200 feet per minute vertically.
For prevention of cross-contamination, separate clean and soiled routes are used to distribute materials and supplies. Stations on the system have separate clean and soiled holding areas for carts as well as separate clean and soiled elevators. A cart dispatched from the soiled areas must travel through a cart sterilizer after it is unloaded in the processing area and before it re-enters the clean cycle. Carts can ride inches off the floor and touch the floor only at designated points where they can be removed from or attached to the system.

Many manufacturers today are attempting to provide systems of this nature to the hospital market. The most prevalent system in use today however is the "Automatic Cart Transportation System" (ACTS), manufactured by Columbus McKennon Corporation, New York. Examples of systems installed and in use in hospitals can be found at the following locations: Buffalo-Mercy Hospital, Buffalo, New York, Wadley Hospital, Texarkana, Texas, plus many more now under construction. The primary operational advantages of the ACTS system are: it eliminates the movement of soiled and contaminated materials through public and patient areas; reduces supply traffic and personnel confusion in the corridors, resulting in a
quieter environment throughout the hospital; provides rapid, dependable twenty-four hour service from a central location under the control of one individual; provides a priority or emergency system for the same single dispatched area; frees nursing personnel for other duties by transporting supplies directly to and from the work areas. The system itself provides additional benefits such as: unlimited horizontal and vertical flexibility; adaptability to new construction; eliminates the use of public and staff elevators for supply carts and soiled returns; and replaces multiple vertical conveyances.

A second major system marketed in the United States is the Cyberail System, manufactured by the Sybron Corporation. The Cyberail System is a self-propelled tractor-driven monorail system. Suspended from the tractor is a carrier. Thus, the system utilizes a vast network of rails and switches and requires a special floor and special architectural construction for tunnels and shafts. Other manufacturers of automated material handling systems in hospitals are: ACCO and Rapistan.

The primary advantage of all of the automated systems is a savings in labor costs. An additional advantage may also be reduced cross-contamination because the carriers are cleaned after each use. Cross-contamination
may also be reduced in an ACT system since separate clean and soiled routes are used. The self-powered monorail and battery-powered carts use containers which enclose the contents being transported and reduce the risk of cross-contamination.

The major disadvantages of all automated material handling systems are their high initial costs. Since they require a network of tracks and elevator shafts, their flexibility is reduced considerably. Skilled maintenance personnel must always be available since the system is always vulnerable to a complete shutdown if key elements malfunction. In the event of a breakdown, a back up system must be available to move materials and supplies throughout the hospital.
3. A MATERIALS DISTRIBUTION SYSTEM FOR THE NEW OLIVE VIEW MEDICAL CENTER AT SYLMAR, CALIFORNIA

The Olive View Medical Center, a 350 bed hospital treating both acute care and mental health patients will be constructed on its former site in Sylmar, California. As the only county hospital in the San Fernando Valley and treating primarily an indigent population, Olive View is growing at a tremendous rate. Its satellite outpatient clinics make primary care immediately available to the community and creates an excellent referral source to the center itself, thus, resulting in increased growth of the Olive View facility itself. Any material distribution system must not only be flexible to accommodate this uncontrollable growth but also economical and efficient. As a public agency, Olive View is directly responsible to the taxpayers to provide a maximum level of patient care at the least cost to the county.

The material distribution system for the medical center must be multiphasic and incorporate the principles of centralization, materials management, inventory control, and cost control. The materials manager will report directly to the assistant administrator in charge of the
facility. Hence, all departments involved in the distribution, processing, and supplies shall report directly to the materials manager. Thus, the locations of each of these departments must be carefully placed to reduce transportation time and to increase communications. All ancillary departments (such as the pharmacy, property, and supply) will also be located nearby to facilitate a complete SPD unit for hospital support. Furthermore, from the SPD unit all material traffic shall be monitored and controlled.

The SPD center must be located at the very lowest level of the structure and centered so that all departments which require use of the distribution center can be strategically located (see Figure 1). Thus, located at the base of the SPD center will be a central dispatcher who will monitor a communication network which links the entire distribution chain. The central dispatcher shall coordinate the transportation traffic and program a continuous material flow. Hence, he shall set up a priority system to prevent a backlog or breakdown in the system. In this manner, dietary will be able to transport food trays at one given time, while central storage and CSR can utilize the transportation system for their exchange carts.
Figure 1

Schematic Plan for Olive View Medical Center
Ground Floor and Patient Floors
correspondingly. Other departments, for example, the pharmacy, housekeeping, and property can utilize the very same system if coordinated properly.

Autoclaves, sterilizers, etc., will be located in the SPD. In this manner the activities of the storage and central sterile supply departments can be coordinated. Utilization of one single cart exchange system can be adapted to fit all patient floor and surgery suites alike. The pharmacy, equipment storage, food service, laundry, housekeeping, printing and other interrelated departments, will ideally use the same system. Thus, by having the dispatcher in the SPD, he will be able to program time for each department to use the system. The dispatcher will also be able to stop the system on a priority or emergency basis as required and then reconvene the program to complete the chain. For a complete description of the exchange cart system to be utilized, please refer to the section of this paper dealing with material distribution systems (Page 18).

A supply system as complex as the one utilized for efficiency in a medical center has a great similarity to the human body. The SPD is the most important element in the system. It provides the brains or the information center. However, a brain without functional limbs is
useless. The body of the system centers around the central core of the facility. Just as the body has a bloodstream which carries the processed blood to the cells and the deoxygenated blood away, a supply system must also have a dual role. The clean central core is a clearing and dispensing area to all of the limbs of the system, and the soiled core functions to provide a holding and dispersing area for all items used in patient care which have become contaminated. The arms and fingers of our system are all contained in the "Decentralized Supply and Care Center." Located near the patient's bedside the DSCC provides all of the expected supplies and needs a patient should require. The following is a brief discussion of each element in the body which composes the entire distribution system.

**PATIENT ROOMS**

The intent of modern hospital planning is to make the patient's room the center for individual care. Hence, in order to allow the nurse to remain at the bedside to maximize her skills and training, the materials responsibility must be assumed elsewhere. The material distribution system must be able to provide all of the anticipated supplies near the bedside for immediate use by the patient.
The Decentralized Supply and Care Center (DSCC) will provide a solution to both of these needs as well as meet budgetary and staffing considerations of the Olive View Medical Center.

The architectural design of the patient floor for the Medical Center (see Figure 1) is conducive to the Decentralized Supply and Care Center concept. Each floor will have 106 beds with twelve clusters of eight beds. Hence, each cluster of rooms will have its own DSCC. The DSCC will function as a super nurse server, stocking all of the patient's daily requirements as well as special procedure trays and supplies, based on each patient's type and medical requirements. As a secondary function, the DSCC will provide storage space for the pharmacy to adopt a unit dosage program. Each center will have adequate work space for nursing with all supplies in anticipation of need. A communications system will link the DSCC with the unit nurse's station, the central clean core and the SPD. Thus, a communications system will also provide the nurse with direct contact to any ancillary function she may need, yet still keep her at the patient's bedside.

All special orders will be available on a moment's notice with the minimum transportation time. Finally, each DSCC will have storage areas for a daily complement of linen
items. The net effect will have all linen items at arms length for the nurse and reduce the linen storage requirements elsewhere on the floor. A careful study of utilization and the patient census will determine which items are to be stocked in the DSCC and what complements will be stored in the clean central core.

The DSCC will be stocked as follows:

1) Each new admission will receive a pre-admit package based upon the diagnosis, to be delivered to the center at the time bed reservations releases the bed.

2) A distribution clerk from the central core will replenish all daily as well as specific supplies from the exchange cart in the core to the DSCC once each day. A given level shall be determined jointly by materials management and the nursing staff for each DSCC.

3) Special orders will be delivered on an as needed basis directly to the area of use.

Linens and disposable isolation needs will be delivered from the central clean core to the DSCC area twice daily, thus, providing immediate linen supplies for both
nursing and housekeeping at all times. The housekeeping staff will make regular rounds of the DSCC and patient rooms where all trash and soiled linens will be collected onto a soiled collector cart which is brought to the soiled core for disposal or processing. All reprocessable surgical trays and equipment will also be collected by the housekeeper, who will put them into clearly marked bags (for SPD) and bring them to the soiled core. Once in the soiled core a housekeeping attendant will sort out the soiled supplies. All disposables and trash will be put into the trash chute. Soiled linens will be placed into the laundry chute. The remaining reprocessable supplies will be directed in the bags to central processing for cleaning and or sterilization, whichever is required. Thus, the transportation mode to the SPD center must be either a simple dumbwaiter or a more sophisticated monorail cart system. Which system used will depend on budgetary and hospital requirements for the new Medical Center. However, the distribution system can be adapted to any material handling equipment.

CLEAN CENTRAL CORE

The clean central core is the decentralized heart of the entire materials distribution network. Since each
floor, as well as each nursing unit, is unique in utilization, as well as patient description, it is necessary to provide an operating center for all material flow. Henceforth, the clean core functions as a clearing house for all materials and supplies used on the floor. This includes items from the laundry, SPD, dietary, property, and supply. Since each of these areas is unique in its use of the clean core, each will be delineated separately.

The centralized SPD center will on a daily basis distribute to each clean core a full complement of anticipated twenty-four hour supplies for each unit. The distribution personnel assigned to the core will restock the decentralized supply and care centers on a replenishment as well as a special requirement basis. Hence, each core will be supplied using the exchange cart method with at least one cart per unit for supplies and I.V. solutions each day. The exchange cart will be replenished each day using all standard level as well as special requests where applicable. Thus, it is the position of the Medical Center to have all supplies at the bedside (DSCC) so that the central core will function as the agency which will insure that all supplies will be available in anticipation of need. Henceforth, the central clean core will distribute all supplies as well as monitor and replenish the
established level of supplies in the DSCC. Support supplies will be kept to a minimum at each central core. In the case of emergency requests as well as inventory adjustments, a direct vertical dumbwaiter will connect each central core with the SPD center below. A communications system linking the DSCC with each central core, and directly with the SPD center, will facilitate an immediate response to all supply needs without the nurse or physician leaving the patient unattended.

Food service (or dietary) will also utilize the clean central core for its distribution center. Each central clean core will be equipped with refrigeration for at least one complete meal for each patient on each floor. In addition, microwave convector type ovens in each core will allow the facility to utilize a convenience foods program. The central kitchen will prepare all convenience foods and freeze them directly on the tray. Thus, trays for each meal will be sent to the central core and refrigerated prior to use. A food service aide at the core is responsible for the complete assembly of the tray and the distribution to the beds. After each meal the food service aide from the core collects all the trash from the meal and disposes of it in the soiled core. Maintenance of the ovens, assembly of the trays, and replenishing
the refrigerators between meals, are ongoing activities of
the food service aide. Food will always be warm and ser­
vice direct under these conditions.

Laundry service will also incorporate the exchange
cart program. Each day the daily complement of antici­
pated linens, and disposable isolation supply needs, will
be delivered to the central core. The remaining cart
will be exchanged for a full one. The former is then
taken down to the laundry area for replenishment and ex­
changed for the used cart again the next day. Hence,
distribution personnel assigned to the core will provide
the linens for housekeeping personnel to replenish each
DSCC as required. However, the supply personnel from the
central core will monitor the linen levels for house­
keeping and inform them as required.

Property and equipment will be distributed through
the clean core. However, it is not the intent of the
Medical Center to make the clean core a storage room for
equipment. A complement of regular floor equipment will
be stored on the floor by the departments responsible for
it. All other supplies will be transported by the SPD
personnel to the clean core or place of use.
SOILED CORE

The soiled core provides a holding area for all trash, soiled linens, and reprocessable instruments. Secondly, it provides a distribution center where all contaminated material can be separated and processed as its composition dictates. A vacuum assisted trash chute provides for the removal of trash from the floors. Once it reaches a trash area in the basement it is processed according to the content and disposed of swiftly. A second vacuum assisted chute is used for the transportation of soiled linens to the laundry. An attendant in the soiled core separates the isolation or other contagious linens into clearly marked plastic bags which are handled separately from the regular soiled material. Since all dietary trays and supplies are disposable, they are treated as regular trash after use. Contaminated or soiled surgical trays or equipment which are reusable are bagged separately and sent to the SPD for reprocessing and preparation for reuse. A single vertical dumbwaiter or a more sophisticated monorail system could be incorporated for these transportation chores.

SURGICAL SUITES

The surgical suites will utilize an exchange cart
system. Each scheduled surgery will receive its own case cart, thus, providing all of the necessary supplies for each surgical patient in anticipation of need, economically and efficiently. The SPD will also have in reserve at least two support cars which can be utilized in short notice for all emergency and non-scheduled surgeries. A central clean core and a soiled core will function very much the same as they would on patient room floors. However, the thrust of the activity generated in these areas will be based around total support to the surgical areas.

OUTPATIENT CLINICS

The outpatient clinics will all be supplied on an exchange cart basis. Once daily, a cart with a predetermined level of supplies will be exchanged for the one used the prior day. Since each clinic is unique in service, the components of each cart will reflect the type of services available. Linens will be supplied on a replenishment basis only. The nature of the clinic and its professional staff will more clearly define the specific supply content.

A complete materials distribution program is one based on a uniform network of transportation functions, all of which stress the following characteristics:
efficiency, speed, consistency, and simplicity. The functional components of the system recommended in this section are all derived based on the above criteria. The system is efficient because it reduces all patient care activities to the bedside. Dollars spent on professional labor costs can now be reduced by replacing them with non-professional hours. The general level of patient care increases as the physician and nurse have more time to deal with the patient. Consistency of service is a major benefit. The Medical Center now has one system to meet all of its needs. The transportation networks are defined and the utility can be expanded to meet future needs.
4. EXPERIMENTAL PROCEDURE AND PRESENTATION OF DATA

The intent of this study was to first design a supply distribution system, and then select a material handling system which would facilitate the supply system economically. The preceding section of this study has been devoted to the first objective. A comparative study was undertaken using a comparable hospital for a standard and then projecting the anticipated utilization from that standard. As a practical matter, this process became necessary since there is no automated system available on the west coast from which to gather direct data (See Limitations of the Study, Page 59).

The Medical Center of Tarzana was selected for the study sample because it was currently utilizing a manual exchange cart system. A secondary consideration was given to the nature of the facility itself. The hospital was constructed only six months prior and had the very latest elevator equipment. Hence, this represented a study sample which could closely parallel the actual new center. The elevators were the latest high speed instruments available and would probably be the same installed in the
new center. The locations of key dispensing departments were also considered. Although not all of these dispensing departments were centralized (as will be the case at the new Olive View Center) their general locations were close enough in proximity that acceptable transportation times could be obtained and used as representative of the study subject.

In May 1974, a time and motion study was undertaken to determine the actual transportation time for all supplies at the Tarzana facility. Data were collected for a week and daily averages for each trip compiled (See "Summary of Average Daily Distribution Times - Manual System" (Table 1). Thus, from the above data an average time per trip was compiled for each of the various supply elements. These elements included: unit supplies, linens, dietary, special orders, supplies and linens for outpatient clinics, and utilization by other ancillary departments.

The next step was to determine the number of trips anticipated for the new Olive View Medical Center. These figures were determined after careful review of the plans with the architects, and needs evaluation with nursing administration, and the various department heads. Thus,
### Table 1

**Summary of Average Daily Distribution Times Manual System**

<table>
<thead>
<tr>
<th>Department</th>
<th>Floor</th>
<th>Total Time (minutes)</th>
<th>Average Time per Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Central Supply:Units</td>
<td>6</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>8.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>2. Laundry</td>
<td>6</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>3. Special Requests</td>
<td>6</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>4. Surgery</td>
<td>2</td>
<td>5.84</td>
<td>5.84</td>
</tr>
</tbody>
</table>

Final Average Time with Exchange Cart = 5.84

Final Average Time without Exchange Cart = 4.00
each trip anticipated for the new facility was determined and summarized (See Summary of Anticipated Material Supply Trips for Olive View Medical Center (Table 2). Mathematically, each trip was multiplied by the average time per trip, and the results of each summed to determine the total daily time utilized for material transportation. Hence, the total daily time was divided by eight hours to ascertain the number of full-time equivalent employees (FTE) required to facilitate the transportation requirements expected in the new center (See Figure 2). Once the number of FTE's were determined, they merely needed to be multiplied by the average annual salary for each distribution clerk to determine the actual budgeted labor cost for the material distribution system.

The data collected which related directly to the fully automated system were secured in two ways. First, as a result of the contractual offer to provide the machinery and anticipated maintenance contracts directly from the manufacturer, and secondly, by securing the specifications of the system, determining the actual energy consumption and other operating expenses were evaluated.

Utilizing the above data, a present value factor analysis was performed to determine the time cost over a
Table 2

Summary of Anticipated Material Supply Trips for Olive View Medical Center

<table>
<thead>
<tr>
<th>Destination</th>
<th>Number of Trips</th>
<th>Average Time/Trip</th>
<th>Total Distribution Time/Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Nursing Units</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplies</td>
<td>15</td>
<td>5.84</td>
<td>262.80</td>
</tr>
<tr>
<td>I.V.</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linens</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>B. Outpatient Clinics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplies</td>
<td>16</td>
<td>5.84</td>
<td>186.88</td>
</tr>
<tr>
<td>I.V.</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linens</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>C. Estimated Scheduled Surgery</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>5.84</td>
<td>204.40</td>
</tr>
<tr>
<td><strong>D. Dietary (3 meals)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>5.84</td>
<td>262.80</td>
</tr>
<tr>
<td><strong>E. Estimated Number of Special Orders</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>4.00</td>
<td>200.00</td>
</tr>
<tr>
<td><strong>F. Other Ancillary Services</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>5.84</td>
<td>584.00</td>
</tr>
<tr>
<td>Respiratory care, Pharmacy, etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL ESTIMATED MATERIALS DISTRIBUTION TIME**

<table>
<thead>
<tr>
<th>Time in Minutes</th>
<th>Time in Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,700.88</td>
<td>28.35</td>
</tr>
</tbody>
</table>
Total Estimated Materials Distribution Time = 28.35 hours

One F.T.E. = 80 hours

X = 3.54 F.T.E.

Average Salary for one F.T.E. = $7,800.

3.54 F.T.E. x $7,800 year = $27,612.

Labor Cost Attributable to Materials Distribution = $27,612.

Figure 2

Determining the Number of Full-Time Equivalent Distribution Personnel for Olive View Medical Center
twenty-year period (Figure 3). Likewise, a similar analysis was performed for a comparable manual system. This stepwise analysis provided us with a true cost comparison over the twenty-year period (which assumed the cost of monies to be eight per cent conservatively). All other analysis to be discussed in the following section addresses itself to the question of whether a large difference in the true cost of each of these systems is economically justifiable.

LIMITATIONS OF THE STUDY

As with most studies, this study has certain internal limitations. First, the ideal comparison would have been between two or more currently and fully operational automated systems. However, currently less than half a dozen of these are now in service in the United States, and there are none on the west coast. All available data and articles come from either the manufacturer or one of the six hospitals who now have operating systems. The manufacturers are marketing their equipment and therefore are not going to disclose the problems with their system. Furthermore, the relative short experience other hospitals have makes a current assessment questionable. As a result, an inductive approach utilizing data
<table>
<thead>
<tr>
<th>Description</th>
<th>Current Cost</th>
<th>Time Mode</th>
<th>PVF @ 8%</th>
<th>True Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AUTOMATED SYSTEM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) Purchase Cost</td>
<td>2,400,000</td>
<td>1 year</td>
<td>1.000</td>
<td>2,400,000</td>
</tr>
<tr>
<td>Salvage Value</td>
<td>(24,000)</td>
<td>20 year</td>
<td>0.215</td>
<td>(5,160)</td>
</tr>
<tr>
<td>Replacement Cost</td>
<td>0</td>
<td>20 year</td>
<td>0.00</td>
<td>0,000</td>
</tr>
<tr>
<td>2) Operating Costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy-Utilization</td>
<td>1,200</td>
<td>1-20 year</td>
<td>9.818</td>
<td>11,782</td>
</tr>
<tr>
<td>Maintenance Contract</td>
<td>23,000</td>
<td>1 year</td>
<td>7.00</td>
<td>23,000</td>
</tr>
<tr>
<td></td>
<td>13,000</td>
<td>2-20 year</td>
<td>9.122</td>
<td>64,789</td>
</tr>
<tr>
<td>Misc. Cost</td>
<td>2,000</td>
<td>1-20 year</td>
<td>9.818</td>
<td>19,636</td>
</tr>
<tr>
<td>Labor Cost</td>
<td>12,000</td>
<td>1-20 year</td>
<td>9.818</td>
<td>117,816</td>
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<tr>
<td><strong>Present Value Cost of System</strong></td>
<td></td>
<td></td>
<td></td>
<td>2,635,863</td>
</tr>
<tr>
<td><strong>Realized Labor Savings</strong></td>
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<td></td>
<td></td>
<td>551,789</td>
</tr>
<tr>
<td><strong>Adjusted Cost of Manual System</strong></td>
<td></td>
<td></td>
<td></td>
<td>2,084,074</td>
</tr>
<tr>
<td><strong>MANUAL SYSTEM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) Purchase Cost</td>
<td>20,000</td>
<td>1 year</td>
<td>1.000</td>
<td>20,000</td>
</tr>
<tr>
<td>Salvage Value</td>
<td>(2,000)</td>
<td>10 year</td>
<td>0.463</td>
<td>(926)</td>
</tr>
<tr>
<td>Replacement Cost</td>
<td>20,000</td>
<td>10 year</td>
<td>0.463</td>
<td>9,260</td>
</tr>
<tr>
<td>2) Operating Costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy-Utilization</td>
<td>000</td>
<td>1-20 year</td>
<td>0.000</td>
<td>000</td>
</tr>
<tr>
<td>Maintenance Cost</td>
<td>1,000</td>
<td>1-20 year</td>
<td>9.818</td>
<td>9,818</td>
</tr>
<tr>
<td>Misc. Cost</td>
<td>1,000</td>
<td>1-20 year</td>
<td>9.818</td>
<td>9,818</td>
</tr>
<tr>
<td>*Labor Cost</td>
<td>27,612</td>
<td>1-20 year</td>
<td>*</td>
<td>551,789</td>
</tr>
<tr>
<td><strong>Present Value of Manual System</strong></td>
<td></td>
<td></td>
<td></td>
<td>606,687</td>
</tr>
</tbody>
</table>

*Labor Cost assumes 8% annual salary increases adjusted to reflect an 8% Present Value Factor (See Figure 4).

Figure 3

A Present Value Cost Analysis Between Two Material Handling Systems
from the manual system and projecting the needs the new Medical Center will have proved to be the most reliable.

A second limitation to the study was the inability of the experimenter to see the project through to completion. The primary research was compiled during the residency of the experimenter at Olive View. The actual construction was to begin some eighteen months in the future which was far beyond the residency period. Therefore, all recommendations were based upon the data and circumstances at the time. Furthermore, all recommendations were subject to approval of the administrator as well as the County Department of Health Services and the County Board of Supervisors.

ANALYSIS OF DATA

A careful review of the data has uncovered some very interesting results. Analysis of the time and motion study at Tarzana Medical Center indicated that the average time necessary for each material distribution trip was 5.84 minutes when an exchange cart method was used. However, special orders which do not require the cart are generally completed on the average in four minutes flat (See Table 1). Using the average time as a base and determining the number of anticipated trips at the new
medical center (Table 2) the study proceeded to measure deductively the total anticipated hours attributable to material distribution. Thus, a total of 28.35 hours were required daily to facilitate the distribution needs. Hence, further analysis (Figure 2) determined these results to be equivalent to 3.54 FTE's. To determine the total labor cost the average salary of a distribution clerk ($7,800) was multiplied by the actual number of FTE's required (3.54). This resulted in a first year labor cost attributable to material distribution of $27,612.

In order to get a more accurate projection of labor costs over the next twenty years, it was assumed that labor wages would increase at a rate of 8 per cent annually (Figure 4). However, since we were interested in the actual current cost of the labor for our own analysis, we again adjusted the inflated labor costs using an 8 per cent present value factor. Thus, a careful analysis of labor costs attributable to material handling resulted in a total twenty-year adjusted labor cost of $551,789.

The final step in our analysis was to objectively compare the true costs of the manual system to that of the automated system (Figure 3). Hence, in order to
<table>
<thead>
<tr>
<th>Year</th>
<th>Labor Salaries (Assumes 8% annual increase)</th>
<th>PVF (8%)</th>
<th>Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27,612</td>
<td>1.00</td>
<td>27,612</td>
</tr>
<tr>
<td>2</td>
<td>29,821</td>
<td>0.926</td>
<td>27,142</td>
</tr>
<tr>
<td>3</td>
<td>32,196</td>
<td>0.857</td>
<td>27,592</td>
</tr>
<tr>
<td>4</td>
<td>34,791</td>
<td>0.794</td>
<td>27,624</td>
</tr>
<tr>
<td>5</td>
<td>37,552</td>
<td>0.735</td>
<td>27,601</td>
</tr>
<tr>
<td>6</td>
<td>40,562</td>
<td>0.681</td>
<td>27,623</td>
</tr>
<tr>
<td>7</td>
<td>43,820</td>
<td>0.630</td>
<td>27,607</td>
</tr>
<tr>
<td>8</td>
<td>47,327</td>
<td>0.583</td>
<td>27,592</td>
</tr>
<tr>
<td>9</td>
<td>51,110</td>
<td>0.540</td>
<td>27,599</td>
</tr>
<tr>
<td>10</td>
<td>55,196</td>
<td>0.500</td>
<td>27,598</td>
</tr>
<tr>
<td>11</td>
<td>59,614</td>
<td>0.463</td>
<td>27,601</td>
</tr>
<tr>
<td>12</td>
<td>64,391</td>
<td>0.429</td>
<td>27,624</td>
</tr>
<tr>
<td>13</td>
<td>69,527</td>
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<tr>
<td>14</td>
<td>75,105</td>
<td>0.368</td>
<td>27,639</td>
</tr>
<tr>
<td>15</td>
<td>81,096</td>
<td>0.340</td>
<td>27,573</td>
</tr>
<tr>
<td>16</td>
<td>87,585</td>
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<td>27,589</td>
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<tr>
<td>17</td>
<td>94,599</td>
<td>0.292</td>
<td>27,623</td>
</tr>
<tr>
<td>18</td>
<td>102,614</td>
<td>0.270</td>
<td>27,706</td>
</tr>
<tr>
<td>19</td>
<td>110,338</td>
<td>0.250</td>
<td>27,585</td>
</tr>
<tr>
<td>20</td>
<td>119,173</td>
<td>0.232</td>
<td>27,648</td>
</tr>
</tbody>
</table>

Total 20-year adjusted labor costs 551,789

**Figure 4**

Projected Future Labor Costs Attributable to Material Handling in the Olive View Medical Center (assumes an 8% annual salary increase adjusted at 8% present value factor).
compare both systems, all costs related to each had to be reviewed over the entire twenty-year life of the system. A present value factor analysis was used to bring all costs up to the base year 1974. Hence, a decision on selection of a system could be made objectively based on cost with all items weighted equally in relation to the economy. The results of this analysis indicate that the manual system would be more favorable than the automated system based upon cost alone. The automated system resulted in a total cost of $2,084,074 while the manual system was $606,687 or 30 per cent the cost of the former. If the selection was based upon the cost comparison solely, the manual system would be selected without doubt.

Our analysis using a life cycle basis showed that equipment costs and personnel were the primary cost factors in material handling. As indicated by the data (Figure 3), the automated systems generally have the lower life cycle personnel costs. However, the automated system has a much higher life cycle cost for equipment than the manual system.

FINDINGS AND INTERPRETATIONS

The results of this study indicate that on the basis of life cycle costs the manual system assisted by
pneumatic trash and linen chutes (as recommended in Chapter 3) appears to be the most desirable material handling system. When the actual differences in initial capital costs were compared with the anticipated labor savings over a twenty-year period, these results were confirmed. Thus, even after twenty years and an assumed inflationary increase in wages of 8 per cent annually, the manual system cost less than a third of the cost of the automated alternative. These results are consistent with similar findings and recommendations made by the Controller General of the United States in his report to the Congress. However, we must consider the time cost analysis as it relates to patient care and efficient operations elsewhere.

Keeping in mind the original objectives of the J.C.H.A. to provide a maximum level of patient care and to retain the spiraling increases in hospital costs through efficient operation, a careful analysis of each system is essential. Hence, to reach a maximum level of patient care, the system must be as swift as possible. The automated system's speed performance is considerably greater than the manual system. Construction of vertical shafts, special high speed elevators and traffic free interstitial space provide the most direct route from the point
direct route from the point of departure to the destination. Secondly, the automated system is free of problems related to shortages in manpower which might also delay the delivery of an important drug or piece of equipment to a patient. Finally, the automated system could be extended to handle other non-bulk functions which could improve the overall efficiency of the system. Utilization of the system by patient records, business office, lab, etc., would introduce additional labor savings to the hospital which could bring the life cycle costs closer in line with the manual system.

The material distribution system discussed earlier in this study is quite flexible. Creation of a central supply, processing and distribution center located at the base of the facility with a central core providing a distribution network on each floor, is adaptable to most systems. However, it appears from the research and the actual study that a compromise system would provide the best solution to the medical center's needs. Olive View needs a system which is cost justifiable in terms of purchase costs of the equipment, yet economical and efficient as it relates to patient care, personnel savings, and adaptability by other departments. The study undertaken by the U. S. Government concluded that with increasing
inflation rates and a reasonable discount rate the life cycle cost differences between automated and manual systems closed considerably. In fact, the same study also analyzed five different semi-automated systems which varied only in the degree of automation they included. As the inflation rate increased relative to the discount rate, semi-automated complements became more desirable based upon life cycle costs. Thus, the current state of our economy which closely resembles the preceding experimental environment is conducive to a degree of automation within reasonable cost limits.

Since the structure of the facility and the planned distribution system both revolve around the central core, an automated vertical dumbwaiter coupled with a manual horizontal system at each floor could provide maximum service and comparatively moderate initial capital costs (relative to a fully automated system). The automatic dumbwaiter could be of full size to accommodate the exchange carts and could be equipped with an automatic ejection device. Thus, the SPD could dispatch an exchange cart to a floor where it will be ejected automatically into a clean core. This procedure will prevent a back up in the automatic system itself, and will also prevent the cross-contamination of the carts. Henceforth,
a dispatcher in the SPD could coordinate the traffic in the automatic vertical dumbwaiter while communicating with the distribution personnel in the cores. Once the material is in the clean core the distribution personnel would continue to follow the distribution system manually. The removal of trash and soiled linens will still be expedited by vacuum assisted chutes in the soiled core. A second vertical dumbwaiter could also be installed in the soiled core. However, the second vertical lift originates in the contaminated part of the SPD and travels only between the soiled cores. Thus, guaranteeing that there will be no cross contamination. The second dumbwaiter provides an outlet for used surgical instruments, trays, and carts. Hence, this semi-automated system would complete the material handling cycle at acceptable economies.

The Olive View Medical Center is a publicly held facility accountable to a board of supervisors elected by the public. As such, all capital expenditures related to the construction of the facility are a public trust and subject to board approval. Hence, the health responsibilities are but one of many that the board deals with in its total budget. In general, board members are laymen in the health areas and tend to give equal weight to all of their departments. Across the board budgetary reductions
effect all of the county's capital projects. Hence the net effect on the new medical center is to reduce construction costs substantially. However, the prime objective is still to provide a maximum level of patient care. Conforming to these objectives the patient areas will generally remain untouched, while expensive equipment (such as the fully automated cart conveyor system), and additional construction costs (interstitial space) are the first items to be removed from the budget. Thus, although the operating advantages of a fully automated system are many, lack of total budgetary control makes a venture of this magnitude merely an exercise unless the equipment on a life cycle basis can currently be shown to be cost justifiable.

A semi-automated system designed to provide vertical straight line movement could currently be cost justifiable. Concurring results of this study and that of the U.S. Controller General support the premise that some degree of automation is justifiable. Further, that in an inflationary economy such as we have today, increasing degrees of automation are becoming more desirable on a life cycle or cost benefit basis. Installation of a simple automatic dumbwaiter system (discussed above) would require little or no additional construction costs,
and the initial capital costs of the equipment very low (compared to the initial investment required for the fully automated system).

In conclusion, this study would like to recommend the adoption of the material distribution system discussed earlier (Chapter 3). Further, that a manual material handling system be adopted with an automatic dumbwaiter for vertical convenience and speed. Thus, a second study should be undertaken to determine the exact costs related to the semi-automated system recommended. The results of this second study should be compared and analyzed along with the original study. Should the results of the second study be favorable to the semi-automated system on a life cycle cost basis, it is further recommended that the Medical Center move ahead with this project as suggested by this study.
5. REFERENCES
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FOOTNOTES


4 Yale Studies of Hospital Function and Design, Yale University, 1970 (U.S. Public Health Service Grant Number W-53).


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11 Friesen, pp. 109-112.


15 J. H. Holmgren, "Central Sterile Supply, Where are you now?" Modern Hospital, 120 (January 1, 1973) 52-61.

16 Controller General, pp. 381-431.


19 Opinion expressed by G. L. Delon, industrial engineer, in a hospital systems paper ("A generalized Methodology for Evaluation Hospital Distribution Systems") presented at the American Institute for Industrial Engineers meeting, Boston May 1, 1971 (tape available from American Institute for Industrial Engineers on request).

20 Holmgren, pp. 60-61.

21 Friesen, pp. 110-112.


23 Friesen, pp. 110-112.

24 Ibid.


26 Controller General, pp. 410-431.

27 Friesen, pp. 111-112.

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29 Controller General, pp.

31 Cargomaster

32 Swindler, pp. 95-96.

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35 Cyberail

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37 A.C.T.S.


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43 Controller General, pp. 410-431.

44 Ibid.
APPENDIX

MATERIAL HANDLING CYCLE