OPTIMAL UTILIZATION OF HUMAN RESOURCES IN SURGICAL INSTRUMENTS DISTRIBUTION IN HOSPITALS

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Abstract
In today's environment, the rising operating cost of providing healthcare is of concern to the various healthcare providers. Hospitals are seeking ways to streamline the process of internal distribution of surgical instruments and optimize the use of human resources involved in the process. Using simulation models, this paper attempts to assess the utilization of human resources involved in the process of surgical instruments distribution within a Singaporean hospital and provide a recommendation for more optimal utilization. The results will prove helpful in streamlining the process of surgical instruments distribution in hospitals and other similar processes.

Keywords:
Hospital, simulation, internal distribution, human resource utilization.

1 INTRODUCTION

With escalating healthcare costs, hospitals seek ways to contain operating costs and at the same time provide quality healthcare service. Hospitals have traditionally emphasized on breakthroughs in technology and procedures for surgical care. As competition among hospitals continues to intensify, however, patients often perceive little difference in such technology and procedures used by different hospitals. Further, the facility for surgical care, which is a critical part of any hospital that provides surgical care service, consumes multitudes of resources, but it also generates significant revenue if managed properly. For this reason as well as others, hospitals seek ways to streamline the process of surgical care and optimize the utilization of resources involved in the process. Given the shortage and rising costs of human resources in healthcare, efficient allocation and utilization of human resources can help hospitals contain costs, improve efficiency, and stay competitive in the marketplace.

The hospital is a dynamic system and the patient arrivals are often scheduled. This gives rise to other problems such as long waiting time and difficulties in scheduling of personnel. This paper looked into the Theatre Sterile Supply Unit (TSSU) of a Singaporean hospital (referred to as 'the Hospital' hereafter, for anonymity and brevity) on how its operation can be optimized and its cost savings will in turn benefit the hospital as well as the patients.

TSSU provides medical and surgical supplies, both sterile and non-sterile are cleaned, prepared, processed, stored and issued for patient care to all 67 various operating theatres of the Hospital. The focus is on the feasibility in employing additional workers in delivering AD Hoc (additional) sterile items to the various operating theatre rooms to lighten the workload of the operating theatre (OT) nurses and TSSU staff. Higher specialized staff nurses from the operating theatres currently deal with these deliveries when unskilled or semi-skilled worker who will command a lower wage can handle it. Using simulation models, this paper attempted to assess the utilization of human resources involved in the process of sterile surgical instruments distribution. The objectives were to capture the real time inventory level in the TSSU, reduce time spent of staff nurses outside of OTs, and recommend the safety stock level of sterile surgical items for the AD Hoc (additional) demand order requests.

2 LITERATURE REVIEW

Young [1] examined the material management departments of 22 general hospitals in the state of Georgia for their effectiveness. He demonstrated the application of DEA and MCPIPMT to the multiple productivity measurement problems presented by material management. Further, Kim et al [2] identified three types of material management systems in the hospitals, including conventional, just-in-time, and stockless systems, and empirically tested the systems' significance on the total inventory cost and service quality improvement. Okogbaa et al [3] modeled the use of automated materials handling system at a 900-bed hospital, using simulation models and provided recommendations for the material handling system. Heinbuch [4] highlighted the value of just-in-time inventory management system for materials management in clinical areas of hospitals.

Motwani et al [5] highlighted that the theory of constraints (TOC) can be applied to service and not-for-profit organizations to improve performance towards non-financial goals and to assure financial survival. Inova Health System materials management staff integrated their processes for vendor selection, purchasing, inventory reduction, and utilization across 3 hospitals and ancillary services. Kilogore and Muller [6] studied the integration of the material management processes by using a team model. The model structured the team to capture process users' and customers' knowledge and involves as many employees as possible.

Healthcare industry has been reluctant to make the comparison between itself and the manufacturing industry and take advantage to the savings associated with adaptation of manufacturing's just-in-time (JIT) system. Jarrett [7] emphasized on JIT system in his study and carried out the investigation of the international healthcare logistical environment to determine whether regulatory policies or industry procedures have hindered the implementation of JIT system.

Chan and Lynn [8] overviewed the survey of 15 randomly chosen Ontario hospitals that are attempting to cope in the current funding cutbacks. The surveyed hospitals claimed

to be innovative, open to change, and have improved their organizational flexibility to deal with the current turbulent environment they face. A recent study by Clare et al [9] highlights how total quality management (TQM) principles improved the healthcare sector in Singapore.

3 MODELING OF AD HOC DEMAND ORDERS

3.1 Background of TSSU

TSSU in the Hospital sterilizes about 6,000 to 7,000 different surgical instruments, which are supplied to 67 different OT rooms. The instruments vary in shapes and sizes as well as in its method of handling and are categorized into (1) Heat sensitive instruments, which can withstand a maximum temperature of 50°C, and (2) Normal instruments. This is to allocate the surgical instruments to the correct sterilization process. A senior nursing officer (SNO) leads the TSSU. Under her supervision are 19 nurses, 19 healthcare assistants (HCA), 2 clerks, and 2 nurse managers. Each nurse in TSSU is cross-trained to handle various functions in the facility. Nurses are assigned to decontamination and packaging areas; whereas the HCAs are assigned to load and unload the trolleys. TSSU operates from 7:00AM to 9:00PM daily. Staffs work in two shifts on a weekday and four shifts on Saturday and Sunday. TSSU is composed of four major areas based upon the tasks that it performs: 1) the decontamination area where used or contaminated surgical instruments are cleaned and rendered safe to handle, 2) the processing area where clean or decontaminated surgical instruments are inspected, assembled, and packaged, 3) the sterilization area where any microorganisms found in packages of surgical instruments are destroyed, and 4) the storage area where sterile packages of surgical instruments are stored in a controlled environment with respect to temperature, humidity, ventilation, and so on.

Types of distribution systems in hospitals

When clean or sterile items are needed in patient care, they must be transferred from TSSU to the various operating theatre rooms (OR). The distribution of the surgical instruments throughout the hospital must be timely and accurate, and care must be taken to ensure that the function, cleanliness, and sterility of the items are not compromised during transport. The six main types of distribution systems, which are demand, par level restocking, exchange cart, case carts, and stockless or just-in time, have been developed to meet these needs. The choice of distribution systems in a hospital depends on the needs, the services that the hospital or facility provides, and its size, physical design, age and financial resources and goals. Most hospitals in Singapore now use computer systems to maintain perpetual inventory for their supply storerooms. The information available from a computerized inventory system can be used to significantly reduce the inventory and improve services.

3.2 Normal demand orders process

Figure 1 shows the processes of normal demand order and distribution of surgical instruments. An OT staff first fills up a request form for surgical instruments needed for an operation before the day of the operation, and sends the request form to TSSU via the automatic lift (dump waiter). TSSU staff collects request forms from the dump waiter between 2:00 to 5:00PM while most requests for surgical instruments are made. TSSU nurses pack instruments on 'clean' trolleys. At 8.30PM every night, each 'clean' trolley containing surgical instruments is delivered to the holding area of the respective OT room for use on the following day, and the surgical instruments issued are recorded on the inventory control system in TSSU. On the day of the operation, an OT staff takes over the 'clean' trolley and delivers it to the OT room for use in the operation. Upon completion of the operation, unused surgical instruments in the 'clean' trolley are taken by a TSSU staff and brought back to TSSU. OT nurses put used or contaminated surgical instruments during the course of operation in a 'dirty' trolley, which is also taken by a TSSU staff and brought to TSSU. An OT nurse fills up the form for return of used surgical instruments and places it on the 'dirty' trolley. Figure 2 illustrates the floor layout of OT rooms. In TSSU, a staff unloads surgical instruments in both trolleys and updates data in the inventory control system. Then, used surgical instruments are sent to the decontamination area for cleaning.

3.3 AD-Hoc demand orders process

In addition to the normal orders, TSSU has to deal with ad hoc (additional) orders in emergency cases. For example, when there is a last-minute adjustment to the surgical instruments already ordered for an operation or when surgical instruments are needed immediately for an emergent operation, OT nurses can take surgical instruments required for the operation without giving a prior notice to TSSU. This often results into the inventory list for order request being not properly filled up and the inventory control of the computer not being updated. This sequence of actions often result in unnecessary wastage of resources since the staff nurses will be better off to spend more time in the theatres than to go and get the instruments themselves. Sometimes, the incoming items are also not being properly collected back after usage. The soiled instruments are pushed to the dirty lift (Lift 8) by the staff nurses of the operating theatre and collected back by the nurses of TSSU (see Figure 2 for floor plan of operating theatre). This often results in differences of the records in and out of TSSU since the instruments out of the unit have not been recorded accurately in the first place.

Since the current AD Hoc demand order process poses several problems to the TSSU, a proposed new system of delivering sterile surgical items is shown in Figure 3. In this system, OT staff will not have to go to TSSU for sterile instruments and they in turn be sent to the operating theatre rooms (OR) by the delivery person instead. This proposed delivery system will be used in the modeling of AD Hoc demand orders in the later section.

3.4 Methodology

The methodology used in this research involves six steps:

1) Arrange the data collected according to the surgical discipline.
2) Group the surgical instruments and sets as a single surgical item in the analysis.
3) Plot histogram charts and fit a mathematical distribution curves for additional demand orders from operating theatre.
4) Use steps in building simulation in creating the model for the project.

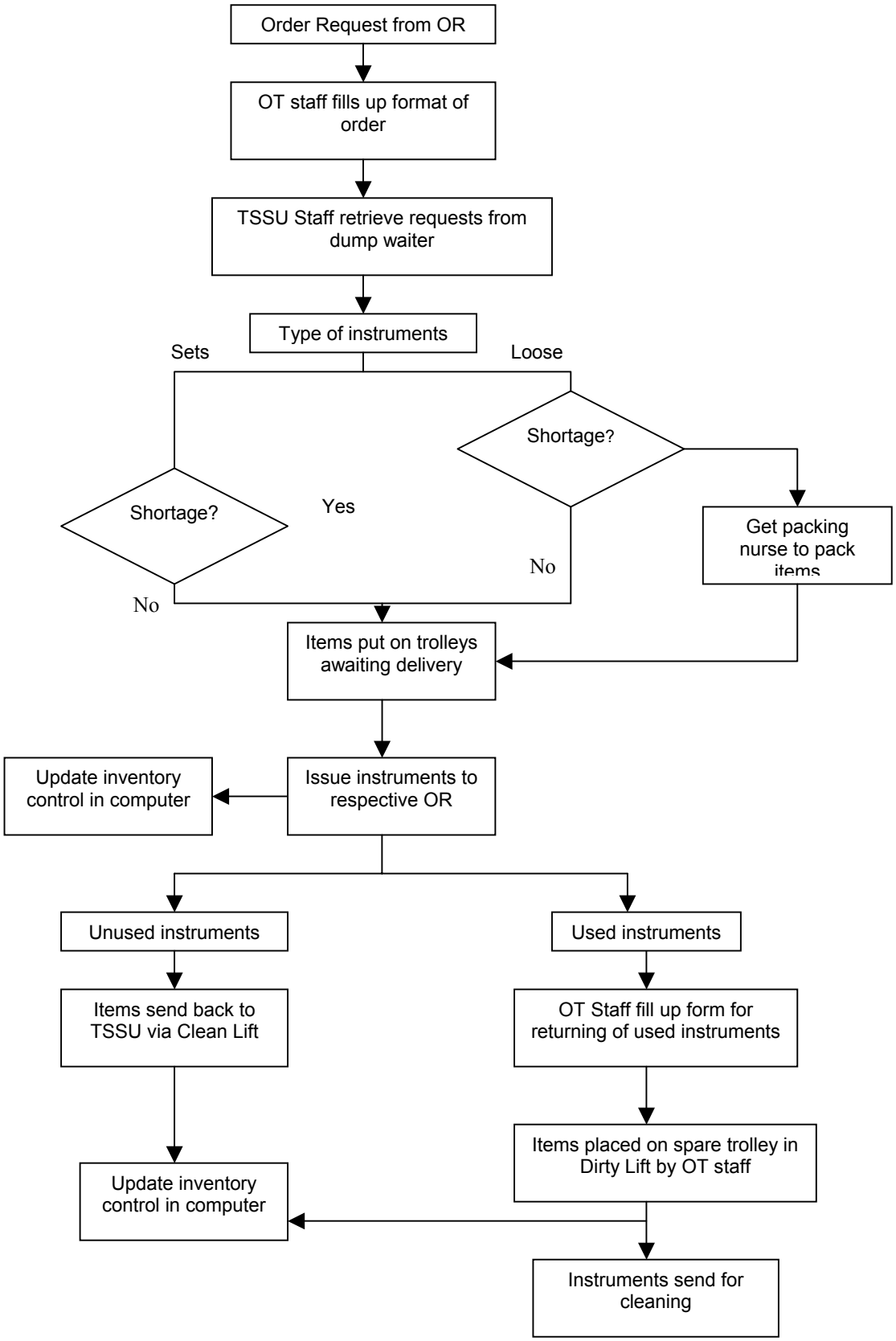

Figure 1: Flow chart of Normal demand orders process.

5) Run the model using PROMODEL software [10] to create different scenarios.
6) Recommend the number of additional workers required to perform the task from the simulation results.

Data was collected over a period of two weeks in July 2004 [11]. The total workload of the TSSU to the 18 elective operating theatres and 3 emergency operating theatres were tabulated and the following data were collected:

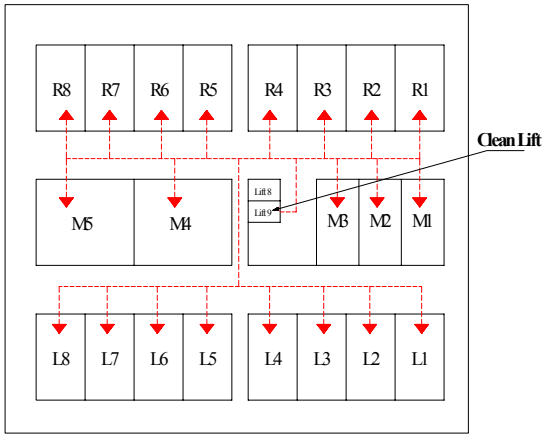

Figure 2: Floor plan of operating theatre.

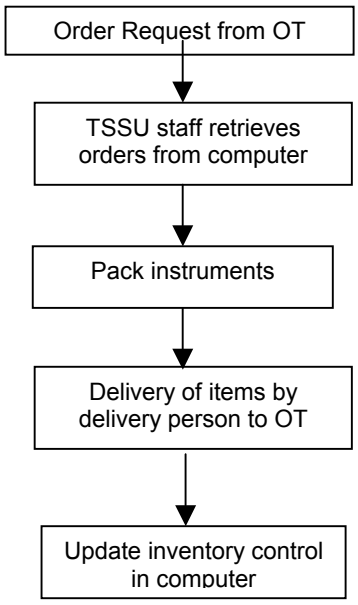

Figure 3: Flow chart of proposed AD-Hoc demand orders process.

- Number of loose and sets instruments issued for Normal and AD Hoc (Additional) demand orders,
- Number of trips made by operating theatre (OT) staff for additional demand orders,
- Number of surgical sets not recorded at Decontamination Area, and
- Number of sets sent to Decontamination Area for cleaning after surgery.

Assumptions

1) There is no distinction of surgical instrument and set. They are grouped under a common category.
2) The surgeons could change rooms for a given type of surgery. They can switch to different rooms.
3) The inter-arrival time between the AD Hoc demand orders is 10 minutes.

3.5 Disciplines of Operating Theatre

The operating theatre (OT) is categorized into 9 main types of surgical disciplines as shown in Table 1. The 21 OT rooms are located in Block 3, Level 2, of the hospital facility. Two lifts (clean and dirty) are used for the transportation of the surgical items to and fro from the operating theatre. These two lifts are situated at the center of Level 2 (see Figure 2). The estimated average time taken to travel from the TSSU to various operating theatre rooms is also listed in Table 1. It is normally distributed with a mean (μ) of 5.14 and variance (σ) of 0.91.

3.6 Modeling of AD Hoc demand orders process

In the model, only proposed AD Hoc demand orders process is involved in the computer simulation and normal demand orders is excluded. In the modeling of the additional demand orders process from the operating theatre, a number of parameters are required for the model building process. The parameters that are used for this simulation are location, entities, path networks, resources, processing and arrivals. Location represents fixed places in the system where entities are routed for processing, storage, or some other activity. They are used to model elements such as machines, workstations, queues and waiting area. A location capacity is the maximum number of entities it can hold at any one time. A downtime stops a location or resource from operating.

Model processes such as parts, products, people or paperwork are modeled as entities. In this simulation, the sterile surgical items are modeled as an entity. The type of surgical sets such as plastic sets and emergency sets are modeled as one unique entity. A path network is the path taken by the resource (delivery man) that travels between the locations. In this model, it is the path from the TSSU to the various operating theatre rooms. Further, the interfaces define the number of location-node interfaces in the path network. If an entity is picked up or dropped off at a particular location by a resource that location must connect to a node through a location-node interface. Two nodes are in existence in the model at the desk and OT.

A resource is a person, piece of equipment, or other device used for one or more of the following functions: transporting entities, assisting in performing entities, assisting in performing operations on entities at locations, or performing maintenance on other resources. In this model, the delivery man who is tasked to deliver the various surgical sets to the operating rooms is modeled as *a* resource. Processing defines the routing of entities through the system and the operations that take place at each location they enter. In this simulation, the process of delivering the surgical items is between the two locations-Desk (TSSU) and OT.

Any time new entities are introduced into the system, it is called an arrival. An arrival record is defined by specifying the following information: number of new entities per arrival, frequency and location of the arrivals, and time of the first arrival. The number of entities to arrive at each arrival time interval is Weibull distributed with parameters as (3.16, 1.2).

4 RESULTS AND DISCUSSION

An efficient utilization of TSSU is important in the smooth running of its facility and will bring about a lower operation cost, passing the lower cost to the patients. Over utilization of workers will cause work related stress, such as work physiological order.

Table 1: Surgical disciplines of operating theatre rooms and travel time from TSSU to OT rooms in minutes.

OR	DISCIPLINE	Time Mins	OR	DISCIPLINE	Time (Mins)	OR	DISCIPLINE	TIME (MINS)
R1	Emergency	6	M1	Orthopaedic	5	L1	Orthopaedic	5
R2	Emergency	6	M2	Orthopaedic	5	L2	Orthopaedic	5
R3	General	5	M3	General	4	L3	General	4
R4	General	5	M4	Cardio thoracic	4	L4	General	4
R5	Cardio thoracic	5	M5	Cardio thoracic	6	L5	Colorectal	4
R6	Ear Norse Throat	6				L6	Gynaecology	4
R7	Plastic	6				L7	Gynaecology	6
R8	Cardio thoracic	7				L8	Ear Norse Throat	6

Table 2: Utilization of human resources in TSSU.

Staff	Average	Min	Max	Staff	Average	Min	Max
Decom HCA AM	85.2	84.3	86.1	Storage Nurse AM	93.4	92.3	95.0
Decom HCA PM	80.9	79.0	82.5	Storage Nurses	93.2	92.7	93.7
Decom Nurse AM	95.4	94.5	96.4	Pack Decom Nurse AM	99.3	98.3	99.8
Decom Nurse PM	94.2	92.7	95.8	Pack Decom Nurse PM	98.5	96.8	99.8
Packing HCA AM	82.9	81.6	85.1	HCA Sat PM	93.8	87.3	96.7
Packing NCA PM	77.6	75.7	79.3	HCA Sun AM	91.0	86.6	98.0
Packing Nurse AM	67.9	66.5	68.6	HCA Sun PM	95.2	92.4	98.0
Packing Nurse PM	61.3	60.0	62.5	Nurse Sat PM	96.0	89.6	100.0
Storage HCA AM	66.9	66.3	67.5	Nurse Sun AM	94.3	88.8	99.4
Storage HCA PM	60.9	60.5	61.6	Nurse Sun PM	92.3	86.8	94.4

4.1 Utilization of human resources

From Table 2, some of the resources are over-utilized. The recommended utilization of Nurse and HCA are 70% and 66.7% respectively. It was analyzed that the staffs from the decontamination, storage, and weekend duty personnel areas within the department are over utilized.

At present, the staffs at these areas extend their daily working hours to cope with the excessive workloads. Therefore, it can be concluded that the current TSSU staff will not be able to handle the delivery of AD Hoc sterile surgical items to the operating theatre. As such, the delivery person has to be someone not from TSSU in order to take over the task from the OT staff.

It is also important for the TSSU to keep safety stock. This is because in cases of emergency, TSSU is given short notice on the instruments that are needed for the surgery. If TSSU does not have additional instruments that are allocated for these cases, the operation might be delayed. Thus, TSSU keeps safety stock. The quantity of sterile instruments kept for emergency cases varies week by week due to the changing demand.

4.2 AD Hoc demand orders

It is found that the AD Hoc demand order of surgical items originates mostly from the Emergency (38%) and Neuro (22%) surgery. One reason is due to the uncertainty that exists in these two surgery disciplines.

A total of five scenarios (from one to five workers) are performed using the simulation software PROMODEL. The information that is relevant in the study is tabulated in Table 3. It is found that utilization of the worker decreases as the number of workers employed increases given the same workload. The recommended utilization of the worker should be between 66.7% and 70%. As such, by employing two additional workers in delivering the sterile surgical items to the OT falls within this range of utilization percentage. Table 3 also shows (last three columns) information on the entity or surgical items. The important perimeter is the percentage of wait for resource. Scenario 1 is deemed to be unacceptable, as the entity will spend most of the time waiting for the resource (72.30). Therefore, by employing two workers as discussed earlier is acceptable since the percentage of wait for resource is only 29.18%.

Table 3: Resources and entity states by percentage.

Scenario	Scheduled Hours	In Use %	Travel to Use %	Travel to Park %	Idle %	Down %	Utilization %	In Move Logic %	Wait for Resource %	In Opera-tion %
1	2.4	51.25	47.02	0.00	1.74	0.00	98.26	15.02	72.30	12.69
2	3.48	34.73	32.83	0.00	32.44	0.00	67.56	38.11	29.18	32.72
3	4.27	29.46	21.69	0.00	48.85	0.00	51.15	41.56	23.93	34.52
4	6.35	18.79	15.23	0.00	65.98	0.00	34.02	39.94	25.33	34.73
5	8.75	13.36	10.15	0.00	76.49	0.00	23.51	40.31	23.97	35.72

5 CONCLUSIONS

An in-depth analysis of the delivery system of the AD Hoc demand orders of sterile items was conducted thoroughly. It was found that the current TSSU staff would not be able to handle the AD Hoc demand orders from the operating theatre due to the fact that they are already currently overworked. Additional workers have to be employed if it is to take over the task currently managed by the OT staff. This will enable the OT staff to spend their valuable time in the operating theatre instead of traveling to and fro obtaining the sterile surgical items. The analysis on the proposed delivery system was successfully conducted through the use of simulation based on two main areas-resources and entity. Different scenarios of using different number of additional workers (Resource) were used.

The results have clearly shown the need for employing additional workers to deliver the AD Hoc demand orders to the operating theatre. A qualitative approach is used to establish the number of workers to be employed. It is found that two workers will be able to deliver these sterile surgical items. This is based on the percentage utilization of each worker. Although, other possible solution of employing more workers is possible but the cost incurred in this way will increase. In cases when there is a sudden increase in additional demand order, additional workers can be employed on a contract basis to meet this demand. It is often perceived that it is easier to get a semi-skilled worker such as a delivery man than a skilled worker like an Operating Theatre staff nurse. This will reduce the number of surgical items that are not being properly entered when sent for sterilization in TSSU. As such, the nurses in TSSU will not have to double check the forms for return of soiled instruments as thorough.

Outsourcing non-core processes and emphasizing on core business processes is the emerging trend in other industries. Health care industry in Singapore is well aware of this trend but is lacking in initiative and research. As such, outsourcing has a very good opportunity for rigorous research to find out what is hindering the hospital to outsource or integrate sterile supplies with other hospital to reap the benefits of economics of scale.

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