Applications of Kitting Materials Feeding Policy to Healthcare: A Case Study in a Perioperative Services Department

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A Thesis

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Abstract

"Kitting," a materials feeding policy used in manufacturing, involves the creation of kits of raw and sub-assembled components that in total amount to all of the material required for one (or sometimes more) final assemblies. Most large hospitals assemble kits of instruments and disposable supplies for use during surgeries. The efficacy of the kitting process directly contributes to the quality of patient care during a surgical event, as well as to the improved flow of patients through the operating room. This paper reviews research on kitting as a materials feeding policy and applies it to a case study in a perioperative services department. After a thorough literature review and description of the four variations on materials feeding policies, the state-of-the-art in kitting research will be described and applied to the kitting process in the operating room. The state-of-the-art was determined to be a mixed-integer linear programming model that was recently published in the kitting literature that determines for each item in a system's inventory if a given item should be supplied in a kit or in a bulk to the point of use.

To apply the model to the perioperative services department a conceptual mapping was performed between terminologies in kitting literature, which is predominantly oriented towards manufacturing, to concepts in the perioperative department's materials feeding system. This conceptual mapping allowed for the application of the state-of-the-art model. The model from the kitting literature was modified from its original formulation to be able to describe the perioperative system. The model became a binary integer program, whereas the original model was mixed-integer linear. The model formulation was coded using AMPL and solved using Gurobi 5.6. The model showed how a cost savings of $31,000 annually could be attained through a reassignment of parts' materials feeding policies.

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Due to the many gracious people to whom I am indebted to for the completion of this work, and due to the unfortunate reality of the constraints of space, these recognitions that follow will pale next to the true depth of gratitude I wish to express to all who supported me during the process of completing this work. I wish to preamble with my humble request for the reader's forgiveness if these words are insufficient or if a name goes unmentioned. Know that you remain in high esteem in my heart.

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1 Problem Statement

1.1 Operating Room Suite Supply Systems

Operating room suites in hospitals must have in place systems by which materials are provided to surgeons and nurses for use during surgeries. The materials being provided are disposable, single use items or reusable, multiple-use items. Care must be taken when handling and preparing these items because quality is highly important in environments where patients are being cared for. Surgical complexity can lead to many items being required to complete a surgery successfully. Medical equipment can be expensive, so inventory is kept as low as possible to free up capital but item availability can be tight given that an item has a high level of utilization, some reusable items can be out of service for repair or sterilization, or a low-utilization item experiences a sudden spike in demand. Medical equipment can also be complicated; some sets of instruments have hundreds of parts. Surgical items must be available immediately during an operation so that the surgeon can continue to perform the surgical procedure uninhibited. Communications about the location of a given kit component is crucial for both kit preparation and to satisfy unforeseen demand for a given kit component. The cost of the materials used in operating room suites reaches on average 47% of an OR suite's annual budget (Park and Dickerson 2009). It has been noted that the efficient supply of materials to operating room suites provides the following benefits (Park and Dickerson 2009):

1. Timely delivery of supplies and instruments eliminates or reduces delays in the operating room.
2. The cost of labor in pulling and restocking unused items is reduced.
3. Information transfer between scheduling, operating room, central sterile supply, billing, accounting, materials management, and purchasing departments is automated.
4. Inventory on hand is reduced.

The supply system does not directly interact with patients in operating rooms. The efforts of the staff involved in the delivery of supplies ultimately supports clinical staff (doctors, nurses, etc.) in the care of patients or administration in the effective management of the hospital's resources. Figure 1 displays the ways in which each of the major subsystems in an operating room interact with each other (patients, patient care staff, supply system, and administration). Effective, timely delivery of supplies and proper stewardship of those supplies directly affect the quality of patient care and the ability of the hospital to deliver proper care to all patients.

1.2 A Comment on Motivation for this Thesis: The Case Study

During the spring and summer of 2012 a project was chartered at a large academic medical center's Perioperative Services suite (the surgery department, or the Operating Room (OR)) with the following problem statement: Supplies, instruments and implants are not reliably available to do surgical procedures.

There were 69 Supply related Quality Reports submitted for the baseline time period of 10/1/2011 to 12/31/2011. The project included the hiring of a Systems Engineering graduate student to aid in analyzing the supply chain of the OR. During discussion of the project with systems engineering faculty, it became evident to the graduate student and the faculty members that the hospital likely uses kitting as a materials feeding policy for delivery of supplies to the OR. The supply system for the OR has never been explicitly modeled as a kitting system nor was it built based on kitting best practices. Review of the literature revealed that kitting in healthcare settings has been given minimal treatment in the broader range of operations management literature; as stated previously, most case studies are in auto or electronics manufacturing, and they will arise in industrial engineering-specific journals. There were 31 Operating Rooms in the Operating Room suite where surgeries could be performed.

The case study demonstrates kitting system phenomena of interest, some of which has not been analyzed to date in a quantitative fashion. First of all, the supply system contains two different kitting operations: the building of case carts for surgeries (kits of material and instruments that doctors require for particular procedures; kits are either made-to-order or made-to-stock depending on the type of procedure) and the reassembly of kits of instruments in the sterilization department (the re-sterilization of instruments involves putting appropriate instruments back in the right tray of instruments; this is the rebuilding of a kit).

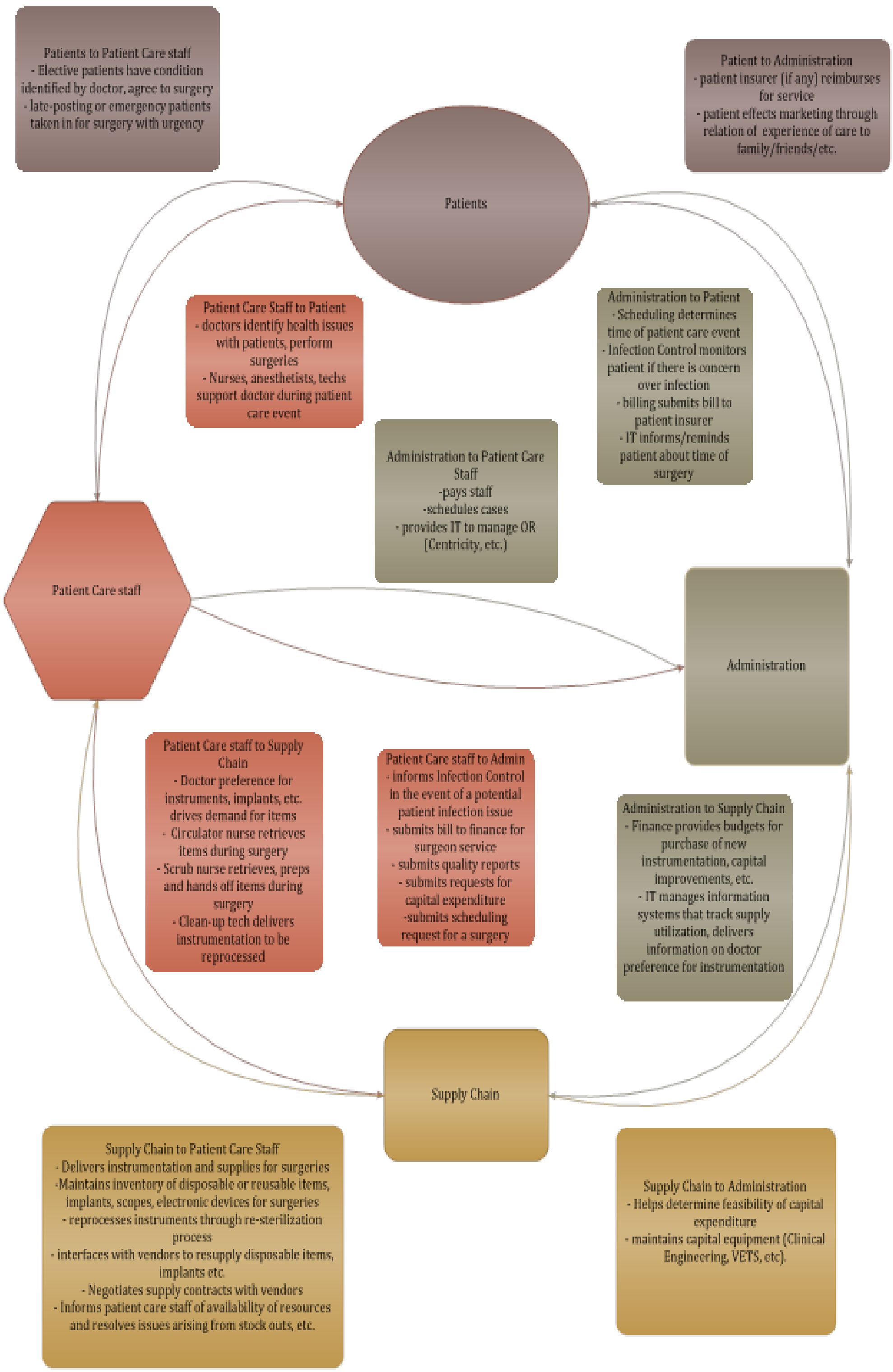


Figure 1: The supply system interacts with patients through both the clinical and administrative systems.

Literature does exist on multi-echelon assembly processes with multiple levels of kitting (kits in one level act as subassemblies in another). Second of all, the re-sterilization process is a unique form of kitting process where material is recaptured after use and kitted again for future use. To date, no literature exists that examines the interplay of kitting and closed-loop supply chains, re-manufacturing, or resource recapture, either qualitatively (e.g., in operations management literature) or quantitatively (e.g., in industrial and systems engineering literature).

The system of case carts is in place to deliver instrumentation and supplies to OR rooms in a way that is timely, accurate, and of sufficient quality. Surgical instrumentation and disposable items are placed on large metal carts that are used to ferry the items on the cart to operating rooms before the surgery scheduled to be performed in that room is started. Every surgery, scheduled or unscheduled, has a case cart built for it. Usually, case carts are built on demand, but in the instance of a surgery involving a trauma, case carts exist that are pre-built for emergencies.

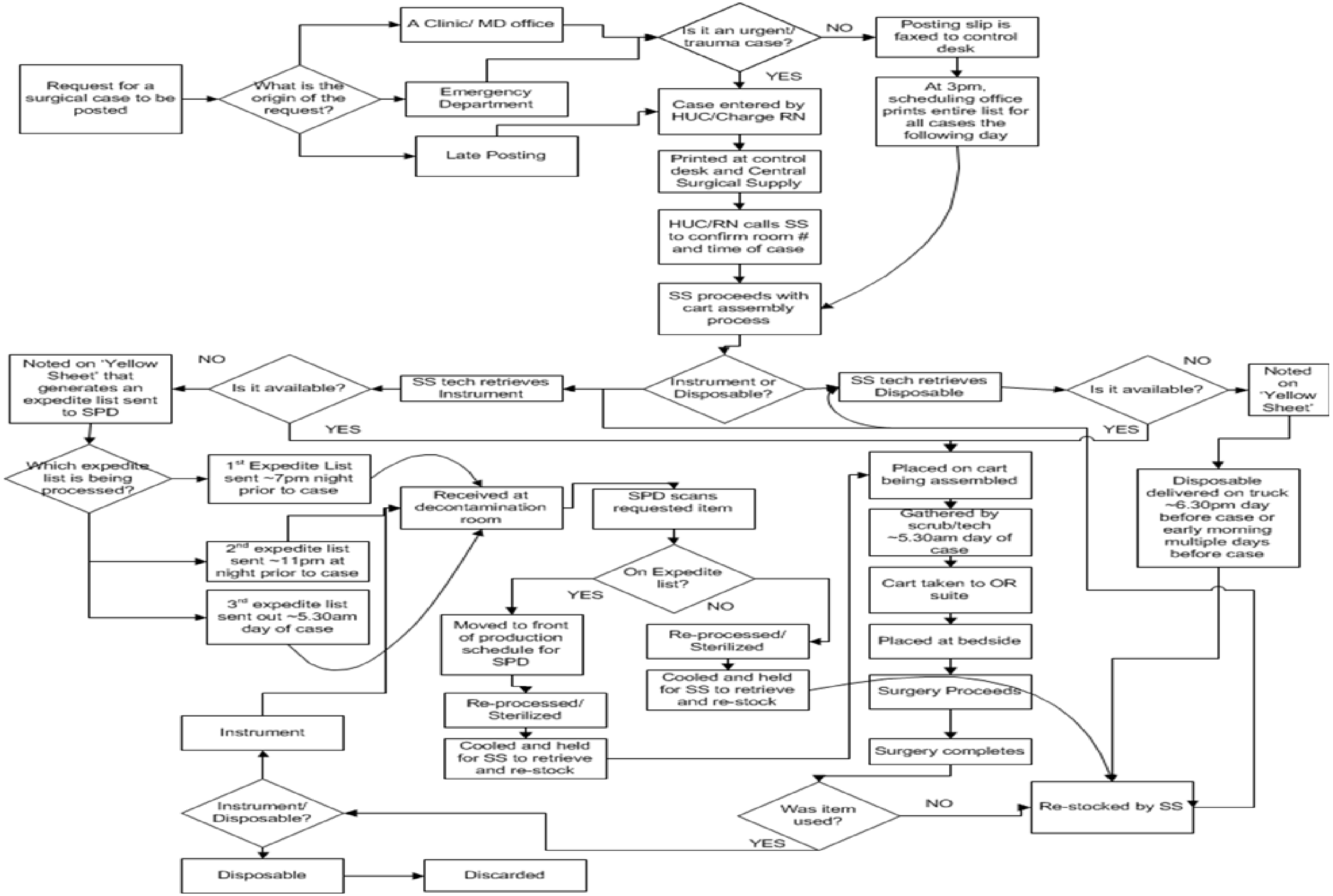
The supply system in the Operating Room at the case study hospital includes a cabinet system for line-stocked items that helps with reporting which items are used. This system helps keep track of how many items are used on each patient, which primarily benefits billing and accountability. The system did provide some assistance with inventory level monitoring for reorders, but due to inaccurate picks on the part of the nursing staff or because the reorder reporting system could not be remotely accessed to generate an inventory reorder report, the inventory monitoring feature was unreliable and little used. Each individual OR room had its own set of cabinets, and there were more cabinets in two large storage rooms that formed a nucleus around fourteen OR rooms that were called 'cores.'

The case cart system is, in effect, designed to mitigate the variability in the overall system of delivering supplies to surgeries. It involves a few key components, namely:

- The system of Doctor Preference Cards (DPCs) that surgeons use to communicate what they anticipate will be the needs of the patient during a surgery in terms of surgical items
- The system by which the DPCs are communicated to the staff who take the information a DPC provides and use it to provide the proper surgical items to the clinical staff
- The system by which the case carts are physically assembled
- The systems that provide the instrumentation and disposable items that are fed to the case cart assembly system
- A response function that provides solutions to supply issues as they arise during surgical events in the OR suite

Initially the project team at the case study hospital had identified the number of quality reports per month that pertain to supply chain functionality as the measurement to see if improvements being implemented were effective. Iteration revealed that the initial metric of number of quality reports (Q.R.s) was too subjective a measurement, as it required participation on the part of a clinician (clinicians are not mandated to fill out Q.R.s). Furthermore, a Q.R. may be filled out for an issue that the clinician believes pertains to supplies but is in fact outside the realm of the supply chain as such. Therefore, the team developed the metrics in Figure 3 to measure the performance of the supply system in a way that was directly related to the operating room's primary goal - the care of patients.

Each of these component systems are sources of variability in the case cart system and could lead to system failure states. The problem identified by the hospital's OR suite administration is that when the case cart system breaks down, the result is that surgical items are not available at the point of use when they are needed and with a satisfactory level of quality. This results, primarily, in sub-optimal outcomes for patients (the most drastic of which is exposure to bio matter left on reusable instrumentation that was not properly prepared for subsequent use), but also clinician morale and confidence in the supply chain is adversely affected. Based on data collected as a part of this project, 21.7% of case carts that were audited were identified as incomplete upon arrival to the OR room.



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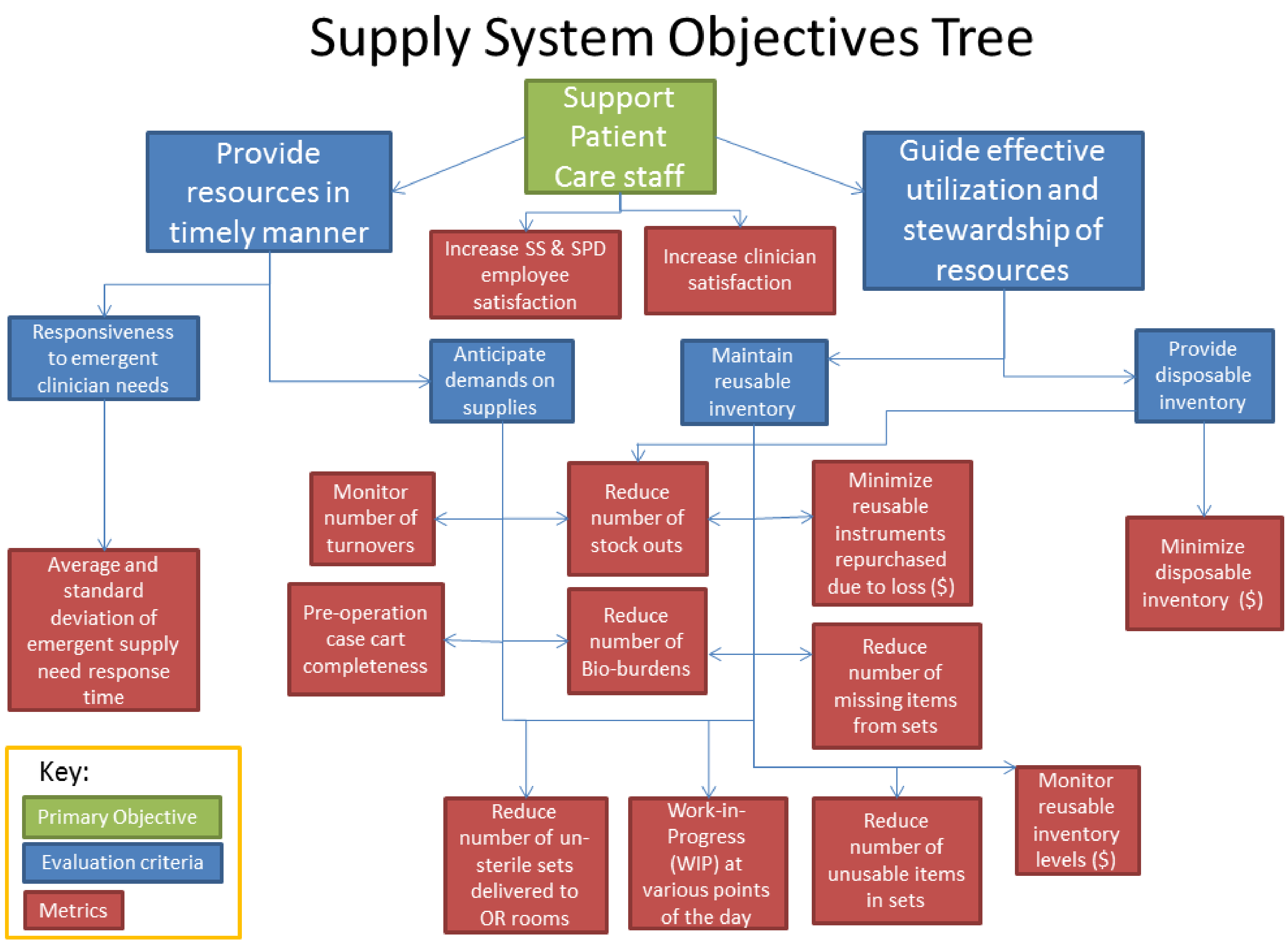

Supply System Objectives Tree
Support Patient Care staff
Provide resources in timely manner
Guide effective utilization and stewardship of resources
Increase SS & SPD employee satisfaction
Increase clinician satisfaction
Responsiveness to emergent clinician needs
Anticipate demands on supplies
Maintain reusable inventory
Provide disposable inventory
Monitor number of turnovers
Reduce number of stock outs
Minimize reusable instruments repurchased due to loss ($)
Minimize disposable inventory ($)
Average and standard deviation of emergent supply need response time
Pre-operation case cart completeness
Reduce number of Bio-burdens
Reduce number of missing items from sets
Reduce number of un-sterile sets delivered to OR rooms
Work-in-Progress (WIP) at various points of the day
Reduce number of unusable items in sets
Monitor reusable inventory levels ($)
Key:
Primary Objective
Evaluation criteria
Metrics

1.3 Quality and Healthcare Supply Chains

1.3.1 General Overview of Quality and Safety in Healthcare

Donabedian (1988) and Kohl et al (2001) will inform this section. The definition of quality in healthcare according to Donabedian begins with the technical and interpersonal skills of the health care practitioners. The performance of practitioners in the technical sense refers to their ability to apply their knowledge and judgment to develop appropriate courses of treatment as well as the ability to implement those plans effectively. Technical aptitude is judged against accepted best practices, which increasingly are determined through measurement of outcomes, not common knowledge (Brook et al, 1996). Underpinning the technical performance of health care practitioners is their ability to manage the interpersonal relationship with the patient. Donabedian goes so far as to state that technical success of a patient interaction depends on the practitioner's ability to effectively manage the patient relationship. Interpersonal skills are what drive the exchange of information between patient and practitioner, as well as the patient's preferences for courses of treatment (which determines the most effective treatment plan). Furthermore, the interpersonal exchange is the vehicle for clinical explanation of the disease to the patient and motivation to collaborate with the practitioner in the course of treatment. It is expected that clinical interpersonal relationships will provide privacy, confidentiality, informed choice, concern, empathy, honesty, tact and sensitivity. Finally, assessments of the quality of the interpersonal aspects of care are challenging to produce; the particularities of each patient make a standard set of guidelines to cover all interactions exceedingly difficult to generate, and the epistemological dimension of the practitioner's application of technical knowledge to the interpersonal process is not well understood.

Donabedian extends the definition of quality in healthcare from practitioner performance to the environment in which healthcare is performed. Environmental concerns include convenience, comfort, quiet and privacy. Next, the definition of quality scopes out to the role of the patient and the patient's family. This is the area where the interpersonal skills of the practitioner will have the greatest effect on the patient's outcomes. However, without committed, responsible involvement on the part of the patient and the patient's family, successful outcomes and maximal quality within the healthcare event are less likely to be attained. Moreover, the definition of quality extends to include the community in which the care is given. This aspect of the definition is concerned with social distribution, i.e. the levels of access to healthcare that each member of a community has been able to attain. Greater access to healthcare for a patient will ostensibly lead to greater quality of outcomes for that patient. Finally, cost as a measurement of quality is confounding, because it has been shown that as quality increases past a certain point, costs grow exponentially (Donabedian 1988).

Having scoped the definition of quality to include practitioner, environment, patient and community factors, we can move on to a full definition of quality in healthcare. Donabedian (1996) and Brook et al (1996) concur that the quality of a healthcare encounter can be judged based on three criteria: Structure, Process, and Outcome.

- Structure: Structural information and data related to quality comes from the features of the settings in which the healthcare event takes place. Examples of sources of structural data are information on facilities, equipment, financial resources, staffing levels, staff qualifications, organizational structure, methods for reimbursement for services, and methods for peer evaluation.
- Process: Information and data that relate to the encounter between the provider and patient itself is process data. Examples can be broken down into provider- and patient-oriented categories. Examples for the provider category include what tests were ordered, how long the provider was able to be with a patient, how long it took the provider to document the encounter, etc. For the patient category, examples of process data are what time the patient arrived for their appointment, how many times the patient contacted the provider between visits, and the like.
- Outcome: Outcome information and data refer to the outcome of the treatment of patients and populations. This includes not only hard data on outcomes related to improvements in health (e.g., a patient's decrease in weight, a population's reduction in the number of people who smoke), but also softer measures such as increases in the patient's satisfaction with the care they received or a population's knowledge of a public health risk.

Structural criteria affect process criteria, and process criteria affect outcome criteria (Donabedian 1988). Credible structural and process data will be demonstrably capable of relating effectively to outcome data. Moreover, valid outcome data will be able to be shown to have been effected by the structural or process elements of the system from which the outcome data was extracted. Process data can be a better indicator of quality than outcome data because a failure of process does not always result in a negative medical outcome (Brook et al 1996). In all cases, data from each of these different categories must accurately reflect the aspect of care that is meant to be captured in the quality assessment. If the total patient outcomes are not at the forefront of a quality assessment, then the quality assessment is shortsighted (Donabedian 1988).

1.3.2 Supply Chain Effects on Healthcare Quality

As was noted above in section 1.2, the case study required the development of additional metrics to measure the effectiveness of the supply system. Here we will provide some motivation for those metrics while giving a descriptive account of how a supply system can affect the quality of care. The primary objective of the supply system feeding a peri-operative services suite is to *support the clinical staff in the care of patients.* All three types of quality data are at play. For example, structural data comes in the form of how much inventory there is; process data comes in the form of kit (i.e., case cart) readiness; outcome data comes in the form of the number of biological contamination incidents where patients are exposed to improperly sterilized instrumentation. Moreover, the primary objective can be broken down into secondary and tertiary evaluation criteria. The secondary criteria fall into categories of effective utilization of resources and timely provision of resources. Effective stewardship implies tertiary evaluation criteria that pertain to the maintenance and provision of reusable or disposable surgical items; timeliness leads to evaluation criteria affecting the responsiveness of the supply system and the supply system's ability to anticipate demands. Drawing on Corrigan et al (2005), Fitzpatrick (2009) confirms our primary objective and our evaluation criteria. He notes that the role that supply systems in healthcare play must be safe, timely, effective, efficient, equitable, and patient-focused. Supply systems must provide clean and safe materials to surgeries in a manner that prevents and reduces delays, makes the right equipment available at the right time, is cost effective, and is focused on the patient (Fitzpatick 2009). From this study, it seems that patient-focus is the core of the supply chain's ontology, and safety, effectiveness, efficiency and timeliness follow naturally from there. However, agreement with healthcare supply chain literature confirms the assertions that were made during the case study.

1.3.3 Observations on Quality from the Case Study

The case study at the case study hospital's operating room suite required data collection and analysis to gauge how prevalent quality issues were. Clinical staff commonly complained about the effectiveness of the case cart system; as was noted previously, 69 quality reports were logged by clinical staff on the case study hospital's quality issue reporting system over a three month period. First, the project team set up two different clinician surveys to gauge what the level of dissatisfaction with the case cart system really was. Both the nursing staff and the surgeons were polled to and what the perceptions from each group were on the aggregate. Second, the project team developed a data collection tool that would capture a ‘snapshot’ of one week’s worth of surgeries and any supply related issues that occurred during any particular surgery. The data tool gave the team statistics to verify the prevalence of the system errors that the clinical staff was bringing to the attention of the OR administration. This tool will be referred to as the “surgical supply audit tool."

Clinical staff are the end users of the OR supply system. Their level of satisfaction is indicative of how well the supply system is performing overall. Notwithstanding the opinions of the more vocal, displeased end users, the overall voice of both the surgeons and the nursing staff will provide insight into how well the supply system is performing at its primary objective: supporting the clinical staff. The surgeons and nursing staff were each given different (but related in content) surveys on how they perceived the supply system to be functioning. Borrowing from Donabedian (1986), we can consider the outcomes of these surveys as quality data under the ‘outcomes’ category because the clinicians are the ones who will go on to see in their patients the adverse effects of any supply system failures.

The surgeon survey was delivered electronically using an online, confidential polling system. It consisted of 10 questions related to the timeliness of deliveries, the quality of the instrumentation delivered, the effectiveness of the supply system and the effect that supply system failures have on a surgeon’s ability to perform the surgery. The survey also included a comments section where the surgeon could leave feedback and suggestions. 51 surgeons, out of 118, responded to the request to take the survey, for a 43% response rate. The results of this survey are displayed in Figures 4, 5, 6 and 7. The highest levels of dissatisfaction revolved around issues of timeliness and communication. Intra-operative delays, followed by surgical schedule delays, are the surgeons' chief observations regarding the effects of unavailable surgical equipment. Patient health outcomes were less affected according to the impressions of the surgeons who were polled.

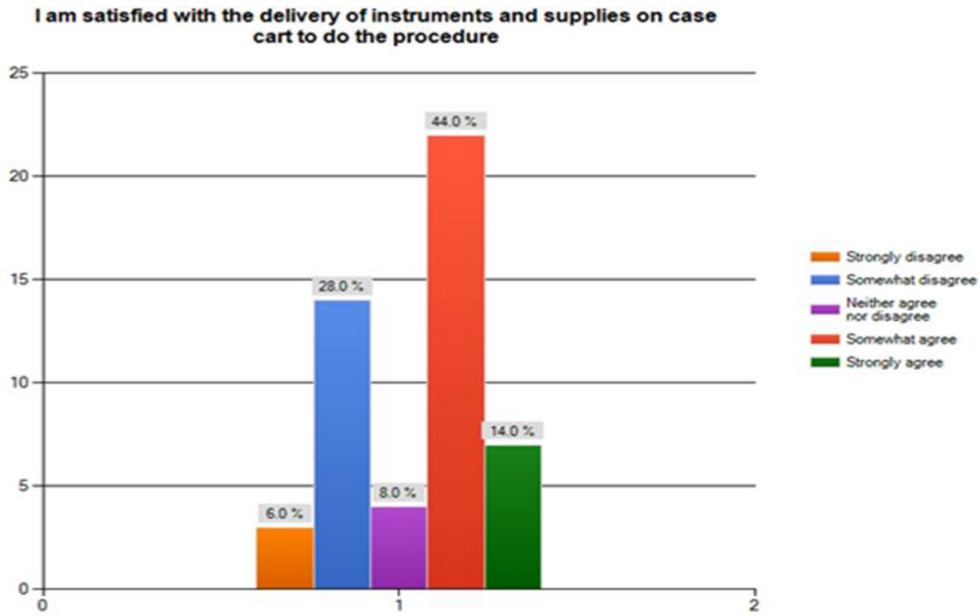


Figure 4: A majority of surgeons, 58%, agreed that the delivery of surgical materials through the case cart system was satisfactory.

The survey that was given to the nursing staff was delivered as a pen-and-paper handout that was distributed during a weekly staff meeting. The survey was also given to surgical technologists, a set of staff members involved with materials handling and patient transport with a lower level of certification than nursing staff. There were 41 questions with a five-point Likert satisfaction scale for each question. Each question also had its own comments field and the survey had two more boxes for suggestions, improvements and other comments at the conclusion of the survey. 97 nurses provided responses. The survey was built to gain insight into all aspects of the supply system - the timing of events, the particular

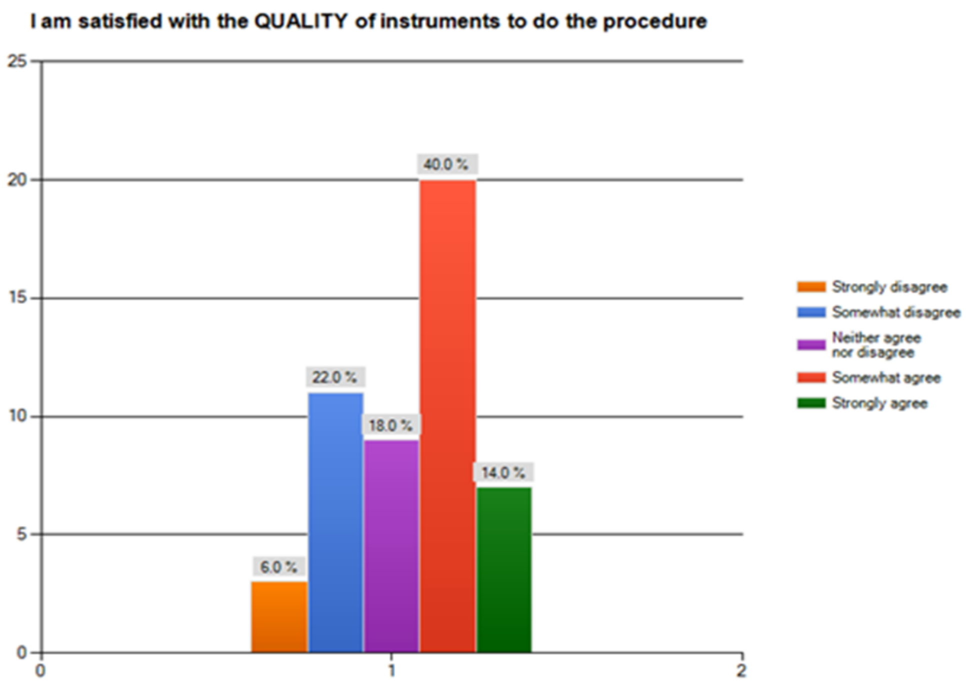


Figure 5: A majority of surgeons, 54%, agreed that the quality of surgical materials was satisfactory; 18% were ambivalent.

functions of the case cart system or the storage cabinet system, the quality of the surgical instrumentation and disposable supplies, and the effectiveness of other specialized supply systems for special surgical items, such as implants (implants are outside the scope of this thesis). In Table i (displayed in Appendix C), the results of the nurse survey are shown. Some members of the nursing staff left certain fields blank (as the question may not have pertained to them for one reason or another), so for each question, the sample size used to generate the percentages was adjusted to reflect the number of responses to a given question.

Table 1 shows the five questions that had the highest combined dissatisfaction score (the percentages for `Dissatisfied' and `Somewhat Dissatisfied' were combined). These five questions also were the only five to have a combined dissatisfaction score of over 50%. All five questions can fundamentally be related to the timeliness of the supply system and how it affects the fundamental goal of the OR: providing care to patients. The cabinet system was often a source of anecdotal complaint amongst the patient care staff, and we see that reflected in response 1 (70.8%) and response 4 (52.6%). Furthermore, the responsiveness of the supply room staff to emergent surgical supply needs was also a concern of the nursing staff. We see this reflected in responses 2 (56%), 3 (52.7%), and 5 (51.6%). Even more specifically, responses 2 and 5 have to deal with surgical instrumentation nomenclature and communication policy and technique, whereas response 3 reflects the ability of the supply system to be timely and efficient (see again, Corrigan (2005) and Fitzpatrick (2009)).

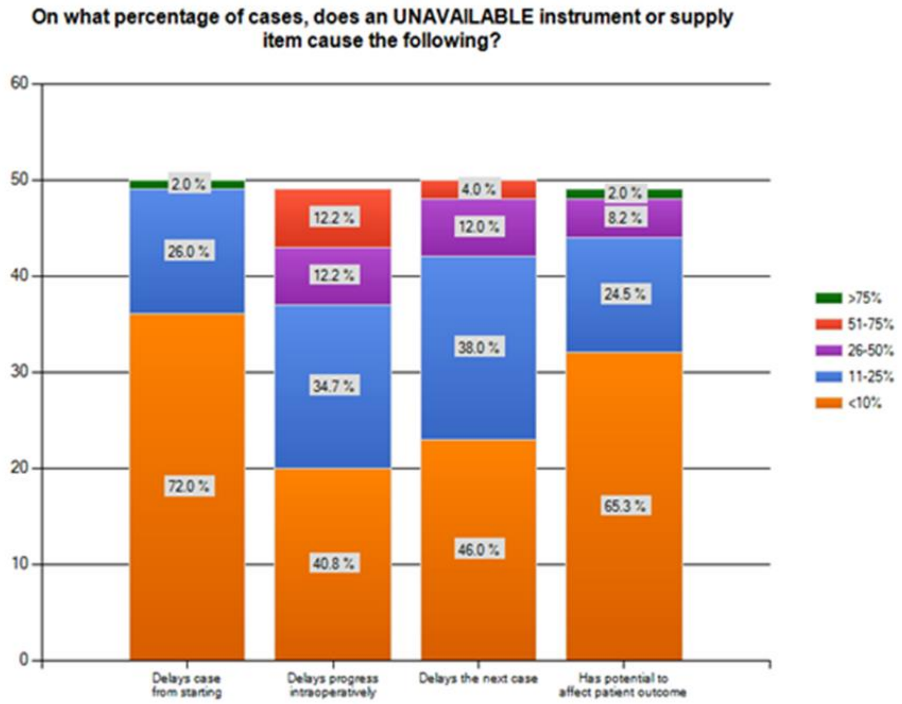


Figure 6: 40.8% and 46% of surgeons, respectively, report that intra-operative delays and delays in the surgical day's schedule happen on less than 10% surgeries due to unavailable surgical supplies.

The surgical supply audit tool collected 83 dimensions of each data point. One surgery was one data point. Since this data had to be collected by hand (there was no automatic reporting system for the sort of supply system quality data that the team was looking for) data collection was an arduous task. The team recruited different members of the nursing staff to assist in recording data. The team with the help of the assistants was able to collect data on 203 surgeries. During the week of July 16-20, 2012, 294 surgeries were scheduled at the case study hospital's Operating Room, so 69% of scheduled surgeries were audited. Below are some key results from the data:

- 21.7% of case carts were incomplete upon arriving to operating room

- 22.7% of surgeries were missing an instrument or disposable item
- 16.8% of case carts had unsterile instrument sets
- 17.2% of OR room cabinets were missing one or more items during a surgery
- 20.2% of Core cabinets were missing one or more items during a surgery

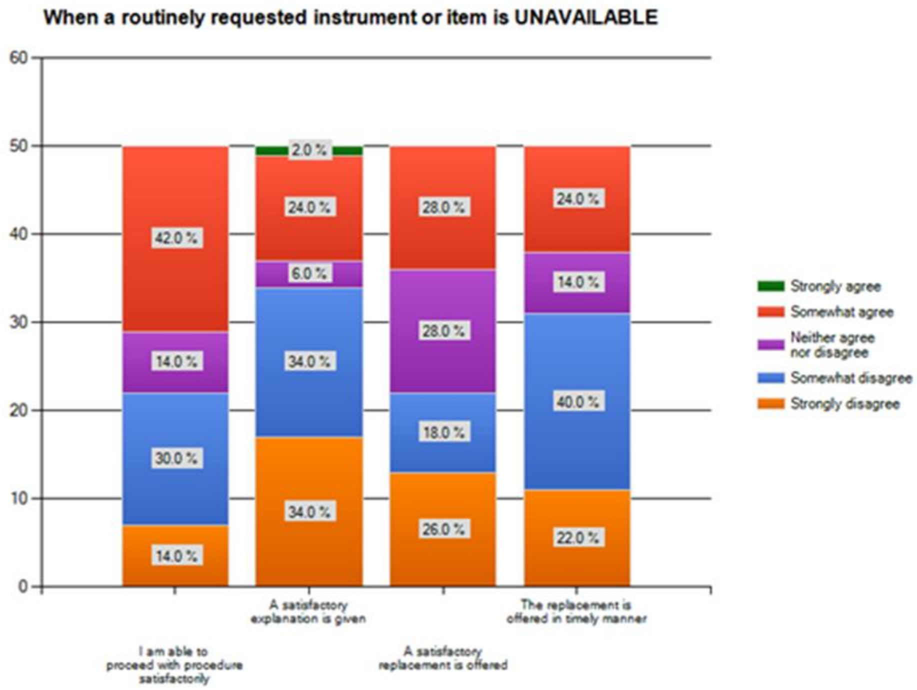


Figure 7: 68% of surgeons disagree that they receive a satisfactory explanation of why a routinely requested item is unavailable. 62% feel that replacements are offered in a tardy fashion. However, 44% say they receive unsatisfactory replacements and are hindered in their ability to perform the surgery.

At the end of the project the team came up with 54 different recommendations based on the total results of the systems study. Those recommendations will not be discussed here, but the motivations for them will be. Both the surgeon and nursing staff surveys revealed dissatisfaction with the communication systems between operating rooms and the supply room, which corroborates with the surgical supply audit tool (17.2% and 20.2% of OR and Core storage cabinets (respectively) were missing items during a surgery). Further, the surgical supply audit tool revealed the extent to which surgical items were unavailable or unusable upon being delivered to the operating room.

Question	Unsatisfied	Somewhat dissatisfied	Sum	# of answers
OR room Omnicell stock levels	34.4%	36.5%	70.8%	96
Resources available to locate and identify items (such as electronic catalogues)	28.6%	27.4%	56.0%	84
Store room response time to emergent supply needs during other surgeries throughout the day	25.8%	26.9%	52.7%	93
Trauma cases: given that you needed to retrieve an item that was not delivered on the case cart, do you feel as if you have to compromise the patient's care to retrieve that item?	36.8%	15.8%	52.6%	76
Satisfaction regarding frequency of store room phone answering by store room staff	21.1%	30.5%	51.6%	95

Table 1: Nursing Dissatisfaction with the Supply System

The reasons for unsterile instrumentation sets were sourced back to one of two problems. First, the system of decontamination, set reassembly, and sterilization that took place for every piece of reusable surgical instrumentation failed to properly clean a piece of instrumentation and biological material from a previous surgery was still present on the instrumentation. Second, improper handling and storage during the transport of the instrument sets from the sterilization process to the storage area, from the storage area to the case carts during case cart preparation, or during the interim holding of the instrument sets in the storage area lead to the outer packaging of the instrument sets becoming torn and therefore by regulation unsterile.

The reasons for incomplete case carts and missing instruments or disposable items were sourced back to multiple systems failures. First of all, when instrument sets were delivered to decontamination after a surgery, the component parts of each set were often jumbled up amongst different instrument set trays. When the technicians in set reassembly received the sets, part of their function is to put the instruments back in the correct sets. Sometimes the technicians failed at this, and one set would be missing a component (conversely, another set could end up with an extra component). Related to this potential system failure is the accidental disposal of reusable instruments after a surgery. Surgical technicians who clean and prep the operating room for the next surgery are instructed to do so as fast as possible, so as they are clearing the area of instrumentation and disposable items instruments can be mixed up with the disposables and thrown out inadvertently. Another system failure leading to missing instruments or disposables had to do with back-ordering of both types of material. In the case of disposable items, an item either was back-ordered from the distributor or there was an emergent need for more copies of a given item than the reordering system could handle. In the case of instrument sets, the set that was missing simply had not finished the re-sterilization process and was unavailable. Additionally, on very rare occasions, instrumentation would be missing from a case cart due to pilfering, for use in a different surgery, without the nurse who took the instrumentation informing the nurse in charge of surgical items for the surgery from which the instrumentation was pilfered. This never occurred during the duration of the project and is offered as an anecdote. Furthermore, the issue of out-of-date pick lists for items to be placed on the case cart would lead to confusion about what the operating room staff believed was supposed to be available and what was still in the master inventory. This, again, was a rare occurrence and at the time of the project another project was running concurrently to make the pick lists up to date. Finally, issues pertaining to the use of lean inventory levels would result in missing or unavailable surgical items during surgeries. One anecdote from the case study / project was an instance where a doctor was scheduled to perform five surgeries with five copies of the same instrument set. The first two surgeries proceeded as normal, but during the course of the second surgery a different doctor in a different operating room needed a copy of the instrument set that the first doctor was using. The storage room technicians took the copy of the instrument set from the case cart that was built for the third surgery and not the fifth surgery; nor did they properly expedite the copy of the set from the first surgery. This lead to a communications mix up where the locations of the various sets were lost and the third surgery began without the required instrumentation, much to the frustration of the surgeon. This is an example of the effects of low par levels and tight inventory utilization.

As mentioned previously, the project team made recommendations based on the findings of the data collection and observations that were made. However, an academic interest arose from the observation that the case cart and instrument set are both examples of what are called "kitting processes" in industrial and systems engineering literature. An introduction to kitting follows.

1.4 Kitting

The supply of systems with continual material needs is a well-studied phenomenon in industrial and systems engineering literature and in operations management literature. In systems with material flows, there are four policies that are used to deliver materials to critical processes in the system. First, there is line-stocking, where a particular process is given the material it needs to continue to operate through a stockpile next to or near the process. There is kitting, where a process is fed through a pre-arranged set of materials that is delivered to the process as or before the materials are needed, and only the materials needed to produce one unit or a few units of that process's output are provided. There is also `downsizing,' where smaller batches of materials are created before being delivered to an assembly process. Finally, there is Sequential Supply or Just-in-Time (JIT), a policy where exactly one unit of material is supplied to a process to be used on exactly one unit of output. Each of these policies brings with itself its attendant pros and cons, and each has to deal with significant tradeoffs in in terms of cost, time frames, service level, and system size and complexity, to name a few of the concerns.

A kit is defined as a specific collection of components and/or tools, and possibly instructions, needed for completing a procedure or producing a product (Choobineh and Mohebbi 2004). A system where kitting makes sense as a form of material supply is one where all of the components necessary to perform a task must be immediately available upon initiation of that task. Ideally, there would be no stockpiling of materials next to a critical process in a kitting system, but some small items that are too insignificant in cost and size may be stored near a critical process at no significant detriment to the overall effectiveness of the kit supply system. The composition of kits is of critical importance to the effectiveness of a kitting system as well. If a kit contains too few of the necessary components, the material shortfall will require extra time and labor to retrieve. If too many components are present in a kit, the unused components will have to be restocked or discarded resulting in non-value added time and labor, in addition to the time and labor that was expended adding the extraneous material to the kit during the kit building operation. It should be noted here that the cost and time required to build a kit increases material handling, adds a chance for reduced component quality, requires additional material planning to determine kit composition and layout, reduces on-hand availability at the point of use of kitted items (which could lead to time-critical shortages and pilfering from other kits), and increase the storage space requirements in the supply area where kits are assembled, all as compared to line-stocking supply systems.

Kitting processes can arise in various industries and contexts. Many case studies in the literature address automotive manufacturing (Limère 2011, 2012) or electronic circuit board manufacturing (Günther et al 1996), but kitting systems can also be found in medical and dental settings, product repair and maintenance settings (Choobineh and Mohebbi 2004), large-scale military logistics, or any manufacturing assembly process settings.

Compared to case studies in manufacturing, kitting supply systems must be much more sensitive to factors of quality, picking accuracy and timeliness in OR settings. This is due to the risks involved with performing surgical operations. Though these factors will be addressed further in the thesis, for now this sample will suffice: there are certain kits that are made-to-stock because they are used in trauma surgeries. Trauma surgeries are unscheduled and instrumentation must be immediately available for all contingencies during a trauma surgery. Kits for each type of trauma surgery (head, chest, leg, etc.) are prepared as soon as the prior trauma surgery ends and the instrumentation go through re-sterilization. As soon as one trauma kit is utilized, another is taken from central storage and taken to the storage room adjoining the operating rooms (taken to the line, analogous to manufacturing assembly operations). When the trauma kits are assembled, they are double-checked by staff members with higher industry certification (registered nurses (RNs)) check the kits before they go to storage as opposed to the lower-certified medical instrumentation technologists). Through this example, we see how critical kit quality is (kits double checked for items), kit accuracy (requirement for immediate availability of instrumentation) and timeliness (kits stored next to the line in the operating room suite itself).

1.5 Research Objectives

This thesis will propose that case cart system currently used in the hospital operating room suite from the case study hospital operates under a mix of the kitting and line-stocking materials feeding policies. A thorough review of the academic literature on kitting was executed and that literature which is applicable to healthcare settings will be laid out for review. Further, to demonstrate the viability of applying existing kitting research to healthcare materials feeding systems as well as to add additional insight into the functioning of the case cart system from the case study, the thesis will execute the latest research on kitting: Limere's (2012) Mixed-Integer Linear Programming model for determining kit compositions.

Limère's model provides a cost model to kitting decisions, allowing for optimal materials feeding policy regarding the location of materials (namely, should a given item be delivered to the assembly line in a kit or should it be stored at the assembly station). Data from the hospital's inventory management systems, human resources information on labor costs, access to the operating room facility's layout schematics and a set of time-motion studies will be required as the variables tracked in this model include average yearly labor costs for operator picking at the line, internal transport, the kit assembly operation and replenishing the ‘supermarket’ (Limère (2012); here, supermarket refers to central storage). Also, special considerations for healthcare settings will be brought up and incorporated into a kitting model for a supply system feeding an operating room suite. There is a possibility that Limère’s model is incomplete in terms of applicability to the operating room setting; modifications to the model will be made accordingly.

2 Literature Review

2.1 Overview

In academic literature on Kitting in Industrial and Systems Engineering Journals and Operations Research journals, there are two main questions that the research has sought to address. The first question asks what sort of materials feeding should a given assembly operation use in the first place. The second question seeks to answer how the performance of the kitting operation affects the performance of the system it is feeding. This includes kit composition, facility layout and kit presentation, and stochastic and deterministic modeling of the operational performance of the kitting system. There is additional literature in the above fields' journals as well as in Operations Management journals that is primarily qualitative in nature. Although this sort of literature is insightful the purpose of this review will be to address the analytic models that have been developed to capture the tradeoffs inherent to kitting systems. Furthermore, relevant motivational literature from healthcare sources will be presented.

It must be noted here that the goal of this research is to expand the field of research on kitting as a materials feeding policy into the realm of healthcare. Most case studies are presented from automotive or electronics manufacturing. Choobineh and Esmail (2004) note in their overview that kitting is done in medical and dental situations but do not offer any specific analysis of healthcare kitting operations. There are additional departments that require kitting of materials in hospitals, such as labor and delivery obstetrics kits, but the function with the highest operational need and demand for kits is the operating room. Furthermore, data collected during the case study revealed that the quality of the materials in the kits was often lacking and was a chief determinant of the success of a given kitting event. Limère (2012) notes in her literature review that there has not been any research done on the effects of different materials feeding techniques on the quality of the end products being assembled. Although we will not explicitly address the effects of quality within the materials feeding system on the effectiveness off the overall system, we offer it here (and later) for future research.

Kitting Process Design Questions		Stochastic Model	Descriptive Model	Deterministic Model	Feeding Policy Decision	Ergonomics	System Performance	Materials Handling	Facilities Layout	Kit Compisition
Authors	Chen, Wilhelm and Wang (1986, 1993, 1994, 1997, 2003)	√					√			√
	Bozer and McGinnis		√		√	√		√	√	√
	Som et al	√					√			
	Choobineh and Mohebbi (2004)	√		√			√			√
	Battini et al (2009)		√		√		√	√	√	
	Caputo and Pelagagge (2011)			√	√		√	√	√	
	Kilic and Durmusoglu (2012)			√		√	√		√	
	Limère (2012)			√	√		√	√	√	√

Table 2: Aspects of kitting systems addressed by different authors.

2.2 Materials Feeding Policy Decision Models

Bozer and McGinnis (1992) set out to quantify the tradeoffs inherent between line supply and kitting systems. This is a seminal work in the field of kitting systems; it was the first to offer a quantitative approach to identifying the tradeoffs between the two material feeding policies. However, the model they put forth mostly involves accounting of various variables, and is therefore merely descriptive and not sufficiently analytic. They also look at tradeoffs in terms of materials *handling* issues, something few other authors had considered to that point. An interesting but insignificantly analytic example of an application of Bozer and McGinnis comes from Carlsson and Hensvold (2007). They apply Bozer and McGinnis's descriptive model to a case study at a Caterpillar plant to determine if the plant should use kitting or line supply. They also use Analytic Hierarchy Process techniques to optimize their model for multiple criteria. Hua and Johnson (2010) revisit Bozer and McGinnis eighteen years later and note that since the 1992 publication, not much work on kitting has been done. They offer suggestions for future research.

Limère (2012) and Limère et al (2011) seek to extend the conversation about the tradeoffs between kitting and line supply by building a mathematical model that could analytically determine the best materials feeding policy for a given facility. Limère's approach is novel, and seems to be an attempt to 'settle the debate' on the best way to model and describe material handling systems' feeding policies. The thrust of the work is to determine if a given component should be kitted or supplied in bulk (line supply policy). The level of mathematical analysis present in Limère's makes it the state-of-the-art in the fields of materials feeding and kitting. Other researcher's papers are significantly more qualitative, and for our purposes we wanted to be able to present the tradeoffs present in the operating room supply system as quantitatively as possible given the current state-of-the-art.

Hanson and Medbo (2012), Hanson and Brolin (2012), Hanson (2012), and Hanson et al. (2011) provide an in-depth look at the tradeoffs involved with kitting versus line supply from the materials handling perspective. Task time, distance from storage area to assembly area, component presentation, and arrangement of components in kits are covered as concerns regarding the handling of materials. The work of Hanson through all of these articles is to build to a comprehensive model, which was compared to Bozer and McGinnis (1992), Battini et al. (2009), Caputo and Pelagagge (2011) and Limère et al. (2011). The research methodology used to analyze the case study in Hanson's work was to perform case studies and analyze them via direct observations, interviews internal company documentation and video recordings. This method lacks a sufficient analytic component for this thesis.

Battini et al. (2009) describe three variations of decentralized line supply materials feeding policies: pallet-to-work station, trolley-to-work station, and kit-to-assembly line. Noting that kitting is an alternative to other decentralized supply systems is novel. The authors describe cost functions for each type of system, chief of which is related to task time (total time to deliver necessary components to an assembly station). A useful paper but Limère's model is broader in scope in terms of including various costs into the model.

Caputo and Pelagagge (2011) layout a methodology to be able to choose the best materials feeding policy for an assembly operation. They consider three different policies: kitting, Just-in-Time and line supply. They also offer empirical criteria for choosing hybrid policies and suggest through demonstration in a case study that a hybrid policy may be best, as each type of material feeding policy has distinct strengths that can help balance out the other policies' weaknesses. They suggest using their methodology for an initial assessment of materials feeding policies for an assembly operation, not for an in-depth performance analysis of an existing system. Furthermore, their methodology groups items in inventory into one of 3 classes, and assigns the entire class of items to either line-stocking, kitting, or just-in-time. This is less flexible than Limère's methodology, where *each* item in inventory is assigned individually to the preferred feeding method for that part.

2.3 Operational Performance

Kit composition, facility layout and kit presentation, and stochastic and deterministic modeling of the operational performance of the kitting system are the main questions addressed by literature seeking insight into the operational performance of kitting systems. In general, this research is less appealing to the surgical setting, because the level of throughput being modeled in the systems analyzed in these papers is significantly higher than what was found in the operating room (dozens of surgeries per day versus thousands of components an hour).

Brynzer and Johansson (1995) provide a good technical overview of the parameters production management must consider when designing or improving a kitting system. Their insights come from analysis of a number of case studies where kitting was used as a materials feeding policy. The parameters they give consideration include where to locate the kitting assembly process, the order and manner in which the work is done, producing kits in batches, dividing the store room into zones to kit certain components according to zone first, the time and distance travelled while kitting, the information available to the staff performing the kitting assembly process and the display of that information, design of the kit holding apparatus, the accuracy of the component picking, and manual vs. automated picking techniques.

Choobineh and Esmail (2004), Wilhelm and Wang (1986), Chen and Wilhelm (1993, 1994, 1997) and Chen (2003) all consider the effects of component commonality amongst kits. Choobineh and Esmail approach kitting from a materials planning perspective. They address the problem of planning kit assembly under uncertainty. They propose three metrics as critical for measuring uncertain kitting system success: average total inventory of kit components per period, average proportion of total kits' demand orders fully satisfied per period and average total backorder of kits per period. They conclude, significantly, that component sharing (allowing multiple kit recipes to utilize the same components) reduces total inventory per period, increases kit availability, and reduces backorders per period. They also conclude that increased safety stock levels, although increasing total inventory, reduce backorders and increase kit availability significantly.

Wilhelm and Wang (1986) formulate models for the following costs for component inventory: kit earliness, kit tardiness and in-process time. They then go on to show through a sensitivity analysis how these costs are affected by the amount of components required by a given kit and how the length of time to accumulate all of the parts necessary for a kit increases with the number of parts to be accumulated. Further, Chen and Wilhelm (1993, 1997) present heuristics that seek to assign parts to kits to minimize production schedule disruption when kit components are substitutable (that is, similar components can be used for different assemblies. Finally, Chen and Wilhelm (1994) propose a dynamic programming algorithm to minimize total cost. A multi-echelon kitting system is one where components are kitted for subassembly operations, and the subassemblies are in turn used in future kits in the string of processes leading to the final assembly. This arises in surgical supply situations where surgical instruments are re-sterilized after use during a surgery and re-kitted into a set of instruments in which those instruments belong. The sets of instruments, viewed as kits, are then fed to either storage or the next set of kits, the surgical case carts. Tardiness or unavailability (due to quality issues, overscheduling, or unforeseen demand) of surgical instrumentation kits is a concern for a surgical supply system; Chen's and Wilhelm's work may lead to insights on how to analytically approach kit tardiness and kit unavailability in the surgical setting.

Stochastic modeling approximations of kitting systems have been offered. Som, et al (1994) look at stochastic kitting systems, shifting from a deterministic analysis to a probabilistic one by treating the kitting process as a queue with Poisson arrival times for components. They show that the output stream of the kitting process is a Markov renewal process as well as give the distribution function for kit completion times. Inderfurth and Minner (1998) determine safety stock levels in multi-stage inventory systems that operate under normally distributed demand. They formulate the problem for the general case and derive the optimal policies properties, then go on to consider how the optimal policies would change given specific inventory systems. The authors note that optimal policies for safety stock levels are always dependent on the parameters of the particular system being considered.

Ramachandran and Dursun (2005) provide analytical models for stochastic kitting systems. Ramakrishnan and Krishnamurthy (2008) analytically model kitting systems that take inputs from multiple sources. Ramakrishnan and Krishnamurthy (2012) expand on their work from 2008, this time using non-exponential inter-arrival distribution times for components arriving at the kitting process that they are describing. The industry for which they are analyzing these systems is electronics manufacturing, where constant streams of parts are necessary to maintain high throughput; in the surgical setting, we're more concerned about the stochasticity of demand on inventory breath – large inventories are required to buffer against numerous possible surgery types and sudden shifts in inventory forecast due to trauma events, late add-on patients, poor quality of recycled surgical instruments, and other factors.

There are deterministic approaches to modeling the performance of kitting systems as well. Limere's (2012) work fits under this category and will be used as such in the thesis. Kilic and Durmusoglu (2012) develop a mixed-integer linear program to model a kitting system based on minimizing the costs of WIP and number of workers needed for the system. Their model is less appealing because it doesn't allow for the mixture of feeding policies that Limere's does.

Teunter and Klein Haneveld (2002), Teunter (2006) and Bijvank et al (2010) are representative of a different sort of work done on kitting systems: the nature and optimal composition of repair kits. Repair kits are used in systems where a specific set of materials must lie in wait in anticipation of a "repair" event. Research of this sort (such as Bijvank et al (2010)) is generally concerned with service level and kit composition (with the view that one affects the other). Although indeed a useful approach, this veers sufficiently from the research done on assembly systems and kitting, and because the demand for surgeries is regular the throughput aspect of assembly research is more appropriate for our case study.

2.4 Application to Healthcare

As stated previously, there is minimal research done on kitting in healthcare settings. Leshno and Ronen (2001) look at the business implications of kitting in healthcare settings. Of note is that they consider *all* situations where materials or any sort could be gathered together – lab results from different labs before a patient exam, instruments before a surgery, etc. Mathematical analysis is not provided, however, and is something we desire. Choobineh and Esmail (2004) briefly mention healthcare applications of kitting but do not delve into healthcare in a significant way.

The most significant contribution to the kitting problem in operating room suites comes from a non-assembly system oriented paper. Güllü and Köksalan

(2012) offer a very useful model that aids in determining the composition of the sets of instruments that surgeons use but not on the feeding policy for a given part. Güllü and Köksalan (2012) certainly would be valuable to apply to a real system – a suitable future case study. Their work looks at the joint probability of a given set being required and a specific part being required from that set. Capturing data to satisfy the requirements of such a model would be exceedingly difficult as individual part utilization is not presently automatically tracked (at least it was not in our case study). Their study is also suitable to address a level of detail in the model that is slightly below what we want – we wanted a model that would address the whole system.

Lin et al provide a discrete-event simulation study of the performance of the re-sterilization process. Indeed, another worthy way to proceed (the team from the case study had thought to do this itself). This work tended towards a capacity analysis of the first echelon of the two-echelon internal supply chain of the operating room suite. A useful model but only really applicable given a large capital expansion, such as was the circumstance from the case study this paper was built on. The paper does inspire a discrete-event simulation of the overall system as they do not explicitly describe the system as a kitting process.

The academic and professional literature is full of examples of articles calling for increased surgical instrumentation quality and system performance. Friesen (1969) introduces many of the key concepts of contemporary materials delivery systems in operating room suites. Ryan (1978) describes through anecdote, observation and interviews how to effectively build a case cart system for a perioperative services department. The author goes through all aspects of the case cart system – how demand is communicated to the case cart building team, how many more personnel a hospital must hire, nurse and doctor concerns over the case cart system, etc. The model offered is descriptive. This piece of literature is furthermore dated and from outside the Industrial and Systems Engineering and Operations Research literature. Additionally, Donabedian's (1988) seminal work on the quality of healthcare continues to inform healthcare systems analyses. Since quality is of such importance in the operating room, this piece will help inform modeling decisions made during this thesis. Pyrek (2013) brings us more contemporary motivation to improve the quality of the output of the sterilization ad case cart assemblies processes in hospitals. Seavey (2010) informs us of the need for effective communications and coordination between operating room nurses and sterile processing staff. As Limere's model will require data from but sets of system actors (nurses and staff), this article helps motivate the application of the model in a system-of-systems fashion. Shelby et al (2012) give an overview of the importance of expedient items availability, proper kit composition and solid inventory accountability all while describing a successful application of systems thinking.

As far as operations management-oriented literature that will help motivate our analysis, we again have a number of good examples of background literature on the importance of materials handling in the Operating Room. The introduction Park and Dickerson (2009) give to the potential for financial and operational gains that could be made by OR suites by utilizing IT and process improvement solutions already recognized in industry and in some healthcare institutions also provides a good overview to the complexities of maintaining inventory for surgical suites. In Operations Management literature, we find motivation in Fredendall et al's (2009) breakdown of the challenges of maintaining high throughput in an operating room suite. They look at the system through a theoretical framework called "Swift, Even Flow" (an amalgamation of five other "laws" of operations management, such as the detrimental effects of variability on a system's performance). Finally, Rossetti et al (2012) introduce the current state-of-the-art in medical supply logistics through case studies and literature review. Their insightful review of inventory modeling in medical supply contexts breaks the issues surrounding medical supply into the following sections: multi-item single location inventory applications, Just-in-Time and stockless applications, outsourcing and multi-echelon applications, logistics coordination and scheduling, and demand management and forecasting.

3 Introduction to Materials Feeding Policies

3.1 Introduction to Materials Feeding

Any system that requires physical materials for the system to function and arrive at the systems ideal state will require a sub-system that makes those physical materials available to the processes within the overall system. The area of research that addresses this requirement of certain systems is called materials handling. A component of materials handling that addresses the way in which materials are presented to operators at the individual processes within a system is called materials feeding. The classic example of this sort of system is in assembly systems or factories and most materials handling and materials feeding research is done within the context of assembly systems. However, materials handling is done in many, many different systems apart from assembly systems; for instance, in this paper, we will look at materials feeding as it is performed in an operating room system in a hospital. The motivation for researching materials feeding systems and policy for assembly systems has been to find ways of making the materials feeding process more efficient and therefore reduce costs and prevent costly line stoppages, and also to find ways to coordinate increasingly disparate varieties of parts that need to be supplied to assembly processes as customer demand further requires customization of goods (Limère 2012). Research into materials feeding systems tends to fall into one of five areas: product characteristics (volume, variety, and size), storage and material handling, production control, performance impact, and implementation (Hua and Johnson 2010).

An ideal materials feeding system will supply the right materials, at the right time, to the right place, and in the exact amount (Limère 2012). There are four materials supply policies that could be used when feeding materials to assembly processes: continual supply / line-stocking; sequential supply; batching / downsizing; and kitting (Johansson 1991; Johansson and Johansson 2006; Carlsson and Hensvold 2008). Although not widely available in the literature, research into which materials feeding policy is best and the tradeoffs between each has been conducted with various approaches to models having been provided (Bozer and McGinnis 1992; Battini et al 2009; Caputo and Pelagagge 2011; Limère 2012; Hanson 2012). Often, a given assembly process will use some combination of these four policies to create a hybrid supply system. The tradeoffs between using each type of policy involve these factors: operator efficiency, space requirements, handling costs, inventory costs, and quality (Limère 2012). We will see in a later chapter of this paper how the operating room uses a hybrid policy. Following is a brief description of each of the four policies.

3.1.1 Continual Supply / Line-stocking

Johansson (1991) describes the situation where materials are supplied to assembly processes in bulk as continual supply. Continual supply is also known as continuous supply, bulk feeding, point-of-use storage, or line-stocking (Limère 2012). This paper will use the term line-stocking to refer to this form of materials feeding. Materials and components supplied in bulk usually are displayed at the assembly process in their packaging as they came from the manufacturer (Johansson 1991) this could include up to an entire pallet in some assembly processes (Bozer and McGinnis 1992). There is no effort to minimize the inventory of a given component at the assembly process; all components are available at all time barring stock-outs (Johansson 1991). Assembly operators are responsible for gathering materials from line-side storage and they typically assemble what amounts to a kit of components to be used on a given assembly. Replenishment in line-stocking systems either requires a signal from the assembly operator or some sort of automatic signal. A system called a two-bin system, where there are two bins of the same component are supplied to the line, allows materials feeding operators from the store room to see that one bin is empty and must be replenished. This also allows assembly operators to continue to work with the second bin of parts while the other bin is refilled.

Sutures are an example of a component that are supplied under the line-stocking materials feeding policy. Sutures are kept supplied in the core supply rooms that every operating room in the operating room suite is connected to. There are many different types of sutures and often the type that will be used is not known prior to the surgery so they cannot be supplied in a kit. Multiple cartons of the same suture type are stored in the core supply room, and when the number of cartons gets low (each carton holds dozens of sutures) store room staff resupply the number of cartons back to the par level or submit a reorder to the manufacturer if necessary. We will discuss these examples and more further in the paper.

3.1.2 Batching / Downsizing

Although there is a slight distinction between certain definitions of batching and downsizing of materials before they are delivered to assembly operations, for the purposes of this paper we will combine the two concepts as in reality batching or downsizing is an application of either kitting (Limère 2012) or line-stocking (Johansson 1991). This paper will use the term downsizing to refer to this form of materials feeding. Downsizing involves the separation of components into smaller batches for delivery to assembly processes in units greater than one. Deliveries to assembly processes under the downsizing materials feeding policy could either be merely repackaged into smaller containers in a central supply area and then supplied to the line (effectively the same as continuous supply) (Limère 2012) or the amount of components could be deliberately chosen and put into containers so that the same component is sent to the assembly area for more than one assembly (i.e., for multiple bills-of-materials (BOMs)) (Johansson 1991). The second action described, deliberately sending a specific number of one component to the assembly process, is effectively the same as kitting for multiple BOMs.

Downsizing is an activity that adds no value to the product being assembled and increases materials handling (Bozer and McGinnis 1992). We will discuss the effects of additional materials handling when we define kitting as a materials feeding policy in depth later in this chapter.

An example of downsizing in the operating room suite is surgical gloves these items are too inexpensive, small, and often-used to be supplied in a kit. They are stored in the individual operating rooms and are retrieved by nursing staff. However, sending an entire pallet of them to the operating room suite core supply areas would be an impractical use of space. The gloves come in multiple sizes and are made of different types of material (some are latex free in case of patient allergies) meaning that there would be multiple pallets of gloves in the core supply areas if the gloves were not downsized into smaller units. The gloves are sent to the operating rooms in their manufacturer packaging, which is simply a cardboard carton containing a few dozen gloves. Although there would be increased materials handling in this instance, we can see how practical the downsizing of surgical gloves is in terms of making the materials available as well as in terms of the effective utilization of space. These tradeoffs will be analyzed further in the paper.

3.1.3 Sequential Supply / Kanban (Just-In-Time)

Sequential supply / Kanban (Just-In-Time) means that components are 'sequenced' coming from storage and delivered through the materials handling system such that only the components needed for one assembly object are presented to assembly operators at a single assembly station as the that object arrives at that station (Limère 2012). We will use the term sequential supply. Sequential supply came into widespread use to help manage the flow of materials to assembly processes in manufacturing centers that had high number of product variants (Johansson and Johansson 2006). In such manufacturing situations, the use of line-stocking as a materials feeding policy is near infeasible. The main benefits are to minimize the utilization of space next to assembly stations and minimize the amount of capital invested in materials flowing through the supply chain (Johansson and Johansson 2006). Interestingly, Limère (2012) notes that sequential supply is essentially the same as kitting, where each kit contains a single component. This will become more evident as a definition and model of kitting is laid out further in this paper.

Limère (2012) states there are tradeoffs between kitting and sequential supply. When it comes to the availability of individual components, in a kitting system, if a single component is missing from a kit, that will lead to materials feeding and possibly production delays; whereas in a sequential supply system, since components are fed individually, there is less of a chance for production delay if a single component is missing and delivered late while the rest of the components are utilized at the assembly process. However, since sequential supply essentially delivers components to the assembly station in kits of one, there is potentially more material handling and therefore labor cost in terms of the number of trips an materials feeding operator must take to the store room to retrieve and deliver components. In kitting systems, operators would have to take one trip to deliver a complete kit, or in the case of an incomplete kit, an additional trip for each missing component (unless two components become available simultaneously).

Caputo and Pelagagge (2011) elaborate on sequential supply when used in Kanban systems. They note that the single-unit component kits are delivered to the line materials holding areas in containers that hold the single item. When the container is emptied, it is replaced with another from a nearby 'supermarket' that holds more containers of single components. The parameters that govern the operation of assembly systems running under Kanban policies are especially sensitive to fluctuations in stock levels and Kanban card levels, so much attention must be paid to setting optimum levels for both levels. The authors note that assembly systems can effectively be controlled by Kanban-based components delivery. The delivery of a component at a given assembly station signals the beginning of an assembly operation at that same station under such a control mechanism.

3.1.4 Kitting

Bozer and McGinnis (1992) informally define kitting as follows: "In manufacturing systems, the practice of delivering components and subassemblies to the shop floor in predetermined quantities that are placed together in specific containers is generally known as 'kitting.'" One kit contains only parts related to one assembly operation (Johansson 1991). Kits are prepared in central store rooms or in materials markets, which are essentially store rooms but are closer to the assembly area and contain only the components needed for a specific set of assembly operations that are close together (Johansson 1991). A kit can contain, in addition to components, tools and instructions on how to carry out the task that the kit was built for (Choobineh and Mohebbi 2004). A formal description of kitting follows below.

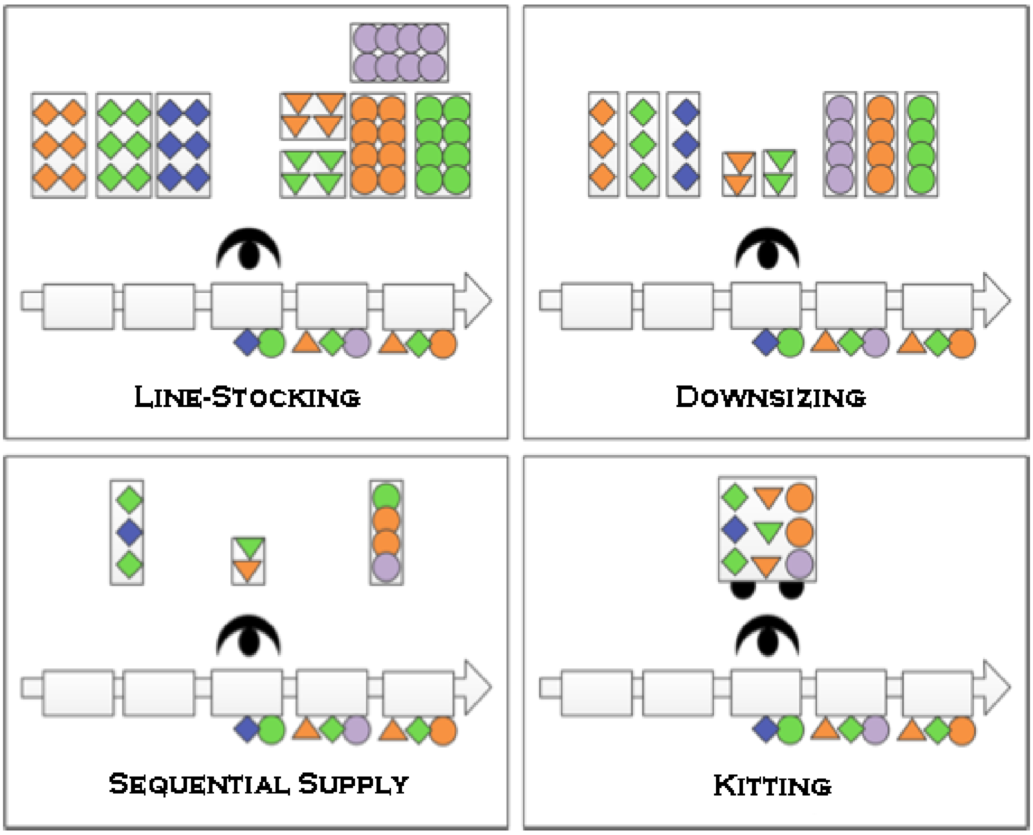


Figure 8: Differentiation between the four materials feeding policies in how each allows components to be displayed at assembly stations. Taken from Limère (2012).

3.2 Kitting - the Formal Definition

Earlier in this thesis in Section 1.4 we briefly introduced kitting as a materials feeding policy and contexts in which it arises. We will begin this section with a list of definitions of concepts important to kitting. Then, the following subsection will provide an overview of kitting by focusing on the benefits and limitations of kitting as a materials feeding policy. Subsequently we will treat assorted operational concerns regarding kitting systems – where and how is the kitting system physically arranged, what items belong in a kit, and who amongst the staff does the kitting. Following the treatment of operational concerns we will introduce some of the different approaches to analyzing kitting systems offered by each of the different models that have been published in the literature. The section will conclude with a description of our preferred model, Limère's (2012) mixed integer programming model. Sections 3.2.1-7 will mostly reference Bozer and McGinnis (1992) and Limère (2012), unless otherwise specified. We are building the reader's understanding of kitting so that we will be able to adapt the terminology and concepts from kitting in manufacturing settings to healthcare.

3.2.1 Overview of Kitting Terminology

This section will detail assorted definitions given by Limère (2012) and Bozer and McGinnis (1992); Carlsson and Hensvold (2007) and Hopp and Spearman (2008) also inspire some of the definitions.

Assembly	**One fully assembled final output of an assembly process (Hopp and Spearman 2008). Also called "end product" (Bozer and McGinnis 1992).**
Component	**A portion of an assembly that is atomistic. (Bozer and McGinnis 1992)**
Subassembly	**An aggregation of two or more components or subassemblies. (Bozer and McGinnis 1992)**
Stock Keeping Unit (SKU)	**A number that uniquely identifies an assembly, component, or subassembly. (Bozer and McGinnis 1992)**
Part	**A component or a subassembly (Limère 2012).**
Variant Parts	**Parts that vary based on style or some other non-critical criteria; function, weight, and volume are all judged to be the same (Limère 2012).**
Part Family	**A single collection of all parts that are variants on each other. There could be multiple part families (Limère 2012).**
Common Parts	**A part that is of a part family with only one part in it (Limère 2012).**
Workstation	**A point in an assembly process where materials are added to the assembly.**
Kitting	**The act of amalgamating specific sets of components and subassemblies together in predetermined quantities to deliver that set of parts to its appropriate work station (Limère 2012).**
Kit	**A unique collection of components or subassemblies that support some activity within the organization, be it assembly, repair, emergency response, etc. (Bozer and McGinnis 1992)**
Kit Number	**A number that uniquely identifies a kit structure. (Bozer and McGinnis 1992)**
Kit Type	**All kits that support the same assembly are said to belong to the same Kit Type (Limère 2012).**
Kit Structure	**List of components and subassemblies in a kit (Bozer and McGinnis 1992). Can either contain the entirety of the bill-of-materials required for an operation, or a portion of it, depending on the kitting system.**
Container	**A device for holding, presenting and transporting the parts defined by a kit structure.**
Kits per Container	**The number of kits that fit into a kit container per kit type (Bozer and McGinnis 1992 , Limère 2012). An integer number.**
Kit Assembly	**The process of gathering all of the components and subassemblies required for a particular kit structure and placing them in a container (Bozer and McGinnis 1992).**
Kit Batch Size	**The number of kits assembled simultaneously of the same kit structure (Bozer and McGinnis 1992).**

Stationary Kit	A kit that is delivered to its point of use and remains there until depleted (Bozer and McGinnis 1992).
Traveling Kit	A kit that travels alongside an assembly as it moves between workstations, supporting the work performed at each of the work stations (Bozer and McGinnis 1992).
Uniform Kit Mix	A daily set of needs for kits where the anticipated output of the assembly process is known prior to the beginning of the work day (Bozer and McGinnis 1992).
Variable Kit Mix	Uncertain demand for kits, resulting from unknown production schedules (Bozer and McGinnis 1992).
Kitting Lead Time	Average amount of time that a batch of kits must be prepared in advance of their use (Bozer and McGinnis 1992).
Supermarket	The location in an operation where materials that go into kits are stored (Limère 2012).
Part-to-Picker	An arrangement of a supermarket where parts are delivered to the person assembling a kit (Limère 2012).
Picker-to-Part	An arrangement of a supermarket where the person assembling a kit travels to retrieve the parts from the storage shelving (Limère 2012).
Border of the Line (BoL)	The area of a workstation, typically behind the workstation operator, where materials are stored (Limère 2012).
Pallet	The largest possible unit of measure in which a particular part is delivered to a workstation. Signifies Line-Supply (Limère 2012). Pallets are only delivered by forklift.
Plastic Box or Tote	A smaller unit of measure than a pallet, but still a container of a given part containing more than one copy of that part. Delivered to a workstation. Signifies Line-Supply or Downsizing (Limère 2012).
Tugger Train	A motorized vehicle that pulls a number of trailers behind it, each capable of holding one or more kits or totes (Limère 2012).
Operator	Either the person assembling a kit or the person performing the assembly process.
Milk Run	A supply run made by the tugger train (Limère 2012).

Table 3: Definitions of Kitting Concepts.

3.2.2 The Benefits of Kitting

The following is adapted from Carlsson and Hensvold (2007), who in turn reference Agervald (1980), Medbo (2003), Schwind (1992), Ding & Balakrishnan (1990), Ding (1992), Bozer and McGinnis (1992), Sellers & Nof (1989), Jiao et al

(2000), and Christmansson et al (2002). The benefits listed below are either theoretical or have been observed in practice.

1. More space is available around individual workstations because pallets or other large units of measure storing parts are not kept there (usually only one kit at a time is displayed).

2. Assembly operators walking and part searching times are reduced because kits are displayed next to the operator and parts are laid out in the kit in a way that facilitates their addition to the assembly.

3. The amount of Work-in-Progress (WIP) is reduced or better controlled because components and subassemblies can be stored in a central location.

4. Changing the assembly line to be able to output a different type of assembly is made easier by the fact that inventory is not staged at the workstations. This lends flexibility.

5. Assembly process facilities are less cluttered, with consistently sized containers moving throughout the facility.

6. Eliminates the need to supply individual part containers, saving on materials handling worker time.

7. Better control and visibility for perishable parts.

8. Potential for increased quality, as the kit assembly process can act as a quality check on the parts going into the kit, as well as a verification that the right parts and the right amount of parts are being sent to a workstation.

9. Kit layout if done in the correct way could facilitate assembly and the training of new staff.

10. Allows for robotic handling at workstations because precise part orientations in the kit allow for robots to be able to identify and collect the parts from the kit.

11. Potential for aid when balancing a line in high variety assembly processes because setups for new jobs are done partially in a different area of the facility.

3.2.3 The Limitations of Kitting

Similar to Section 3.2.2, this section is adapted from Carlsson and Hensvold (2007). They reference the same others mentioned in the preamble of 3.2.2.

1. Kit assembly does not typically add value to the assembly process, while requiring a commitment of resources to achieve.
2. Storage space requirements are increased overall, especially when kits are prepared in advance.
3. Requires planning to coordinate available inventory with the kits which need it. This is made more difficult when a common component is required by multiple kits.
4. Part shortages will require in incomplete kits being sent to the assembly line; with either disrupt assembly flow or require a second kit container to be delivered with the part, increasing handling costs and storage space requirements.
5. Defective parts in kits will automatically cause a flow disruption at a workstation as safety stock is not on-hand.
6. Parts that are anticipated to fail as a result of being used in the assembly process will need to either not be included in a kit, be delivered with extra copies as backup, or be kept in a small amount near the workstation.
7. Assembly operators may cannibalize parts from kits in the event of a part shortage. "Cannibalizing" means to take parts from another kit that has not been used yet to fill another kit at a workstation. This is suboptimal because it significantly increases the total amount of materials handling required to fill an assembly order. It also complicates accounting for parts, throwing off cost estimations and Work-in-Progress tabulations.

8. Retrieving parts for kits from the supermarket can be a very monotonous activity, leading to a lack of motivation and unsafe work practices amongst the materials handling staff.
9. Product quality could decrease with a high rate of wrong or missing parts from kits over time. This is due to the assembly process flow disruptions.

3.2.4 Kitting Spatial Concerns

The location of where the kitting process occurs and the materials to be kitted are stored are critical decision points in the design of a kitting system. The high-level decisions about work organization and spatial location are critical. Also, kitting can occur either at the central storage point of a facility or at sub-storage locations closer to assembly workstations (Brynzèr and Johansson 1995). Kitting can also occur off-site by third party logistics providers (Carlsson and Hensvold 2007).

Communication between central storage facilities and assembly workstations regarding kitting issues becomes labored the further the storage facility is from the workstation (Carlsson and Hensvold 2007). Sub-storage locations can mitigate this (Carlsson and Hensvold 2007).

The kitting process and the kits themselves take up floor space in the supermarket, throughout the facility as they are transported, and at the assembly stations. If the kits are prepared in advance of their delivery to an assembly station, this also increases the amount of space required as they must be stored until they are used (Bozer and McGinnis 1992). The kit assembly process requires as much space as is required to present a kit (or kits) to an assembly operator as they pick parts to be placed on the kit (Brynzèr and Johansson 1995). If the kits are movable by the operator, there must be enough space in the supermarket between aisles to move the kit container as the operator picks parts and places them in the kit. Naturally, sufficient space must be given to the materials storage apparatuses to store all of the materials that are used in kits. If more than one kit is produced at once, sufficient space must be allotted so that the kitting operator can access all of the kits that he is preparing at once in a safe and efficient manner (Bozer and McGinnis 1992).

Transportation of kits requires enough space for the kit to travel throughout the facility, both on the initial and return trips, as well as the material materials handling equipment or personnel that are required to deliver the kit (Limère 2012). The travel time and distance it takes to deliver kits must be considered (Brynzèr and Johansson 1995). Kitting accrues a double cost as each time the kit travels to the BoL, it must return to the kit assembly process when it is empty. Line-supply does not incur this cost as line-supplied materials usually come in disposable packaging which is discarded when empty (Limère 2012). It could be the case that a disposable kit container could be used in certain circumstances but as this will generally not add value to the process and create material waste, such practices are only done when absolutely necessary. Kitting, compared to line-supply, should reduce the amount of space required at the BoL to store and present materials (Hua and Johnson 2010). This is because line-supply typically requires that an entire unit of measure be delivered to the BoL, meaning and entire pallet/box/etc. Finally, Hua and Johnson (2010) note that part sharing amongst multiple assembly workstations is a spatial concern to be addressed. They note that the determining factors between kitting and line-supplying a particular part depend on the demand for that part, the amount of safety stock required for that part, and how far the assembly workstations that need the same part are from each other. However, they declare that these reasons are not sufficiently researched in the academic literature and additional research is required to verify the tradeoffs involved with the need to stock parts at multiple locations.

3.2.5 Kit Composition

The question of what goes into a kit structure versus what does not is one of the central questions to the design of a kitting system that will affect the performance of the system. Aside from materials feeding policy decision modeling this is the most researched aspect of kitting systems with many different approaches offered. As we will see, production scheduling and performance significantly affect kit compositions considerations. Furthermore, demand forecasting, part and kit container volume and weight dimensions, resupply costs and resupply travel distances (e.g., facility layout), part retrieval costs and operator knowledge all affect the decision to include a part in a kit structure. Master kit composition, if master kits are used, is a contributing factor to kit composition decisions (Carlson et al 1994). Component commonality among different assembly products can lead to more efficient line supply scenarios as commonly kitted parts will have to be considered as special cases in models that identify tradeoffs between kitting and line-supply (Choobineh and Mohebbi 2004). Using kits for repair activities will also affect composition decisions (Bijvank 2010). We will offer an overview of each of these considerations below without significant elaboration except where necessary.

The most significant factor affecting the composition of kits is the demand placed on the parts that the kits will provide. In known production schedule environments, this reduces composition decisions to deterministic factors, such as yearly demand or part dimensions (Limère 2012). Production schedules that have a stochastic element to them will require the following tradeoffs be made when kit compositions are determined:

1. How many copies of a given part should be included in a kit? (Choobineh and Mohebbi 2004)
2. How far in advance should the kit be prepared? (Choobineh and Mohebbi 2004)
3. What are the costs associated with a missing or defective part in the kit? (Bozer and McGinnis 1992)
4. How will the flow of the assembly process be disrupted if a part is missing, defective or unavailable? (Chen, Wang, and Wilhelm 1986, 1993, 1994, 1997, 2003)
5. Should a part be kept in a kit at all? Should it be line-supplied or downsized? If so how many units of that part should be stored at the BoL? (Bozer and McGinnis 1992, Limère 2012)

6. If kits contain common components or similar parts are substitutable, to what existent is demand for a given kit softened? (Choobineh and Mohebbi 2004, Chen, Wang, and Wilhelm 1986, 1993, 1994, 1997, 2003)

7. How will master kits soften demand? What is the optimal number of master kits and supplemental kits to have? (Carlson et al 1994)

8. If a kit is used as a repair kit and the entire contents of the kit are not required, how will the replenishment (given known or random lead time) of that kit affect random production schedules? (Güllü and Köksalan 2012)

All of these questions are addressed, unfortunately, across numerous journal articles, so a tractable single model that combines all of these factors does not yet exist in the literature. For our purposes, we will assume a known production schedule in our case study, although stochastic models that explain the interplay between the operating room schedule and the inventory available for use on surgeries certainly would be a pertinent avenue of research. The addition of stochastic lead times, random demand, service level constraints, and component commonality to kitting systems requires "exceedingly difficult" levels of mathematical modeling, so simulation methods are appropriate (Choobineh and Mohebbi 2004). Again, we assume known demand so a simulation of the demand for kits will not be our analytical method of choice, although it certainly could be appropriate. In general, stochastic demand imbues significant modeling, managerial, inventory control and demand management questions into kitting systems (as it does in any supply delivery system), and kitting does not explicitly negate the effects of that randomness on demand; it may, in some cases and given certain tradeoffs, exacerbate it.

Two closely-related concepts that significantly affect a kit's composition are "component commonality" and "master kits." Models concerned with component commonality acknowledge that different kit structures may call for the same parts. Questions that arise are related to safety stock - where should it be located in relation to the various workstations in which it is used and how much should be kept there – and operational: Choobineh and Mohebbi (2004) offer three metrics to judge system performance when kit demand is unknown and kits share components. The first metric they list is average total inventory of parts per period, which is used to measure in addition to part usage the amount of money tied up in inventory per period and, by way of keeping track of stock outs, the effects of different part resupply lead times on safety stock levels. The second metric is average ratio of kit orders to kit deliveries per period; this is a surrogate for kit availability. The third and final metric is total backorders per period. Each of these metrics offers a strategic viewpoint on the operational phenomenon that is kitting. Component commonality amongst kit structures will affect each of these metrics by reducing the need for safety stock and total inventory through a risk-pooling effect. Related to the concept, yet differing in focus, of component commonality is the concept of Master Kits. The Master Kit concept is similar to component commonality in that both seek to optimize kit composition by identifying opportunities to pool demand for parts. However, Master Kits seeks to create kits that have commonly used parts in an effort to specifically address the demand for those parts and free up inventory of parts that were being assigned to kit structures that in fact were not needed (Carlson et al 1994); this is in contrast to component commonality, which looks at optimizing kit composition and safety stock levels, not create new kits of commonly used parts and specialty parts.

Another way production scheduling can be affected by the composition of the kits. In assembly systems where there is a significant amount of setup time between assembly jobs at a given workstation, kits must contain the right type and right amount of parts to minimize the frequency of new setups (Günther et al 1996). This will also affect WIP, total production capacity, and the number of assembly station operators required to complete an assembly procedure (Günther et al 1996). Günther considers a system where demand is known, but clearly these considerations could apply to systems where demands is unknown.

In addition to part demand calculations (which is at the heart of both Choobineh and Mohebbi (2004) and Carlson et al (1994)), explicit tactical level operations are affected by kit composition as well and are modeled stochastically in academic literature. On a day-to-day basis, as kits are prepared, on-hand inventory must be matched to kits for use in assembly operations. Chen, Wang, and Wilhelm (1986, 1993, 1994, 1997, 2003) address the composition of kits under conditions of part scarcity: given you do not have enough parts to assemble all of the kits required for a time period's assemblies, how should you decide which kits get parts and which don't? Further modelling complexity is added by considering that there is component commonality amongst kits, the assembly process is capable of producing multiple product types, assembly lot sizes are variable and finally the assembly process could have multiple echelons of assembly, each requiring a kit to be produced prior to the assembly operation (Chen, Wang, and Wilhelm 1986, 1993, 1994, 1997, 2003). To determine which kits receive parts and which do not, it is possible to determine for each set of jobs to be performed what the stochastic effects of not having a given kit available will be on the overall system. This is measured by job earliness (unnecessary materials cost and not functioning just-in-time), job tardiness (delays of downstream processes), and subassembly holding cost (also known as WIP; more money invested in inventory than necessary) (Chen and Wilhelm 1994).

If a kit belongs to a system as a *repair kit* it will require some different composition concerns than if it were a production kit. Repair kits typically are used in product services operations. Repair kit composition questions typically seek to ensure a sufficient level of parts for the serviceman as he travels from customer to customer (Bijvank et al 2010) without having to return for additional parts. This means that the key metric measured is usually service level as it is considered very costly for a serviceman to travel to a customer, discover that he has insufficient parts to complete the repair job, and travel to retrieve the needed parts. Service level can also be broken down to be measured under different strategies, such as "all-or-nothing" service (a serviceman only uses parts to complete a job if all the parts needed to complete the job are on-hand (Bijvank et al 2010)) or deliberate minimization of parts in a kit so that a serviceman has to return to replenish the supply of parts in the kit or kits after a set number of customer visits (Teunter 2005). This definition of a repair kit is slightly different from the one being used for kits in assembly systems; a repair kit will likely be used on multiple jobs, whereas an assembly kit will be used for one job. Still, it is apropos to mention repair kits here as the materials planning involved can lead to research and insights that could be applied to other kitting systems.

Kit composition decisions can also be weighed against materials handling concerns. Bozer and McGinnis (1992) provide a descriptive model that is later expanded by Limère (2011, 2012). The costs of kit assembly, internal kit container transport, facility floor space requirements, as well as assembly WIP (which is an assembly operation metric, not a materials handling metric) Bozer and Ginnis (1992) use to describe the tradeoffs between one set of kit structures versus another. Limère (2011, 2012) expands on this by presenting a mixed integer programming model that assigns individual parts to the two materials supply system alternatives (Kitting or Line-stocking). The goal is to minimize the total costs, given the average part and production mix characteristics. This is a deterministic optimization problem, where the costs are the "average yearly labor costs for operator picking at the line, internal transport, the kit assembly operation and replenishment of the supermarket (Limère 2012)." We will describe Limère's model in greater detail in an ensuing section.

Finally we will mention heuristic methods of determining kit composition here. Operator preference and/or need is often the deciding factor in non-assembly kitting operations (Bozer and McGinnis 1992). In the case of the operating room suite this is most certainly the predominant decision method for determining kit composition (we base this on observations from the case study). In our literature review we did not find any examples of explicit demonstrations of optimal heuristic methods; indeed, most of what we found we intended to add formal structure to kit compositions decisions. Given the complexity of the knowledge involved to determine the composition of kits in operation room settings leaving the decisions to those who hold that knowledge (the surgeons) is apposite; decision models such as the one we will offer are meant to give appreciation for costs that would not otherwise be considered in surgical kit composition decisions.

3.2.6 The Kit Assembly Operator

Determining who performs the kitting operation requires some careful planning as well. In some kitting systems, the question of wither or not the order picking activity should be performed by a robot or by a human employee must be considered (Carlsson and Hensvold 2007), but we will not concern ourselves with that possibility as our case study in the hospital would not feasibly be able to install such a system. In kitting systems which use human labor there are three feasible potential workforce arrangements: dedicated kit assembly staff, cross training for production assembly staff, and third party logistics providers (Brynzèr and Johansson 1995). There is some kitting from a third party provider in our case study but we'll see later how the form their kit takes allows us to simply count it as one item in a kit container (case cart), so we will not be considering third party logistics kitting assembly for our forthcoming model.

There are key tradeoffs between using dedicated kit assembly operators and production assembly operators. We will refer to dedicated kit assembly operators as "pickers" (Brynzèr and Johansson 1995). The benefits of using pickers over production operators for kitting purposes are cost savings and workforce skillset utilization optimization. Pickers have lower levels of training than do production operators, so the costs to train and subsequently employ the pickers are less than they are to do the same for production operators. Furthermore, because production operators have higher levels of training, it stands to reason that they would most optimally be used to do the work of assembly rather than picking (Carlsson and Hensvold 2007), as that way their skillset is being used to maximize the throughput of the assembly process.

The benefits of using production operators over pickers regard the efficiency of the kitting process and cost (Brynzèr and Johansson 1995). The production operators are more intimately involved with the end assembly product through their training and job function and presumably would be more accurate than pickers would be during manual part picking activities due to their increased understanding of the nature of the assembly products. Further, they would exhibit more care when it came to handling the parts as they would have more of an appreciation for assembly sequence disruptions and a desire to avoid having defective parts or missing parts (Brynzèr and Johansson 1995).

3.2.7 Materials Handling for Kits

The physical layout of the kit preparation area will affect how the kit preparation operators will physically do their job. The main considerations are how long it will take them to do it (Hanson 2012), how the items to be kitted are presented to the operator (Bozer and McGinnis 1992), how far they must travel in the kit preparation area (Limère 2012), in which order should parts be picked for kits (Goetschalckx and Ashayeri 1989) and what are the safety and ergonomic limitations of the particular system in question (for example, what are the environmental distraction such as phone calls, paperwork, etc. that interrupt the flow of parts kitting) (Christmansson et al 2002). Goetschalckx and Ashayeri (1989) define a term called "zone picking" that refers to the practice of laying out kit preparation and parts storage areas to arrange parts with some determining factor that makes them common to each other in the same sector of the storage area. This is actually something that is done in the hospital case study – different parts for different types of surgeries (orthopedic, neurological, etc.) are stored in their own unique rows of the storage area. Finally, in addition to not adding any value to the product directly, kitting also may increase the defect rate as the extra materials handling can lead to flaws in the components (Bozer and McGinnis 1992).

Choobineh and Mohebbi (2004) describe two different ways parts are assembled: either by the components being picked from storage areas (picked kits) or by components gathering together in a staging area as they arrive at the appropriate place in the facility (staged kits). Choobineh and Mohebbi (2004) note that staged kits are typically made of larger components or subassemblies and exist in continuous flow assembly facilities. This does not match the reality of our case study, where parts are picked, so the difference between staged and picked kits is mentioned here for posterity.

The presentation of the materials in the kits significantly affects both the kit assembly operator's and the assembly operator's jobs. The design of the kit container can facilitate where the component should go in the kit, preventing some unnecessary handling (Brynzèr and Johansson 1995) as well as aid the assembly operator in locating the part, speeding the assembly process (Brynzèr and Johansson 1995). Picking accuracy and parts counting can either take place during the preparation of the kit or after, and can be performed by the kit assembly operator, another operator, or a supervisor (Brynzèr and Johansson 1995). The way in which the component needs is presented to the kit assembly operator and how they are informed of the accuracy of their picks can either be a help or a hindrance (Bozer and McGinnis 1992). In addition to aiding the kit assembly operator, the kit container's design and the way it presents parts to the assembly operator can aid the operator's tasks at the point of use (Medbo 2003). Both ergonomic and cognitive-task issues can be addressed, which will lead to efficiencies in the flow of assemblies through the facility.

3.2.8 Models of Kitting Systems

Given all of the considerations above, we will briefly review some of the models available to determine which is most applicable to our case study. Kitting models, as we have noted above, will address kit composition, facility layout, materials handling and ergonomics, and system performance. In addition to incorporating these factors, models will either take a stochastic, deterministic or descriptive approach to analyzing the system. We did not discover any dynamic models of kitting systems. Finally, given the incorporated factors and choice of modeling approach, kitting models will fall into one of two areas: ones that look at the operational performance of the system, and others that determine which of the four materials feeding policies should be applied to a given assembly system. We will review some models in the table below. This does not cover all analytic frameworks available to describe kitting systems, but mostly the ones that would be applicable to our case study. This section also functions as an extension of our literature review earlier in the thesis.

Authors	Stochastic Model	Descriptive Model	Deterministic Model	Feeding Policy Decision	Ergonomics	System Performance	Materials Handling	Facilities Layout	Kit Composition
Chen, Wilhelm and Wang (1986, 1993, 1994, 1997,	√					√			√
Bozer and McGinnis (1992)		√		√		√	√	√	√
Som et al (1994)	√					√			
Choobineh and Mohebbi (200	√		√			√			√
Battini et al (2009)		√		√		√	√	√	
Caputo and Pelagagge (2011)			√	√		√	√	√	
Kilic and Durmusoglu (2012)			√		√	√		√	
Limère (2012)			√	√		√	√	√	√
Güllü (2012)	√	√				√			
Hanson (2012)		√		√	√	√	√	√	

Table 4: Kitting process design questions. Different authors model and present different aspects of kitting systems; choosing the method that would best address a given system is critical. (taken from the Literature Review.)

The case study in the hospital setting requires a model that would allow the current system to be optimized, rather than call for an entirely new kitting process. As such, we wanted to uncover and apply a model that could be applied to an existing kitting system. We also wanted it to be thoroughly analytic so purely descriptive models were initially considered but decided against. Furthermore, the hospital administration took an interest in the cost breakdown of running their system so a cost analysis is beneficial to the case study client. Storage area layout and materials presentation was also a continual concern for the client. Ideally the model would be recently published in an academic journal as well. Finally, optimal kit composition is especially crucial to the hospital's system as incorrect kit structures would result in wasted or unavailable materials. Hence, of the models available, the model that best accomplishes these objectives is the one presented in Limère (2012). We will now describe the model.

3.2.9 Limère's Mixed-Integer Linear Programming Model

Limère's model provides a cost model to kitting decisions, allowing for allowing for optimal materials feeding policy regarding the location of materials (namely, should a given item be delivered to the assembly line in a kit or should it be stored at the assembly station). Also, special considerations for healthcare settings will be brought up and incorporated into a kitting model for a supply system feeding an operating room suite. There is a possibility that Limère's model is incomplete in terms of applicability to the operating room setting; modifications to the model will be made accordingly.

Limère (2011, 2012) presents a mixed integer programming model that assigns individual parts to the two materials supply system alternatives (Kitting or Line-stocking). The goal is to minimize the total costs (C_{total}), given the average part and production mix characteristics. This is a deterministic optimization problem, where the costs are the "average yearly labor costs for operator picking at the line (C_{pick}), internal transport (C_{tpt}), the kit assembly operation (C_{kit}) and replenishment of the supermarket (C_{repl}) (Limère 2012)." Please refer to Appendix B for descriptions of the variables involved for each formula if that variable is not described below. Of critical importance is to understand the variable x_{is} in

Limère's formulation. This variable is a binary decision variable that, for each part *i* and for each workstation (operating room) *s*, returns a one if a part should be supplied via line-supply and a zero if the part should be supplied via kit. The linear program solver will return this binary variable's value as part of the solver's output. The linear program will be coded in AMPL Student Version 20131012 and solved with Gurobi 5.6.

3.2.9.1 Picking at the Line (Cpick)

The first cost that is described is for the cost of an operator to pick materials at the point of assembly. It can be thought of as the product of the yearly cost for an operator, the yearly usage of a given part, and the sum of the cost to pick the part from bulk supply and the cost to pick it from a kit. The formula for C_{pick} is given as:

$$C_{pick} = OC \cdot \sum_{s \in S} \sum_{i \in I_s} q_{is} \left[x_{is} tp_{is}^{bulk} + (1 - x_{is}) tp^k \right] \ (1.1)$$

With,

$$tp_{is}^{bulk} = \frac{2\Delta_{is}^{bulk}}{OV} + \tau^{bulk} (1.2)$$

the cost to pick the part from bulk supply, and

$$tp^k = \frac{2\Delta^k}{OV} (1.3)$$

the cost to pick the part from a kit.

Note that the cost to pick the part from bulk supply is different for each part and workstation, whereas the cost to pick a part from a kit is considered to be the same for each part in inventory because the part will be displayed clearly for the assembly operator. The yearly usage of part i at station s is denoted q_{is}.

3.2.9.2 Internal Transport to the Line (C_{tpt})

In Limère (2012) model is based on the three different ways an item could be delivered to the assembly line: pallet & forklift, totes carried by a tugger train on milk-runs, and kit containers carried by a tugger train on milk-runs (the difference between the totes and kits is that the kits are built in-house). The model defines the total cost of transport to the line as the summation of each of the particular sub-costs that are calculated based on the mode of transportation best utilized for a given item. Loading and unloading is not explicitly modelled, but rather is implicitly accounted for by adjusting the average velocities of the materials handling equipment.

Pallet transport is performed using forklifts that must travel to and from an assembly station (D_s^p) each time a pallet is required. Forklifts are assumed to travel at a constant velocity (V^p). The total number of loads to be delivered is the yearly usage of the part, q_{is}, divided by the quantity of the part that comes on a pallet, n_i. Therefore the cost to transport a pallet to the line is:

$$C_{tpt}^{pallet} = OC \cdot \sum_{s \in S} \sum_{i \in I_s \cap I_p} x_{is} \left(2 \cdot \frac{D_s^p}{V^p} \cdot \frac{q_{is}}{n_i} \right) (1.4)$$

The box/tote transport cost function is similar to the pallet cost function. One difference between pallet transport and box/tote transport is that the distance a forklift travels differs for each workstation to deliver pallets, but the distance a tugger train travels is constant as it always takes the same route through the facility. Additionally, the number of box/totes required per year is divided by the capacity of the tugger train (A^b) and the expected utilization of the tugger train (ρ^b). The cost to deliver box/totes by tugger train per year is derived as:

$$C_{tpt}^{box} = OC \cdot \frac{\sum_{s \in S} \sum_{i \in I_s \cap I_b} x_{is} \left(\frac{D^b}{V^b} \cdot \frac{q_{is}}{n_i} \right)}{A^b \rho^b} (1.5)$$

The third component of the materials transport cost function accounts for the transport of the kits themselves. Kits are delivered on the tugger trains as well so the distance travelled is always the same (D^k). The number of trips that tugger trains will make per year depends on the number of kits required at one station to assembly one product (K_s), the yearly demand for products (d), the capacity of the tugger train for kits (A^k) and the expected utilization of the tugger train (ρ^k). The cost to transport kits is:

$$C_{tpt}^{kit} = OC \cdot \sum_{s \in S} \sum_{i \in I_s} \frac{\frac{D^k}{V^k} K_s d}{A^k \rho^k} \quad (1.6)$$

Finally, the total cost to transport materials from storage to the line is:

$$C_{tpt} = C_{tpt}^{pallet} + C_{tpt}^{box} + C_{tpt}^{kit} \quad (1.7)$$

3.2.9.3 The Kit Assembly Operation (C_{kit})

The cost to assemble kits is described as follows. The formulation from Limère (2012) acknowledges the possibility of multiple copies of the same part being picked at the same time (i.e., in the event of batch kit assembly). This is formulated as the maximum of two values, each contingent upon part usage rates and characteristics. The first of the two values of the maximization function is itself the minimum of two other values: the ratio of yearly usage of a part q_{is}, to the yearly demand for assemblies (d) multiplied by the number of kits prepared per batch (B^k), and the maximum number of copies of a given part that can be picked at once due to the part's weight or volume (a_i). The second value that the maximum function considers is the number of parts required by an assembly for a given part and assembly station (m_{is}), divided by the ratio, rounded up, of m_{is} to a_i. This takes the final form, for each part *i* and assembly station *s*, as follows:

$$\theta_{is} = \max\left\{\min\left(\frac{q_{is}}{d} B^k, a_i\right), \frac{m_{is}}{\lceil m_{is}/a_i \rceil}\right\} \quad (1.8)$$

This gives us only one coefficient of the kit assembly cost function. θ_{is} becomes the divisor of another formula, the average amount of time it takes to gather a component from the supermarket. This is twice the distance to walk from the kit prep area to the location of the specific item in the supermarket (Δ_{is}^{k}) divided by the walking speed of the kit assembly operator OV, plus the amount of time it takes the operator to retrieve the part from the place where it is kept on the shelf (τ^{k}). All of this is divided by θ_{is} to give:

$$tk_{is} = \left(\frac{2\Delta_{is}^{k}}{OV} + \tau^{k}\right) / \theta_{is} \ (1.9)$$

Finally, tk_{is} is fit into the double summation and we have:

$$C_{kit} = OC \cdot \sum_{s \in S} \sum_{i \in I_s} [(1 - x_{is}) q_{is} tk_{is}] \ (1.10)$$

3.2.9.4 Replenishment of the Supermarket (C_{repl})

Limère (2012) defines the final cost of the kitting problem, how the supermarket is replenished, as:

$$C_{repl} = \sum_{s \in S} \sum_{i \in I_s \cap I_p} \left[(1 - x_{is}) \frac{q_{is}}{n_i} R^p\right] + \sum_{s \in S} \sum_{i \in I_s \cap I_b} \left[(1 - x_{is}) \frac{q_{is}}{n_i} R^b\right] (1.11)$$

R^p and R^b are both the constant costs to replenish one tote and one pallet, respectively, from the warehouse to the supermarket. Both are known in advance, are coefficients and are not optimized through this function. If the cost to replenish a part to the supermarket is sufficiently high, the tradeoff could be made to send that part straight to the assembly line packed in its original packaging (pallet or tote).

3.2.9.5 The Complete Model

Finally, we come to the complete model. Again, the objective function will minimize the summation of the four costs above:

$$\text{Min}\, C_{total} = C_{pick} + C_{tpt} + C_{kit} + C_{repl} \qquad (1.12)$$

Subject to the following constraints:

$$K_s \geq \sum_{i \in I_s} \left[(1 - x_{is}) \cdot \frac{m_{is} w_i}{|V_i|} / w^k \right] \qquad \forall s \in S \quad (1.13)$$

the weight constraint for kits,

$$K_s \geq \sum_{i \in I_s} \left[(1 - x_{is}) \cdot \frac{m_{is} v_i}{|V_i|} \right] \qquad \forall s \in S \quad (1.14)$$

the volume constraint for kits,

$$\sum_{i \in I_s \cap I_b} (x_{is}/H^b) \leq N_s^b \qquad \forall s \in S \qquad (1.15)$$

the constraint which holds for the length of space required at an assembly station to display box/totes based on the stacking height of box/totes,

$$N_s^b L^b + \sum_{i \in I_s \cap I_p} x_{is} L^p + K^s L^k \leq L^s \qquad \forall s \in S \; (1.16)$$

the constraint which holds for the length of space required at an assembly station to display box/totes, pallets and kits,

$$x_{is} = x_{js} \qquad \forall s \in S, \forall i \in I_s, \forall j \in V_i \; (1.17)$$

and the constraint that guarantees that similar, variant parts are all kitted or all supplied in bulk.

4 Adaptations of Limère (2012) to the Case Study

This chapter will proceed with a more technical overview of the case study and what materials feeding policies the case study presently uses (i.e., how is it a kitting process). Then we will move on to a detailed description of our deterministic model of the case study. This will include changes to the four sub-costs of the cost function as well as the constraint functions. We will conclude with requirements for data that this model will need.

4.1 Description of the Case Cart System

The purpose of the case cart system was mentioned earlier in the thesis but will be reiterated and added to here. We noted from Fitzpatrick (2009) that "supply systems in healthcare must be safe, timely, effective, efficient, equitable, and patient-focused." This is indeed the primary goal of the system of supply in any operating room – but using kits may or may not be the best way to achieve this goal. We must ask why else are case carts used and what other functions they serve in addition to supporting healthcare activity.

4.1.1 The Purpose behind Case Carts

The history of case carts is a tale of efficiency and necessity. More than half a century ago, hospitals had a much more simple labor model than they do

Figure 9: Case Carts. These have been prepared in advance of a day's scheduled surgeries.

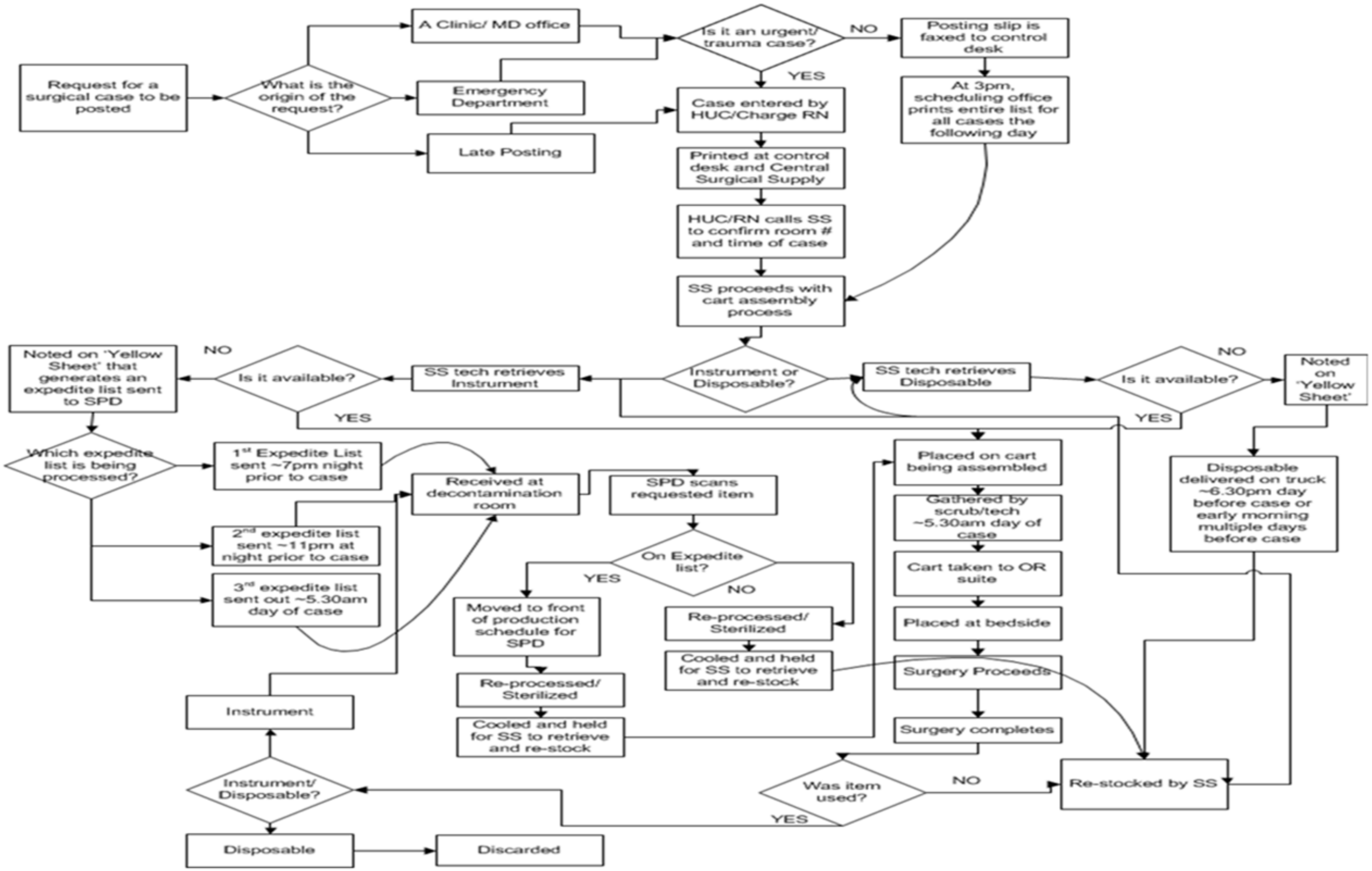
today (Ryan 1976). There were nurses, and there were doctors. Nurse aids, surgical techs, patient transport specialists, etc. had not come into existence yet. Nurses were responsible for doing all of the work behind the scenes such as collecting and prepping instrumentation for surgeries. At the same time, an emphasis began to be put on the efficiency of the nurses' workflows. This meant that nurses were encouraged to not waste their time or their steps – they were encouraged to carry multiple items at once, even if they would not immediately need one of the items they were carrying (Ryan 1976). The impetus to reduce workflow waste led some nurses to pilfer wheeled carts from such areas as hospital cafeterias to use them for the transportation of multiple items between storage and patient care areas (Ryan 1976). This concept was deliberately adopted by various hospital administrators, and became formalized in the 1960's by Gordon Friesen (Ryan 1976). Friesen developed many concepts and functions for the facilities of the modern hospital, one of which was the concept of the Supply Technician (Friesen 1969). The ideas behind the development of the supply technician role were three-fold: 1), to develop a work force dedicated to the handling, delivery, and maintenance of medical supplies, and thereby increasing the quality of those supplies and benefiting the health outcomes of the patient; 2) removing the clinically trained staff from the less technical tasks surrounding the retrieval of materials and utilizing their nursing skills appropriately; and 3) maximizing the value the hospital receives from the nursing staff, as their higher certification level demands greater compensation and supply technicians do not have the same levels of certification (Friesen 1969, Ryan 1976). The supply technician became the "owner" of the case cart – the assembly of the case cart, the transport of it, the return of the empty cart to be cleaned, and the resupply of the case cart preparation area are all the responsibility of the supply technician.

An additional reason for the use of carts (and of the use of a separate supply depot altogether) was to minimize the amount of space devoted to indirect clinical activities. The flow of patients through the operating room is carefully orchestrated to ensure that the sterility of the environment is maintained and the proceedings of the surgical event conclude in a timely fashion (Friesen 1969). It is expensive and prohibitive to create multiple operating room environments in most hospitals for this reason. Furthermore, maximizing the number of operating rooms in the suite increases the ability of the hospital to generate revenue. Therefore, the layout of the operating room suite is maximized to enable the flow of patients and as little space is given to storage of materials as possible. This is why materials are stored in a separate supply depot, typically located on another floor (Friesen 1969).

4.1.2 Communications and Workflow in Case Cart Systems

This section will draw from observations from the case study unless otherwise specified. There are five methods by which supply needs are communicated throughout the case cart system. Those are "doctor preference cards (DPCs)," the internal phone system, a hands-free voice communication system[1], electronic storage cabinet usage reports, and hand-written expedite requests. There are three different sources of requests for materials – scheduled surgeries from a doctor's office, trauma surgeries by way of the emergency department, and "late-postings." A late posting is a surgical case that is not the result of a medical event that requires a visit to the Emergency Department. Rather, the case came from a doctor's office as a means to fill the day's schedule of surgeries when another patient cancelled last minute, or when an inpatient needed to have additional work done prior to their discharge from the hospital. Late-

[1] http://www.vocera.com/


Request for a surgical case to be posted
What is the origin of the request?
A Clinic/ MD office
Emergency Department
Late Posting
Is it an urgent/ trauma case?
NO
YES
Posting slip is faxed to control desk
At 3pm, scheduling office prints entire list for all cases the following day
Case entered by HUC/Charge RN
Printed at control desk and Central Surgical Supply
HUC/RN calls SS to confirm room # and time of case
SS proceeds with cart assembly process
Instrument or Disposable?
SS tech retrieves Instrument
SS tech retrieves Disposable
Is it available?
NO
YES
Noted on 'Yellow Sheet' that generates an expedite list sent to SPD
Is it available?
NO
YES
Noted on 'Yellow Sheet'
Disposable delivered on truck ~6.30pm day before case or early morning multiple days before case
Which expedite list is being processed?
1st Expedite List sent ~7pm night prior to case
2nd expedite list sent ~11pm at night prior to case
3rd expedite list sent out ~5.30am day of case
Received at decontamination room
SPD scans requested item
On Expedite list?
YES
NO
Moved to front of production schedule for SPD
Re-processed/ Sterilized
Cooled and held for SS to retrieve and re-stock
Re-processed/ Sterilized
Cooled and held for SS to retrieve and re-stock
Placed on cart being assembled
Gathered by scrub/tech ~5.30am day of case
Cart taken to OR suite
Placed at bedside
Surgery Proceeds
Surgery completes
Was item used?
NO
YES
Re-stocked by SS
Instrument/ Disposable?
Instrument
Disposable
Discarded

: P
10

Fig

postings are the most difficult surgical case to prepare for because they are not known in advance like scheduled surgeries and cannot be anticipated like trauma surgeries.

The way the material needs for scheduled cases are communicated to the supply technicians is as follows. The doctor's office that is requesting the surgery notifies the operating room scheduling staff through fax, email, phone or electronic request to the operating room management system. All scheduled surgeries are entered into the hospital's operating room management system and fit into a complex set of constraints on the operating room schedule (such constraints are doctor work day preference, availability of materials, availability of operating rooms, etc., but surgery scheduling is a whole topic unto itself and will not be gone into here). The surgery request comes with a signifying code called a CPT code (Current Procedural Terminology). This is an industry standard code that the American Medical Association provides for every approved type of procedure that can be performed2. The CPT code is associated with a specific DPC for that code. The DPC is setup in advance by the surgeon. It is more of a recipe that expresses the surgeon's needs and preferences for materials for each time a specific CPT code is requested. DPCs are reviewed periodically for a variety of reasons, such as updates in technology or concerns about overburdening the supply system and removing little used items. DPCs tell the supply technicians everything that the

2 http://www.ama-assn.org/ama/pub/physician-resources/solutions-managing-your-practice/coding-billing-insurance/cpt.page. Accessed February 13, 2014.

surgeon believes he *might* need; not everything on the case cart is expected to be utilized.

At 6pm the night before a day of surgeries (Monday-Friday, limited on Saturday and Sunday) a copy of every DPC that has been requested is faxed from the operating room schedulers' station to the supply room. In the case study, the operating room and most of its administration (including scheduling) were on the second floor of the hospital, whereas the supply room was in the basement (hence the use of fax). The DPC cards were sorted first by surgery start time, then by type of surgical service. From there, four to six staff members would spend three to six hours assembling the case carts while attending to assorted other tasks (such as responding to requests for additional instrumentation). The amount of time it took to complete assembling all of the case carts would depend on the number of surgeries scheduled, the availability of materials to be put on the case carts, and the amount of time interruptions would add to the supply technicians' work. If some component of a DPC's list of materials was not available, a handwritten carbon copy form was used to initiate an expedite order. One copy of the form went to the appropriate technician, who would act as expeditor, and the other copy (which was yellow) would stay with the case cart. All missing items from the initial case cart assembly were listed on one form. As items were delivered to the cart, they would be crossed off the yellow sheet. The yellow sheet would also serve to notify the nurses in the operating room that the items listed were missing from the case cart.

Items for the carts are retrieved from either storage racks or from totes. The storage racks contain a mixture of re-sterilized equipment and disposable, single use items. The totes contain disposable items and were delivered by the distributor for use the following day in a low-unit-of-measure supply chain scheme. The disposable items kept on the shelves were kept for posterity. If an item is unavailable, it means that the distributor was out of it, it was out of stock from the hospital's stores, or it had not been re-sterilized yet. Finally, when a cart is complete, if it is for the first surgery of the day, it is pushed by hand up to its appropriate operating room and remains there throughout the night until staff come to prepare for the first surgery; otherwise, it remains in the case cart preparation area until it is called for by nursing staff in the operating room. In either case, first surgeries or subsequent, the presence of a yellow sheet will not prohibit the delivery of a case cart. Supply technicians know where to deliver the cart because the DPC has room information added to it by the supply technician supervisor by hand (the DPC is matched to the room by way of the CPT code and the next day's surgical schedule, available on the operating room's computer systems).

Late-postings are prepared in much the same way as scheduled surgeries, except that they are done as needed and not in a batch. Trauma surgeries have a different method of preparation altogether. Case carts for different types of trauma surgeries are prepared in closed and locked carts that lie in wait until needed. A trauma case cart contains everything a trauma surgery team could need to perform a surgery on a moment's notice. They are stored in the OR core rooms. As soon as one is used, a replacement is sent to the core room and a replacement for that is expedited to the top of the work schedule for both the re-sterilization process and the case cart assembly process. Because of the specialized nature of the trauma carts, they will not be considered for analysis here.

After surgeries end, there are two separate materials flows that take materials out of the operating room. The first is the used materials stream, which includes both instruments and disposable items. The second is the stream for items which are unused. We will first describe what happens with used items. If the item was disposable it was discarded in a hazardous biological refuse container. If the item was an instrument, it is first decontaminated and rinsed of all biological matter from the surgery. This involves a chemical bath, a forceful hand cleaning if necessary, and a wash and rinse in a dishwasher-type machine. It should be noted that if an item has an expedite order on it, when it arrives in the decontamination process it is placed at the top of the queue for processing. Following the decontamination, the instruments are sorted and replaced into their proper instrumentation trays. They are also inspected for wear, additional biological matter that may have been missed, and if the item is broken or not. Then the trays of instruments are sealed in either specialized blue wrapping paper that preserves the sterility of the instrumentation set or, if the tray is the closed metal type, a filter is placed into a hole that allows the instruments in the tray to dry after the final step of the process (the special blue wrap allows water to evaporate as well). That final step is to place the trays in a steam chamber, chemical vapor bath, or radiation treatment to sterilize the instruments. Items lie in wait to be shelved after this phase of the process.

The alternative route for materials to exit the operating room occurs if the parts went unused. If an item is brought on a case cart as requested on a DPC but either goes unused during a surgery or is known prior to surgery start that it won't be required, it is placed on an overflow cart in the OR Core storage room. At the end of the day the overflow cart is delivered to the main storage area in the basement level where the items are restocked. If an item is required for another surgery, it has been placed on the overflow cart, and is otherwise unavailable, the string of communications between the nurses and supply staff will occur to inform the nurse of the item's location. The overflow-item is not scanned to the "location" of the overflow cart; its location is not known to the computer information systems. Lastly, if a tray of instruments is opened and only one item from that tray is used, the entire tray is considered as having been used and every item in the tray must be re-sterilized.

4.1.3 The Case Cart Itself

We will briefly describe the case cart itself here. A case cart is a stainless steel cart on four castor wheels. It is not motorized or capable of being connected to a motorized delivery vehicle and must be pushed by hand. Carts would have a bumper around the entire bottom frame that would protect the cart or whatever it collided with from some damage. The cart could take one of three different shapes: an open cart, with three shelves and protective metal rails along certain edges to prevent spillage; and two sizes of closed cart, one twice the size of the other, which was enclosed on all sides with stainless steel and features a latched door that enabled access to the its contents. The smaller closed cart basically held as much as the open cart. There were few of the closed carts available in the system so the majority of the carts used were the open type. Our analysis will assume all carts are the open type. An open case cart's dimensions were 36 inches long by 25 inches wide by 52 inches high. A limit of two was placed on the number of blue-paper wrapped or metal

Figure 11: An open case cart. Note the yellow sheet, indicating that this cart is missing materials. Also, the white piece of paper is a DPC, which functions as a bill of materials.

instrument sets that could be stocked on top of each other to prevent abrasions to the wrapping (if the wrapping was compromised, the set was considered unusable).

Figure 12: A closed case cart, with doors open.

4.1.4 Staff Roles that Handle Materials

There are four main personnel roles that are the primary handlers of materials in the case cart system. They are surgeons, circulator nurses, scrub nurses or technicians, and supply technicians. We will briefly describe the function of each here.

The surgeon is the central figure in the case cart system. Their knowledge of how to treat the patient is what drives their selections on the DPCs; therefore, the entire system is set up to provide the surgeon what they need when they need it. The surgeons choose to place items on DPCs for some mix of the following reasons: they prefer one brand/type of item over another; they have an agreement with their fellow surgeons to use a specific item; it is the only option to perform a procedure; it is the only item they have been trained to use. The surgeons only ever handle the materials when they are performing the surgery, fully covered in sterile protective equipment (non-latex gloves, mask, gown, surgical cap, etc.) to minimize the occurrence of infections. They will never move to retrieve an item from a case cart or from storage themselves because they are in a sterile environment and to leave the surgery table would compromise their sterility. During a surgery, the surgeon is also the one who creates additional demands for materials – either when something they are using becomes unusable and needs to be replaced (i.e., and item is dropped on the floor) or some aspect of the patient's condition becomes apparent and alternative materials become required to proceed.

The person handling the materials to be used by the surgeon is the scrub nurse or scrub technician. This staff member is also in sterile protective equipment and is solely responsible for handling surgical items once they are out of their sterile packaging. Prior to the beginning of the surgery the scrub nurse comes to the operating room and begins to prepare the instrumentation in a sterile fashion. After they put on their protective equipment, they cover a few tables with sterile disposable paper coverings and begin to unwrap and display the surgical items on the case cart. They will only display the items that have not been marked as "hold" items by the supply technicians (which, in turn, the supply technicians were notified of which items to mark as hold items by the surgeon via the DPC).

The scrub nurse remains there for the duration of the surgery, similar to the surgeon. The area in which the instruments are displayed, as well as the area containing the patients themselves, is called a “sterile field” and will not be breached by anyone or anything that has not been properly prepared and sterilized.

Figure 13: A sterile field.

If an additional item is needed by the surgeon, they tell the scrub nurse, who informs the circulator nurse. The circulator nurse is responsible for keeping track of all the events that occur during a surgery, such as surgery start time and end time, as well as what materials are used during the surgery for billing purposes. Once notified of a material need, the circulator takes the appropriate set of actions to retrieve the item. If it is kept in an operating room storage cabinet, they walk from their work desk to the location of the item. If the needed item is held in the central supply storage area, and it is small enough to fit into a vacuum tube container, the circulator calls the central supply storage area's phone, informs the technician on the other end of the line of the material need, then walks to the vacuum tube discharge point in the adjacent OR core storage room and gathers the requested item after it has been delivered. If the item is too large to be sent by vacuum tube, the circulator nurse again calls the central supply storage area and speaks to a supply technician, but instead this time another technician takes the order from the technician answering the phone, retrieves the requested item, and walks it upstairs to the operating room that requested. The circulator accepts the item from the supply technician when they arrive. The circulators are also the ones to take unused materials to the overflow cart.

The supply technicians are the ones with the majority of the materials handling tasks. They perform the following tasks:

- Assemble case carts
- Restock central supply storage area shelves with sterile instrument sets and disposable items
- Unload totes from the distributor's delivery truck
- Take requests for additional materials
- Deliver additional materials to operating rooms
- Deliver case carts
- Resupply OR in-room or core storage cabinets
- Reconcile case cart contents with DPCs
- Inform circulator nurses of unavailable items and work to provide alternatives

- Retrieve the overflow cart and return overflow items to central supply storage area shelves
- Assist in the return or disposal of used materials
- Retrieve the case carts themselves from reprocessing (case carts are run through a washing machine)
- Maintain and organize shelves of materials
- Develop, monitor and act on lists of expedited items

There are a number of tools used to accomplish these tasks. The expedite list is created in the sterile reprocessing department's production management software. Scanners and barcodes are used to track materials. As have been previously mentioned, there are the case carts themselves, storage shelves, a phone system with hands-free headsets, carbon paper, a vacuum tube system and numerous labels and signifiers to inform technicians of the proper place for materials on the shelving.

4.1.5 Operating Room and Case Cart System Facility Layout

This section will describe the layout of the operating room and the storage areas as they pertain to the utilization of surgical items and their delivery to the operating room. We will describe the layout following the order of the workflow to deliver the items to the surgeons; that is, we will begin with the case cart assembly area, then the path the carts take to the operating room, the operating rooms themselves, and where the materials go after being used.

Figure 14: Packs of disposable items being stored next to case cart assembly.

The case cart assembly area can be described in different sections. The first is the rows of storage shelves and the second is the case cart staging and assembly area. The storage shelves are organized into zones, where each zone represents a different surgical service ("neuro," "ortho," general, etc.). This benefits the supply technicians in that it allows them to retrieve materials for different surgeries without interfering with each other's work. It also makes it mentally easier to find materials as there is commonality associated to the designation of space on a shelf for a given part (if something is not used often, and it is a "neuro" item, then the supply technician can begin to search for it by automatically beginning with the other "neuro" items). The shelves are not wide enough for supply technicians to be able to push a case cart through them, so they use smaller carts to do their order picking and then transfer the materials onto the case cart. The transfer of materials onto the cart happens in the left most

Figure 15: Two views on the storage of materials in the central supply area.

portion of G044B (Figure 16). After the materials are transferred, the carts lie in wait in G044B for a supervisor's verification of materials, then they either remain there until needed or, if the case cart is to be used on a late-posting or for one of the first surgeries of the day, is sent to the Operating Room through the "clean" elevator (G094 – Figure 16).

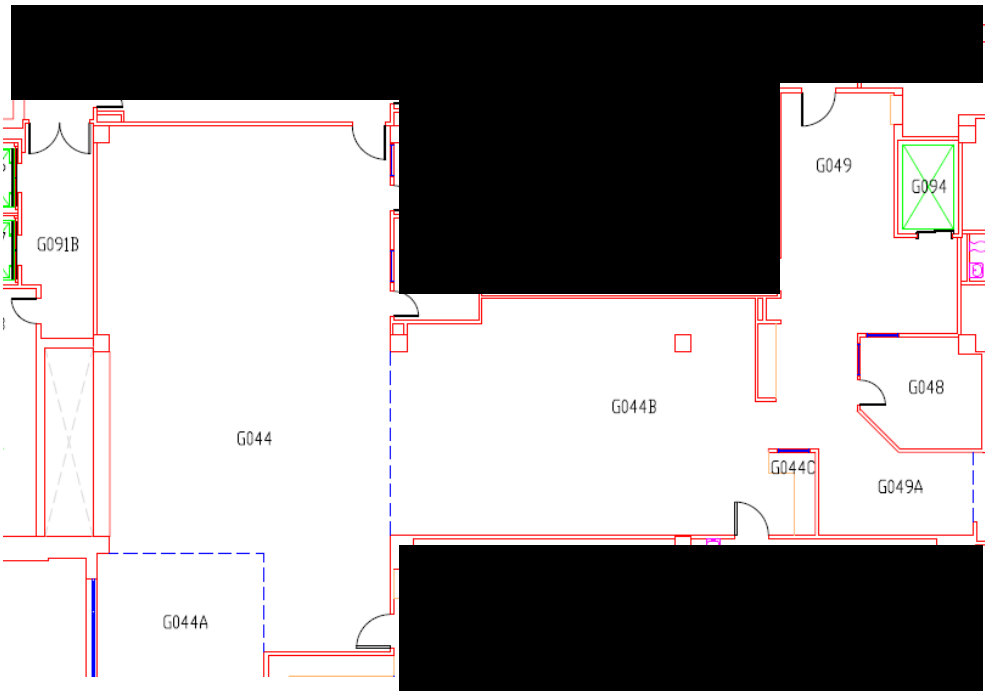
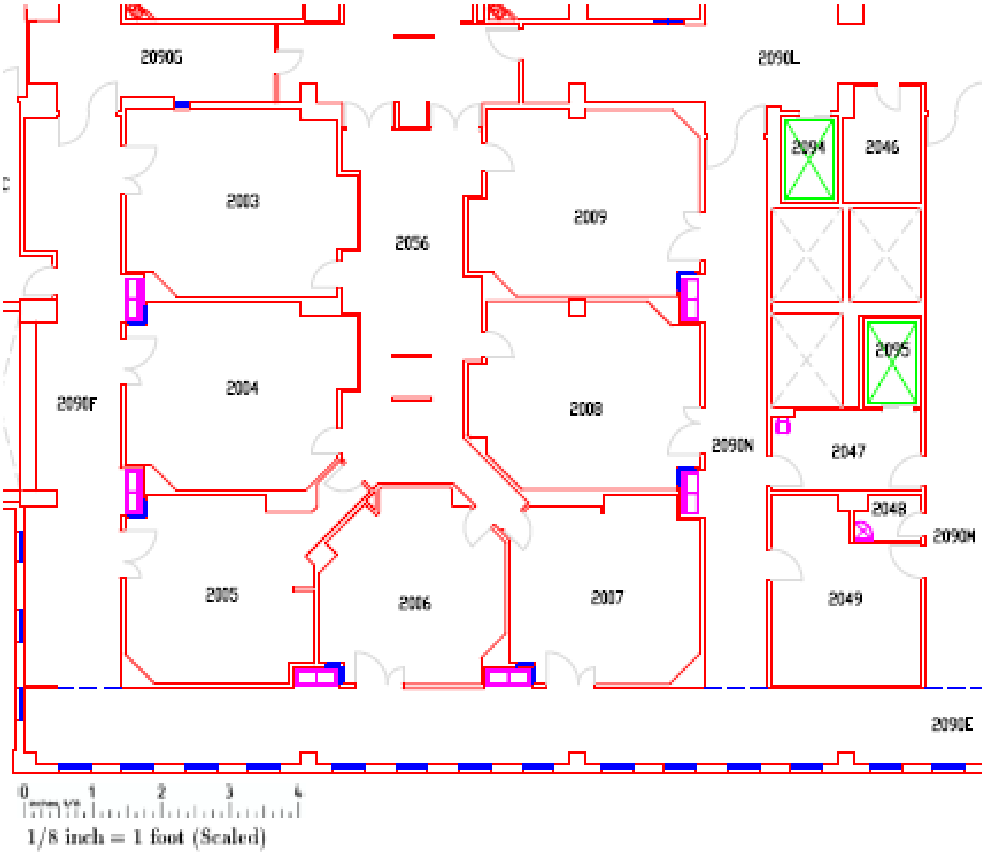


Figure 16: Case cart assembly and staging (G044B) and central supply storage (G044). The elevator to the Operating Room is in the top right of the schematic (G094).

We consider G049 and G094 part of the path to the operating room. The elevator can hold two case carts at a time. Again, the central supply area is on the basement level and the Operating Room is on the second level, so that distance must be taken into account as the carts traverse between levels. In addition, since there are 27 operating rooms and a 28th room called a procedure room, the case carts have twenty eight different paths they might follow. See Table ii in



Appendix C for a list of distances to each of the operating rooms.

Figure 17: A block of seven operating rooms (2003-2009), their adjoining core room (2056), adjoining hallways (2090, G, L, N), and the "clean (2094)" and "dirty (2095)" elevators.

There are two areas where materials are stored in line-supply fashion in the Operating Room. One is in the individual operating rooms themselves. The other is in the core rooms that are surrounded by a block of operating rooms. Materials in the operating rooms themselves are mostly kept in the electronic storage cabinets and to a lesser extent some incidental items are kept in unlocked shoulder level cabinets. Materials in the core rooms are kept in either electronic storage cabinets, open shelves, or other specialized storage equipment such as refrigerators for biological materials or hot boxes for warming blankets. The shelves are either plastic or metal wire and are similar to what is in the central storage area in the basement (Figure 18).

Figure 18: Line-supplied items in an Operating Room core.

The electronic storage cabinets are specialized cabinets designed especially for healthcare applications. There are a number of benefits they offer to the nurses and supply technicians. The enable more efficient and accurate capture of material utilization for the purposes of billing. When the operator of the cabinet comes to retrieve an item from it, they enter information into a keypad to align the patient with the item they are retrieving. The keypad is located on the right, and a visual readout is given on the left to aid in the process of creating the billing information to the patient and verifying that the right item has been chosen (Figure 20). The electronic cabinets have adjustable shelves, allowing for items of many different shapes and sizes to be stored in them. The cabinets have indicator lights to show which slots need to be filled – this speeds the process of restocking. The keypad and readout are linked to a block of four cabinets. Cabinets with the keypad have twelve shelves and an

Figure 19: An electronic cabinet.

effective storage facing of 22 inches by 57 inches. Cabinets without the keypad have a storage frontage of 22 inches by 69 inches (Figure 19). The cabinets additionally afford the organization of materials as well as the user's ability to locate the items in the shelves. When a product code or description is entered, an indicator light lights up to signify the location of the requested item. Finally, the cabinets have material utilization reports to tell supply technicians what the levels of each item in the cabinets are. This is very useful for resupplying the cabinets, and in fact these reports are run nightly and all materials below par inventory levels are restocked.

Figure 20: An electronic storage cabinet with keypad and readout.

The final set of locations to be discussed in relation to the flow of materials in the Operating

Room pertains to the removal of materials. As has been noted previously, there is an overflow cart in each of the cores where unused materials from the case carts are placed. These carts are taken down to the central supply room again and unloaded – costing time and resources. Ideally the use of the carts would be minimized through optimal DPC composition. Additionally, there is a “dirty” elevator (2095 - Figure 17) through which used materials travel. The clean and dirty elevators exist to help maintain the sterility of the environment – dirty materials are effectively quarantined in this way.

Figure 21: The over flow cart. Also called the clean cart by the hospital staff.

Materials arrive in decontamination and are separated into reusable items and disposable items – see Figure 17. After traveling through reprocessing, reusable materials are put back into service on a case cart if needed or storage shelving if otherwise.

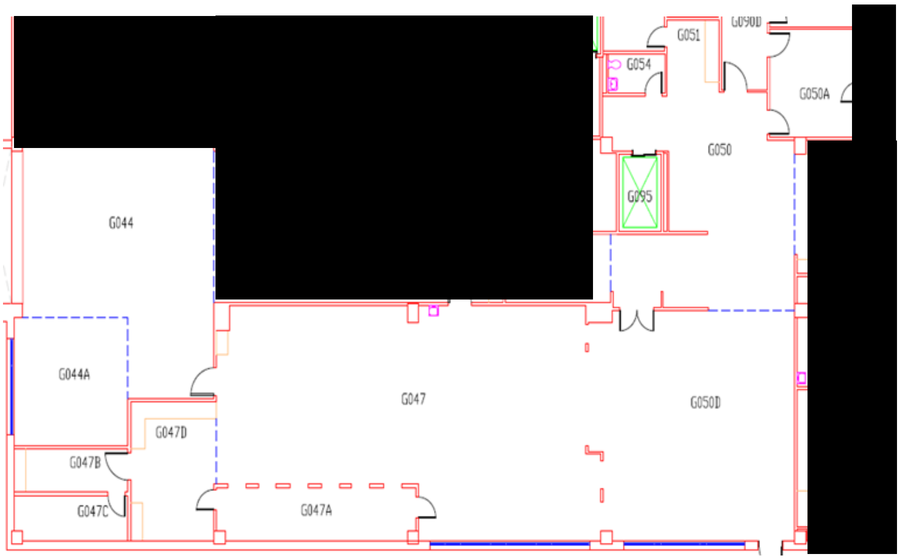


Figure 17: Material disposal and recycling. Used materials arrive at G095. Disposable items are gathered in G050A. Reusable instruments are decontaminated (G050D), reprocessed (G047), and re-sterilized (G047A-D). Finally, the reusable instruments arrive in G044A, where they proceed to storage in G044 or onto a case cart in G044B.

4.1.6 Characterization of Surgical Materials

This section will discuss the various materials used in the Operating Room, especially those provided through the case cart and electronic storage cabinet system. Table five offers a brief description of the general types of materials required in the Operating Room. We will describe in further detail each of those that are delivered on case carts as they are the ones we will be examining further with our adaptation of Limère's model.

It has been noted previously that instrument sets come in either specialized blue wrapping paper or in solid metal containers. Both of them must be handled carefully to preserve sterility. A slight tear in the blue wrap causes the

Name	Examples	Function	Supply Method
Instrument Sets – Dexterous	Forceps	Skilled, precise surgical motions. Comes in a set which provides multiple cutting lengths in the case of forceps	Case Cart; open core shelf
Instrument Sets - Powered	Drills, saws	Powered surgical motions. For cutting through hard biological material. Powered with a battery.	Case Cart; open core shelf
Peel Packs	Scalpels	Single-unit instrument sets. Convenient in that they minimize the amount of instrumentation being recycled.	Case Cart; open core shelf; elec. cabinet
Totes	(Contents) Table covers, Iodine	Premade package of disposable items. Intended to ease the burden of disposable item preparation for supply technicians.	Case cart
Disposables - Situational	Catheter tubes, IV lines	Non-standard disposable items, that may not always be used or come in various sizes.	Case Cart; elec. cabinet
Disposables - Incidental	Gloves, gowns, table covers, etc.	Ensure sterility of environment and protect patient.	Case cart; in-room cabinet
Sutures	~	Close surgical incisions.	Open core shelf; in-room cabinet
Transplants	Skin grafts, organs, blood transfusions	Addition of foreign biological matter to a patient. To replace lost or no-longer-functioning bodily systems.	Other
Implants - Artificial	Screws, Plates, Joint Replacement Prostheses, Other instrumentation	Replacement of damaged and/or improperly functioning bodily systems with implants formed to replicate the function of the original system	Case Carts; one-of delivery; elec. storage cabinets
Scopes	~	Minimally invasive surgery.	One-of delivery
Robots	~	Hi-tech, minimally invasive technique used on especially delicate areas of the human body. Operated through human dexterity.	Other

Table 5: Different classes of material in the Operating Room, and their function and form of materials presentation.

entire set of instruments to become unusable. As for the contents of the sets, that varies from two to three large items (drills, saws) to 10-30 medium sized items (forceps) to hundreds of small specialized items (orthopedic implant screw sets). The weight of instrument sets does not exceed twenty-five pounds per regulatory requirement. There are some sets that are common in that they are used by multiple surgeons; others are specific to a particular surgeon.

Figure 22: A blue sterile-wrapped tray and a metal tray.

The instrument containers are highly variable in size. They range from the plastic peel-pack items to twenty-five pound contents-max-weight containers. They come in multiple shapes and sizes. Not every sterilized set comes in rectangular dimensions. For the purposes of the optimization model below, reusable parts were characterized into one of three different volume sizes. The case study hospital did not have information on part volume and size data had to be collected by hand and by eye. The three category volume generalization was chosen for the time instead of accuracy, although improved data in this regard would certainly benefit.

Figure 23: Above - Trays of instruments being sorted. Below - This tray has 111 parts.

Additionally, peel pack items are essentially instrument sets with only one item. Rather than coming in a metal tray, single instruments that don't come in various sizes and therefore don't need to come in a whole tray of similar items. This is more convenient for surgeons and supply technicians because peel packed items are generally more available – one a peel pack is used, only one item has to be reprocessed, not a whole set of similar items. In fact, one of the constraints

Figure 24: Peel-pack items.

of the whole system is the fact that, even though a set of instruments will contain twenty items, a surgeon will only even use one or two during a surgery. There is a lot of waste in this regard – items are being reprocessed that were never used on a patient.

Disposable items come either packaged together in totes, in boxes of quantity greater than one, or as individual units. Totes were set up by the operating room administration to aid the delivery of standard disposable items to the Operating Room. Individual totes are prepared by the medical supply distributor (a 3rd party) the day before a surgery. The tote composition was

Figure 25: A tote. Also known as a pack.

standardized in a project to determine what disposable items were standard to different surgical services. This aids the supply technician as they do not have to spend time and cognitive effort picking redundant items for every case cart. This aids the surgical team because the tote provides the same items every time with much higher confidence that everything will be there – this speeds operating room setup and turnover, and aids in materials presentation. Other specific disposable items that are not standardized either come from the central storage area, the electronic supply cabinets or directly from the distributor as per the low-unit-of-measure inventory scheme. They range in size and function (catheters, IV lines, etc.). Similar to how reusable parts and sets were characterized into three categories, disposable items were also give three categories based on hand and eye data collection. Part size data was not kept by the hospital, and part dimensions were highly variable. It should be noted here that because a certain part has a given size category assignment does not mean that is the number of copies of the par that fit into a slot in the hospital's shelves.

Figure 26: A random disposable item.

The final type of materials that we must consider for the case cart system is implants. They can be delivered on case carts or stored in the electronic supply cabinets, but the most typical form of delivery is for the implants to be brought to operating rooms as needed by either a supply technician or a 3rd party sales representative. On rare occasion circulator nurses will come to retrieve the implant item themselves from the special implant storage room, G043 (Figure 27)

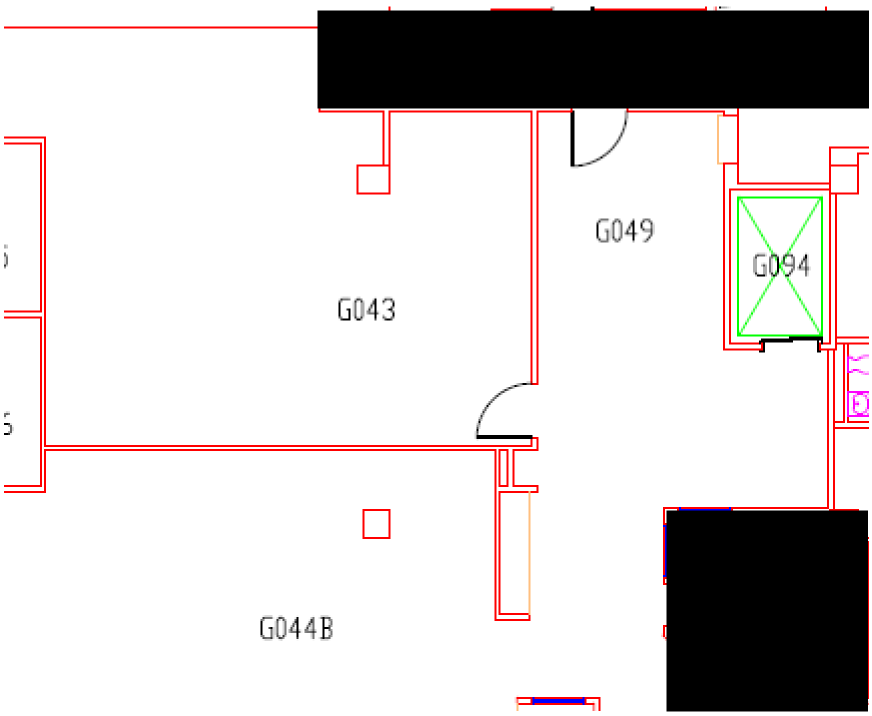


Figure 27: G043 is the implant room. It lies next to the rest of the central storage areas.

(e.g., when a supply technician is unavailable to deliver the implant). Many items are held at par levels of one, and some are even customized. Similar to instrument sets, implant sets come with a large variety of small implant parts (screws, etc.) that the surgeon will determine to use during a surgery. They must all be re-sterilized after the surgery once opened. This type of implant set also is delivered on the case carts. Implants come on the DPCs as well. Some highly specialized sets of implants are delivered by sales representatives, which saves the hospital the materials handling cost of delivering these materials to the Operating Room. Finally, the large sets of implants are tracked through the reprocessing system by the hospital's production scheduling and materials tracking software.

4.2 Discussion of Feeding Policies and the Case Cart System

This section will demonstrate descriptively how the case cart system (and the overall system of materials handling) in the Operating Room is a mixture of the kitting and line-supply feeding policies. We will map the concepts delivered in Chapter 3 describing kitting systems to what we have seen in Section 4.1. As we noted previously, there is little evidence in the literature that such a description of case carts exists aside from passing mention in Choobineh and Mohebbi (2004) and Güllü and Köksalan (2012) and broad, non-specific treatment in Leshno and Ronen (2001), case carts systems as kitting systems does not receive formal treatment. This section serves as the intellectual motivation for the coming section on the adaptation of the model from Limère (2012). Understanding the case cart system as a kitting process could lead to many different types of analyses besides a deterministic one; we hope this section will motivate such research in the future.

Kitting Terminology	Definition	Analogous Case Cart System Concept	Analogous Case Cart System Concept Description
Assembly	One fully assembled final output of an assembly process (Hopp and Spearman 2008). Also called "end product" (Bozer and McGinnis 1992).	Surgery	A surgery. This analogy is one made for convenience rather than precision.
Component	A portion of an assembly that is atomistic. (Bozer and McGinnis 1992)	Instrument or Disposable Item	Any item that is required by a surgeon to operate on a patient, in a container or packaging containing exactly one object.
Subassembly	An aggregation of two or more components or subassemblies. (Bozer and McGinnis 1992)	Instrument Set	A set of instruments can be considered a subassembly of a case cart.
Stock Keeping Unit (SKU)	A number that uniquely identifies an assembly, component, or subassembly. (Bozer and McGinnis 1992)	SKU, Surgery ID Number	Same concept. The surgery ID number is unique as well and will serve as the SKU for a surgery.
Part	A component or a subassembly (Limère 2012).	Instrument or Disposable Item	Any item that is required by a surgeon to operate on a patient. Could include a set of instruments or a tote of disposables.

Variant Parts	Parts that vary based on style or some other non-critical criteria; function, weight, and volume are all judged to be the same (Limère 2012).	No Analogy.	~~~~~~
Part Family	A single collection of all parts that are variants on each other. There could be multiple part families (Limère 2012).	No Analogy.	~~~~~~
Common Parts	A part that is of a part family with only one part in it (Limère 2012).	No Analogy.	~~~~~~
Workstation	A point in an assembly process where materials are added to the assembly.	Surgery Table	The place in an operating room where the materials transported by the case cart system are used on the patient.
Kitting	The act of amalgamating specific sets of components and subassemblies together in predetermined quantities to deliver that set of parts to its appropriate work station (Limère 2012).	Case Cart System	The system by which DPC orders are filled. Includes the communications required, the case cart assembly process itself, the necessary staff and facilities, and the presentation of materials.
Kit	A unique collection of components or subassemblies that support some activity within the organization, be it assembly, repair, emergency response, etc. (Bozer and McGinnis 1992)	Doctor Preference Card Materials List	The aggregate collection of materials requirements, staff, room selection and special equipment required to perform a surgery as indicated on the DPC. Includes the materials delivered through the case cart system.

Kit Number	A number that uniquely identifies a kit structure. (Bozer and McGinnis 1992)	Doctor Preference Card Number	Unique identifier for a DPC. Tied to appropriate CPT codes.
Kit Type	All kits that support the same assembly are said to belong to the same Kit Type (Limère 2012).	Number of Case Carts	The number of case carts required for a given DPC.
Kit Structure	List of components and subassemblies in a kit (Bozer and McGinnis 1992). Can either contain the entirety of the bill-of-materials required for an operation, or a portion of it, depending on the kitting system.	Doctor Preference Card	A bill of materials developed by a surgeon that delivers requirements for surgical materials to supply staff.
Container	A device for holding, presenting and transporting the parts defined by a kit structure.	Case Cart or Instrument Tray	A metal cart used to gather, organize, deliver and display surgical materials used during a surgery, or a metal tray used to hold, protect, and present surgical instruments.
Kits per Container	The number of kits that fit into a kit container per kit type (Bozer and McGinnis 1992, Limère 2012). An integer number.	No Analogy.	~~~~~~
Kit Assembly	The process of gathering all of the components and subassemblies required for a particular kit structure and placing them in a container (Bozer and McGinnis 1992).	Case Cart Assembly Process / Cart Picking	The act of gathering materials necessary to fulfill surgeon requests, so that they may perform an operation on a patient.

Kit Batch Size	The number of kits assembled simultaneously of the same kit structure (Bozer and McGinnis 1992).	Case Cart Batch Size	The number of case carts assembled at the same time for the same DPC but different patients. Does not occur in practice. Does not refer to the total amount of case carts prepared for a day's surgeries.
Stationary Kit	A kit that is delivered to its point of use and remains there until depleted (Bozer and McGinnis 1992).	Case Cart	Case carts do not travel from point to point during a surgery.
Traveling Kit	A kit that travels alongside an assembly as it moves between workstations, supporting the work performed at each of the work stations (Bozer and McGinnis 1992).	No Analogy.	~~~~~~
Uniform Kit Mix	A daily set of needs for kits where the anticipated output of the assembly process is known prior to the beginning of the work day (Bozer and McGinnis 1992).	No Analogy.	~~~~~~
Variable Kit Mix	Uncertain demand for kits, resulting from unknown production schedules (Bozer and McGinnis 1992).	Surgical Schedule	The highly variable schedule of surgeries day-to-day. Each surgery has unique requirements making case cart preparation impossible prior to the night before a surgery is scheduled.
Kitting Lead Time	Average amount of time that a batch of kits must be prepared in advance of their use	Case Cart Assembly Start	Amount of lead time between case cart assembly and utilization. Occurs either when the known

	(Bozer and McGinnis 1992).	Time	demand for case carts is delivered to the surgical supply technicians the evening before a surgery or when a late-posting surgery is scheduled.
Supermarket	The location in an operation where materials that go into kits are stored (Limère 2012).	Surgical Supply	Area of the hospital where materials for surgeries are stored.
Part-to-Picker	An arrangement of a supermarket where parts are delivered to the person assembling a kit (Limère 2012).	No Analogy.	~~~~~~
Picker-to-Part	An arrangement of a supermarket where the person assembling a kit travels to retrieve the parts from the storage shelving (Limère 2012).	Individual Cart Assembly	Supply Technicians must travel to the individual parts to gather for a case cart.
Border of the Line (BoL)	The area of a workstation, typically behind the workstation operator, where materials are stored (Limère 2012).	Electronic Cabinets, Core Room, or Sterile Field	The area and storage devices for materials retrieved during surgeries.
Pallet	The largest possible unit of measure in which a particular part is delivered to a workstation. Signifies Line-Supply (Limère 2012). Pallets are only delivered by forklift.	No Analogy.	~~~~~~

Plastic Box or Tote	A smaller unit of measure than a pallet, but still a container of a given part containing more than one copy of that part. Delivered to a workstation. Signifies Line-Supply or Downsizing (Limère 2012).	No Analogy.	~~~~~~
Tugger Train	A motorized vehicle that pulls a number of trailers behind it, each capable of holding one or more kits or totes (Limère 2012).	No Analogy.	~~~~~~
Milk Run	A supply run made by the tugger train (Limère 2012).	Case Cart Delivery, One-of Delivery, Cabinet Resupply	A delivery of a case cart to an operating room. Alternatively, the delivery of a single item to an operating room, or the resupply of the electronic cabinets in an operating room or in the core rooms.

Table 6: Conceptual mappings from Manufacturing-oriented literature on kitting to Operating Room terminology.

Some of the conceptual mappings in Table 6 are intuitive and obvious; others require a little more thought. We will discuss some of the less intuitive mappings here.

The first mapping that requires additional explanation is that of mapping an assembly to a surgery. An assembly is the result of a sequence of events that typically occur at different places throughout a facility. A surgery could be thought of as a sequence if we were to pull back our focus a little bit and look at the entire sequence of events surrounding a given surgical event (i.e., Pre-op, intra-op, post-op, and all of the events that happen in parallel to the patient's flow through the surgical event), but for our purposes we are strictly looking at the system during the intra-operative period and what must happen to provide materials for that portion of the surgical event. This reduces the number of "assembly stations" to one; the number of assembly stations in a manufacturing setting could be in the hundreds. Finally, the surgery event happens in the healthcare context and the output is a healthy patient, which is in contrast to the output of a manufactured product in the industrial context. Despite this gulf of domain context we still believe the operational management concepts from kitting literature can pertain to the arrangement of operating room systems and specifically the materials handling needs of such systems.

Associating kitting as a materials feeding policy to the case cart system requires some explanation. In many examples of kitting systems in the academic literature we found that systems used either kitting or line-supply as their feeding policy of choice. The case cart system in the case study effectively uses both, and in the case of line-supplied items not simply incidental items. This is another reason why the model from Limère (2012) appeals: it finds the optimal mix of materials under both policies.

The concept of a kit extends beyond just the materials delivered in the kit. Choobineh and Mohebbi (2004) define a kit as a specific collection of components and/or tools, and possibly instructions, needed for completing a procedure or product. In this light, we see how a Doctor Preference Card's material requests, which delivers much more than the material requirements for a surgery but also includes location, time, staff involvement, etc., is a broadly enough defined communication mechanism so as fit this encompassing definition of a kit.

The variability of the surgical schedule is the source of the variability in the kit mix. The surgical schedule varies from day to day based on number of surgeries, type of surgical service that works that day, the CPT code signifying the procedure being performed, the availability of resources and staff, and the unforeseen arrivals of trauma or late-posting surgeries. All of this lends itself to associating variable kit mix to the surgical schedule.

The definition of an Operator in Limère (2012) defines the cost of a materials handling technician as the same as an assembly operator. We must make a distinction in our model because a nurse is significantly more costly than a supply technician. Furthermore, when the assembly operator must leave their assembly station to retrieve materials from the Border of the Line (BoL), they are performing an anticipated action given their job function. A surgeon is never going to leave the sterile field around the patient to retrieve materials, so in effect the job functions in the assembly example map to different staff positions in the healthcare case study. The surgeon receives materials for use on the patient from the scrub nurse; the scrub nurse retrieves the materials from the sterile field; the circulator nurse retrieves materials from the core rooms or from the supply technicians and places them in the sterile field. The multiple roles involved with materials handling are required for patient safety reasons, but it is not a straightforward mapping from the assembly model to our new healthcare model.

The way we are ascribing the Border of the Line (BoL) to the electronic cabinets, core room, or sterile field is different from the description of the BoL from Limère (2012). The assembly system BoL is set of pallet-sized empty areas where materials are stored and presented to the assembly operator. It is literally all parallel and facing towards the assembly line. In the healthcare system there are four electronic cabinets in each operating room and a number in the core rooms. The cabinets in the core rooms are shared with multiple operating rooms. Additionally the sterile field is not to the back of the scrub nurse but rather they are standing right next to the materials presented for the surgery the entire duration of the surgery. The Bo L in the healthcare setting is not the same layout as the assembly setting's BoL and our model adjusts for that accordingly.

Kit type refers to which assembly a given kit provides materials for. Kit type could encompass scores of individual kits required for one final assembly, depending on the system. We will map this to how many case carts are required for a given doctor preference card. Kit batch size refers to how many copies of the same kit are being assembled at once. This could happen in theory in the case cart system as the same surgeon will perform the same CPT code more than once in a given day, but in practice each case cart is prepared individually. To refer to a batch of case carts in the hospital would refer to the entire mixture of carts prepared for a given day's surgeries – we must be careful with this distinction.

Case cart assembly begins in the early evening of the day before a set of scheduled surgeries. Late-posting surgery case carts are prepared on demand. In In the scheduled case, the lead time is significant and is allowable due to the relatively low throughput of surgeries – there is not a pressing demand for the case carts. In the late-posting case, the lead time should be as short as possible to allow for smooth patient flow.

The final mapping we will discuss is that of the Milk Run concept to either Case Cart Delivery, One-of Delivery, or Cabinet Resupply. In the Limère (2012) formulation, materials were brought to the BoL either by forklift or tugger train. The tugger trains were what would go on the milk run; the milks were circuits with constant paths and distances (only the stopping locations would change). The case cart system se materials delivered four ways: on case carts, through the core room electronic cabinets, by hand as a one-of, or through vacuum tubes as a one-of. Our cost model will address these accordingly.

4.3 Description of Materials Feeding Policy Decision Model for Case Cart Systems

This section will discuss in detail the Mixed Integer/Linear program we will use to model the case cart system. The cost function we will seek to minimize will consist of four parts: in-room part retrieval, internal transport, case cart assembly, and replenishment costs. There are a number of parameters and variables that are common to each of the four parts of the cost function and to the cost function's constraints; we will introduce them below.

The formulation from Limère (2012) has as a portion of the cost function the cost of replenishing the kit preparation area, called the supermarket. The supermarket is separate from the warehouse in the original model. In our case study there is no distinction between a warehouse and a supermarket – the central supply storage area functions as both, as it is where all replenishment actions occur with regards to the case cart system. There is therefore no tradeoff between supplying materials to the supermarket vs. supplying them directly to the line.

Variables:

x_i **Decision variable that assigns a part as follows: 1 – case cart; 0 – either bulk supply or one-of delivery**

z_i **Decision variable that assigns a part as follows: 1 – one-of delivery; 0 – either bulk supply or case cart**

y_i **Decision variable that assigns a part as follows: 1 – bulk supply; 0 – either case cart or one-of delivery**

Sets:

$s \in S$ **– The set of all unique CPT code and surgeon bill of materials, called Doctor Preference Cards**

$i \in I$ **– The set of all parts used on surgeries**

$i \in I_s$ **- Set of items used on DPC** S; $\bigcup_S I = I;\ \bigcap_S I = \emptyset$

Parameters:

q_{is} **– Units of item** i **required on DPC** s**, per year**

m_{is} **– The average number of copies of part** i **required per DPC** s **for one surgery**

OC_{nurse} **- Cost (wage) of a nurse ($/hr)**

OC_{tech} **- Cost (wage) of a supply technician ($/hr)**

OV **- Walking velocity of a nurse or a supply technician (ft/hr)**

τ^{prep} **– The amount of time it takes for a supply technician to search for a part on a shelf in the central supply area on average (hr)**

τ^{lift} **– The amount of time a supply tech waits for an elevator during a supply run on average (hr)**

The set $s \in S$ requires justification as it refers not to locations as it does in Limère (2012) but rather to individual bills of materials. This is a drastic change of assumptions from the original model of the kitting process. Since a case cart is used in one room at a time and can generally be used in any room (there are exceptions to this, admittedly, but for the sake of this model they are irrelevant), to talk about a set *S* that indexes all of the different rooms is not terribly insightful. What this model does is rather than assigning parts to polices based on which operating rooms they are used in, parts are assigned to policies given which surgeries they are used on. Therefore, when we refer to a DPC, we're referring to all of the parts a doctor automatically requests for a surgery and any part they might otherwise require according to the dataset. This allows us to think of the model as defining one 'ideal' operating room's materials feeding policies. Many parameters are averaged accordingly, such as distances involved with certain actions throughout the process. Additionally, since one of the goals of the model is to identify optimal kit composition, we are doing this directly by amalgamating part assignments across multiple kits/DPC's in one decision model through the use of the index set *S*.

Some final considerations for implementation of this model follow. A significant difference between the automotive case study and the operating room case study is that when supplying materials to the line in the automotive factory in bulk, the only workstation that a particular item will be supplied to is the only workstation that the item will be used at. In the operating room suite, the layout is designed to facilitate access to the same item for multiple operating rooms. Many items are stored in the core rooms, each of which adjoins fourteen of the operating rooms, which means that to fit this reality into the model some modifications will need to be made to how we build the constraints for each operating room's volume and "line-facing."

The cost to replenish a sterile instrument set will not be included in this model. There are instances where an instrument set is opened and presented to the scrub nurse, yet nothing from the set is actually used. The set must still go through the sterile reprocessing sequence regardless. Set re-sterilization happens with every set that is used on any surgery; hundreds of sets are re-sterilized daily. If data were available on set utilization, a cost function could be added to the model to describe how the unnecessary presentation of re-sterilizable materials leads to added and unnecessary costs and additional tradeoffs; unfortunately such data is unavailable. However, operating room administration has identified many such items that have a tendency to go unused during a surgery but still must be present just in case. Such items are sequestered as "hold" items in a special bag on the case cart, and if they go unused then they all go on the overflow cart to be restocked in the central storage area. Given the existence of hold items, materials from instrument sets that are presented are likely to be required, so in the event that they are not the probability of them not being needed was likely small and therefore negligible. Additionally, data on set-instrument utilization is not presently tracked[3] making the inclusion of a cost function to describe this aspect of the case cart system difficult.

4.3.1 Retrieval of Materials during a Surgery

Similar to the formulation from Limère (2012), there are two ways that a scrub nurse can gather materials for the surgeon at the point-of-use (surgery table). The first is for them to walk to the sterile field and retrieve a part from the case cart that has already been presented. We were not able to gather data on the time to search for the part in a sterile field. As a surrogate we will use the time to setup one part of a sterile field as the time to search for a part and retrieve it. This is a reasonable assumption because there was observed some time accrued to collect a part when the part was delivered to the sterile field from bulk-supply or as a one-of during the surgery. Hence we will use the same parameters to assign costs to both one-of delivery and case cart part retrieval (bulk-supply has additional costs as well). We introduce the following parameters:

T^{Field} – Average time to setup a sterile field

C^{Cart} – Average number of items on a case cart as per DPC (static number)

3 Information of this sort is not collected automatically and would require immense amounts of direct observation to develop a sufficient dataset. Such a study, however, would be immensely valuable to the hospital and clinicians.

τ^{Field} - Average time to set up one part of a sterile field;

$$\tau^{Field} = T^{Field}/C^{Cart}$$

Δ^{Field} - Distance from surgeon to sterile field that scrub nurse travels (an average) (ft)

The time parameter to retrieve a part from a case cart is therefore the travel time plus the sterile field setup time:

$$tp^k = \frac{2\Delta^{Field}}{OV} + \tau^{Field} \qquad (2.1)$$

The second time parameter is the time of retrieving the item from bulk supply. We are modeling the trip to bulk supply as the average distance a nurse must walk to the electronic cabinets. This assumption is admitting a modeling error in that some of the cabinets are closer to the circulator than others by a significant margin (the in-room operating room cabinets vs. the core room cabinets). Admitting this error allows us to simplify the model and still lets us do a sensitivity analysis later on this parameter. The circulator nurse must travel to the bulk storage from their desk, find the item, walk back to the sterile field, drop off the item and travel back to their desk. We assume the sterile field is on the way to and from the desk so we effectively are simply modeling the trip from the desk to the electronic storage cabinets and back. The scrub nurse must then retrieve the part from the sterile field; there is no setup time now. We introduce these parameters:

τ^{bulk} - Time to find a part in the electronic supply cabinet (hr)

Δ^{bulk} - Distance from circulator desk to location of part in electronic supply cabinet (walks past sterile field each time both directions) (an average) (ft)

The time to retrieve a part from an electronic supply cabinet is therefore the sum of the time it takes to walk to and from the electronic supply cabinet, the time it takes to find that part in the cabinet, and the time it takes a scrub nurse to walk to the circulator field to collect the part:

$$tp^{bulk} = \frac{2\Delta^{bulk}}{OV} + \tau^{bulk} + \frac{2\Delta^{Field}}{OV} \quad (2.2)$$

The final equation to model the cost of in-room part retrieval is therefore the sum of:

$$C_{pick} = OC_{nurse} \cdot \sum_{s \in S} \sum_{i \in I_s} q_{is}[x_i tp^k + y_i tp^{bulk} + z_i tp^k] \quad (2.3)$$

4.3.2 Internal Transport of Case Carts and Materials

There are three ways materials travel to the Operating Room from the central supply area that we will model here (not counting electronic cabinet replenishment, which we will describe later). These three ways are on a case cart, as a one-of by hand, or as a one-of that is small enough to be sent by vacuum tube. All of these methods are different from the ways in which the hospital supply room staff delivers materials to the operating room suite because everything is delivered without motorized delivery vehicles. The first of these we will describe will be case cart transport. We assume the case cart is already prepared for this portion of the formulation; it will simply calculate the cost to move the cart from case cart prep to an operating room. We also need to consider the number of case carts needed per DPC. We need these parameters and variables:

Parameters:

D^{cart} – Distance a cart travels to front door of rooms on average from central storage area (ft)

d_S – Demand for DPC S

C_S^{Cart} – The number of parts on DPC *s*; includes instances where a given part *i* is required to have multiple copies. q_{iS}/d_S

The yearly cost to deliver a set of case carts for one DPC is therefore the time to deliver the part, $\frac{2D^{cart}}{OV} + 2\tau^{lift}$, multiplied by the number of parts used per year and divided by the number of parts on a case cart, rounded up (this accounts for the sharing of the cost of the ride on the case cart for each part):

$$C_{tpt}^{cart} = OC_{tech} \cdot \sum_{s \in S} \sum_{i \in I_S} \left(\frac{2D^{cart}}{OV} + 2\tau^{lift} \right) x_i \frac{m_{is}}{C_S^{Cart}} d_S \quad (2.4)$$

The cost to transport a single item is accrued one of two ways. Either is it delivered by hand by a supply tech or it is sent by the supply tech to one of the core rooms via the vacuum tube system. We will break the sets of items down into two subset based on its size and ability to travel via the vacuum tubes. We will also consider the likelihood of an item needing to be sent as a one-of to account for the fact that items that are kept in the central storage area are not always required by the surgery (which is why they were left off the DPC in the first place). To calculate this number we will consider instances only where the item was not scheduled to be used and was used (this is opposed to the instance where an item was scheduled to be used, and more copies of it were used in a given day than were originally scheduled).

Sets:

$i \in I \cap I_w$ - The set of all items that must be walked up by a supply technician if not provided in an electronic cabinet or on a case cart; $I_w \cap I_t = \emptyset$; $I_w \cup I_t = I$

$i \in I \cap I_t$ – The set of all items that can go through the vacuum tube if not provided in an electronic cabinet or on a case cart; $I_w \cap I_t = \emptyset$; $I_w \cup I_t = I$

Parameters:

D^{single} - Distance a part goes from central sterile to an OR room. Will include finding the part, walking from central sterile to core, then through core into room (ft)

D^{tube} – Distance a supply tech walks to retrieve item then walk it to the vacuum tube (time to use the vacuum system and take phone call negligible) (ft)

Δ^{tube} – Distance a nurse walks to vacuum tube from circulator desk, back to desk (stops at sterile field along the way) (time to use vacuum system and place phone call negligible) (ft)

The costs to transport one-of items ($walk$, $tube$) is therefore the sum of the time to deliver and find the part, the yearly utilization of the part, and the likelihood of the part being needed when it was not initially present:

$$C_{tpt}^{walk} = OC_{tech} \cdot \sum_{s \in S} \sum_{i \in I_s \cap I_w} \left(\frac{2D^{single}}{OV} + \tau^{prep} + \tau^{lift} \right) q_{is} z_i \theta_{is} \quad (2.5)$$

$$C_{tpt}^{tube} = \sum_{s \in S} \sum_{i \in I_s \cap I_t} \left(OC_{tech} \cdot \frac{(2D^{tube} + \tau^{prep})}{OV} + OC_{nurse} \cdot \frac{2\Delta^{tube}}{OV} \right) q_{is} z_i \theta_{is} \quad (2.6)$$

The cost that we will model next is the cost to restock items that are kept in the electronic storage cabinets in both the core rooms and the operating rooms themselves. This is a nightly process where a utilization report is printed out to see what has been used the previous day. If the items are available in the central supply area (we assume they are for this model although in reality they could be on manufacturer backorder) a milk run is made to reset all utilized items back to par. After gathering all of the materials for a set of electronic cabinets on a cart, the supply technician travels to the locations of the electronic cabinets and restocks them. We will need parameters to account for the costs to gather the materials, travel with them, and restock the cabinets. The technician will also perform a spot check to verify the levels of various materials in the cabinets; we will include this activity as part of the restocking cost, $\tau^{restock}$. We introduce the following new parameters:

$D_{gather}^{restock}$ – The distance the supply technician walks while gathering materials for a milk run (ft)

$D_{cabinet}^{restock}$ – The distance the supply technician walks on the milk run (ft)

$\tau^{restock}$ - The average time it takes to place one part in the electronic cabinet (hr)

n_i – The average daily utilization of a given part (averaged over 365 days)

σ – The average number of parts on a milk run, on a daily basis

We define the cost to perform one milk run as:

$$tr^{restock} = \left(\frac{D_{gather}^{restock}+D_{cabinet}^{restock}}{OV\sigma}\right) + (\tau^{prep} + \tau^{restock})\sigma + 2\frac{\tau^{lift}}{\sigma} \quad (2.7)$$

Therefore the cost to restock one part on a yearly basis to the electronic supply cabinets is the cost to perform one milk run times the average total daily usage of a given part:

$$C_{tpt}^{restock} = OC_{tech} \cdot \sum_{s\in S}\sum_{i\in I_s}[y_i tr^{restock} n_i] \quad (2.8)$$

Finally, the total cost to transport materials for surgeries is the sum of the three cost functions described:

$$C_{tpt} = C_{tpt}^{cart} + C_{tpt}^{walk} + C_{tpt}^{tube} + C_{tpt}^{restock} \quad (2.9)$$

4.3.3 Case Cart Assembly

Case Cart assembly will be broken down by the tasks involved in preparing the cart. Materials must be gathered for the cart, the materials must be transferred to case cart, and the materials on the cart must be verified against the bill of materials. Transference of materials and verification of materials will both be static averages. Materials picking will be modeled as the distance an operator must travel on average to assemble a case cart plus a search cost to locate a part on the shelf. We need these parameters:

D^{prep} – The distance an operator walks on average to gather parts for a case cart; a circular path (ft)

$\tau^{transfer}$ – The amount of time it takes to transfer one part to a case cart from the picking cart (hr)

τ^{check} – The amount of time it takes to check for one part on a case prior to sending the cart to the operating room (an average) (hr)

The cost to place one item on a case cart is therefore:

$$tk^{kit} = \left(\frac{D^{prep}}{OV} + \tau^{prep} + \tau^{transfer} + \tau^{check} \right) \quad (2.10)$$

We multiply by the yearly utilization of that part for a given DPC and obtain:

$$C_{kit}^{prep} = OC_{tech} \cdot \sum_{s \in S} \sum_{i \in I_s} \left[x_i \frac{q_{is}}{m_{is}} tk^{kit} \right] \qquad (2.11)$$

A significant difference between the automotive assembly system that Limère (2012) models and the surgical case cart system we are modeling is that the kits do not move in the formulation from Limère (2012) during kit assembly. This induces an assumption into Limère's model that is insignificant to our case study: the notion that you can pick items for multiple kits at once. This is not a functional protocol that would typically characterize how orders are picked in the case cart system. In the case cart system, when an operator picks items for a surgery, the operator pushes the case cart through the aisles in the storage area, places each item on the cart immediately, and then pushes the cart back to the staging area. We are defining this as the parameter D^{prep}. In the automotive assembly case study, an operator will pick multiple copies of one item for multiple kits, walking to-and-from the kit preparation area and the aisles of storage racks. This will require us to introduce some significant changes to the model.

The original formulation from Limère (2012) also contained a parameter, θ, to model the potential to have multiple parts picked at once for a batch of kits. The case cart system, as we have noted, does not do batch assembly as defined in kitting literature. Therefore, basing the choice to include an item in a kit on opportunities for batch picking is irrelevant.

In addition to case cart preparation, the cost to restock items that have not been used even though they were on the case cart (i.e., they went to the overflow cart) must be considered. There is a probability with every part delivered on a case cart that it won't actually be needed. In this instance, the part is taken from the case cart by the circulator nurse to the overflow cart. A supply technician later comes and retrieves the overflow cart, delivers it the cart to central sterile supply, and places the parts back into storage. To model this, we introduce the following new parameters:

φ_{is} **- Probability of item *i* not being needed when it was present on the DPC initially**

$\Delta^{overflow}$ **– The distance to the overflow cart from sterile field (ft)**

$D^{overflow}$ **– The distance to the overflow cart from central storage (ft)**

μ **– The average number of parts that are sent back to central storage on the overflow shelf**

ρ **- The average number of bins used to sort overflow parts when they are returned to storage**

The time it takes a supply technician to gather the overflow cart and return the parts that were unused to the shelves is as follows. The overflow cart must be retrieved, meaning the supply technician must travel to and from the overflow cart; the overflow parts are sorted into bins, which are taken one bin at a time to the area of central storage where the parts are held; and finally, the part

must be placed back onto the shelf from which it came. Therefore the time to do all of these activities is:

$$tk_{tech}^{overflow} = \left(\frac{2D_{core}^{overflow}}{OV} + 2\tau^{lift} + \frac{2D^{prep}}{OV} + \tau^{sort} + \tau^{prep}\right) \qquad (2.12)$$

The cost to handle overflow materials that were delivered on case carts or as one-of deliveries is therefore:

$$C_{kit}^{overflow} = \sum_{s\in S}\sum_{i\in I_s}((OC_{tech} \cdot (tk_{tech}^{overflow} +) + OC_{nurse} \cdot \frac{2\Delta^{overflow}}{OV})\frac{q_{is}}{\mu}(x_i + z_i)\varphi_{is} \qquad (2.13)$$

Finally, we sum the costs to handle overflow parts and prepare case carts to obtain:

$$C_{kit} = C_{kit}^{overflow} + C_{kit}^{prep} \qquad (2.14)$$

4.3.4 System Constraints and the Complete Cost Function

Our complete model follows. As in the model from Limère (2012), the objective function will minimize the summation of the four costs described in the preceding four sections:

$$\text{Min } C_{total} = C_{pick} + C_{tpt} + C_{kit} \qquad (2.15)$$

The constraints on this objective function will now be described. The Limère (2012) model had five sets of constraints on this function: kit weight capacity, kit volume capacity, line-facing capacity (length and height), and variant part consistency. We will not use all of these constraints because they do not address an aspect of the case cart system that is relevant. Kit weight capacity is irrelevant because surgical materials do not weigh so much to be a concern for a case cart's ability to handle all of the materials on it. The spatial constraints will be adjusted as well. Stacking height nor BoL length devoted to material presentation are issues. Kit volume is negligible because rarely do DPCs ever require more than one case cart. We will instead give special attention to modeling the spatial characteristics of the electronic cabinets and open shelves in the core rooms. We will introduce constraint function parameters, sets, and the constraint function formulations now.

Sets

$i \in I_e$ – The set of instruments that can fit in the electronic supply cabinets; $I_e \cap I_c = \emptyset$; $I_e \cup I_c = I$

$i \in I_c$ – The set of instruments that can fit on the core room open shelving; $I_e \cap I_c = \emptyset$; $I_e \cup I_c = I$

Parameters

b_i – The size parameter for part *i*. Calculated as the product of the part's horizontal and vertical dimensions (1x1 = 1, 2x1 = 2, 2x2 = 4)

The first constraint on our cost function that we will introduce regards the number of items that can fit into electronic supply cabinets. We begin by putting a general size parameter on each part that signifies how many slots from a bulk-supply storage unit a part will take up: 1x1, 2x1, and 2x2. Supposing that there are eight cabinets, each of which contains eight slots on the horizontal axis and fifteen slots on the vertical axis to insert supplies into, there are a total of 8x8x15=960 slots. The constraint does not take into account the par level of a given item in an electronic cabinet; two items could both be designated as 2x1 sized items but one could be relatively skinny so that as many as fifty copies of the item could be fit into that 2x1 slot, whereas the other item could be bulkier and perhaps as few as four copies would be all that could fit into the slot. It is believed that the utilization parameter q_{is} within the objective function is sufficient to capture this reality.

We provide a constraint on the number of items that cannot fit into the electronic supply cabinets as well. These items go onto the open shelves in the operating room core rooms. We will construct this constraint similarly to the preceding electronic cabinet space constraint. We assume that there are sixteen slots on the horizontal axis of the supply shelf and five on the vertical axis. Parts come in three sizes: 1x1, 1x2 and 1x4. The constraints are written as:

$$0 \leq \sum_{i \in I_e} y_i b_i \leq 960 \qquad \forall\, i \in I_e \quad (2.16)$$

$$0 \leq \sum_{i \in I_c} y_i b_i \leq 80 \qquad \forall\, i \in I_c \quad (2.17)$$

Figure 28: Electronic cabinet storage space discretization. Two cabinets are shown. Accessed from http://www.hgpauction.com/auctiondata/201003-Vion/Omnicell9.JPG on 3/21/14.

Figure 29: Open storage shelf discretization. Accessed from www.metro.com/literature.download/7B7B47DC-112F-1523-E85546C3F7B1FF28 on 3/21/14.

To ensure that a part is assigned to only one materials feeding policy, the sum of the three binary variables must add up to one. That way only one of them can take the value of one for any particular part. This will also assign the part to the same materials feeding policy for every DPC.

$$x_i + y_i + z_i = 1, \qquad \forall i \in I \qquad (2.18)$$

We finally present the entire model here:

$$\text{Min}\, C_{total} = C_{pick} + C_{tpt} + C_{kit} \quad (2.15)$$

Where,

$$tp^k = \frac{2\Delta^{Field}}{OV} + \tau^{Field} \qquad (2.1)$$

$$tp^{bulk} = \frac{2\Delta^{bulk}}{OV} + \tau^{bulk} + \frac{2\Delta^{Field}}{OV} \; (2.2)$$

$$C_{pick} = OC_{nurse} \cdot \sum_{s \in S} \sum_{i \in I_s} q_{is}[x_i tp^k + y_i tp^{bulk} + z_i tp^k] \; (2.3)$$

$$C_{tpt}^{cart} = OC_{tech} \cdot \sum_{s \in S} \sum_{i \in I_S} \left(\frac{2D^{cart}}{OV} + 2\tau^{lift} \right) x_i \frac{m_{is}}{C_S^{Cart}} d_S \; (2.4)$$

$$C_{tpt}^{walk} = OC_{tech} \cdot \sum_{s \in S} \sum_{i \in I_S \cap I_w} \left(\frac{2D^{single}}{OV} + \tau^{prep} + \tau^{lift} \right) q_{is} z_i \, \theta_{is} \, (2.5)$$

$$C_{tpt}^{tube} = \sum_{s \in S} \sum_{i \in I_S \cap I_t} \left(OC_{tech} \cdot \frac{(2D^{tube} + \tau^{prep})}{OV} + OC_{nurse} \cdot \frac{2\Delta^{tube}}{OV} \right) q_{is} \, z_i \theta_{is} \, (2.6)$$

$$tr^{restock} = \left(\frac{D_{gather}^{restock} + D_{cabinet}^{restock}}{OV\sigma} \right) + (\tau^{prep} + \tau^{restock})\sigma + 2\frac{\tau^{lift}}{\sigma} \; (2.7)$$

$$C_{tpt}^{restock} = OC_{tech} \cdot \sum_{s \in S} \sum_{i \in I_s} [y_i tr^{restock} n_i] \quad (2.8)$$

$$C_{tpt} = C_{tpt}^{cart} + C_{tpt}^{walk} + C_{tpt}^{tube} + C_{tpt}^{restock} \quad (2.9)$$

$$tk^{kit} = \left(\frac{D^{prep}}{OV} + \tau^{prep} + \tau^{transfer} + \tau^{check} \right) \quad (2.10)$$

$$C_{kit}^{prep} = OC_{tech} \cdot \sum_{s \in S} \sum_{i \in I_s} \left[x_i \frac{q_{is}}{m_{is}} tk^{kit} \right] \quad (2.11)$$

$$tk_{tech}^{overflow} = (\frac{2D_{core}^{overflow}}{OV} + 2\tau^{lift} + \frac{2D^{prep}}{OV} + \tau^{sort} + \tau^{prep}) \quad (2.12)$$

$$C_{kit}^{overflow} = \sum_{s \in S} \sum_{i \in I_s} ((OC_{tech} \cdot (tk_{tech}^{overflow} +) + OC_{nurse} \cdot \frac{2\Delta^{overflow}}{OV}) \frac{q_{is}}{\mu} (x_i + z_i) \varphi_{is} \quad (2.13)$$

$$C_{kit} = C_{kit}^{overflow} + C_{kit}^{prep} \quad (2.14)$$

Subject to,

$$0 \leq \sum_{i \in I_e} y_i b_i \leq 960 \qquad \forall\, i \in I_e \quad (2.16)$$

$$0 \leq \sum_{i \in I_c} y_i b_i \leq 80 \qquad \forall\, i \in I_c \quad (2.17)$$

$$x_i + y_i + z_i = 1, \qquad \forall i \in I \quad (2.18)$$

4.4 Data Requirements

We will describe the nature of the data required to run this model. One simplifying assumption is the restriction we are making to the dataset to just orthopedic surgeries. There are a few reasons for doing this. One is a simplification of the data set, making analysis of the data easier. Another is the reality that orthopedic surgeries require the most materials out of any type of surgery; we can extrapolate the results here to make inferences about the rest of the surgical services. Additionally, we are afforded a reasonable justification for many of the averages we make on such parameters as distances and times – most of the orthopedic surgeries share the same operating rooms in the Operating Room suite. As we are no longer separating parts by location of use but rather by their frequency on bills of materials (DPCs), given the restriction to orthopedic surgical materials it is as if there was one operating room which served as the location for all these surgeries (hence the restriction to eight electronic storage cabinets). Room usage data revealed that four of the twenty-seven (~15%) operating rooms (2021, 2022, 2023 and 2025) held ~71% of all orthopedic surgeries, so some of our parameters will be calculated using only those four rooms. We will note when we use a parameter that is restricted to just orthopedics (most of distance related ones will be).

The data required for this model is complicated. Data from the hospital's inventory management systems, human resources information on labor costs,

access to the operating room facility's layout schematics and a set of time-motion studies will be required. All of these requirements are meant to allow us to adapt the equations from Limère (2012) to the case cart system. Inventory management data will need to provide annual part usage, part package characteristics, part shape characteristics, in which operating room the parts are used, and if a part fits on or in a case cart, the vacuum-tube, the open shelves or the electronic cabinets. Layout schematics will provide average distances between part storage and point-of-use. Distances will be assumed to be *Manhattan.* Operator costs for both nurse and supply technician will be averages provided by human resources. Operator velocity will be fixed at 1 m/s, or 11,811 ft/hr (Limère (2012), adapting Meyers and Stewart (2002)).

The parameter θ_{is} needs special mention. It is defined as the probability of item i being needed when it wasn't present on the DPC initially. A 0 probability in this case would imply that it was available every time it was needed because the parameter is calculated as the sum of the number of times it was not available divided by the number of times it was needed. If the part was always available, the then the numerator would be equal to zero. Therefore a θ_{is} that was equal to 0 would reduce the rest of its cost function to zero, biasing the result. To account for this, we are saying that having the part n times out of n times is functionally equivalent to not having the part n times out of n times; in other

words, we change every $\theta_{is} = 0$ to $\theta_{is} = 1$during preprocessing. This allowed the model to find an optimal solution that was reasonable.

Below we will present a table displaying the parameter, variable, or set that a term from the model belongs to, a description of the term, the corresponding parameter, variable, or set from Limère (2012) if applicable, and the static value of the parameter if applicable.

Sets

Term	Mapped term from Limère (2012)	Description	Static Value	Cardinality
$s \in S$	$s \in S$	The set of all unique CPT code and surgeon bill of materials combinations, called Doctor Preference Cards	~	868
$i \in I$	$i \in I$	The set of all parts used on surgeries	~	1124
$i \in I_s$	$i \in I_s$	Set of items used on DPC *S*	~	[2, 216]
$i \in I_s \cap I_w$	I_b	The set of all items that must be walked up by a supply technician if not provided in an electronic cabinet or on a case cart	~	610
$i \in I_s \cap I_t$	I_p	The set of all items that can go through the vacuum tube if not provided in an electronic cabinet or on a case cart	~	514
$i \in I_e$	~	The set of instruments that can fit in the electronic supply cabinets	~	704
$i \in I_c$	~	The set of instruments that can fit on the core room open shelving	~	420

Parameters

Term	Mapped term from Limère (2012)	Description	Static Value	Cardinality
q_{is}	q_{is}	Usage of item i with DPC s, per year	~	57847
d_s	d	Demand for DPC S	~	3204
m_{is}	m_{is}	The number of copies of part i required per DPC s (an average, rounded up)	~	57847
b_i	~	The storage slot utilization parameter for part i. Calculated as the product of the part's horizontal and vertical dimensions (1x1 = 1, 2x1 = 2, 2x2 = 4)	~	1124
OC_{nurse}	OC	Cost (wage) of a nurse ($/hr)	36.15	~
OC_{tech}	OC	Cost (wage) of a supply technician ($/hr)	13.84	~
OV	OV	Walking velocity of a nurse or a supply technician (ft/hr)	11,811	~
τ^{prep}	τ^{k}	The amount of time it takes for a supply technician to search for a part on a shelf (hr)	0.00151	~
τ^{bulk}	τ^{bulk}	Time to find a part in the electronic supply cabinet (hr)	0.0129	~
T^{Field}	~	Average time to setup a sterile field (hr)	0.5	~
C^{Cart}	~	Number of items on a case cart as per DPC; calculated as the average size of a DPC, $i \in I_s$ (hr)	67	~
τ^{Field}	~	Average time to set up one part of a sterile field; T^{Field}/C^{Cart} (hr)	.0075	~
τ^{lift}	~	The amount of time a supply tech waits for an elevator during a supply run on average (hr)	.0075	~
$T^{transfer}$	~	Average time to transfer materials from picking cart to a set of case carts (hr)	.1	~

$\tau^{transfer}$	~	**The amount of time it takes to transfer one part to a case cart from the picking cart (hr) $T^{transfer}/C^{Cart}$**	**0.0015**	~
T^{check}	~	**Average time to audit one case cart (hr)**	**.2**	~
τ^{check}	~	**The amount of time it takes to check for one part on a case prior to sending the cart to the operating room (an average) (hr) T^{check}/C^{Cart}**	**0.003**	~
$\tau^{restock}$	~	**The average time it takes to place one part in the electronic cabinet (hr)**	**.0027**	~
τ^{sort}	~	**The average amount of time it takes to sort the items on the overflow cart**	**2**	~
θ_{is}	~	**Probability of item i being needed when it wasn't present on the case cart (and was not listed on the DPC initially)**	~	**57847**
φ_{is}	~	**Probability of item i not being needed when it was present on the DPC initially**	~	**57847**
n_i		**The average number of part *i* used on a daily basis**	~	**1124**
σ	~	**The average number of parts on a milk run**	**374**	~
C_s^{Cart}		**The number of parts on DPC s**	~	**868**
μ	~	**The average number of parts that are sent back to central storage on the overflow shelf on a daily basis (weekdays only)**	**267**	~
Δ^{Field}	Δ^k	**Distance from surgeon to sterile field that scrub nurse travels. Not restricted to allow for variation in sterile field setup locations – each room's setup when observed functions as a sample location for the restricted case (an average) (ft)**	**6.2963**	~
Δ^{bulk}	Δ_{is}^{bulk}	**Distance from circulator desk to location of part in electronic supply cabinet (walks past sterile field each time both directions) (an average of the average distances to electronic cabinets and open shelves in the four high**	**39.583**	~

		utilization rooms) (ft) (restricted)		
Δ^{tube}	~	**Distance a nurse walks to vacuum tube from circulator desk, back to desk (stops at sterile field along the way) (time to use vacuum system and place phone call negligible) (an average) (ft) (restricted)**	**52.25**	~
$\Delta^{overflow}$	~	**The distance to the overflow cart from sterile field (an average) (ft)**	**45**	~
D^{cart}	D^{k}	**Distance a cart travels to front door of rooms on average from central storage area (an average) (ft) (restricted)**	**305**	~
D^{single}	D^{b}	**Distance a part goes from central sterile to an OR room. Will include finding the part, walking from central sterile to core, then through core into room (an average) (ft)**	**317.9375**	~
D^{tube}	D_{s}^{p}	**Distance a supply tech walks to retrieve item then walk it to the vacuum tube (time to use the vacuum system and take phone call negligible) (an average) (ft)**	**145.1875**	~
D^{prep}	Δ_{is}^{k}	**The distance an operator walks on average to gather parts for a case cart; a circular path. Orthopedic parts determined the path used to model this parameter (an average) (ft)**	**312.75**	~
$D_{core}^{overflow}$	~	**The distance to the overflow cart from central storage (an average) (ft)**	**275.6875**	~
$D_{cabinet}^{restock}$	~	**The distance the supply technician walks on the milk run (a circular path – calculated over the four highly utilized orthopedic surgery rooms) (an average) (ft)**	**740**	~

Variables

Term	**Mapped term from Limère (2012)**	**Description**	**Static Value**
x_i	x_{is}	**Decision variable that assigns a part as follows: 1 – case cart; 0 – either bulk supply or one-of**	~

		delivery	
y_i		Decision variable that assigns a part as follows: 1 – bulk supply; 0 – either case cart or one-of delivery	~
z_i		Decision variable that assigns a part as follows: 1 – one-of delivery; 0 – either bulk supply or case cart	~

Cost and Time Factors

Term	Mapped term from Limère (2012)	Description	Static Value
C_{pick}	C_{pick}	Yearly cost of in-room part retrieval ($)	~
C_{tpt}	C_{tpt}	Yearly total cost to internally transport materials for surgeries	~
C_{tpt}^{tube}	C_{tpt}^{pallet}	The costs to transport one-of items via vacuum tube ($)	~
C_{tpt}^{walk}	C_{tpt}^{box}	The costs to transport one-of items via hand delivery ($)	~
C_{tpt}^{cart}	C_{tpt}^{kit}	The yearly cost to deliver case carts for one DPC ($)	~
$C_{tpt}^{restock}$	~	The cost to restock one part on a yearly basis to the electronic supply cabinets	~
$C_{kit}^{overflow}$	~	The cost to handle overflow materials ($)	~
C_{kit}^{prep}	C_{kit}	The yearly cost to prepare case carts	~
C_{kit}	~	The costs associated with handling materials delivered on case carts	
C_{total}	C_{total}	The yearly total labor cost ($); we seek to minimize this cost factor	~
tp^k	tp^k	The cost to retrieve a part from a case cart (hr)	0.00857
tp^{bulk}	tp^{bulk}	The cost to retrieve a part from bulk supply (hr)	0.0207
$tr^{restock}$	~	The cost to perform one milk run (hr)	1.5748
$tk_{tech}^{overflow}$	~	The time it takes a supply technician to gather the overflow cart and return the parts that were unused to the shelves	2.0897

tk^{kit}	~	The cost to place one item on a case cart	0.0325

5 Model Results

This chapter will present the initial results of the model, verification of the model's output, adjustments to the parameters of the model and a sensitivity analysis on the parameters in the model.

5.1 Initial Results and Model Adjustments

The initial run of the model was coded in AMPL and solved using Gurobi 5.6.2. The prior assignment of parts to a given feeding policy was found using extrapolation from the part usage data set. Since some items are currently stored in more than one location, we made an assignment to one of the three policy choices based on where the part was most likely to be drawn from given its use. The list of initial policy assignments, as well as all optimal assignments, is presented in Appendix C, Table iii. The base, non-optimized cost to run the system based on the part assignments from our data set is $207,930.92. The optimal policy assignments for parts feeding cost on a yearly basis is $176,909.01 according to the initial model formulation. AMPL/Gurobi took 0.15 seconds to find the optimal solution using an Intel i5 2.7 Ghz with 8.00 GB RAM. When setting all variables to assign parts to case carts, the yearly cost was $204,048.69. When setting all variables to assign parts to line-supply and removing the space constraints, the yearly cost was $188,517.77. Finally, when setting all parts to one-of delivery, the yearly cost was $232,775.62.

We reached out to hospital administration again to validate these results. Including fringe benefits, the total cost to employ supply technicians is about $760,000 annually. The yearly cost to employ scrub nurses is about $1.96 million. The descriptive part-policy assignment results in 65% of the labor cost to run the system is accrued by the nurses and 35% is accrued by the supply technicians. Alternatively, $135,155.10 is accrued by nurses and $72,775.82 by the supply technicians. Seeing as how both figures are ~ 7% and ~ 10% of the overall yearly labor costs, and given the amount of time each role's workday is committed to each set of tasks described in the model, our analysis seems reasonable. Regarding the supply technician time and cost for labor, orthopedic surgery is just one of twenty different types of services provided, but it is commonly assumed that orthopedic surgeries have significantly more requirements for surgical instrumentation. Although data is not offered to verify this assumption this analysis assumes that assigning ~ 10% of the overall cost to run the entire materials feeding system in the Operating Room suite to orthopedics is appropriate. Below in Table 7 we display the cost breakdown across the various sub-cost functions and the percentages of the total cost function that those sub-costs represent.

Cost Function	Descriptive Cost	Optimal Cost	All Case Cart	All Bulk Supply	All One-of Delivery
C_{pick}	**$129,630.86** **62.34%**	**$115,520.90** **65.30%**	**$89,454.16** **43.84%**	**$174,566.68** **92.60%**	**$66,263.51** **28.47%**
C_{tpt}^{tube}	**$162.74** **0.13%**	**$10,946.51** **6.19%**	**$0.00** **0.00%**	**$0.00** **0.00%**	**$76,639.13** **32.92%**
C_{tpt}^{walk}	**$258.90** **0.12%**	**$6,857.12** **3.88%**	**$0.00** **0.00%**	**$0.00** **0.00%**	**$80,242.10** **34.47%**
C_{tpt}^{cart}	**$2,850.76** **1.37%**	**$1,861.24** **1.05%**	**$5,550.12** **2.72%**	**$0.00** **0.00%**	**$0.00** **0.00%**
$C_{tpt}^{restock}$	**$6,747.90** **3.25%**	**$5,721.24** **3.23%**	**$0.00** **0.00%**	**$13,951.09** **7.40%**	**$0.00** **0.00%**
$C_{kit}^{overflow}$	**$11,273.03** **5.42%**	**$5,899.20** **3.33%**	**$13,001.46** **6.37%**	**$0.00** **0.00%**	**$9,630.88** **4.14%**
C_{kit}^{prep}	**$60,274.52** **28.99%**	**$30,102.80** **17.02%**	**$96,033.43** **47.06%**	**$0.00** **0.00%**	**$0.00** **0.00%**
Total:	**$207,930.92**	**$176,909.01**	**$204,048.69**	**$188,517.7**	**$232,775.62**

Table 7: Sub-cost function values under various part-policy assignment schemes. Displays total dollar value and percentage of overall total cost.

5.2 Sensitivity Analysis

To add additional insight to the analysis of the case cart system, a sensitivity analysis on the parameters within the part-policy assignment model was performed. The sensitivity analysis was performed in Microsoft Excel 2010 and Palisade @Risk 6. We seek to identify which parameters, within reason, most significantly affect the sum total of the cost function. The same methods for sensitivity to parameter input were performed on both the descriptive case and the optimal case. Random samples were drawn from Triangle distributions with means equal to the original parameter and maximum and minimum values equal to the mean plus or minus 10% of the mean, respectively. Each simulation was run for 10,000 iterations. Due to file size constraints and computer RAM limitations, random samples were not drawn for each $i \in I$ and $s \in S$ (which would be possible with sufficient computing power). Rather, *i/s* indexed parameters were summed or averaged (as necessary) for each $s \in S$ and a Triangle distribution was assigned for each $i \in I$. To perform the sensitivity analysis on the optimal case, the variables were held constant according to the result from the AMPL/Gurobi BIP optimization; no new set of optimal policy assignments was obtained. Rather, by identifying which parameter changes the value of the total cost function to the greatest extent while holding the optimal assignments constant, we will either identify which parameters are the best opportunity to address in terms of operational improvements or we will identify those parameters that significantly affect the model but which about which not much can be done operationally. Finally, distance parameters were not included in the sensitivity analysis because there is no opportunity at this time to change the physical layout of the hospital from the case study (those wishing to adopt this model to another hospital that does have an opportunity to optimize the physical layout of the operating room with regards to the layout of the case cart system may also wish to include such an analysis).

We designed three different parameter sensitivity analysis experiments. The first was to add the Triangle distribution mentioned above to every parameter that was not related to walking distances. The results of that experiment prompted the design of the second, where operator wage parameters were held constant while the rest of the parameters that previously had Triangle distributions continued to have the same distributions as the first experiment. The third experiment was to remove the Triangle distributions from all non-indexed parameters to identify which part parameter (and therefore which part) most affects the output of the model. @RISK performs parameter sensitivity analyses by developing a multi-variate stepwise regression model. Every input variable is mapped to the output parameter of interest and a unique regression hyper-plane is developed that serves as the regression curve for the entire model. The closer the regression coefficient is to one, the closer the random variable that represents the input for a given parameter is to the hyper-plane. A regression coefficient above

0.60 is considered significant. This coefficient is not the same as the R^2 for the regression model. The regression coefficient in the tornado graph is interpreted to mean the extent to which a one unit change in the input distribution for a given parameter changes the output distribution function, on average. We see in the "Regression – Mapped Values" graphs how much a one-standard deviation change in a given input distribution changes the output function. For both experiments we will present the descriptive part-policy assignment parameter sensitivities, then the optimal case.

The initial sensitivity experiment clearly showed that the two most significant parameters in terms of effect on the total cost function were the two parameters for operator costs, OC_{nurse} and OC_{tech}. This implies that the biggest change the hospital administration could make to affect the total cost to run the case cart system would be to adjust the amount of wages it paid its employees. For instance, a one standard deviation change in the hourly wage of a scrub nurse based on our input distribution is $3.62 and a shift of that much hourly wage cost in the input function corresponds to a $4,757.32 annual change in the cost function. Similarly, the optimal case is even more sensitive the cost of a scrub nurse, with a regression coefficient of 0.82 and a $4,824.04. The results of both the descriptive and optimal sensitivity analyses under the parameter randomization conditions we have just been describing are in tables (8-11).

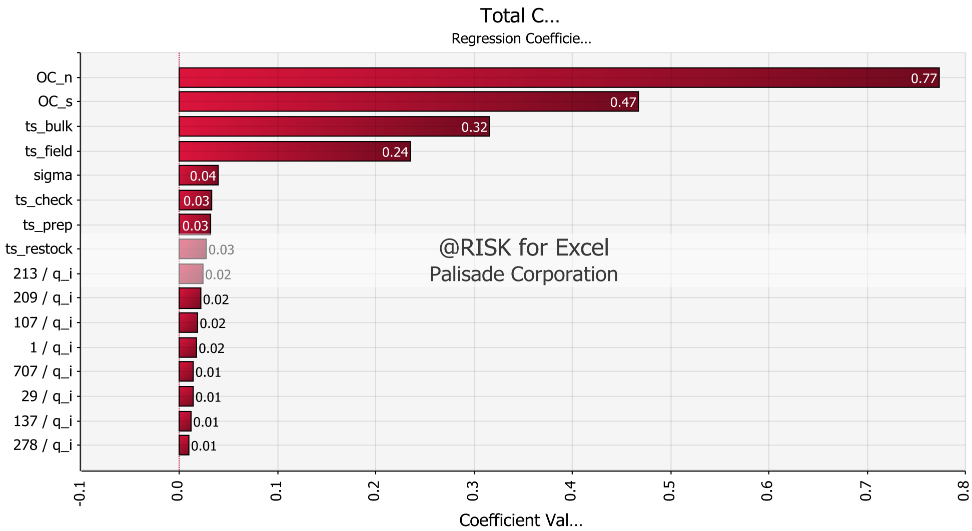


Table 8: Regression coefficients tornado graph displaying which part-policy model parameters most affect the total cost function. This is for the descriptive case where all non-distance parameters are included.

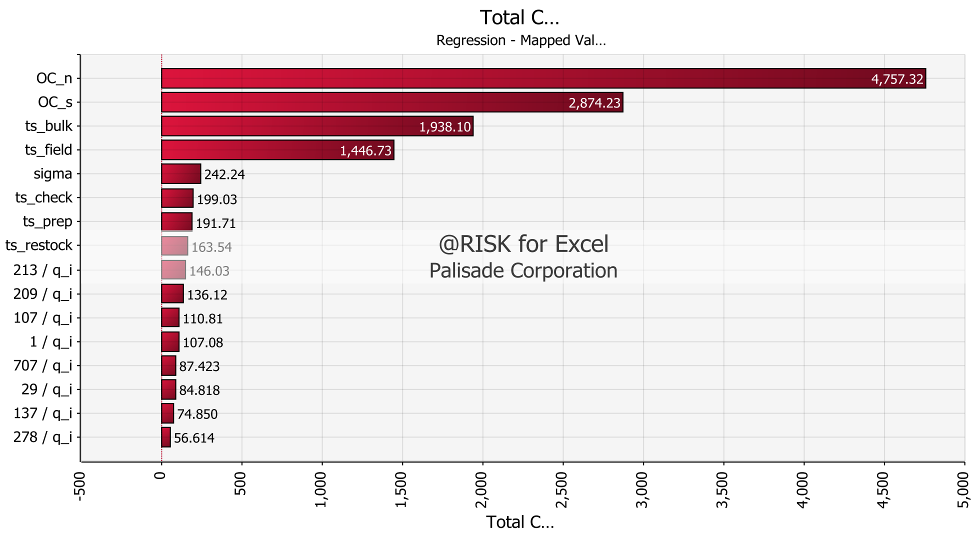


Table 9: Regression mapped values for the descriptive case. The operator cost for a nurse ($36.15/hour) is the most significant driving factor of this model.

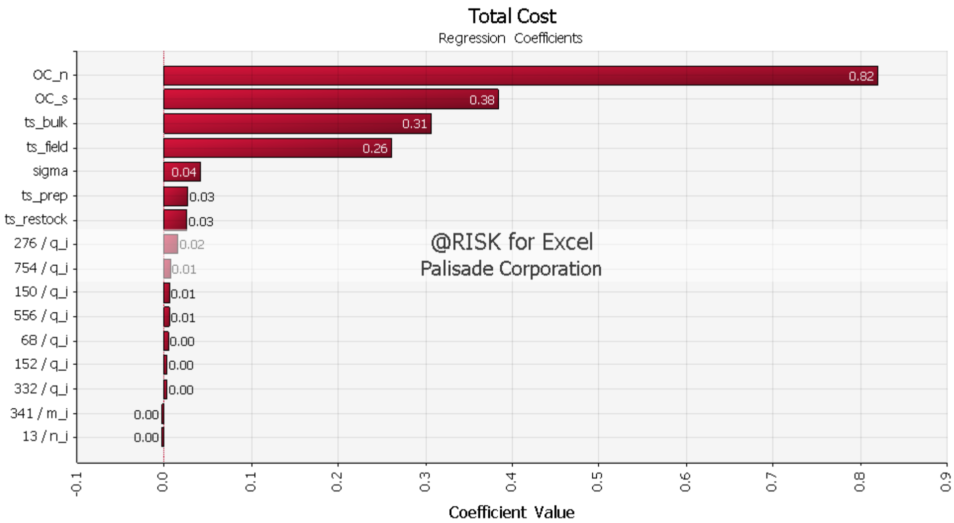


Table 10: This tornado graph is for the optimal case where all non-distance parameters are included.

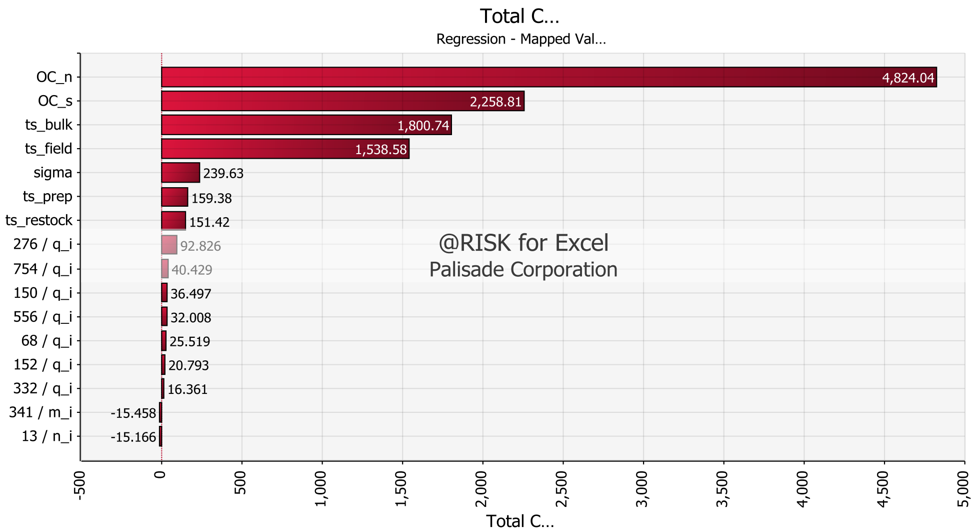


Table 11: Mapped regression values for the optimal case, all non-distance parameters.

Given the clear impact that the wage parameters have on the cost function, the next step was to hold for those parameters and identify the extent to which the other parameters in the model affect the cost function. For both the descriptive and optimal cases without variation on the distance or wage parameters, see Tables (12-15). The parameters τ^{bulk} and τ^{field} are the most senstitive paramters in the new experiement for both the descriptive and optimal cases with regression coefficients of 0.75 (descriptive)/0.73 (optimal) and 0.56/0.61 respectively. That the sensitivity to τ^{field} goes from 0.56 to 0.61 suggests that the optimal case finds a solution that is more weighed towards assigning parts to policies where sterile field setup times are a factor. Furthermore, mapped value regression tornado charts display the extent to which a standard deviation change in input effects the output of the cost function. For the optimal case, a one standard deviation change of in the input results in a positive change of $1,780.93 for the parameter τ^{bulk}, for example.

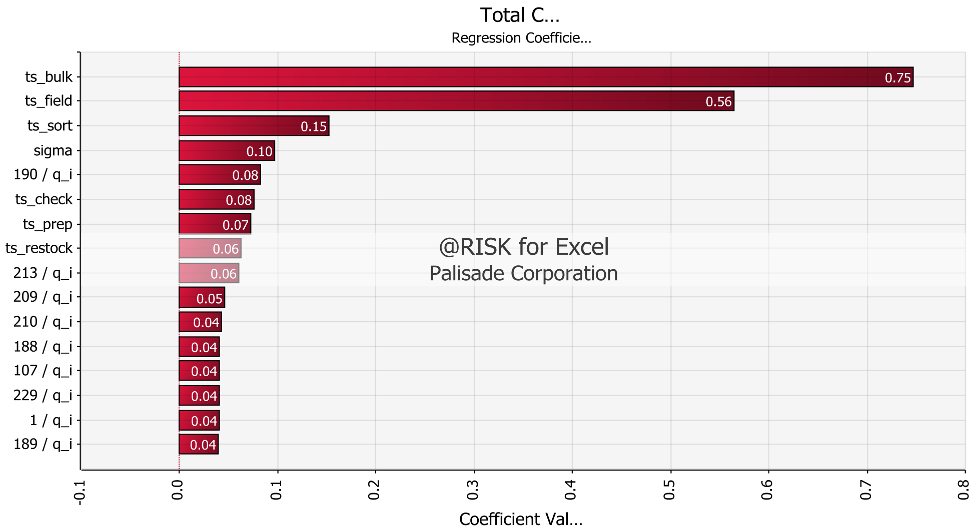


Table 12: Regression coefficients tornado graph displaying which part-policy model parameters most affect the total cost function. This is for the descriptive case where all non-distance and non-wage parameters are included.

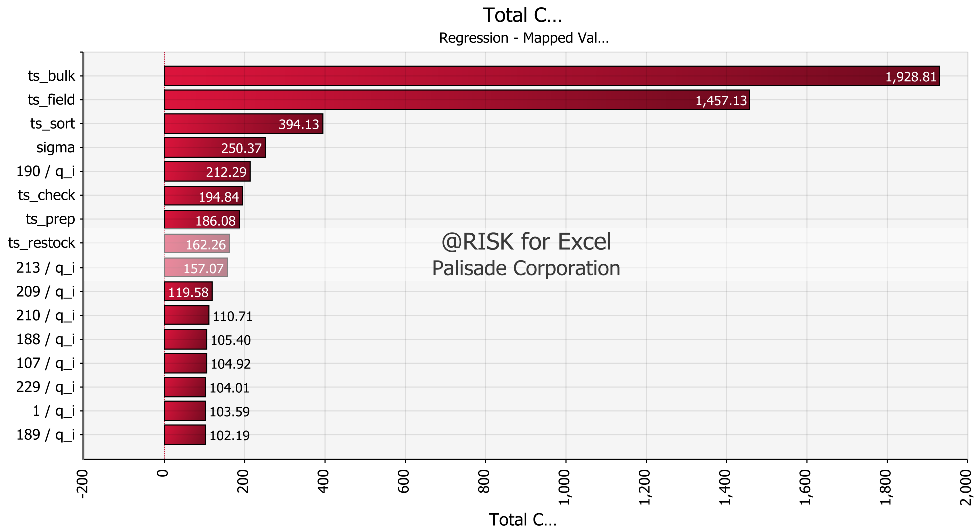


Table 13: Regression mapped values for the descriptive case without distance or wage parameters. The time it takes for an operator to search for a part in bulk supply is the most sensitive parameter.

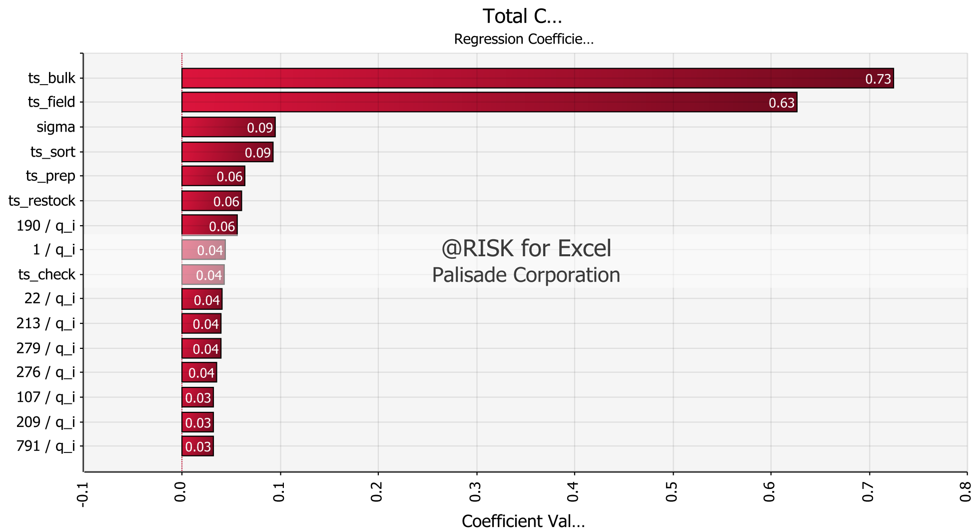


Table 14: This tornado graph is for the optimal case where all non-distance and non-wage parameters are included.

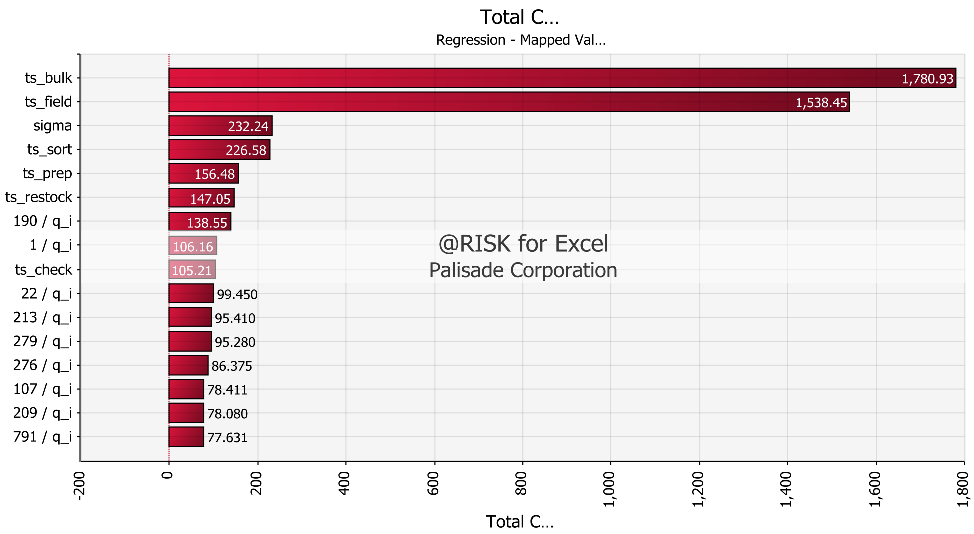


Table 15: Mapped regression values for the optimal case, not including distance or wage parameters.

The third experiment that was performed involved at only looking at indexed parameters and the sensitivity they add to the cost function. The descriptive and optimal cases are presented in Tables 17, 18, 20, and 21. The q_i parameter that refers to the number of times part *i* is used per year was shown to be the most significant (for varying *i*'s). Tables 16 and 19 display some additional information about each of the parts displayed in the tornado graphs for the third experiment. None of the regression coefficients are above 0.60 so none of these parameters can reliably be said to indicate any sort of correlation. However, seeing the ranking of these parameters confirms for us an intuition: items that have the highest annual utilization are the primary cost drivers of the system. A possible suggestion to administrative decision makers would be to focus on limiting the number of trips made to supply these high utilization items. Additionally, the optimal case found a part-policy assignment strategy that reduced the model sensitivity to any particular q_i. This suggests that optimal strategy reduces the total variability in the system, which could result in fewer costs due to unforeseen or adverse events (such as stock-outs, etc.).

Part #	q_i	Std. Dev. q_i	θ_i	$\frac{m_i}{C^{Cart}} d$	m_i	φ_i	n_i
190	7,146.00	291.73	0.99	124.97	2.78	0.00	19.58
213	4,939.00	201.63	1.00	68.69	2.54	0.00	13.53
209	4,127.00	168.48	1.00	7.07	2.46	0.00	11.31
210	3,773.00	154.03	0.99	56.95	2.13	0.00	10.34
1	3,516.00	143.54	0.81	56.06	1.36	0.16	9.63
107	3,625.00	147.99	0.98	65.54	1.96	0.01	9.93
189	3,487.00	142.36	1.00	66.09	2.08	0.00	9.55
188	3,436.00	140.27	1.00	57.52	1.98	0.00	9.41
229	3,272.00	133.58	0.94	42.22	1.95	0.05	8.96
279	3,200.00	130.64	0.99	48.37	1.00	0.41	8.77
276	2,938.00	119.94	0.99	46.22	1.00	0.24	8.05
214	2,747.00	112.15	1.00	46.67	2.12	0.00	7.53
191	2,946.00	120.27	1.00	49.08	1.88	0.00	8.07
24	119.00	4.86	1.00	1.01	1.00	0.57	0.33
791	2,619.00	106.92	1.00	38.08	1.00	0.36	7.18
22	2,652.00	108.27	0.85	40.81	1.09	0.33	7.27

Table 16: Indexed-part only sensitivity analysis part-parameter graph for the descriptive case. The parts parameters that are the most sensitive are the most highly utilized parts.

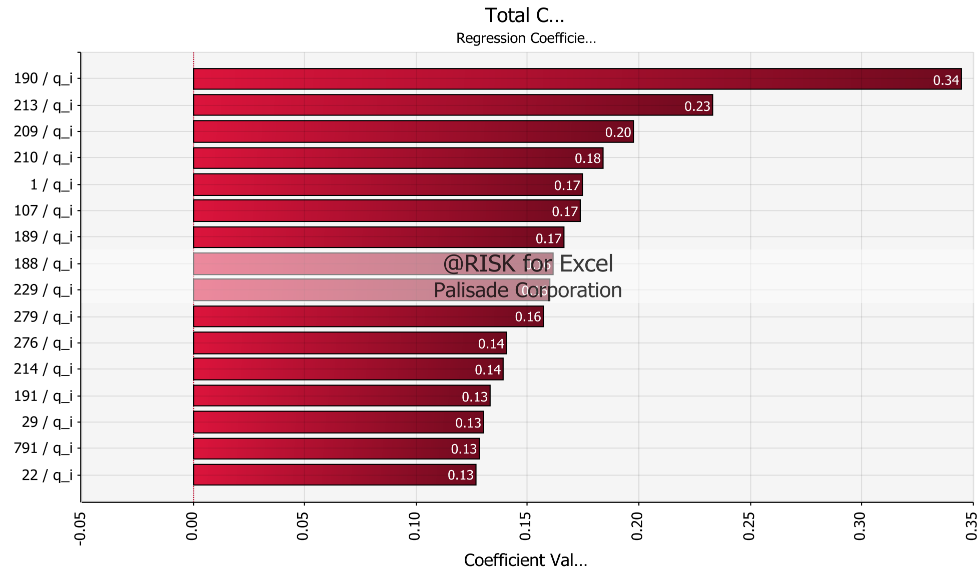


Table 17: Regression coefficients tornado graph displaying which indexed parameters most affect the total cost function. This is for the descriptive case.

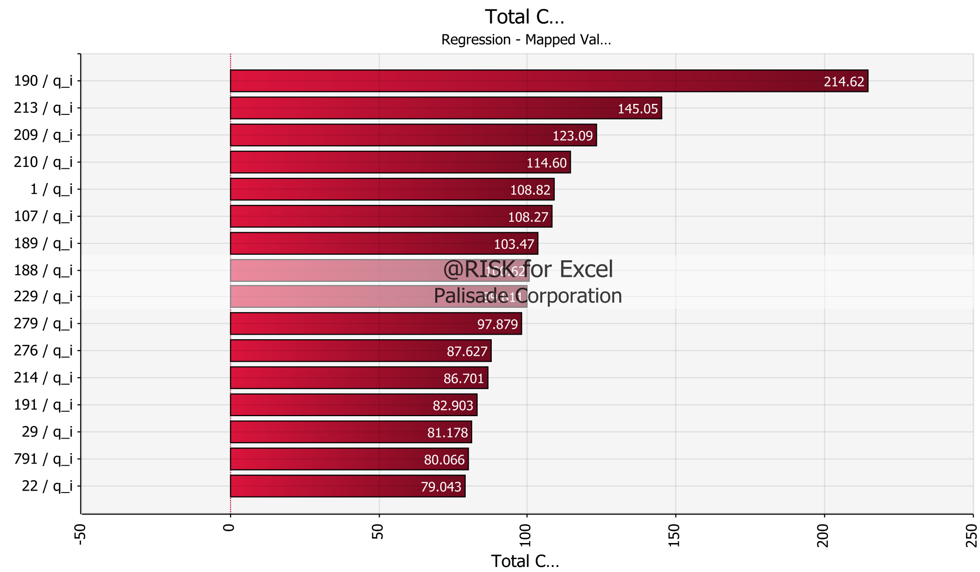


Table 18: Regression mapped values for the descriptive case with only indexed part parameters. The yearly utilization for the part #190 is the most sensitive parameter in the descriptive case for this experiment.

Part #	q_i	Std. Dev. q_i	θ_i	$\frac{m_i}{C^{Cart}} d$	m_i	φ_i	n_i
190	7,146.00	291.73	0.99	124.97	2.78	0.00	19.58
1	3,516.00	143.54	0.81	56.06	1.36	0.16	9.63
279	3,200.00	130.64	0.99	48.37	1.00	0.41	8.77
22	2,652.00	108.27	0.85	40.81	1.09	0.33	7.27
213	4,939.00	201.63	1.00	68.69	2.54	0.00	13.53
276	2,938.00	119.94	0.99	46.22	1.00	0.24	8.05
29	3,923.00	160.16	0.84	75.03	2.07	0.26	10.75
107	3,625.00	147.99	0.98	65.54	1.96	0.01	9.93
707	2,685.00	109.61	1.00	41.40	1.00	0.34	7.36
210	3,773.00	154.03	0.99	56.95	2.13	0.00	10.34
209	4,127.00	168.48	1.00	67.07	2.46	0.00	11.31
791	2,619.00	106.92	1.00	38.08	1.00	0.36	7.18
100	1,657.00	67.65	0.91	24.07	1.63	0.13	4.54
189	3,487.00	142.36	1.00	66.09	2.08	0.00	9.55
188	3,436.00	140.27	1.00	57.52	1.98	0.00	9.41
229	3,272.00	133.58	0.94	42.22	1.95	0.05	8.96

Table 19: Indexed-part only sensitivity analysis part-parameter graph for the optimal case.

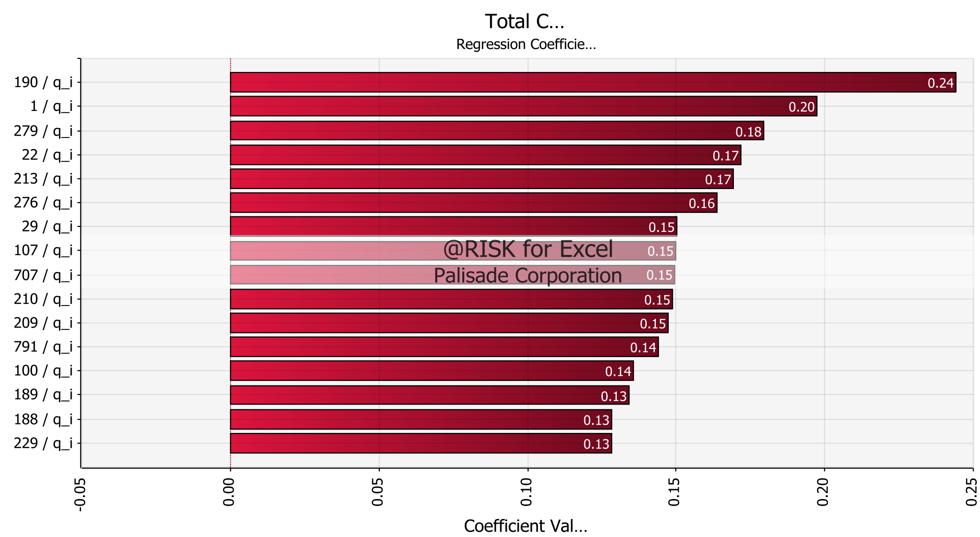


Table 20: This tornado graph is for the optimal case where only indexed parameters are included.

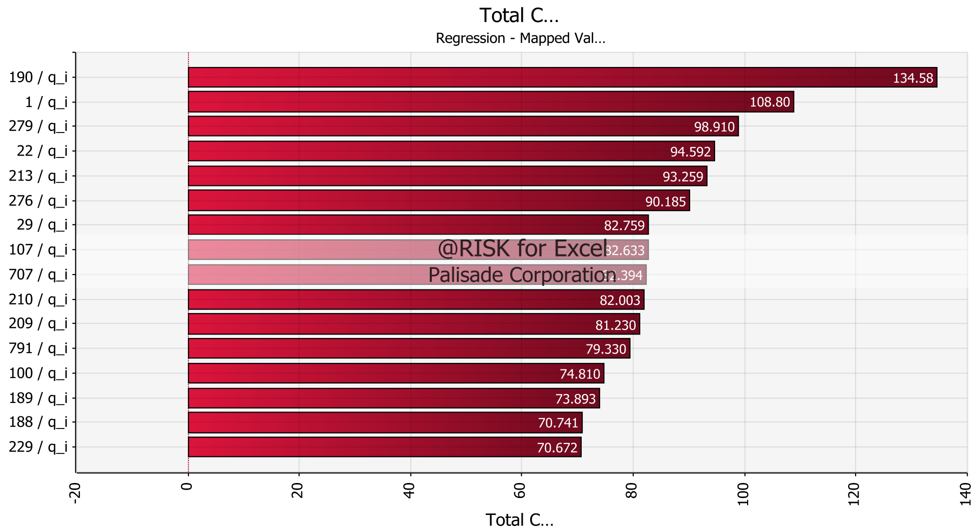


Table 21: Mapped regression values for the optimal case, indexed parameters only.

The preceding section on the sensitivity analysis experiments performed on part-policy assignment model concludes the analysis portion of this document. Any additional insights from the sensitivity analysis not described above will be discussed in the Conclusions chapter.

5.3 Differences between Initial Part Assignments and Optimal Part Assignments

To describe how this model might benefit the case study hospital system we sought to look into the differences between the initial case and the optimal case in terms of the parameters of the model. We prove a quantitative look at these differences here and in Appendix E.

The constraints on the objective function were exhaustive in the optimal case. This means that the optimal solution for the objective function was found when the constraint was maximized – 960 storage space units for line-supplied disposable items, 80 storage space units for line-supplied reusable items. In the initial case, 667 units of storage space are used by disposable items and 0 units of stage space are used by reusable items. To address the reusable item storage units number change, we must note that in the operating room reusable items are always stored as 'back-up' items in the operating room, and are not intended to be primarily delivered to clinicians through the open shelves in the operating room cores. To use the results of this model would suggest that this policy be changed – that some reusable items deliberately arrive at the surgery table by way of bulk supply. The discrepancy in the disposable item storage space unit numbers can be explained by the fact that presently the four electronic cabinets in the operating room cores hold a mixture of disposable items and implant items that could be used by multiple surgical services, not just orthopedics. To allow this much orthopedics this much space in the core room electronic cabinets may be too generous and a more reasonable assumption would involve reducing the size of the constraint on electronic cabinet space from 960 units (8 cabinets) to 840 units (7 cabinets), 720 units (6 cabinets), or less. Alternatively, the constraint could be eliminated and the results of the unbounded function could be analyzed as well. Finally, regarding the exhaustiveness of the constraints, we see many individual part assignments that are actually more costly to perform than they were previously. This provides the intuition that there are many parts that could be assigned to bulk supply that, in doing so, would increase the cost to deliver that one part per year, but would free up resources elsewhere to provide other parts less expensively.

To describe the differences between the initial case and the optimal case, an analysis of all the parameters and how they relate to the parts that changed policy assignments (or those parts that did not change) was performed in MS Excel. Parts were sorted according to which policy assignment they had in the optimal case. There were seven possible policy assignment outcomes – cart-to-line-supply, cart-to-one-of, line-supply-to-cart, line-supply-to-one-of, one-of-to-cart, one-of-to-line-supply, or no change. Table 22 some descriptive statistics are offered regarding each of these new arrangements. Parameters indexed over i and s are averaged over s are averaged over both indices. Appendix E has a list of all parts sorted by optimal policy assignment. Overall, it was not obvious why the model put out the results that it did; the intuition remains that because the optimal assignments were found along the boundary of the objective space and is therefore exhaustive, we can infer that the model found the mix of parameters and variable that minimizes this cost. As a final note, we did look at the extent to which the model found the objectively lowest amount of dollars per part; this was not always the case, as the difference between the cost to provide a given part via one policy over another would not necessarily ensure that the model assigned that part to the cheapest policy. Some combination factors related to the difference in costs between policies and the size of the part were likely what affected the model's

no change	q	theta	m	phi	n	b	initial cost	optimal cost	count
average	154.2949495	0.993381769	1.210591707	0.243302843	0.4227259	2.743434343	119.7950807	118.719189	495
standard deviation	389.5181102	0.022639828	0.524290051	0.26115127	1.0671729	1.237419413	261.3339156	257.5765479	
max	3923	1	7.714285714	1	10.747945	4	2837.041529	2837.041529	
min	1	0.813294103	1	0	0.0027397	1	0.990667671	0.990667671	
cart to shelf	q	theta	m	phi	n	b	initial cost	optimal cost	count
average	231.1515152	0.981487937	1.115397699	0.577827962	0.6332918	2.443181818	187.6038985	193.3794204	264
standard deviation	446.3488297	0.068572309	0.299425912	0.230901874	1.2228735	1.223343561	360.3502649	340.3517238	
max	3200	1	3	1	8.7671233	4	2582.062825	2481.825093	
min	1	0.77	1	0	0.0027397	1	1.613789266	2.646903866	
cart to one-of	q	theta	m	phi	n	b	initial cost	optimal cost	count
average	126.5211268	0.968518582	1.042424867	0.392316417	0.3466332	2.802816901	129.8492942	101.8906092	213
standard deviation	352.8010501	0.077754352	0.13484512	0.328208739	0.9665782	1.288040617	325.1517005	246.6227882	
max	2652	1	2.01555514	1	7.2657534	4	2363.299424	1958.277541	
min	1	0.45	1	0	0.0027397	1	0.990667671	1.577913957	
shelf to cart	q	theta	m	phi	n	b	initial cost	optimal cost	count
average	1596.232558	0.985001067	2.2162378	0.026444103	4.3732399	2.11627907	925.0452773	1287.991484	43
standard deviation	1586.671071	0.02573761	0.684239035	0.059409444	4.347044	0.762492852	823.9230513	1280.276371	
max	7146	1	4	0.31	19.578082	4	3471.651997	5766.069047	
min	2	0.892490297	1.243858998	0	0.0054795	1	1.887581205	1.613789266	
shelf to one-of	q	theta	m	phi	n	b	initial cost	optimal cost	count
average	2.333333333	0.991857298	1.015185185	0.016748366	0.0063927	2.3	2.791846077	1.882754144	90
standard deviation	8.060167004	0.056336099	0.111863247	0.11731109	0.0220826	1.075258004	8.283682343	6.503705496	
max	71	1	2	1	0.1945205	4	68.55967344	57.28951894	
min	1	0.5	1	0	0.0027397	1	0.990667671	0.806894633	
one-of to cart	q	theta	m	phi	n	b	initial cost	optimal cost	count
average	35.27272727	0.990909091	3.973232323	0.188814617	0.0966376	2.727272727	23.38429919	41.66869016	11
standard deviation	68.04570656	0.030151134	6.482891453	0.236329708	0.1864266	1.009049958	25.36589146	65.95794329	
max	236	1	22	0.651960784	0.6465753	4	89.91705257	233.7975705	
min	2	0.9	1	0	0.0054795	2	1.887581205	1.981335343	
one-of to shelf	q	theta	m	phi	n	b	initial cost	optimal cost	count
average	60.19694298	0.639628046	5.223998146	0.313488028	0.1649231	2.258797241	5.256705353	8.384895376	8
standard deviation	79.71947164	0.469056643	7.374422599	0.364179045	0.2184095	1.48139016	5.431309951	7.913790324	
max	236	1	22	1	0.6465753	4	5.60591455	8.26914896	
min	1	0.030151134	0.111863247	0	0.0027397	1	5.959448669	8.833594622	

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outcome.

We noted that in Section 5.1 that the optimal case cost $176,909.01 whereas the hypothetical scenario where all part were supplied in bulk cost $188,517.70. This merits some discussion. First of all, all bulk-supply is going to expose the system to the greatest amount of nurse labor cost. There are indeed many items that warrant handling by supply technicians for this reason alone. This may be why the model made some surprising assignments, such as assigning surgical gloves to case carts. This removes the nurse from having to retrieve these gloves; some gloves are used thousands of times per year, meaning that a nurse, as the system functions now, collects these loves thousands of times per year. To assign the gloves to the role of supply technician alone makes a certain amount of logical sense in this regard. The operating room administration should do a large degree of verification before they considered adopting some of these part-policy assignments.

6 Conclusions

We offer concluding remarks in this chapter. The contribution to the academic literature on kitting and materials feeding policy is described first, followed by the contribution to hospital management and any improvements in the clinical portion of the materials feeding system in the Operating Room. Section 6.2 follows with a description of the benefit of this study to the hospital from the case study and some potential approaches to implementing the ideas. We will conclude finally with suggestions for future research.

6.1 Academic Contribution

We will describe contributions to kitting literature, hospital administration literature and clinical literature here.

6.1.1 Contribution to Materials Feeding Policy Literature

One of the main goals of this thesis was to explore the potential for applying academic literature on materials feeding policy to healthcare. The case study performed at the hospital's Operating Room was fitting because of its relative size compared to other materials feeding systems in hospitals. This initial treatment of the conceptual mapping between healthcare materials feeding terminology, kitting literature concepts and assembly system terminology should generate additional interest in identifying opportunities for modeling and optimizing materials handling systems in healthcare systems at the provider level. Additionally, this thesis applies a state-of-the-art approach to modeling materials feeding policy decisions in a domain outside of which the approach was originally developed. The approach is, to reiterate, the modeling of the tradeoffs between three different transportation methods for every item in a parts inventory for all orthopedic surgeries and parts using a binary integer program. The use of this approach adds to the body of academic literature on kitting systems by broadening the set of domains in which in-depth analysis of the tradeoffs involved in a kitting system can be performed. Finally, the reasonableness of the model shows the extent to which describing materials feeding systems as kitting systems outside of manufacturing settings can be done. It should be noted here that many of the parameters in the model were taken to be averages, not cardinal numbers – this suggests that there is heavily stochastic nature to the system; indeed, as we have noted in preceding chapters, the system's demand for materials is difficult to forecast more than a day out. A mixed deterministic/stochastic approach to materials policy assignment tradeoffs is given a very brief and simplistic genesis within this paper.

6.1.2 Contribution to Healthcare Administration and Clinical Literature

The literature review that was performed for this thesis motivated the need for an analytical characterization of the materials supply system in the case study hospital's operating room suite. The characterization of the system as a kitting process was deemed to be novel, and therefore the conceptual mapping between assembly systems kitting processes and operating room suite case cart materials handle systems adds value to future attempts to develop analytic frameworks to improve materials delivery in hospitals. The emphasis on efficiency and expedience in the manufacturing sector leads to many insights into how to optimally run many process-driven systems – the operational benefits derived from such frameworks can, on a case by case basis, be applied to different processes in healthcare settings. It is hoped that this model demonstrates the practicality and effectiveness of using Operations Research techniques to model hospital processes outside the clinical processes that directly affect the patient, and that there are many opportunities to improve processes as well as advance the academic literature on managing hospitals.

Clinicians with an interest in hospital operations management would benefit to learn about this work as well. Mathematical programming is classic technique used to model systems in operations management and the new application of the classic methodology in this paper contributes to the hospital operations management literature. The tradeoffs involved with assigning parts to case carts vs. one-of delivery vs. bulk storage in electronic cabinets could be considered when making inventory purchasing decisions. This model provides a way to develop an appreciation for these tradeoffs. Cost saving measures such as this could strengthen the hospital/clinician relationship while saving the hospital money and making the parts the surgeons do need more available.

6.2 Contribution to Healthcare and the Case Study

The primary benefit of this thesis to the hospital case study's administration will be the identification of the costs and tradeoffs associated with the material requests of the surgeons who perform the surgeries. Primarily this benefit is demonstrated through the optimal assignments of parts to feeding polices that result in the lowest possible yearly labor cost. The benefit of $31,021.91 is roughly equal to the yearly cost in wages for one full time supply technician at the case study hospital. However, even if the optimal set of policy assignments for each part contains numerous assignments that are infeasible due to other practical concerns, the model formulation should provide an appreciation for the cost and labor involved with current part assignment policies. Surgeons may be presented with this information when making choices based on what parts to use, and the awareness of the costs involved could result in material requests that are closer to optimal than historical preferences or practices.

A potential limitation to the applicability of this work to healthcare in general must be noted here. The case study hospital was a large trauma level 1 academic medical center. Such an institution also has research and education missions on top of the healthcare delivery mission. Therefore, the inventory in the Operating Room suite is likely going to be more expansive than it would otherwise be in hospitals that solely focus on providing healthcare. The great variety of surgeries provided by the surgeons in an academic medical center is due in part to the educational prerogative to teach how to perform these surgeries. The model from this paper would therefore better suit academic healthcare settings; it could, however, still offer insight to the non-academic Operating Room materials handling systems as long as the level of complexity with the model was appropriately adjusted.

One of the beauties of the part-policy assignment model is that it could be extended in multiple ways: it is flexible. The first model extension would be to include all surgical services besides just orthopedics; this would give a broader picture of the supply costs involved with the entire system. As it is now, we can only extrapolate the findings from the orthopedics-limited model. The second model extension would be to fix the policy assignments for some of the parts and rerun the model in Gurobi; this would allow us to find the optimal policy mix given the existence of the aforementioned practical constraints that were not previously taken into account in the model. Finally, we could extend the model by removing specific parts altogether from the formulation. This would be of benefit if we wanted to see the effects of substitutes or alternatives between parts or if we were able to identify parts for retirement from service.

In addition to the above, this model can be used to address questions of staffing levels, materials placement (are the electronic cabinets used frequently and efficiently enough to just their use?), and facilities layout. If the operating room ever expands its capacity, the model could (and should) be modified prior to the beginning of the expansion project to understand the costs associated with feeding the expansion rooms with materials. We see a confirmation of the intuitive insight that was known prior: the fewer trips to and from the operating room from the storage area, the better. Fewer trips frees up the supply technician to perform other tasks that could add value to the operation rather than correct a materials feeding system fault state (such as an electronic cabinet going empty in the middle of the day, which requires a one-of delivery to be made to restock the cabinet).

The sensitivity analysis could provide insights into the effects of variability in the case cart system. If every part experiences an additional standard deviation worth of yearly utilization the total cost for the year will be significantly more costly. Attempts to standardize materials feeding polices for a given component could reduce costs to the system. Anecdotally, from the case study, it was observed that the electronic cabinets would be incorrectly used, which mean that inventory restocking reports could be off and the cabinet would need to be resupplied with one item in the middle of the day. The less this sort of circumstance occurs, the few times the cost is accrued unnecessarily to deliver a part via the one-of policy.

Questions of quality are not explicitly captured in this model but there is a maxim that the fewer times a part is handled, the less likely it is to become damaged. Damaged parts are considered unsterile and if an unsterile part comes into contact with a patient the results are catastrophic. If a part experiences few restocking events, it will be less likely to become unusable, and therefore we minimize implicitly a source of risk associated with quality and patient safety.

6.3 Future Research

This section provides suggestions for additional research into materials feeding systems in the operating room and for kitting in general. Additional work breaks down into applying alternative methods, expansions on the work presented here, and using the domain to address issues in materials handling not otherwise covered in the literature.

This work used a deterministic approach to model the case cart system. Additional refinements to the model include: allowing multiple paths through storage; better data fidelity; non-*Manhattan* distances; the inclusion of implants to the data set; integrating the disposal, re-sterilization, and restocking activities; and extending the model to every surgical service besides orthopedics. Given the high level of variability in the system for material demands, a suitable addition to kitting in healthcare would be a discrete-event simulation of the case system. This would allow researchers to apply some of the stochastic analysis to kitting systems that has been demonstrated in the literature. Additionally discrete-event modeling would provide a better picture of some of the stochastic demands on inventory that we had to aggregate into averages in the deterministic model. Furthermore, the case cart system offers a concise opportunity to study a closed-loop supply chain. The re-sterilization process is in itself a kitting process, which in turn feeds the case cart system –an analysis of a multi-echelon kitting process that is also a closed-loop supply chain will be a unique contribution to kitting and closed-loop supply chain literature. To add an additional wrinkle, the analysis of the closed-loop kitting process could be specifically formulated to characterize the fact that this system is almost entirely contained with the confines of one organization.

Another analytic technique with stochastic underpinnings that could assist the understanding of the case cart system is agent-based simulation. Combined with a detailed and complete human factors analysis of how doctors choose instruments before and during surgeries, an agent-based model could be developed to track inventory levels as the simulation progresses. Attempts to model instances where a stock out leads to a disruption in the flow of surgeries would be beneficial and novel. As an extension to this idea, an agent-based model of the whole operating room suite that included pre-op, inter-op, post-op, materials feeding, etc. would be a novel application of agent-based modeling to a healthcare delivery system. Such a model would be very time consuming and expensive to make so it would take a lot of buy-in from interested parties prior to the study's initiation.

It must be noted that the materials supply system was observed to possess many opportunities for human factors and ergonomics improvement. Many technologies and process arrangements from other industries could be applied to the tracking and handling of materials in the operating room. Wither or not this is an opportunity for future academic research or not would require an in-depth literature review outside the field of kitting in healthcare settings. As such it is offered here as food for thought and a recommendation for additional case studies and systems engineering engagements. The expansion of the corpus of literature on kitting could include a more generalized analytic model that could be applied with more flexibility to domains outside of auto manufacturing. The level of modification to the model from Limère (2012) suggest that the model from that paper is not generalized enough to be used outside traditional manufacturing settings (undoubtedly it was not created to be applied in non-manufacturing settings, so this is not a criticism but an identification of an opportunity for further development). Additionally, a more generalized model of kitting systems could include a merger of both materials feeding policy decision making and system performance. As Limère (2012) was only deterministic, an opportunity remains to incorporate stochastic techniques (such as stochastic programming) into general kitting models. The expansion of the notion of a general kitting model should include part feeding policy decisions based on the part's ability to add variability and randomness to the overall performance of the system.

A final consideration for future research may also be the one with the most value for materials feeding in operating room suites and materials handling research. It was noted in Limère (2012) that research on the effects of kitting on the quality of the final assembly product had not yet been performed. The operating room suite could provide an ideal place to study this phenomenon as there are many delicate parts that require gentle handling. Parts that are poor quality (unsterile) are hazardous to the patient and a substitute must be found. First of all, there are the effects of these quality defects on the overall cost to run this system. A delay in a factory at one station holds up all the preceding assembly processes; a delay in the operating room is much more difficult to determine the effects of as the upstream processes are significantly more prone to variability than in the factory, and downstream effects are often unknown or chaotic. Analysis such as this should consider both defect rates per activity or assembly station (in the case of the operating room, per DPC) as well as the overall kitting-related defect rate of the system. Incidentally, agent-based modeling may be useful to understand the effects of disruptions on the overall operating room system. Understanding the effects of materials stock outs and other adverse materials handling events would be a significant component of the overall model of the dynamic effects of disruptions on operating rooms. Once the effects of kitting on quality in one domain begin to become discussed in the academic literature, we should begin to see significant development of research regarding this crucial issue around kitting systems.

Appendix A

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Appendix B

Equations, Variables, and other Nomenclature from Limère (2012)

Sets

I_b	Set of all parts supplied in small boxes
I_p	Set of all palletized parts
I	Set of all parts; $I = I_p \cap I_b$
I_s	Set of all parts used at station s
S	Set of all work stations s
V_i	Set of variant parts of $i \in I$; the family of part i

Parameters

a_i	Maximum number of units of a part i in one pick due to physical characteristics (weight, volume) of part i	
A^b	Capacity of the milk run tours for boxes (number of boxes per hour)	
A^k	Capacity of the milk run tours for kits (number of kits per hour)	
B^k	Batch size for assembling kits	
Δ_{is}^{bulk}	Average distance for the operator at workstation s to pick from a bulk container of part i	(m)
Δ_{is}^{k}	Average distance for the operator in the supermarket to pick from a bulk container of part i to kit for station s	(m)
Δ^k	Average distance for the line-operator to pick from a kit	(m)
d	Yearly demand for end product (= vehicle)	
D^b	Distance of the milk run tour for boxes	(m)
D^k	Distance of the milk run tour for kits	(m)
D_s^p	Distance of transport between the pallet warehouse and work station s	(m)
f_{is}	Percentage of end products for which part i is assembled at station s (frequency)	

H^b	Vertical stacking height of boxes (units) on the Border of the Line	
L^b	Length of a box along the line	(m)
L^k	Length of a kit container/rack along the line (we assume no stacking of kit containers)	(m)
L^p	Length of a pallet along the line (we assume no stacking of pallets)	(m)
L_s	Available length along workstation *s*	(m)
m_{is}	Number of units of part *i* assembled per vehicle (if the specific part variant *i* is used) at station *s*	
n_i	Number of units of part *i* contained in the original packaging; packing quantity of part *i*	
OC	Cost of labour (per hour) of an operator	(€/h)
OV	Average walking speed of an operator	(m/h)
$pack_i$	Supplier packaging of part *i* {Box, Pallet}	
q_{is}	Yearly usage of part *i* at station *s*; $q_{is} = m_{is} f_{is} d$	
ρ^b	Expected capacity utilization of the milk run tours for boxes	
ρ^k	Expected capacity utilization of the milk run tours for kits	
R^b	Constant cost for the replenishment of one box in the supermarket	(€)
R^p	Constant cost for the replenishment of one pallet in the supermarket	(€)
τ^{bulk}	Average time to search for the required part from bulk stock at the line	(hr)
τ^k	Average time to search for the required part from bulk stock in the supermarket	(hr)
θ_{is}	Number of units of part *i* that will on average be picked in one pick when part *i* is kitted for station *s*	
v_i	Number of units of part *i* that a kit can maximally hold; this categorical parameter represents the volume (small, medium, large, extra-large) of a part *i* {100, 20, 5, 1}	
V^b	Velocity of the material handling equipment for milk run tours for boxes	(m/h)
V^k	Velocity of the material handling equipment for milk run tours for kits	(m/h)
V^p	Velocity of the material handling equipment for pallets	(m/h)

w_i	**Weight of part *i***	**(kg)**
w^k	**Weight constraint on one kit; maximum weight per kit**	**(kg)**

Variables

K_s	**Integer auxiliary variable** **Number of kits needed at station *s* to assemble one vehicle**
N_s^b	**Integer auxiliary variable** **Number of facings needed to store boxes along station *s* (with vertical stacking of boxes)**
x_{is}	**Binary decision variable** $x_{is} = 1$, **if part *i* is bulk fed** **0, if part *i* is kitted**

Cost and Time Factors

C_{kit}	**The yearly labor cost for kit assembly**	**(€)**
C_{pick}	**The yearly labor cost for operator picking at the assembly line**	**(€)**
C_{repl}	**The yearly labor cost for the replenishment of the supermarket**	**(€)**
C_{total}	**The yearly labor cost**	**(€)**
C_{tpt}	**The yearly internal transport cost**	**(€)**
C_{tpt}^{pallet}	**The yearly labor cost for pallet transport**	**(€)**
C_{tpt}^{box}	**The yearly labor cost for box transportation**	**(€)**
C_{tpt}^{kit}	**The yearly labor cost for kit transport**	**(€)**
tp_{is}^{bulk}	**Average time to pick a unit of part *i* from a bulk container**	**(hr)**
tp^k	**Average time for the line-operator to pick a unit from a kit**	**(hr)**
tk_{is}	**Average time for the operator in the supermarket to pick a unit from a bulk container of part *I* to kit for station *s***	**(hr)**

Equations from Limère (2012)

$$tp_{is}^{bulk} = \frac{2\Delta_{is}^{bulk}}{OV} + \tau^{bulk} (1.2)$$

$$tp^{k} = \frac{2\Delta^{k}}{OV} (1.3)$$

$$C_{pick} = OC \cdot \sum_{s\in S}\sum_{i\in I_s} q_{is}\left[x_{is} tp_{is}^{bulk} + (1 - x_{is}) tp^{k}\right] \ (1.1)$$

$$C_{tpt}^{pallet} = OC \cdot \sum_{s\in S}\sum_{i\in I_s\cap I_p} x_{is}\left(2 \cdot \frac{D_s^p}{V^p} \cdot \frac{q_{is}}{n_i}\right) \ (1.4)$$

$$C_{tpt}^{box} = OC \cdot \frac{\sum_{s\in S}\sum_{i\in I_s\cap I_b} x_{is}\left(\frac{D^b}{V^b} \cdot \frac{q_{is}}{n_i}\right)}{A^b \rho^b} \ (1.5)$$

$$C_{tpt}^{kit} = OC \cdot \sum_{s\in S}\sum_{i\in I_s} \frac{\frac{D^k}{V^k} K_s d}{A^k \rho^k} \ (1.6)$$

$$C_{tpt} = C_{tpt}^{pallet} + C_{tpt}^{box} + C_{tpt}^{kit} \ (1.7)$$

$$\theta_{is} = \max\left\{\min\left(\frac{q_{is}}{d} B^k, a_i\right), \frac{m_{is}}{\lceil m_{is}/a_i \rceil}\right\} \ (1.8)$$

$$tk_{is} = \left(\frac{2\Delta_{is}^{k}}{OV} + \tau^{k}\right) / \theta_{is} \ \ (1.9)$$

$$C_{kit} = OC \cdot \sum_{s\in S}\sum_{i\in I_s}\left[(1 - x_{is}) q_{is} tk_{is}\right] \ (1.10)$$

$$C_{repl} = \sum_{s\in S}\sum_{i\in I_s\cap I_p}\left[(1 - x_{is}) \frac{q_{is}}{n_i} R^p\right] + \sum_{s\in S}\sum_{i\in I_s\cap I_b}\left[(1 - x_{is}) \frac{q_{is}}{n_i} R^b\right] \ (1.11)$$

$$\text{Min}\, C_{total} = C_{pick} + C_{tpt} + C_{kit} + C_{repl} \ (1.12)$$

$$K_s \geq \sum_{i\in I_s}\left[(1 - x_{is}) \cdot \frac{m_{is} w_i}{|V_i|} / w^k\right] \qquad \forall s \in S \ \ (1.13)$$

$$K_s \geq \sum_{i\in I_s}\left[(1 - x_{is}) \cdot \frac{\frac{m_{is}}{v_i}}{|V_i|}\right] \qquad \forall s \in S \ (1.14)$$

$$\sum_{i \in I_s \cap I_b} (x_{is}/H^b) \leq N_s^b \qquad \forall s \in S \ (1.15)$$

$$N_s^b L^b + \sum_{i \in I_s \cap I_p} x_{is} L^p + K^s L^k \leq L^s \qquad \forall s \in S \ (1.16)$$

$$x_{is} = x_{js} \qquad \forall s \in S, \forall i \in I_s, \forall j \in V_i \ (1.17)$$

Data Requirements

Sets

Term	Mapped term from Limère (2012)	Description	Static Value	Cardinality
$s \in S$	$s \in S$	The set of all unique CPT code and surgeon bill of materials combinations, called Doctor Preference Cards	~	868
$i \in I$	$i \in I$	The set of all parts used on surgeries	~	1124
$i \in I_s$	$i \in I_s$	Set of items used on DPC *S*	~	[2, 216]
$i \in I_s \cap I_w$	I_b	The set of all items that must be walked up by a supply technician if not provided in an electronic cabinet or on a case cart	~	610
$i \in I_s \cap I_t$	I_p	The set of all items that can go through the vacuum tube if not provided in an electronic cabinet or on a case cart	~	514
$i \in I_e$	~	The set of instruments that can fit in the electronic supply cabinets	~	704
$i \in I_c$	~	The set of instruments that can fit on the core room open shelving	~	420

Parameters

Term	Mapped	Description	Static	Cardin

	term from Limère (2012)		Value	ality
q_{is}	q_{is}	**Usage of item i with DPC s, per year**	~	**57847**
d_s	d	**Demand for DPC S**	~	**3204**
m_{is}	m_{is}	**The number of copies of part i required per DPC s (an average, rounded up)**	~	**57847**
b_i	~	**The storage slot utilization parameter for part *i*. Calculated as the product of the part's horizontal and vertical dimensions (1x1 = 1, 2x1 = 2, 2x2 = 4)**	~	**1124**
OC_{nurse}	OC	**Cost (wage) of a nurse ($/hr)**	**36.15**	~
OC_{tech}	OC	**Cost (wage) of a supply technician ($/hr)**	13.84	~
OV	OV	**Walking velocity of a nurse or a supply technician (ft/hr)**	**11,811**	~
τ^{prep}	τ^{k}	**The amount of time it takes for a supply technician to search for a part on a shelf (hr)**	**0.00151**	~
τ^{bulk}	τ^{bulk}	**Time to find a part in the electronic supply cabinet (hr)**	**0.0129**	~
T^{Field}	~	**Average time to setup a sterile field (hr)**	**0.5**	~
C^{Cart}	~	**Number of items on a case cart as per DPC; calculated as the average size of a DPC, $i \in I_s$ (hr)**	**67**	~
τ^{Field}	~	**Average time to set up one part of a sterile field; T^{Field}/C^{Cart} (hr)**	**.0075**	~
τ^{lift}	~	**The amount of time a supply tech waits for an elevator during a supply run on average (hr)**	**.0075**	~
$T^{transfer}$	~	**Average time to transfer materials from picking cart to a set of case carts (hr)**	**.1**	~
$\tau^{transfer}$	~	**The amount of time it takes to transfer one part to a case cart from the picking cart (hr) $T^{transfer}/C^{Cart}$**	**0.0015**	~
T^{check}	~	**Average time to audit one case cart (hr)**	**.2**	~
τ^{check}	~	**The amount of time it takes to check for one part on a case prior to sending the cart to the operating room (an average) (hr) $T^{check}/$**	**0.003**	~

		C^{Cart}		
$\tau^{restock}$	~	**The average time it takes to place one part in the electronic cabinet (hr)**	**.0027**	~
τ^{sort}	~	**The average amount of time it takes to sort the items on the overflow cart**	**2**	~
θ_{is}	~	**Probability of item *i* being needed when it wasn't present on the case cart (and was not listed on the DPC initially)**	~	**57847**
φ_{is}	~	**Probability of item *i* not being needed when it was present on the DPC initially**	~	**57847**
n_i	~	**The average number of part *i* used on a daily basis**	~	**1124**
σ	~	**The average number of parts on a milk run**	**374**	~
C_s^{Cart}		**The number of parts on DPC s**	~	**868**
μ	~	**The average number of parts that are sent back to central storage on the overflow shelf on a daily basis (weekdays only)**	**267**	~
Δ^{Field}	Δ^k	**Distance from surgeon to sterile field that scrub nurse travels. Not restricted to allow for variation in sterile field setup locations – each room's setup when observed functions as a sample location for the restricted case (an average) (ft)**	**6.2963**	~
Δ^{bulk}	Δ_{is}^{bulk}	**Distance from circulator desk to location of part in electronic supply cabinet (walks past sterile field each time both directions) (an average of the average distances to electronic cabinets and open shelves in the four high utilization rooms) (ft) (restricted)**	**39.583**	~
Δ^{tube}	~	**Distance a nurse walks to vacuum tube from circulator desk, back to desk (stops at sterile field along the way) (time to use vacuum system and place phone call negligible) (an average) (ft) (restricted)**	**52.25**	~
$\Delta^{overflow}$	~	**The distance to the overflow cart from sterile field (an average) (ft)**	**45**	~
D^{cart}	D^k	**Distance a cart travels to front door of rooms on average from central storage area (an**	**305**	~

		average) (ft) (restricted)		
D^{single}	D^b	**Distance a part goes from central sterile to an OR room. Will include finding the part, walking from central sterile to core, then through core into room (an average) (ft)**	**317.9375**	~
D^{tube}	D_s^p	**Distance a supply tech walks to retrieve item then walk it to the vacuum tube (time to use the vacuum system and take phone call negligible) (an average) (ft)**	**145.1875**	~
D^{prep}	Δ_{is}^k	**The distance an operator walks on average to gather parts for a case cart; a circular path. Orthopedic parts determined the path used to model this parameter (an average) (ft)**	**312.75**	~
$D_{core}^{overflow}$	~	**The distance to the overflow cart from central storage (an average) (ft)**	**275.6875**	~
$D_{cabinet}^{restock}$	~	**The distance the supply technician walks on the milk run (a circular path – calculated over the four highly utilized orthopedic surgery rooms) (an average) (ft)**	**740**	~

Variables

Term	Mapped term from Limère (2012)	Description	Static Value
x_i	x_{is}	**Decision variable that assigns a part as follows: 1 – case cart; 0 – either bulk supply or one-of delivery**	~
y_i		**Decision variable that assigns a part as follows: 1 – bulk supply; 0 – either case cart or one-of delivery**	~
z_i		**Decision variable that assigns a part as follows: 1 – one-of delivery; 0 – either bulk supply or case cart**	~

Cost and Time Factors

Term	Mapped term from Limère (2012)	Description	Static Value
C_{pick}	C_{pick}	Yearly cost of in-room part retrieval ($)	~
C_{tpt}	C_{tpt}	Yearly total cost to internally transport materials for surgeries	~
C_{tpt}^{tube}	C_{tpt}^{pallet}	The costs to transport one-of items via vacuum tube ($)	~
C_{tpt}^{walk}	C_{tpt}^{box}	The costs to transport one-of items via hand delivery ($)	~
C_{tpt}^{cart}	C_{tpt}^{kit}	The yearly cost to deliver case carts for one DPC ($)	~
$C_{tpt}^{restock}$	~	The cost to restock one part on a yearly basis to the electronic supply cabinets	~
$C_{kit}^{overflow}$	~	The cost to handle overflow materials ($)	~
C_{kit}^{prep}	C_{kit}	The yearly cost to prepare case carts	~
C_{kit}	~	The costs associated with handling materials delivered on case carts	
C_{total}	C_{total}	The yearly total labor cost ($); we seek to minimize this cost factor	~
tp^{k}	tp^{k}	The cost to retrieve a part from a case cart (hr)	0.00857
tp^{bulk}	tp^{bulk}	The cost to retrieve a part from bulk supply (hr)	0.0207
$tr^{restock}$	~	The cost to perform one milk run (hr)	1.5748
$tk_{tech}^{overflow}$	~	The time it takes a supply technician to gather the overflow cart and return the parts that were unused to the shelves	2.0897
tk^{kit}	~	The cost to place one item on a case cart	0.0325

Modified Equations

$$\text{Min } C_{total} = C_{pick} + C_{tpt} + C_{kit} \quad (2.15)$$

Where,

$$tp^{k} = \frac{2\Delta^{Field}}{OV} + \tau^{Field} \quad (2.1)$$

$$tp^{bulk} = \frac{2\Delta^{bulk}}{OV} + \tau^{bulk} + \frac{2\Delta^{Field}}{OV} \quad (2.2)$$

$$C_{pick} = OC_{nurse} \cdot \sum_{s\in S}\sum_{i\in I_s} q_{is}[x_i tp^{k} + y_i tp^{bulk} + z_i tp^{k}] \quad (2.3)$$

$$C_{tpt}^{cart} = OC_{tech} \cdot \sum_{s\in S}\sum_{i\in I_S}\left(\frac{2D^{cart}}{OV} + 2\tau^{lift}\right) x_i \frac{m_{is}}{C_S^{Cart}} d_S \quad (2.4)$$

$$C_{tpt}^{walk} = OC_{tech} \cdot \sum_{s\in S}\sum_{i\in I_s\cap I_w}\left(\frac{2D^{single}}{OV} + \tau^{prep} + \tau^{lift}\right) q_{is} z_i \theta_{is} \quad (2.5)$$

$$C_{tpt}^{tube} = \sum_{s\in S}\sum_{i\in I_s\cap I_t}\left(OC_{tech} \cdot \frac{(2D^{tube} + \tau^{prep})}{OV} + OC_{nurse} \cdot \frac{2\Delta^{tube}}{OV}\right) q_{is} z_i \theta_{is} \quad (2.6)$$

$$tr^{restock} = \left(\frac{D_{gather}^{restock} + D_{cabinet}^{restock}}{OV\sigma}\right) + (\tau^{prep} + \tau^{restock})\sigma + \mathbf{2}\frac{\tau^{lift}}{\sigma} \quad (2.7)$$

$$C_{tpt}^{restock} = OC_{tech} \cdot \sum_{s\in S}\sum_{i\in I_S}[y_i tr^{restock} n_i] \quad (2.8)$$

$$C_{tpt} = C_{tpt}^{cart} + C_{tpt}^{walk} + C_{tpt}^{tube} + C_{tpt}^{restock} \quad (2.9)$$

$$tk^{kit} = \left(\frac{D^{prep}}{OV} + \tau^{prep} + \tau^{transfer} + \tau^{check}\right) \quad (2.10)$$

$$C_{kit}^{prep} = OC_{tech} \cdot \sum_{s \in S} \sum_{i \in I_s} \left[x_i \frac{q_{is}}{m_{is}} tk^{kit} \right] (2.11)$$

$$tk_{tech}^{overflow} = (\frac{2D_{core}^{overflow}}{OV} + 2\tau^{lift} + \frac{2D^{prep}}{OV} + \tau^{sort} + \tau^{prep})(2.12)$$

$$C_{kit}^{overflow} = \sum_{s \in S} \sum_{i \in I_s} ((OC_{tech} \cdot (tk_{tech}^{overflow} +) + OC_{nurse} \cdot \frac{2\Delta^{overflow}}{OV}) \frac{q_{is}}{\mu} (x_i + z_i) \varphi_{is} \quad (2.13)$$

$$C_{kit} = C_{kit}^{overflow} + C_{kit}^{prep} \qquad (2.14)$$

Subject to,

$$0 \leq \sum_{i \in I_e} y_i b_i \leq 960 \qquad \forall\, i \in I_e \quad (2.16)$$

$$0 \leq \sum_{i \in I_c} y_i b_i \leq 80 \qquad \forall\, i \in I_c \quad (2.17)$$

$$x_i + y_i + z_i = 1, \qquad \forall i \in I \quad (2.18)$$

Appendix C

Tables, Graphs and Assorted Images*

*That are not otherwise displayed in the body of the thesis document

Table i: Nursing Satisfaction with OR Supply System Survey Results

First Starts:	**unsatisfied**	**somewhat dissatisfied**	**neutral**	**somewhat satisfied**	**satisfied**	**# of answers**
Satisfaction with case cart **timeliness** for first surgery of the day	1.3%	9.1%	6.5%	18.2%	64.9%	77
Satisfaction with **accuracy** of case carts for first surgery of the day	1.3%	13.2%	9.2%	47.4%	28.9%	76
Communication with store room regarding resolution of items for first surgery of the day	6.8%	29.7%	12.2%	31.1%	20.3%	74
Overall satisfaction with store room regarding preparation for first surgery of the day	0.0%	19.7%	11.8%	32.9%	35.5%	76
Store room response time to emergent supply needs during first surgery of the day	8.1%	13.5%	24.3%	40.5%	13.5%	74
Other than First Starts:						
Satisfaction with case cart **timeliness** for other than first surgery of the day	3.2%	9.6%	17.0%	34.0%	36.2%	94
Satisfaction with **accuracy** of case carts for other than first surgery of the day	4.3%	18.1%	19.1%	33.0%	25.5%	94
Communication with store room regarding resolution of items for other than first surgery of the day	9.8%	23.9%	17.4%	30.4%	18.5%	92
Overall satisfaction with store room regarding preparation for other than first surgery of the day	3.3%	18.7%	15.4%	40.7%	22.0%	91
Store room response time to emergent supply needs during other	25.8%	26.9%	17.2%	15.1%	15.1%	93

surgeries throughout the day						
Accuracy of items delivered from store room vs. what was requested	20.9%	22.0%	23.1%	20.9%	13.2%	91
Communication between store room and clinician	14.0%	24.4%	22.1%	26.7%	12.8%	86
Satisfaction regarding frequency of store room phone answering by store room staff	21.1%	30.5%	18.9%	18.9%	10.5%	95
Resources available to locate and identify items (such as electronic catalogues)	28.6%	27.4%	21.4%	14.3%	8.3%	84
Instrument (s) / sets / pans :						
Receiving the correct set on the case cart	2.2%	6.6%	14.3%	52.7%	24.2%	91
Quality of instrument sets	11.7%	16.0%	18.1%	36.2%	18.1%	94
Store room response to instrument set issues	13.8%	19.5%	10.3%	36.8%	19.5%	87
If an instrument set needs to be 'turned over,' is that done in a satisfactory manner? Is 2.5 hours acceptable?	28.2%	20.0%	17.6%	25.9%	8.2%	85
Communication regarding flashing or 'turning-over' an instrument set	8.6%	16.0%	23.5%	30.9%	21.0%	81
Nomenclature of instrument (s) / pans.	14.8%	11.1%	23.5%	30.9%	19.8%	81
Omnicells:						
OR room Omnicell stock levels	34.4%	36.5%	7.3%	14.6%	7.3%	96
Core Omnicell stock levels	23.2%	24.2%	17.9%	25.3%	9.5%	95
Communication regarding resolution of Omnicell supply issues	21.1%	26.7%	22.2%	18.9%	11.1%	90
Layout of Omnicell cabinets / ease of use when finding items during critical patient care event	26.9%	21.5%	16.1%	21.5%	14.0%	93
Instruments in Core + Trauma carts:						
Trauma (emergency) cart availability	1.3%	0.0%	17.7%	31.6%	49.4%	79
Core instrument cart	16.9%	16.9%	15.7%	28.9%	21.7%	83

stock selection						
Core instrument cart stock availability	13.3%	25.3%	15.7%	27.7%	18.1%	83
Communication regarding core instrument cart or trauma cart	11.7%	9.1%	26.0%	26.0%	27.3%	77
Sutures:						
Suture availability	3.1%	11.5%	9.4%	30.2%	45.8%	96
Communication regarding Suture availability	5.6%	7.8%	22.2%	22.2%	42.2%	90
Layout of suture shelves / ease of use when finding items during critical patient care event	5.3%	10.6%	12.8%	38.3%	33.0%	94
Other:						
Scheduled cases: given that you needed to retrieve an item that was not delivered on the case cart, do you feel as if you have to compromise the patient's care to retrieve that item?	31.0%	13.8%	27.6%	11.5%	16.1%	87
Trauma cases: given that you needed to retrieve an item that was not delivered on the case cart, do you feel as if you have to compromise the patient's care to retrieve that item?	36.8%	15.8%	23.7%	9.2%	14.5%	76

Table ii: Materials Handling Distances

	Starting Room	Starting Location	Ending Room	Ending Location	Model Parameter	Distance (ft)
1	2001	Surgery Table	2001	Sterile Field	Δ^{Field}	8
2	2002	Surgery Table	2002	Sterile Field	Δ^{Field}	8
3	2003	Surgery Table	2003	Sterile Field	Δ^{Field}	12
4	2004	Surgery Table	2004	Sterile Field	Δ^{Field}	5

5	**2005**	**Surgery Table**	**2005**	**Sterile Field**	Δ^{Field}	**4**
6	**2006**	**Surgery Table**	**2006**	**Sterile Field**	Δ^{Field}	**4**
7	**2007**	**Surgery Table**	**2007**	**Sterile Field**	Δ^{Field}	**12**
8	**2008**	**Surgery Table**	**2008**	**Sterile Field**	Δ^{Field}	**8**
9	**2009**	**Surgery Table**	**2009**	**Sterile Field**	Δ^{Field}	**4**
10	**2010**	**Surgery Table**	**2010**	**Sterile Field**	Δ^{Field}	**4**
11	**2011**	**Surgery Table**	**2011**	**Sterile Field**	Δ^{Field}	**3**
12	**2012**	**Surgery Table**	**2012**	**Sterile Field**	Δ^{Field}	**4**
13	**2014**	**Surgery Table**	**2014**	**Sterile Field**	Δ^{Field}	**4**
14	**2015**	**Surgery Table**	**2015**	**Sterile Field**	Δ^{Field}	**6**
15	**2016**	**Surgery Table**	**2016**	**Sterile Field**	Δ^{Field}	**8**
16	**2017**	**Surgery Table**	**2017**	**Sterile Field**	Δ^{Field}	**4**
17	**2018**	**Surgery Table**	**2018**	**Sterile Field**	Δ^{Field}	**6**
18	**2019**	**Surgery Table**	**2019**	**Sterile Field**	Δ^{Field}	**4**
19	**2020**	**Surgery Table**	**2020**	**Sterile Field**	Δ^{Field}	**4**
20	**2021**	**Surgery Table**	**2021**	**Sterile Field**	Δ^{Field}	**4**
21	**2022**	**Surgery Table**	**2022**	**Sterile Field**	Δ^{Field}	**4**
22	**2023**	**Surgery Table**	**2023**	**Sterile Field**	Δ^{Field}	**12**
23	**2024**	**Surgery Table**	**2024**	**Sterile Field**	Δ^{Field}	**8**
24	**2025**	**Surgery Table**	**2025**	**Sterile Field**	Δ^{Field}	**8**
25	**2026**	**Surgery Table**	**2026**	**Sterile Field**	Δ^{Field}	**7**
26	**2027**	**Surgery Table**	**2027**	**Sterile Field**	Δ^{Field}	**12**
27	**2028**	**Surgery Table**	**2028**	**Sterile Field**	Δ^{Field}	**3**

28	2021	Circulator Desk	2021, 2036	Electronic Cabinet, Open Shelf, Sterile Field	Δ^{bulk}	(24+30+30)/3=28
29	2022	Circulator Desk	2022, 2036	Electronic Cabinet, Open Shelf, Sterile Field	Δ^{bulk}	(28+51+51)/3=43.3
30	2023	Circulator Desk	2023, 2036	Electronic Cabinet, Open Shelf, Sterile Field	Δ^{bulk}	(32+31+82)/3=48.3
31	2025	Circulator Desk	2025, 2035	Electronic Cabinet, Open Shelf, Sterile Field	Δ^{bulk}	(19+32+65)/3=38.7
32	2021	Circulator Desk	2035	Vacuum tube (core)	Δ^{tube}	71
33	2022	Circulator Desk	2035	Vacuum tube (core)	Δ^{tube}	46
34	2023	Circulator Desk	2035	Vacuum tube (core)	Δ^{tube}	51
35	2025	Circulator Desk	2035	Vacuum tube (core)	Δ^{tube}	41
36	2021	Circulator Desk	2035	Overflow Shelf	$\Delta^{overflow}$	58.5
37	2022	Circulator Desk	2035	Overflow Shelf	$\Delta^{overflow}$	33.5
38	2023	Circulator Desk	2035	Overflow Shelf	$\Delta^{overflow}$	38.5
39	2025	Circulator Desk	2035	Overflow Shelf	$\Delta^{overflow}$	49.5
40	G044B	Case Cart Holding	2001	Front door of operating room	D^{cart}	353
41	G044B	Case Cart Holding	2002	Front door of operating room	D^{cart}	380

42	G044B	Case Cart Holding	2003	Front door of operating room	D^{cart}	388
43	G044B	Case Cart Holding	2004	Front door of operating room	D^{cart}	362
44	G044B	Case Cart Holding	2005	Front door of operating room	D^{cart}	338
45	G044B	Case Cart Holding	2006	Front door of operating room	D^{cart}	280
46	G044B	Case Cart Holding	2007	Front door of operating room	D^{cart}	256
47	G044B	Case Cart Holding	2008	Front door of operating room	D^{cart}	195
48	G044B	Case Cart Holding	2009	Front door of operating room	D^{cart}	169
49	G044B	Case Cart Holding	2010	Front door of operating room	D^{cart}	155
50	G044B	Case Cart Holding	2011	Front door of operating room	D^{cart}	185
51	G044B	Case Cart Holding	2012	Front door of operating room	D^{cart}	287
52	G044B	Case Cart Holding	2014	Front door of operating room	D^{cart}	182
53	G044B	Case Cart Holding	2015	Front door of operating room	D^{cart}	178
54	G044B	Case Cart Holding	2016	Front door of operating room	D^{cart}	169
55	G044B	Case Cart Holding	2017	Front door of operating room	D^{cart}	193
56	G044B	Case Cart Holding	2018	Front door of operating room	D^{cart}	217

57	**G044B**	**Case Cart Holding**	**2019**	**Front door of operating room**	D^{cart}	**281**
58	**G044B**	**Case Cart Holding**	**2020**	**Front door of operating room**	D^{cart}	**306**
59	**G044B**	**Case Cart Holding**	**2021**	**Front door of operating room**	D^{cart}	**365**
60	**G044B**	**Case Cart Holding**	**2022**	**Front door of operating room**	D^{cart}	**388**
61	**G044B**	**Case Cart Holding**	**2023**	**Front door of operating room**	D^{cart}	**340**
62	**G044B**	**Case Cart Holding**	**2024**	**Front door of operating room**	D^{cart}	**312**
63	**G044B**	**Case Cart Holding**	**2025**	**Front door of operating room**	D^{cart}	**247**
64	**G044B**	**Case Cart Holding**	**2026**	**Front door of operating room**	D^{cart}	**260**
65	**G044B**	**Case Cart Holding**	**2027**	**Front door of operating room**	D^{cart}	**225**
66	**G044B**	**Case Cart Holding**	**2028**	**Front door of operating room**	D^{cart}	**205**
67	**G044A**	**Central Sterile Storage**	**2021**	**Circulator Desk**	D^{single}	**334.1875**
68	**G044A**	**Central Sterile Storage**	**2022**	**Circulator Desk**	D^{single}	**309.1875**
69	**G044A**	**Central Sterile Storage**	**2023**	**Circulator Desk**	D^{single}	**314.1875**
70	**G044A**	**Central Sterile Storage**	**2025**	**Circulator Desk**	D^{single}	**314.1875**
71	**G044A**	**Central Sterile Storage**	**2035**	**Vacuum tube (storage)**	D^{tube}	**145.1875**

72	G044A	Central Sterile Storage	G044B	Case Cart Holding	D^{prep}	312.75
73	2035	Core room overflow shelf	G044A	Central Sterile Storage	$D^{overflow}$	275.6875
74	G044A	Central Sterile Storage	G044A	Central Sterile Storage	$D^{overflow}_{core}$	169
75	G044A	Central Sterile Storage	2021, 2022, 2023,2025, G044A	Operating Room Electronic Cabinet, Central Sterile Storage	$D^{restock}_{cabinet}$	740

Table iii: Part-Policy Assignments

(Assignment Columns Key: 1 – Case cart; 2 – cabinet or shelf; 3 – One-of)

Part #	Mapped Part #	Descriptive Assignment	AMPL Solution 1	X Fixed	Y Fixed	Z Fixed
		$207,930.92	$176,909.01	$204,048.69	$188,517.77	$232,775.62
90001	1	2	2	1	2	3
90007	2	2	2	1	2	3
90009	3	3	3	1	2	3
90056	4	1	2	1	2	3
90064	5	1	2	1	2	3
90066	6	1	1	1	2	3
90151	7	2	2	1	2	3
90164	8	3	3	1	2	3
90167	9	2	2	1	2	3
90182	10	2	3	1	2	3
90206	11	1	2	1	2	3
90211	12	1	2	1	2	3
90257	13	1	2	1	2	3
90268	14	2	3	1	2	3
90269	15	2	2	1	2	3
90293	16	2	2	1	2	3
90294	17	2	2	1	2	3
90412	18	1	2	1	2	3
90581	19	2	2	1	2	3
90604	20	2	3	1	2	3
90605	21	2	2	1	2	3
90658	22	1	3	1	2	3
90662	23	2	3	1	2	3
90664	24	1	2	1	2	3
90668	25	2	2	1	2	3

90681	26	2	2	1	2	3
90748	27	1	2	1	2	3
90845	28	1	2	1	2	3
90899	29	1	1	1	2	3
90915	30	1	1	1	2	3
90916	31	2	2	1	2	3
90920	32	2	2	1	2	3
91217	33	2	2	1	2	3
91312	34	2	2	1	2	3
91313	35	1	3	1	2	3
91332	36	2	2	1	2	3
91340	37	1	2	1	2	3
91341	38	1	2	1	2	3
91342	39	1	3	1	2	3
91343	40	1	3	1	2	3
91363	41	2	1	1	2	3
91366	42	1	3	1	2	3
91403	43	2	2	1	2	3
91408	44	1	2	1	2	3
91411	45	1	2	1	2	3
91417	46	2	2	1	2	3
91425	47	1	2	1	2	3
91426	48	2	2	1	2	3
91428	49	2	2	1	2	3
91433	50	1	2	1	2	3
91440	51	2	2	1	2	3
91442	52	2	2	1	2	3
91445	53	1	2	1	2	3
91449	54	1	2	1	2	3
91450	55	2	2	1	2	3
91451	56	1	3	1	2	3
91453	57	2	2	1	2	3
91454	58	2	2	1	2	3
91456	59	2	2	1	2	3
91476	60	1	3	1	2	3
91484	61	1	2	1	2	3
91493	62	1	3	1	2	3
91494	63	1	2	1	2	3
91495	64	1	3	1	2	3
91498	65	1	2	1	2	3
91499	66	1	2	1	2	3
91500	67	2	2	1	2	3
91503	68	2	2	1	2	3
91510	69	2	2	1	2	3
91511	70	2	3	1	2	3
91517	71	1	1	1	2	3
91519	72	2	1	1	2	3
91522	73	2	2	1	2	3
91524	74	2	2	1	2	3
91531	75	1	1	1	2	3
91532	76	2	2	1	2	3
91533	77	2	1	1	2	3
91540	78	1	2	1	2	3
91541	79	1	2	1	2	3

91543	80	2	2	1	2	3
91551	81	3	3	1	2	3
91558	82	2	1	1	2	3
91561	83	2	1	1	2	3
91565	84	2	2	1	2	3
91574	85	2	3	1	2	3
91577	86	1	3	1	2	3
91578	87	2	2	1	2	3
91608	88	1	2	1	2	3
91630	89	2	2	1	2	3
91632	90	2	3	1	2	3
91636	91	1	2	1	2	3
91637	92	2	2	1	2	3
91638	93	1	1	1	2	3
91640	94	1	2	1	2	3
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RU608060	1026	1	1	1	2	3
RU608061	1027	1	1	1	2	3
RU608063	1028	1	1	1	2	3
RU608064	1029	1	1	1	2	3
RU608065	1030	1	1	1	2	3
RU608066	1031	1	1	1	2	3
RU608068	1032	1	1	1	2	3
RU608069	1033	1	1	1	2	3
RU608072	1034	1	1	1	2	3
RU608077	1035	1	1	1	2	3
RU608080	1036	1	1	1	2	3
RU608084	1037	1	1	1	2	3
RU608085	1038	1	1	1	2	3
RU608086	1039	1	1	1	2	3
RU608090	1040	1	1	1	2	3
RU608091	1041	1	1	1	2	3
RU608092	1042	1	1	1	2	3
RU608117	1043	1	1	1	2	3
RU608118	1044	1	1	1	2	3
RU608120	1045	1	1	1	2	3
RU608121	1046	1	1	1	2	3
RU608122	1047	1	3	1	2	3
RU608123	1048	1	3	1	2	3
RU608124	1049	1	1	1	2	3
RU608125	1050	1	1	1	2	3
RU608126	1051	1	1	1	2	3

RU608131	1052	1	1	1	2	3
RU608170	1053	1	1	1	2	3
RU608182	1054	1	3	1	2	3
RU608184	1055	1	1	1	2	3
RU608187	1056	1	1	1	2	3
RU608188	1057	1	1	1	2	3
RU608200	1058	1	1	1	2	3
RU608201	1059	1	1	1	2	3
RU608205	1060	1	3	1	2	3
RU608295	1061	1	1	1	2	3
RU608308	1062	1	3	1	2	3
RU608319	1063	1	3	1	2	3
RU608321	1064	1	3	1	2	3
RU608328	1065	1	1	1	2	3
RU608329	1066	1	1	1	2	3
RU608330	1067	1	1	1	2	3
RU608347	1068	1	1	1	2	3
RU608378	1069	1	3	1	2	3
RU608379	1070	1	1	1	2	3
RU608380	1071	1	1	1	2	3
RU608382	1072	1	1	1	2	3
RU608383	1073	1	1	1	2	3
RU608384	1074	1	1	1	2	3
RU608386	1075	1	1	1	2	3
RU608387	1076	1	1	1	2	3
RU608389	1077	1	1	1	2	3
RU608390	1078	1	1	1	2	3
RU608392	1079	1	3	1	2	3
RU608393	1080	1	3	1	2	3
RU608398	1081	1	3	1	2	3
RU608399	1082	1	3	1	2	3
RU608411	1083	1	1	1	2	3
RU608412	1084	1	1	1	2	3
RU608416	1085	1	1	1	2	3
RU608417	1086	1	1	1	2	3
RU608418	1087	3	3	1	2	3
RU608423	1088	3	3	1	2	3
RU608444	1089	1	3	1	2	3
RU608461	1090	1	1	1	2	3
RU608462	1091	1	3	1	2	3
RU608492	1092	1	3	1	2	3
RU608493	1093	1	1	1	2	3
RU608494	1094	1	1	1	2	3
RU608495	1095	1	1	1	2	3
RU608496	1096	1	1	1	2	3
RU608497	1097	1	1	1	2	3
RU608498	1098	1	1	1	2	3
RU608499	1099	1	1	1	2	3
RU608501	1100	1	1	1	2	3
RU608502	1101	1	3	1	2	3
RU608503	1102	1	1	1	2	3
RU608504	1103	1	1	1	2	3
RU608505	1104	1	1	1	2	3
RU608506	1105	1	1	1	2	3

RU608507	1106	1	1	1	2	3
RU608508	1107	1	1	1	2	3
RU608509	1108	1	1	1	2	3
RU608510	1109	1	1	1	2	3
RU608517	1110	1	1	1	2	3
RU608549	1111	1	1	1	2	3
RU608556	1112	3	3	1	2	3
RU608667	1113	1	3	1	2	3
RU608670	1114	1	1	1	2	3
RU608671	1115	1	3	1	2	3
RU608692	1116	1	3	1	2	3
RU614798	1117	3	1	1	2	3
RU615756	1118	3	3	1	2	3
RU615786	1119	1	3	1	2	3
RU617009	1120	1	3	1	2	3
RU617011	1121	3	1	1	2	3
RU617068	1122	1	1	1	2	3
RU617772	1123	3	1	1	2	3
RU618155	1124	3	3	1	2	3

Appendix D

Ampl Code

.dat file

```
data;

param OV := 11811; # Average walking speed of a nurse
or supply tech
param OC_n := 36.15; # Cost of labour (per hour) of a
nurse
param OC_s := 13.84; # Cost of labour (per hour) of a
supply tech
param d_bulk := 39.583; # Average distance for the
operator at workstation s to pick from a bulk container
param d_field := 6.2963; # Average distance for the
scrub nurse to retrieve part from sterile field
param D_cart := 305; # Distance a cart travels to front
door of rooms on average from central storage area (ft)
param D_single := 317.9375; # Distance a part goes from
central sterile to an OR room (ft)
param D_tube := 145.1875; # Distance a supply tech
walks to retrieve item then walk it to the vacuum
tube  (ft)
param d_tube := 52.25; # Distance a nurse walks to
vacuum tube from circulator desk, back to desk (ft)
param D_prep := 312.75; # The distance an operator
walks on average to gather parts for a case cart; a
circular path (ft)
param ts_transfer := 0.0015; # The amount of time it
takes to transfer one part to a case cart from the
picking cart (hr) T^transfer/C^Cart
param d_overflow := 45; # The distance to the overflow
cart from sterile field (an average) (ft)
param D_overflow_core := 275.6875; # The distance to
the overflow cart from central storage (an average)
(ft)
param mu := 267; # The average number of parts that are
sent back to central storage on the overflow shelf
param D_re_gather := 169; # The distance the supply
technician walks while gathering materials for a milk
run (ft)
param D_re_cabinet := 740; # The distance the supply
```

```
technician walks on the milk run (ft)
param ts_restock := 0.0027; # The average time it takes
to place one part in the electronic cabinet (hr)
param sigma := 374; # The average number of parts on a
milk run
param ts_sort := 2; # The average amount of time it
takes to sort the items on the overflow cart into bins
for reshelving
param ts_field := 0.0075; # Average time to set up one
part of a sterile field;  T^Field/C^Cart (hr)
param ts_prep := 0.00151; # The amount of time it takes
for a supply technician to search for a part on a shelf
(hr)
param ts_bulk := 0.0129; # Time to find a part in the
electronic supply cabinet (hr)
param ts_lift := 0.0075; # The amount of time a supply
tech waits for an elevator during a supply run on
average (hr)
param ts_check := 0.003; # The amount of time it takes
to check for one part on a case prior to sending the
cart to the operating room (an average) (hr)
T^check/C^Cart




table COMBI IN: COMBI <- [i,s], q, m, phi,
theta;            # combined (i,s) parameters

table I IN: I <- [i], b, n, x_val, y_val, z_val,
x_val_0, x_val_1, y_val_0, y_val_1, z_val_0,z_val_1,
omni_or_shelf, x OUT, y OUT, z OUT;  # x_val, y_val,
z_val, x_val_0,x_val_1,y_val_0,y_val_1,z_val_0,z_val_1,
omni_or_shelf     # part only parameters

table S IN: S <- [s], C_Cart_s,
d_s;                      # DPC only parameters

table WALK IN: WALK <- [i,s];                 # parts
that must be walked ad hoc

table TUBE IN: TUBE <- [i,s];              # parts that
can fit in the vacuum tube

#table SHELF IN: SHELF <- [i,s];              # parts
that fit in bulk supply on open shelves

#table OMNICELL IN: OMNICELL <- [i,s];       # parts
that fit in bulk supply on omnicells
```

```
read table COMBI;
read table I;
read table S;
read table WALK;
read table TUBE;
#read table SHELF;
#read table OMNICELL;

fix {i in I} x[i] := x_val[i];
fix {i in I} y[i] := y_val[i];

fix {i in I} z[i] := z_val[i];

bend;
```

.mod file

```
### SETS ###

set I; # part numbers
set S; # DPCs
set COMBI within {I,S}; # Just the existing
combinations - set of every DPC + Part # combo
set WALK within {I,S}; # The set of all items that must
be walked up by a supply technician if not provided in
an electronic cabinet or on a case cart
set TUBE within {I,S}; # The set of all items that can
go through the vacuum tube if not provided in an
electronic cabinet or on a case cart
#set OMNICELL within {I,S}; # The set of instruments
that can fit in the electronic supply cabinets
#set SHELF within {I,S}; # The set of instruments that
can fit on the core room open shelving

### PARAMETERS ###

### GENERAL PARAMETERS ###

param OV; # Average walking speed of an operator
param OC_n >= 0; # Cost of labour (per hour) of a nurse
param OC_s >= 0; # Cost of labour (per hour) of a
supply tech
param q {COMBI} >= 0; # Yearly usage of part i for DPC
```

```
s
param m {COMBI} >= 0; # Number of units of part i
assembled per vehicle at station s
param ts_prep >= 0; # tau_prep - The amount of time it
takes for a supply technician to search for a part on a
shelf (hr)
param ts_lift >= 0; # The amount of time a supply tech
waits for an elevator during a supply run on average
(hr)

### PART RETRIEVAL PARAMETERS ###

param d_bulk >= 0; # Average distance for the operator
at workstation s to pick from a bulk container
param ts_bulk >= 0; # Average time to search for the
required part from electronic storage cabinet or open
shelf (Tau_bulk)
param d_field >= 0; # Average distance for the scrub
nurse to retrieve part from sterile field
param ts_field >= 0; # Average time to setup one part
for presentation during a surgery within a sterile
field

# if a parameter exists inside another indexed
parameter, you have to attach the first parameter to
each member of the indexed set?????

param tp_bulk = 2 * d_bulk/OV + ts_bulk + 2 *
d_field/OV;
# Average time to pick a part from a cabinet or shelf
for DPC s

param tp_k = 2 * d_field/OV + ts_field;
# Average time to pick a unit from a kit

### MATERIALS TRANSPORT PARAMETERS ###

param omni_or_shelf {I} >= 0;                       #
assigns a part to with omnicell cabinets or open shelfs
(for variable y)
param D_cart >= 0; # Distance a cart travels to front
door of rooms on average from central storage area (ft)
param D_single >= 0; # Distance a part goes from
```

```
central sterile to an OR room (ft)
param D_tube >= 0; # Distance a supply tech walks to
retrieve item then walk it to the vacuum tube  (ft)
param theta {COMBI} >= 0; # Probability of item i being
needed when it wasn't present on the DPC initially
param d_tube >= 0; # Distance a nurse walks to vacuum
tube from circulator desk, back to desk (ft)
param C_Cart_s {S} >= 0;                        # The
number of parts on DPC s; includes instances where a
given part i is required to have multiple copies
param D_re_gather >= 0; # The distance the supply
technician walks while gathering materials for a milk
run (ft)
param D_re_cabinet >= 0; # The distance the supply
technician walks on the milk run (ft)
param ts_restock >= 0; # The average time it takes to
place one part in the electronic cabinet (hr)
param psi {COMBI} >= 0; # number of copies of a given
part that need to be resupplied on average to the
electronic storage cabinets
param d_s {S} >= 0; # Number of surgeries performed per
year, by surgery type
param sigma >= 0; # The average number of parts on a
milk run

param tr_restock = (D_re_gather +
D_re_cabinet)/(OV*sigma) + (ts_prep + ts_restock)*sigma
+ 2 * (ts_lift/sigma);
# the time to gather materials, walk with them, pull
them off the shelf, put them into the cabinet, and wait
for the elevator

### CASE CART ASSEMBLY PARAMETERS ###

param D_prep >= 0; # The distance an operator walks on
average to gather parts for a case cart; a circular
path (ft)
param ts_transfer >= 0; # The amount of time it takes
to transfer one part to a case cart from the picking
cart (hr)
param ts_check >= 0; # amount of time it takes to check
for one part on a case cart (an average) (hr)
```

```
param tk_kit = D_prep/OV + ts_prep + ts_transfer +
ts_check;
# time to place one item on a case cart

param phi {COMBI} >= 0; # the likelihood of item i
being returned on DPC s
param d_overflow >= 0; # The distance to the overflow
cart from sterile field (ft)
param D_overflow_core >= 0; # The distance to the
overflow cart from central storage (ft)
param mu >= 0; # The average number of parts that are
sent back to central storage on the overflow shelf
#param rho >= 0; # The average number of bins used to
sort overflow parts when they are returned to storage
param ts_sort >= 0; # The average amount of time it
takes to sort the items on the overflow cart into bins
for reshelving

param tk_over_tech = (2 * D_overflow_core + D_prep)/OV
+ ts_prep + ts_sort + 2 * ts_lift;
# The time to reshelve overflow parts

param n {I} >= 0; # average daily total usage of a
given part

### CONSTRAINT PARAMETERS ###

param b {I} >= 0; # The electronic cabinet or open
shelf slot utilization parameter for part i. Calculated
as the product of the part's horizontal and vertical
dimensions (1x1 = 1, 2x1 = 2, 2x2 = 4)

### VARIABLE FIXING PARAMETERS ###

param x_val {I} >= 0;
param y_val {I} >= 0;
param z_val {I} >= 0;
param x_val_0 {I} >= 0;
param y_val_0 {I} >= 0;
param z_val_0 {I} >= 0;
param x_val_1 {I} >= 0;
param y_val_1 {I} >= 0;
param z_val_1 {I} >= 0;
```

```
### VARIABLES ###

var x {i in I} binary; # =1 if the part is supplied on
case cart
var y {i in I} binary; # =1 if the part is supplied in
bulk
var z {i in I} binary; # =1 if the part is supplied
through one-of delivery



### OBJECTIVE ###

minimize Total_Cost:


OC_n * sum {(i,s) in COMBI} (q[i,s] * (x[i]*tp_k +
y[i]*tp_bulk + z[i]*(2 * d_field/OV))) +
OC_s * sum {(i,s) in WALK} (((2 * D_single/OV) +
ts_prep + ts_lift) * q[i,s] * z[i] * theta[i,s]) +
sum {(i,s) in TUBE} ((OC_s * (2 * D_tube/OV + ts_prep)
+ (OC_n * 2 * (d_tube/OV))) * q[i,s] * z[i] *
theta[i,s]) +
OC_s * sum {(i,s) in COMBI} (((2 * D_cart/OV) +
ts_lift) * x[i] * ceil((m[i,s] * d_s[s]) /
C_Cart_s[s])) +
OC_s * sum {(i,s) in COMBI} (x[i] * (q[i,s]/m[i,s]) *
tk_kit) +
sum {(i,s) in COMBI} (((OC_s * tk_over_tech) + (OC_n *
((2 * d_overflow)/OV))) * (q[i,s]/mu) * (x[i] + z[i]) *
phi[i,s]) +
OC_s * sum {i in I} (y[i] * n[i] * tr_restock);

# picking in the operating room + transport walking +
transport vacuum tube + transport case carts + case
cart assemby + replenishment overflow + replenishment
milk run for restock



### CONSTRAINTS ###
```

```
subject to ElectronicCabinetSlots:              # 0 <=
0 <= sum {i in I: omni_or_shelf[i]=1} y[i] * b[i] <=
960;
# limit the total number of cabinet slots to max of 960

subject to OpenShelfSlots:
0 <= sum {i in I: omni_or_shelf[i]=2} y[i] * b[i] <=
80;
# limit the total number of shelf slots to max of 80


subject to VarBinaryConstraint {i in I}:
x[i] + y[i] + z[i] = 1;
# Ensures that part i is assigned to only one delivery
method
```

.run file

```
model model_CODECODECODE.mod;
data model_DATADATADATA.dat;

option gurobi_options 'timing=1 mipgapabs=0 mipgap=1e-
9';    #mipgapabs: absolute MIP optimality gap
(default: 1e-10)  mipgap: maximum relative MIP
optimality gap (default: 1e-4)

option solver gurobi;

option presolve 0;

solve;
```

Appendix E

Parameters Affecting Output Assignments and Variables

Cart-to-line-supply, cart-to-one-of, line-supply-to-cart, line-supply-to-one-of, one-of-to-cart, one-of-to-line-supply, or no change(white)

Item ID	Item Description	q	theta	m	phi	n	b	1=walk, 2 = tube	1=omnicell, 2= shelf	cost per part per year for optimal	cost per part per year for initial
90056	BUNDLE PLASTIC MICRO ACCESSORY	29	1	1	0.75	0.079452055	4	1	1	23.39994436	46.18937343
90064	PACK FRACTURE	456	0.989375	1.005	0.355708657	1.249315068	4	1	1	367.9439526	363.8717525
90206	DRAPE MINI C-ARM	324	0.932184355	1.007843137	0.521498599	0.887671233	2	1	1	261.4338611	267.5107216
90211	PAD MAGNETIC	13	1	1	0.5	0.035616438	2	2	1	10.48963023	25.15702722
90257	PACK SHOULDER	285	1	1	0.320103372	0.780821918	4	1	1	229.9649704	231.4889509
90412	PACK HAND	223	0.993415638	1.001481481	0.291590241	0.610958904	4	1	1	179.9375031	185.0481297
90664	GAUZE PLAIN PACKING 1/4 IN.	119	1	1	0.57306615	0.326027397	1	2	1	96.02046132	108.6406224
90748	BOVIE NEEDLE TIP	5	1	1	0.4	0.01369863	2	2	1	4.034473165	16.18569623
90845	DRESSING WOUND VAC XLARGE	33	0.975	1	0.933333333	0.090410959	4	1	1	26.62752289	52.90101463
91340	ACE BANDAGE 2IN	237	0.980963481	1.001165501	0.574084249	0.649315068	2	2	1	191.234028	203.9462333
91341	ACE BANDAGE 3IN	363	0.968505477	1.016197183	0.480156867	0.994520548	2	2	1	292.9027518	297.7406408
91408	COTTON ROLL	40	1	1	0.775862069	0.109589041	4	1	1	32.27578532	54.48086892
91411	COVER MICROSCOPE FOR ZEISS MD	12	1	1	0.636363636	0.032876712	1	2	1	9.682735595	29.16125059
91425	COVER C-ARM	1361	0.893405142	1.154194504	0.315939251	3.728767123	2	2	1	1098.183595	986.6378512
91433	DRAPE EXTREMITY SHEET LOWER	146	0.994047619	1.05952381	0.369642857	0.4	4	1	1	117.8066164	122.0120258
91445	GAUZE XEROFORM 1 IN.X 8 IN.	8	1	1	0.1875	0.021917808	1	2	1	6.455157064	12.31742086
91449	GAUZE VASELINE 3 IN.X9 IN.	37	1	1.096774194	0.5	0.101369863	1	2	1	29.85510142	42.74375009
91484	PACK WOUND	9	0.928571429	1	0.571428571	0.024657534	4	1	1	7.262051697	24.18412717
91494	PACK LOWER EXTREMITY CUSTOM	934	0.990022525	1.000164204	0.360978905	2.55890411	4	1	1	753.6395872	737.9351612
91498	PACK ARTHROSCOPY	99	1	1	0.392753623	0.271232877	4	1	1	79.88256866	89.02768771
91499	PACK GENERIC	28	1	1	0.353333333	0.076712329	4	1	1	22.59304972	32.30861101
91540	STOCKINETTE 4IN	348	0.991757529	1.004672897	0.507441403	0.953424658	2	2	1	280.7993323	289.0160944
91541	STOCKINETTE 6IN	143	0.97761194	1.089552239	0.434861407	0.391780822	2	2	1	115.3859325	120.0319198

91608	DRAPE FLUID CONTROL	23	1	1	0.496794872	0.063013699	2	1	1	18.55857656	32.66264053
91636	DRAPE ATHROSCOPY	34	1	1	0.44	0.093150685	2	1	1	27.43441752	40.19485833
91640	STERIDRAPE U #1015	2147	0.872442032	1.106913007	0.311904067	5.882191781	4	1	1	1732.402777	1581.93094
91660	PACK BASIC	3	1	1.5	0	0.008219178	4	1	1	2.646903866	2.646903866
91661	DRAPE SPLIT SHEET	249	0.983695652	1.711956522	0.230430216	0.682191781	4	1	1	200.9167636	156.59926
91664	DRAPE LAP SHEET	13	0.958333333	1	0.333333333	0.035616438	4	1	1	10.48963023	20.33461344
91667	STERIDRAPE INSTRUMENT #1018	209	0.979375697	1.101449275	0.507078027	0.57260274	2	1	1	168.6409783	168.910104
91671	DRAPE LOWER EXTREMITY	7	1	1	0.5	0.019178082	4	1	1	5.648262431	20.59799616
91673	ABDUCTION PILLOW LARGE	10	1	1	0.266666667	0.02739726	4	1	1	8.06894633	16.12685459
91674	ABDUCTION PILLOW MEDIUM	402	0.974789916	1	0.258181438	1.101369863	4	1	1	324.3716424	314.4588548
91794	NEEDLE INTRACATH 18GA	7	1	1	0.6875	0.019178082	1	2	1	5.648262431	26.02205099
91804	TUBE CHEST 32FR AXIOM	2	1	1	0.5	0.005479452	2	2	1	16.44290233	16.79880361
91931	GOWN XXL	117	0.990196078	1.191176471	0.125	0.320547945	4	1	1	94.40667206	87.3018095
91933	DRAPE TRANSVERSE LAP	104	1	1	0.669218501	0.284931507	4	1	1	83.91704183	100.851651
92120	SYRINGE TOOMEY	187	0.914396587	1.102564103	0.679517237	0.512328767	1	2	1	150.8892964	156.4106623
92255	FRED ANTIFOG	18	1	1	0.091269841	0.049315068	2	2	1	14.52410339	17.12771565
92555	COLLAR ADULT VISTA UNIVERSAL	106	0.970779221	1	0.30590994	0.290410959	2	2	1	85.53083109	91.82467323
92621	BLADE BEAVER #6900	86	0.987804878	1.695121951	0.560162602	0.235616438	1	2	1	69.39293843	71.42445918
92634	PLS/BLADE WECK	26	1	1	0.892857143	0.071232877	1	2	1	20.97926046	47.22590637
92638	STAPLER SKIN ROTATING HEAD REG	8	1	1	0.75	0.021917808	4	1	1	6.455157064	28.59016571
92639	STAPLER SKIN ROTATING HEAD WIDE	41	1	1.789473684	0.587719298	0.112328767	4	1	1	33.08267995	43.29545299
92658	STAPLER SKIN FIXED HEAD PX WIDE	1135	0.880662828	1.147328804	0.297286491	3.109589041	2	1	1	915.8254084	824.8880462
92659	STAPLER SKIN FIXED HEAD PX REG	96	0.942857143	1	0.371953071	0.263013699	4	1	1	77.46188476	84.50768714
92704	BLADE GIGLI SAW 12IN	48	1	1.25	0.769444444	0.131506849	1	2	1	38.73094238	56.05923951

92851	TONGUE DEPRESSOR	34	1	1	0.67184265	0.093150685	1	2	1	27.43441752	46.9081285
92927	TAPE MEASURE	4	1	1	0.75	0.010958904	1	2	1	3.227578532	25.54977997
93180	STERIDRAPE IRRIGATION #1016	146	0.9251294	1.023809524	0.3842333	0.4	4	1	1	117.8066164	122.9604601
93323	CONECTOR CHEST TUBE STRAIGHT	1	1	1	1	0.002739726	1	2	1	29.91276995	30.50001623
93573	VESSEL LOOP MAXI BLUE	17	1	1.666666667	0.958333333	0.046575342	1	2	1	13.71720876	38.40225378
93575	VESSEL LOOP MINI BLUE	46	0.972222222	1.125	0.388888889	0.126027397	2	2	1	37.11715312	47.17050775
93594	PLS/COMB	41	1	1	0.882407407	0.112328767	1	2	1	33.08267995	58.32690412
93639	MAYFIELD SKULL PINS ADULT	7	1	1	0	0.019178082	1	2	1	5.648262431	6.133849922
93647	TOTE COMPLEX SPINE	398	0.985082305	1.005658436	0.281015986	1.090410959	1	2	1	321.1440639	314.3576875
93994	TUBING CYSTO	442	0.91144951	1.023410966	0.347844671	1.210958904	2	2	1	356.6474278	351.9345253
94257	COVER IMPAD RIGID SOLE FOOT REG	1094	0.961623894	1.008130081	0.464604055	2.997260274	2	2	1	882.7427285	846.4232441
94268	COVER IMPAD RIGID SOLE FOOT LG	1073	0.97873913	1.008695652	0.641716918	2.939726027	2	2	1	865.7979412	835.5935706
94600	KIT TURNOVER ROOM MOR	2938	0.988788049	1.001000461	0.239768026	8.049315068	4	1	1	2370.656432	2275.70451
94601	KIT TURNOVER ROOM - SPINE	300	1	1	0.301754411	0.821917808	4	1	1	242.0683899	240.7102113
94750	GOWN PATIENT WARMING STANDARD BAIR PAWS	3200	0.990176081	1.000988619	0.412839407	8.767123288	2	1	1	2582.062825	2481.825093
96784	MASTISOL	253	1	1.686468647	0.677196291	0.693150685	1	2	1	204.1443421	175.3871441
98289	BAIRHUGGER BLANKET LOWER BODY	576	0.924897415	1.034897564	0.162776163	1.578082192	2	1	1	464.7713086	444.9007869
98337	SCD SLEEVE REGULAR	1533	0.927637751	1.019407969	0.225943376	4.2	2	2	1	1236.969472	1184.823395
98813	TOURNIQUET CUFF 18IN	482	0.962362637	1.005494505	0.537378627	1.320547945	2	2	1	388.9232131	394.5340284
98814	TOURNIQUET CUFF 34IN	820	0.912769643	1.007711878	0.427347876	2.246575342	2	2	1	661.653599	647.2783737
98815	TOURNIQUET CUFF 24IN	230	0.972222222	1.018162393	0.540644078	0.630136986	2	2	1	185.5857656	196.7495592
99308	SUCTION TONSIL TIP PEDS	117	1	1.032258065	0.572093229	0.320547945	2	2	1	94.40667206	106.2670779
99422	SPONGES GAUZE STERILE 4X4 12PLY	2	1	1	1	0.005479452	1	2	1	1.613789266	31.26037059
99514	TOOTHPICKS	9	1	1	0.6875	0.024657534	1	2	1	7.262051697	28.3607062

99516	RUBBER BAND	29	1	1	0.888888889	0.079452055	1	2	1	23.39994436	50.21034425
99563	COBAN 3IN X 5YD SELF ADH WRAP	8	1	1	0.875	0.021917808	2	2	1	6.455157064	32.20633123
99641	DRESSING WOUND VAC GRANUFOAM	38	1	1	0.667582418	0.104109589	4	1	1	30.66199605	49.82481419
99665	ADAPTIC	71	0.927536232	2.384057971	0.557971014	0.194520548	1	2	1	57.28951894	54.82998815
99668	PACKING VAGINAL 1 IN	16	1	1	0.3125	0.043835616	2	2	1	12.91031413	22.01074692
99671	NEEDLE 27GA X 1 1/4	94	0.991071429	1.089285714	0.433928571	0.257534247	2	2	1	75.8480955	85.41508089
99720	GAUZE FINE MESH	23	1	1	0.75	0.063013699	1	2	1	18.55857656	40.81020353
99865	IMMOBILIZER SHOULDER SLING MED	70	1	1.075	0.097619048	0.191780822	4	1	1	56.48262431	56.2426659
99866	IMMOBILIZER SHOULDER SLING LG	229	0.978666667	1	0.350050794	0.62739726	4	1	1	184.7788709	190.6401661
99960	WOUND VAC CANNISTER ASSEMBLY	55	0.868229167	1	0.2015625	0.150684932	4	1	1	44.37920481	49.24076958
99962	WOUND VAC DRESSING ASSEMBLY MEDIUM	47	0.929597701	1.034482759	0.502873563	0.128767123	4	1	1	37.92404775	51.18891358
99963	WOUND VAC DRESSING ASSEMBLY LARGE	41	0.905092593	1.041666667	0.657407407	0.112328767	4	1	1	33.08267995	50.25411964
99977	TOTE TOTAL HIP	446	0.963751602	1.000166168	0.336275529	1.221917808	4	1	1	359.8750063	350.9605431
99978	TOTE TOTAL KNEE	591	0.981456044	1.00103022	0.281295063	1.619178082	4	1	1	476.8747281	460.0674319
99983	SURGILAV SPLASH SHIELD SM	266	0.941059757	1.019607843	0.390363667	0.728767123	4	1	1	214.6339724	216.8066699
99984	SURGILAV SPLASH SHIELD MED	354	0.987719298	1.023684211	0.828690476	0.969863014	4	1	1	285.6407001	299.2098068
GD201293	STOCKINETTE IMPERVIOUS	198	0.983695652	1	0.474627249	0.542465753	2	2	1	159.7651373	169.0811179
GD206185	ESMARK SMALL	18	1	1	0.590909091	0.049315068	2	2	1	14.52410339	31.58709624
GD206193	ESMARK LARGE	722	0.977394035	1.000152625	0.450494446	1.978082192	2	2	1	582.577925	579.5547762
GD207399	BLADE BEAVER 6700	1	1	1	1	0.002739726	1	2	1	29.91276995	30.50001623
GD208637	SPONGE TONSIL W/STRING LG	2	1	2	1	0.005479452	2	2	1	30.81071518	30.81071518
GD208744	COTTON SMALL	32	1	1.866666667	0.833333333	0.087671233	4	1	1	25.82062825	43.38331715
GD208801	BRUSH FEMORAL CANAL	86	0.895923521	1.055555556	0.606885178	0.235616438	4	1	1	69.39293843	82.50926465
GD220145	GEL DOPPLER ULTRASONIC	47	1	1.171428571	0.828571429	0.128767123	1	2	1	37.92404775	60.69171974

GD220434	BLADE DERMATOME PADGETT	30	0.979166667	1	0.5	0.082191781	2	2	1	24.20683899	38.89287319
GD221705	BLUE BACKGROUND	44	1	2	0.5	0.120547945	1	2	1	35.50336385	42.09396713
GD223883	C-WIRE .028	46	1	2.571428571	0.904761905	0.126027397	1	2	1	37.11715312	50.95392423
GD224592	NEEDLE TAPER LARGE	7	1	1	0.6	0.019178082	1	2	1	5.648262431	23.4908254
GD227363	NEEDLE TAPER SMALL	139	0.963888889	1.525	0.743303571	0.380821918	1	2	1	112.158354	108.9068272
GD227371	NEEDLE TAPER MEDIUM	141	1	1	0.462808884	0.38630137	1	2	1	113.7721432	122.1539308
GD227413	NEEDLE KEITH LARGE	123	1	1.626149425	0.767241379	0.336986301	1	2	1	99.24803985	96.84304788
GD228825	CLIP MULTI APPLIER SMALL	203	1	2.038961039	0.909090909	0.556164384	2	2	1	163.7996105	144.7543379
GD230748	SUCTION FRAZIER TIP 8FR	339	1	1.322506158	0.689473133	0.928767123	2	2	1	273.5372806	245.3310372
GD230755	SUCTION FRAZIER TIP 10FR	425	0.962396958	1.007575758	0.691248255	1.164383562	2	2	1	342.930219	347.3001337
GD230870	STAPLER LINEAR CUTTER 55MM 3.5	2	1	1	1	0.005479452	2	1	1	1.613789266	31.26037059
GD230888	RELOAD LINEAR CUTTER 55MM 3.5	4	1	2	0.5	0.010958904	2	1	1	3.227578532	17.4191698
GD231944	BOWL SMART MIX CTS	321	0.899545421	1.155946887	0.610051884	0.879452055	4	1	1	259.0131772	246.2083297
GD232025	CATHETER RED RUBBER 24FR	11	1	1	0.46875	0.030136986	1	2	1	8.875840963	22.7332121
GD232207	BOVIE EXTENDER 8IN	13	1	1	0.477272727	0.035616438	1	2	1	10.48963023	24.49942534
GD232868	BIPOLAR ADSON WITH CORD	377	0.978385307	1.000491642	0.471990448	1.032876712	4	1	1	304.1992766	312.2942603
GD232991	CLIP MULTI APPLIER MEDIUM	148	0.994505495	1.203296703	0.71978022	0.405479452	4	1	1	119.4204057	128.6117644
GD362459	PLS/SKIN TUBE	23	1	1	0.9	0.063013699	1	2	1	18.55857656	45.15192348
GD363135	BLADE MENISCUS BANANA 4MM	18	1	2	0.857142857	0.049315068	1	2	1	14.52410339	36.06349848
GD363481	IMMOBILIZER SHOULDER VELC LG	46	1	1	0.649425287	0.126027397	2	1	1	37.11715312	56.19751138
GD373795	NEEDLE BONE MARROW 15GA X 2	5	1	1	0.8	0.01369863	2	2	1	4.034473165	27.75618786
GD373803	NEEDLE BONE MARROW 13GA X 3.5	5	1	1	0.8	0.01369863	2	2	1	4.034473165	27.75618786
GD373811	NEEDLE BONE MARROW 11GA X 4	15	1	1.444444444	0.777777778	0.04109589	4	1	1	12.10341949	32.63930102
GD375204	SLING ARM LATERAL	134	0.992424242	1	0.577962315	0.367123288	4	1	1	108.1238808	122.6373839

GD375220	SURGILAV TUBING AND SHORT TIP	837	0.951739971	1.022457241	0.57166075	2.293150685	4	1	1	675.3708078	658.2294051
GD375246	SURGILAV LONG TIP	101	0.968549422	1.079268293	0.418538725	0.276712329	4	1	1	81.49635793	87.95998361
GD375352	ZIMMER SKIN CARRIER	56	0.980769231	1.769230769	0.509615385	0.153424658	2	2	1	45.18609945	49.616368
GD388223	BLADE SHAVER TAPERED BUR 6.0MM LINVATEC	117	1	1	0.941815476	0.320547945	2	2	1	94.40667206	119.4671137
GD388231	BLADE SHAVER GATOR MICROBLADE 2.9MM LINVATEC	25	0.925925926	1	0.576388889	0.068493151	2	2	1	20.17236582	37.30489934
GD388249	BLADE SHAVER SPHERICAL BUR 3.5MM LINVATEC	24	1	1	1	0.065753425	2	2	1	19.36547119	48.8067578
GD388272	BLADE SHAVER GATOR 4.2MM LINVATEC	209	0.919475128	1	0.430245109	0.57260274	2	2	1	168.6409783	175.3273134
GD388280	BLADE SHAVER SPHERICAL BUR 4.5MM LINVATEC	44	0.937254902	1	0.988235294	0.120547945	2	2	1	35.50336385	63.67306305
GD388298	BLADE SHAVER SPHERICAL BUR 5.5MM LINVATEC	166	0.972624799	1	0.913929147	0.454794521	2	2	1	133.9445091	156.7288489
GD388306	BLADE SHAVER GATOR 5.5MM LINVATEC	203	0.956415344	1	0.597424525	0.556164384	2	2	1	163.7996105	176.4573263
GD389098	DRAPE IOBAN 2 6651	306	0.966101695	1.116525424	0.454053643	0.838356164	2	1	1	246.9097577	237.8165635
GD390237	VESSEL LOOPS MINI RED	51	0.966269841	1.023809524	0.700396825	0.139726027	1	2	1	41.15162628	61.7595872
GD436402	ESMARK 6 INCH	256	0.967957953	1.010498688	0.331504286	0.701369863	2	2	1	206.565026	208.5957877
GD436428	DRAIN PENROSE 3/4IN LONG	76	1	1.071428571	0.639358312	0.208219178	2	2	1	61.3239921	75.60850912
GD438127	BURR METAL CUTTER WHEEL	55	1	1.466666667	0.723809524	0.150684932	2	1	1	44.37920481	56.50537697
GD438838	PROBE & PEN SET	165	0.984848485	1	0.785799168	0.452054795	4	1	1	133.1376144	152.2411155
GD451344	PLUG BONE TUNNEL CANNULATED	115	0.980324074	1	0.949189815	0.315068493	2	2	1	92.79288279	118.1606738
GD452086	BOVIE NEEDLE TIP INSULATED	121	1	1	0.54439946	0.331506849	1	2	1	97.63425059	109.3278002
GD452417	DRAIN BLAKE 10MM FLAT	7	1	1.166666667	0.5	0.019178082	2	2	1	5.648262431	20.96693204
GD454801	BLADE COATED INSULATED 6IN	28	1	1.125	0.346590909	0.076712329	1	2	1	22.59304972	31.53308146
GD455089	JACKSON SPINAL FRAME KIT	330	0.947750227	1	0.38131752	0.904109589	4	1	1	266.2752289	265.8273691
GD455584	SUTURE RETRIEVER DISP MED	3	1	1	1	0.008219178	2	2	1	2.420683899	32.02072495
GD455592	SUTURE RETRIEVER DISP SM	2	1	1	1	0.005479452	2	2	1	30.90446932	31.26037059
GD455758	DRESSING AQUACEL 4 X 5 HYDRO	4	1	2	0.5	0.010958904	2	1	1	3.227578532	17.4191698

GD479154	BOVIETIP (E1450X)	70	0.972868217	1	0.516666667	0.191780822	1	2	1	56.48262431	70.58822638
GD482166	BURR MATCHHEAD 3MM	210	0.991666667	1	0.721619769	0.575342466	2	2	1	169.4478729	184.5770753
GD482182	BURR MATCHEAD 3MM LONG	9	1	1	0.9375	0.024657534	2	2	1	7.262051697	34.77470387
GD482737	NEEDLE TIP BOVIE 6IN	121	1	1	0.544110276	0.331506849	1	2	1	97.63425059	109.3194005
GD495267	BURR TAPERED 1.6MM STRYKER	26	0.92	1.07	0.425714286	0.071232877	1	2	1	20.97926046	32.93826967
GD495309	BURR OVAL CUTTING 5.5MM STRYKER	27	1	1	0.910714286	0.073972603	1	2	1	21.78615509	48.5030953
GD522383	BURR METAL CUTTER 3MM	201	0.844223876	1.241384064	0.427317605	0.550684932	2	1	1	162.1858212	149.1338223
GD600040	RESTON	24	0.975	1	0.725	0.065753425	2	2	1	19.36547119	40.84665418
GD602190	BURR DIAMOND 2MM SHORT	34	1	1.818181818	0.763636364	0.093150685	2	2	1	27.43441752	43.50498436
GD602192	BURR MATCHHEAD 2.5MM X 12CM	16	1	1	0.418181818	0.043835616	2	2	1	12.91031413	25.06892275
GD602196	MICROSCOPE ZEISS DRAPE	259	0.865319541	1.033898305	0.568909948	0.709589041	2	1	1	208.9857099	213.5446435
GD602202	RETRACTOR WOUND ALEXIS MEDIUM 5-9CM	8	1	1	0.428571429	0.021917808	2	2	1	6.455157064	19.29145437
GD602248	STERI DRAPE IOBAN 2 (SHOWER CURTAIN)	189	0.995934959	1.037398374	0.545697087	0.517808219	2	1	1	152.5030856	161.2483627
GD603067	TIBIAL TUNNELER CANNULA BLUE	29	1	1	0.843137255	0.079452055	2	2	1	23.39994436	48.06719786
GD603636	IMMOBILIZER KNEE ADULT MED 22IN	685	0.980271178	1.020816327	0.294807834	1.876712329	4	1	1	552.7228236	527.501101
GD606079	TUBE SET BONE LAVAGE SYSTEM CARBOJET	373	0.968307866	1.064516129	0.603031136	1.021917808	1	2	1	300.9716981	293.1905555
GD606102	RETRACTOR WOUND ALEXIS LARGE 9-14CM	7	1	1	1	0.019178082	2	2	1	5.648262431	35.06214239
GD607005	DRAIN BLAKE 15FR RND	8	1	2	0.5	0.021917808	2	2	1	6.455157064	20.37780431
GD607408	ULTRA SLING II BLACK MED	32	1	1	0.627272727	0.087671233	4	1	1	25.82062825	44.09761556
GD607409	ULTRASLING II BLACK LARGE	186	0.946666667	1	0.648080395	0.509589041	4	1	1	150.0824017	163.3759229
GD607429	BAG COLLECTION WASTE 10L	66	0.959090909	1	0.572916667	0.180821918	4	1	1	53.25504578	68.36085267
GD607484	TRAPS FINGER	29	1	1	0.87394958	0.079452055	4	1	1	23.39994436	48.95924516
GD607502	BLADE SHAVER SPHERICAL BUR MICROBLADE 2.9MM LINVATEC	24	1	1	0.833333333	0.065753425	2	2	1	19.36547119	43.98245258
GD607508	BURR OVAL 4.0MM LINVATEC	115	0.982510288	1	0.89223251	0.315068493	2	2	1	92.79288279	116.5066498

GD607609	TUBING PATIENT REUSE MITEK (ORANGE)	149	0.984375	1.1	0.239652778	0.408219178	4	1	1	120.2273003	117.2905098
GD607902	SEALANT MICROBIAL INTEGUSEAL	253	1	1.020833333	0.456917894	0.693150685	2	2	1	204.1443421	206.3951275
GD607936	TUBING IRRIGATION FMS SOLO	150	0.985008818	1	0.145612875	0.410958904	2	2	1	121.0341949	121.4065788
GD607994	STRAP FOOT & ANKLE DISTRACTOR GUHL	23	1	1	0.431818182	0.063013699	4	1	1	18.55857656	31.60049455
GD608003	KIT SUSPENSION SHOULDER	73	0.947712418	1.346405229	0.732026144	0.2	4	1	1	58.90330821	69.84862128
GD608029	BLADE SHAVER GATOR MICROBLADE 3.5MM LINVATEC	24	1	1	0.822916667	0.065753425	2	2	1	19.36547119	43.6809335
GD608132	BURR ROUND CUTTING 4MM STRYKER	278	0.96744186	1.011627907	0.754806273	0.761643836	1	2	1	224.316708	235.7941194
GD608137	BURR OVAL CUTTING 4MM STRYKER	241	0.987804878	1.048780488	0.74174633	0.660273973	2	2	1	194.4616065	204.5045109
GD608147	BLADE OSCILLATING 18 X 90X 1.27MM STRYKER	318	0.940858774	1.027076841	0.518006546	0.871232877	4	1	1	256.5924933	255.3019732
GD608148	BLADE OSCILLATING 25 X 90 X 1.19MM DEPUY KNEE STRYKER	17	1	1	0.690909091	0.046575342	1	2	1	13.71720876	33.72102488
GD608151	BLADE OSCILLATING SAW LARGE 13 X 70 X 1.27MM STRYKER	14	1	1	0.958333333	0.038356164	4	1	1	11.29652486	39.17897648
GD608155	BLADE OSCILLATING SAW LARGE 33 X 71 X 1.2MM STRYKER	8	1	1	1	0.021917808	1	2	1	6.455157064	35.82249675
GD608164	BURR CARBIDE CUTTING ROUND 2.5MM STRYKER	27	1	1.2	0.883333333	0.073972603	1	2	1	21.78615509	46.50558807
GD608166	BLADE SAGITTAL SAW 9.5 X 25.5 X 0.4MM STRYKER	582	0.949950329	1.078068916	0.679624744	1.594520548	1	2	1	469.6126764	453.6799299
GD608167	BLADE SAGITTAL SAW 13.3 X 42 X 0.38MM STRYKER	571	0.960933732	1.079937497	0.634038165	1.564383562	1	2	1	460.7368354	441.4647274
GD608168	BLADE SAGITTAL SAW 5.5 X 25.5 X 0.4MM STRYKER	201	0.978927203	1.103448276	0.721027887	0.550684932	1	2	1	162.1858212	170.0646274
GD608170	BLADE OSC AND SAG STRYKER	18	0.916666667	1	0.851851852	0.049315068	1	2	1	14.52410339	39.1386861
GD608176	BLADE PRECISION OSC TIP STRYKER	4	1	1	0.5	0.010958904	1	2	1	3.227578532	18.31848063
GD608177	BLADE RECIP 12.7 X 73.5 X 0.8MM ZIMMER KNEE STRYKER	15	1	1	0.53968254	0.04109589	1	2	1	12.10341949	27.82497988
GD608179	BLADE SAGITTAL SAW 9.5 X 13.5MM 70DEG STRYKER	2	1	1	1	0.005479452	1	2	1	1.613789266	31.26037059
GD608181	BLADE SAGITTAL SAW 19.5 X 41MM STRYKER	25	1	1.363636364	0.954545455	0.068493151	1	2	1	20.17236582	45.2536429
GD608182	BLADE SAGITTAL SAW 14 X 25.5 X 0.4MM STRYKER	190	0.976731602	1.022727273	0.690191039	0.520547945	1	2	1	153.3099803	168.1992564
GD608191	BLADE SAGITTAL 25 X 75 X .89 STRYKER	3	1	1	0.5	0.008219178	1	2	1	2.420683899	17.55864212
GD608195	BLADE SAGITTAL 13 X 90 X 1.37 SNEPH KNEE STRYKER	27	1	1	0.977272727	0.073972603	1	2	1	21.78615509	50.42989073

GD608196	BLADE SAGITTAL 18 X 90 X 1.37 SNEPH KNEE STRYKER	27	1	1	0.954545455	0.073972603	1	2	1	21.78615509	49.77196059
GD608197	BLADE SAGITTAL 25 X 90 X 1.07 STRYKER	16	1	1	0.833333333	0.043835616	1	2	1	12.91031413	37.9009933
GD608201	BLADE SAGITTAL 9 X .51 X 31MM STRYKER	13	1	1	0.952380952	0.035616438	1	2	1	10.48963023	39.06502734
GD608225	BURR MATCHHEAD 2.5MM X 15CM	6	1	1	0.5	0.016438356	2	2	1	4.841367798	20.65674894
GD608308	BLADE INTRA ORAL 4.5 X 12MM STRYKER	10	1	1	1	0.02739726	1	2	1	8.06894633	38.16179677
GD608354	ELECTRODE VAPR S90	149	0.980034722	1	0.701519097	0.408219178	4	1	1	120.2273003	137.628556
GD608401	BAIRHUGGER BLANKET SPINAL UNDERBODY	266	0.922298535	1	0.441015235	0.728767123	2	1	1	214.6339724	218.1298543
GD608414	HEMOCLIP SMALL WECK	6	1	2	1	0.016438356	2	2	1	4.841367798	33.77141309
GD608415	HEMOCLIP MEDIUM WECK	13	1	1.75	0.857142857	0.035616438	2	2	1	10.48963023	33.80413931
GD608417	BLADE CLIPPER SURGICAL	43	1	1	0.529583333	0.117808219	2	2	1	34.69646922	50.44625919
GD608585	MILL BONE MEDIUM STRYK	177	0.958806818	1	0.644229729	0.484931507	2	2	1	142.82035	156.4239328
GD608602	STAPLER SKIN INSORB 30	3	1	3	1	0.008219178	2	1	1	2.420683899	31.12141413
GD608626	CRADLE ARM FOAM	137	1	1	0.438234441	0.375342466	4	1	1	110.5445647	118.4005376
GD608650	CLIP LIGATING SMALL HORIZON	57	0.955555556	1.416666667	0.271895425	0.156164384	1	2	1	45.99299408	46.07832089
GD608652	CLIP LIGATING LARGE HORIZON	115	0.966830467	1.921375921	0.571580672	0.315068493	1	2	1	92.79288279	84.0350206
GD608671	PIN SKULL ADULT MAYFIELD IMRIS	40	1	1	0.422402597	0.109589041	2	2	1	32.27578532	45.06244734
GD608683	COUNTER NEEDLE FOAM IMRIS	241	1	1	0.470313683	0.660273973	2	2	1	194.4616065	200.8086315
GD608698	DRESSING RESTORE 4 X 4.75 SILVER	8	1	2	0.5	0.021917808	2	1	1	6.455157064	20.37780431
GD608752	HANDPIECE VERSAJET PLUS 8MM	3	1	1	0.666666667	0.008219178	4	1	1	22.82120807	22.3793364
GD608753	HANDPIECE VERSAJET 8MM	3	1	1	0.666666667	0.008219178	4	1	1	22.82120807	22.3793364
GD608754	HANDPIECE VERSAJET 14MM	3	1	1	0.666666667	0.008219178	4	1	1	22.82120807	23.19792769
GD608757	BURR ACORN 9MM PRECISION STRYK	45	1	1	0.656973461	0.123287671	1	2	1	36.31025848	54.83757911
GD608767	SHUTTLE ACU-PASS 45 DEG RT SNEPH	29	1	1	0.570261438	0.079452055	4	1	1	23.39994436	40.16717285
GD608768	SHUTTLE ACU-PASS 45 DEG LFT SNEPH	26	1	1	0.704481793	0.071232877	4	1	1	20.97926046	41.77283656

GD608771	SHUTTLE ACU-PASS 45 DEG SNEPH	28	1	1	0.564338235	0.076712329	4	1	1	22.59304972	39.23578539
GD608903	MASK FACE BEACH CHAIR	151	1	1	0.404610854	0.41369863	4	1	1	121.8410896	128.8783076
GD608916	TRAY FOLEY 14FR TEMP W/METER	412	0.972644928	1.001358696	0.465797807	1.128767123	4	1	1	332.4405888	331.9890708
GD608919	TOWER SMARTMIX MINI	52	0.77	1	0.17	0.142465753	4	1	1	41.95852091	45.22907188
GD608951	Holder Foley StatLock 3Way	133	0.975694444	1.006944444	0.633978811	0.364383562	1	2	1	107.3169862	122.2741744
GD609089	TUBING ARTHROSCOPY INFLOW DAY USE (BOX OF 4)	56	1	1	0.66504065	0.153424658	2	1	1	45.18609945	64.24995329
GD609090	TUBING ARTHROSCOPY INFLOW PATIENT (BOX OF 12)	56	1	1	0.628455285	0.153424658	2	1	1	45.18609945	63.18975162
GD609091	TUBING ARTHROSCOPY OUTFLOW SUCTION (BOX OF 10)	79	0.990566038	1.009433962	0.732389937	0.216438356	4	1	1	63.744676	84.17006073
GD609109	TUBING ARTHROSCOPY INFLOW TUBESET	23	1	1	0.947368421	0.063013699	2	2	1	18.55857656	46.52299293
GD612861	CANNULA 6.5 X 72MM THRD ORANGE SNEPH	20	0.9375	1	0.390625	0.054794521	4	1	1	16.13789266	28.12898915
GD612884	CANNULA 5.5 X 72MM THRD BLUE SNEPH	65	1	1	0.835588235	0.178082192	4	1	1	52.44815114	76.03388807
GD612898	CANNULA 8 X 72MM THRD CLEAR GREEN SNEPH	71	0.927083333	1	0.844362745	0.194520548	4	1	1	57.28951894	80.84940744
GD612931	CANNULA 6.5 X 72MM SM ORANGE SNEPH	52	1	1	0.768627451	0.142465753	4	1	1	41.95852091	63.3927253
GD612940	WATERBUG ASPN	190	0.987107172	1.002417405	0.690679559	0.520547945	4	1	1	153.3099803	168.2688114
GD614060	CANNULA 8 X 90MM THRD LIME SNEPH	4	1	1	0.75	0.010958904	4	1	1	3.227578532	25.54977997
GD617813	CANNULA PASSPORT 8 X 4CM ARTHX	42	0.878968254	1	0.629960317	0.115068493	4	1	1	33.88957458	51.77515818
GD617814	CANNULA PASSPORT 8 X 5CM ARTHX	48	0.953125	1	0.712928922	0.131506849	2	2	1	38.73094238	58.73864331
GD618207	KIT SHOULDER SUSPENSION STERILE	4	1	1.333333333	0.333333333	0.010958904	4	1	1	3.227578532	13.86655028
GD619776	DRAPE SWITCH SPIDER	154	1	1	0.41546003	0.421917808	4	1	1	124.2617735	131.4730215
GD619777	KIT SHOULDER STABILIZATION SPIDER	156	1	1	0.412762695	0.42739726	4	1	1	125.8755627	132.9140801
GD95182	TELFA MULTIPACK	4	1	1	0.5	0.010958904	2	2	1	3.227578532	19.13707192
RU208645	CUP MEDICINE LG 7OZ	151	0.975490196	1.022058824	0.584593838	0.41369863	1	2	2	121.8410896	134.283406
RU210088	BASIN EMESIS LG 1200CC	2685	0.9959094	1.000191498	0.335958044	7.356164384	4	1	2	2166.512089	2083.577931
RU353763	ORT/DRILLBITS (METAL CASE)	716	1	1	0.418823269	1.961643836	1	2	2	577.7365572	565.1017299

RU354019	ORT/BONE PAN	228	1	1	0.328782642	0.624657534	4	1	2	278.5068372	189.2603817
RU354043	ORT/CLAMP PAN	1066	0.997975709	1	0.374402282	2.920547945	4	1	2	860.1496787	841.9612092
RU354423	ORT/OSTEOTOME SET	1978	0.998251748	1.000041625	0.462285367	5.419178082	4	1	2	1596.037584	1536.681159
RU354456	ORT/CUTTER PIN	241	1	1.007692308	0.577677045	0.660273973	2	1	2	194.4616065	205.5689348
RU354464	ORT/MINOR RETRACTOR PAN	1104	0.998322148	1	0.333938091	3.024657534	4	1	2	890.8116748	869.6137923
RU354472	ORT/PLATE BENDER	169	1	1	0.612077252	0.463013699	2	1	2	136.365193	150.2271356
RU354480	ORT/MAJOR RETRACTOR PAN	957	1	1	0.311659228	2.621917808	4	1	2	772.1981637	749.9090693
RU354605	ORT/STEINMANN PIN SET SMOOTH	300	0.996212121	1	0.479540548	0.821917808	4	1	2	242.0683899	249.1813684
RU354704	ORT/MALLET & OSTEOTOME SMALL	166	0.98828125	1.03125	0.450843254	0.454794521	2	1	2	133.9445091	140.1761058
RU358861	RETRACT GELPI	170	1	1.025974026	0.575804588	0.465753425	1	2	2	137.1720876	148.8150491
RU358911	ORT/CURETTES STRAIGHT BONE	738	1	1	0.541881182	2.021917808	4	1	2	595.4882391	591.1991358
RU358960	MALLET	2619	0.996767058	1.000027346	0.358485835	7.175342466	2	1	2	2113.257044	2031.895336
RU361527	ORT/RETRACT CHANDLER	129	1	1	0.51702381	0.353424658	2	1	2	104.0894077	117.8858634
RU372847	ORT/SPINE CAPENER GOUGES	269	1	1	0.547269084	0.736986301	2	1	2	217.0546563	224.330242
RU376996	ORT/RETRACT HAWKINS SHOULDER	210	1	1	0.479323842	0.575342466	2	1	2	169.4478729	178.3357139
RU377762	SUCTION TIP FRAZIER #12	248	0.992346939	1	0.40844204	0.679452055	1	2	2	200.109869	205.1406532
RU403022	ORT/LARGE WEDGE	173	1	1	0.428262446	0.473972603	2	1	2	139.5927715	148.7366145
RU452813	ORT/HAND PAN	265	1	1	0.306768215	0.726027397	4	1	2	213.8270777	219.9995363
RU600113	ORT/SCREWDRIVER SET UNIVERSAL	172	1	1	0.296534947	0.471232877	2	1	2	138.7858769	144.1437743
RU600899	ORT/SYN LOCKING SMALL FRAG SET	459	0.997354497	1	0.35756465	1.257534247	4	1	2	370.3646365	368.862674
RU607684	VETS/ARTHROSCOPY SET	186	0.993333333	1	0.328895425	0.509589041	2	1	2	150.0824017	155.7206842
RU607743	PWR/STRYKER CORDLESS DRIVER	1186	0.997276688	1.00739032	0.345251842	3.249315068	4	1	2	956.9770347	929.1538615
RU607744	PWR/CORE TPS BASE TRAY	731	1	1	0.437570144	2.002739726	4	1	2	589.8399767	576.2357781
RU607747	PWR/STRYKER BATTERY DRILL REAMER	453	1	1.029647059	0.297463106	1.24109589	4	1	2	365.5232687	355.8545995

RU607975	ORT/PLASTIC PAN	561	1	1	0.093356948	1.536986301	4	1	2	452.6678891	441.0128985
90658	COBAN 4IN	2652	0.848102072	1.090922028	0.327837979	7.265753425	2	2	1	2363.299424	1958.277541
91313	SEALANT TISSUE DERMABOND	490	0.935862043	1.1417753	0.200088316	1.342465753	1	2	1	469.9128701	354.6902558
91342	ACE BANDAGE 4IN	1617	0.824925568	1.136960784	0.308545443	4.430136986	2	2	1	1418.559765	1179.145037
91343	ACE BANDAGE 6IN	1692	0.794098764	1.236348236	0.24975083	4.635616438	2	2	1	1446.618476	1171.54808
91366	BANDAGE SPONGE (FINGER ROLL) 1INX5YD	23	0.867346939	1	0.433673469	0.063013699	2	2	1	18.55857656	30.83560418
91451	PACK MAJOR PLASTICS	1	1	1	1	0.002739726	4	1	1	30.10157926	30.50001623
91476	EYE PAD	1	1	1	0	0.002739726	1	2	1	0.990667671	1.577913957
91493	PACK TOTAL HIP CUSTOM	2	1	1	0	0.005479452	4	1	1	2.35895397	2.337236618
91495	PACK MAJOR ABDOMINAL	1	1	1	1	0.002739726	4	1	1	30.10157926	30.50001623
91577	BOVIE TIP CLEANER	460	0.851059368	1.537430297	0.170868559	1.260273973	1	2	1	414.0727502	288.5556068
91653	DRAPE MEDIUM SHEET	1657	0.911967977	1.63333115	0.132529318	4.539726027	4	1	1	1831.574486	993.8143021
91679	DRAPE PEDIATRIC LAP SHEET	1	1	1	0	0.002739726	4	1	1	1.179476985	1.577913957
91694	BASIN SET OR	1	1	1	0	0.002739726	4	1	1	1.179476985	1.577913957
92545	DRAIN PENROSE 1/4IN	113	0.917344173	1.177506775	0.368224932	0.309589041	2	2	1	116.2772167	91.29195698
92625	BLADE #11	205	0.905512656	1.151351351	0.244809095	0.561643836	1	2	1	165.4133998	154.7685452
92732	DRAIN JP 7MM FLAT	679	0.785845053	2.01555514	0.249316654	1.860273973	2	2	1	581.0234107	375.6778158
92739	DRAIN JP BULB 100CC	874	0.863876349	1.661646657	0.161291508	2.394520548	2	2	1	789.6336743	523.4312863
92800	GLOVE SURGICAL ORTHOPAEDIC 9.0	1263	0.790987103	1.650231384	0.16493015	3.460273973	2	2	1	1076.425404	750.0602157
92944	BAG URINARY DRAINAGE	3	0.75	1	0.25	0.008219178	1	2	1	9.692294115	10.3276007
93002	BASIN SALINE	728	0.908832256	1.08110284	0.110134133	1.994520548	2	1	1	804.1977869	538.0462639
93181	DRAIN HEMOVAC MEDIUM	1464	0.910268681	1.165956658	0.166363865	4.010958904	1	2	1	1365.939425	1037.747101
93189	PLEUROVAC ADULT DRY	1	1	1	1	0.002739726	4	1	1	30.10157926	30.50001623
93201	BASIN 7 LITER	229	0.867389306	1.071557971	0.193780415	0.62739726	4	1	1	249.3360983	175.1144377

93340	PACK OPHTHALMOLOGY	1	1	1	0	0.002739726	4	1	1	1.179476985	1.577913957
93431	BUNDLE BURN	2	1	1	1	0.005479452	4	1	1	31.28208795	31.26037059
93843	TUBING IV 1 SITE 15 DRPS/ML	1	1	1	0	0.002739726	2	2	1	0.990667671	1.577913957
99505	NEEDLE SPINAL 18GA	330	0.891080774	1.071019657	0.300430675	0.904109589	1	2	1	311.2339602	254.4395452
99709	CATHETER MALECOT 24FR	1	1	1	0	0.002739726	1	2	1	0.990667671	1.577913957
99766	TOTE BRONCHOSCOPY	1	1	1	1	0.002739726	4	1	1	30.10157926	30.50001623
GD201327	DRAIN JP 7FR RND	80	0.939480519	1.085714286	0.072900433	0.219178082	2	2	1	78.07068583	62.4760333
GD206987	LINEN SHODS	1	1	1	1	0.002739726	2	2	1	29.91276995	30.50001623
GD225581	BOWL MIXING AND SPATULA	598	0.896587683	1.198514329	0.138592033	1.638356164	4	1	1	655.631446	418.542344
GD390062	DRAIN BLAKE 19FR RND	16	0.851851852	1.333333333	0.203703704	0.043835616	2	2	1	20.13115128	17.06382398
GD390153	RETRIEVER HEWSON SUTURE	420	0.913819548	1.011856618	0.456085079	1.150684932	2	2	1	404.8191702	334.1836239
GD422964	KIT PERCUTANEOUS ENDOSCOPIC GASTROSTOMY (PEG) 24FR	1	1	1	0	0.002739726	2	2	1	0.990667671	1.577913957
GD438085	BURR ROUND CUTTER 4MM 10BA40	30	0.925925926	1	0.569444444	0.082191781	2	1	1	49.93796684	40.90343024
GD438754	BURR RND DIAMOND 4.0MM 15BA40D	1	1	1	1	0.002739726	2	2	1	29.91276995	30.50001623
GD439091	SKIN MARKER WIDE	712	0.888264511	1.045434448	0.174711251	1.950684932	1	2	1	656.3591125	538.4537583
GD522951	BLADE COATED INSULATED 4IN	8	0.8	1	0.2	0.021917808	1	2	1	12.62160553	12.67903742
GD600958	BLADE EZ CLEAN 2.5IN MODIFIED MEGADYNE	118	0.850952381	1.358333333	0.097738095	0.323287671	2	2	1	107.7601982	80.89718803
GD602062	TOWER SMARTMIX W/SNAP OFF NOZZLE	316	0.842384671	1.074050221	0.463495822	0.865753425	4	1	1	254.978704	246.9797799
GD607008	SEALER BIPOLAR 6.0 AQUAMANTYS	19	0.638888889	1	0.138888889	0.052054795	2	2	1	18.16980408	19.26525975
GD607546	STIMULATOR/LOCATOR NERVE	1	1	1	0	0.002739726	2	2	1	0.990667671	1.577913957
GD607571	BURR CARBIDE CUTTING ROUND 4.0MM	1	1	1	0	0.002739726	2	2	1	0.990667671	1.577913957
GD607664	BRACE POST OP T-SCOPE REG	27	0.865546218	1	0.68487395	0.073972603	4	1	1	48.51461555	41.14666873
GD607907	SURGIFLO W/THROMBIN ETH	970	0.580764121	1.439636053	0.189283585	2.657534247	2	2	1	689.6765336	616.3777164
GD607932	DRAPE TABLE DOUBLE DECKER	1373	0.91037206	1.012509676	0.194575978	3.761643836	4	1	1	1518.28681	1050.648312

GD608124	BLADE RECIPROCATOR SAW 7.9 X 83.3 X 1.3MM STRYKER	19	0.772727273	1	0.465909091	0.052054795	1	2	1	29.36572469	28.72944443
GD608125	BLADE OSCILLATING SAW LARGE 19.5 X71 X 0.8MM STRYKER	588	0.936590143	1.02808642	0.525517107	1.610958904	1	2	1	474.4540442	460.5060753
GD608133	BURR ROUND CUTTING 5MM STRYKER	470	0.896302614	1.05374078	0.456683922	1.287671233	2	2	1	445.8525958	363.6256001
GD608186	BLADE SAGITTAL 18 X 90 X 1.19 DEPUY KNEE STRYKER	561	0.864583032	1.048400839	0.56588158	1.536986301	1	2	1	520.7231214	434.3020313
GD608192	BLADE RECIP 70 X 1 X 12.5 STRYKER	944	0.869612405	1.026833333	0.615663237	2.58630137	1	2	1	869.7739878	728.2063725
GD608429	SUCTION FILTER REDI-FLOW	1158	0.754285877	1.030594747	0.320438688	3.17260274	4	1	1	1127.991595	879.2182532
GD608594	SCISSOR UTILITY 7 1/2IN	933	0.93741432	1.000200481	0.603091236	2.556164384	1	2	1	752.8326925	730.4794731
GD608746	KIT INTRODUCER J/TJ LAP MIC 18FR	1	1	1	0	0.002739726	2	2	1	0.990667671	1.577913957
GD608751	HANDPIECE VERSAJET PLUS 14MM	2	1	1	1	0.005479452	4	1	1	31.28208795	31.26037059
GD608966	TUBE FEEDING GASTROSTOMY 18FR MIC	1	1	1	1	0.002739726	2	2	1	29.91276995	30.50001623
GD609049	DRESSING FOAM 4 X 10 MEPILEX (ORTHO)	523	0.753632783	1.134961803	0.274128219	1.432876712	2	1	1	512.8674263	380.5113491
GD615818	BLADE CARPAL TUNNEL RELEASE SYSTEM	7	0.45	1	0.35	0.019178082	2	2	1	14.43772443	16.25875229
GD617812	CANNULA PASSPORT 8 X 3CM ARTHX	43	0.939285714	1	0.719642857	0.117808219	2	2	1	34.69646922	55.13282442
RU203075	SCISSORS NURSE 5 1/2IN	1	1	1	1	0.002739726	1	2	2	29.91276995	30.50001623
RU211409	URO/NEEDLEHOLDER STRATTE 9IN	1	1	1	0	0.002739726	1	2	2	0.990667671	1.577913957
RU212670	RETRACT WEITLANER SHRP 5 1/2IN	15	1	1.444444444	0.407407407	0.04109589	1	2	2	26.64897828	22.74065304
RU219329	PLS/TONGS MAYFIELD	1	1	1	0	0.002739726	4	1	2	1.179476985	1.577913957
RU350272	PEDO/PEDIATRIC TRACTION BOW	5	1	1	1	0.01369863	2	1	2	34.823614	34.36002497
RU350355	ORT/PARK RING CURETTES	9	1	1	1	0.024657534	4	1	2	39.54564873	36.58285111
RU351130	NSG/LAMINECTOMY SET PART 1	37	1	1	0.054166667	0.101369863	4	1	2	45.20927412	31.30074673
RU351510	PLS/BASIC PAN	10	1	1	0.5	0.02739726	4	1	2	26.26046363	23.69610298
RU351536	PLS/BONE PAN	3	1	1	0.666666667	0.008219178	4	1	2	22.82120807	22.3793364
RU351544	PLS/EXTRA SET	8	1	1	0.5	0.021917808	4	1	2	23.90047796	22.17642596
RU351569	PLS/BURN SET	4	1	1	0.5	0.010958904	4	1	2	19.18050663	19.13707192

RU351619	PLS/CURETTE SET	28	1	1.15	0.575	0.076712329	2	1	2	49.67158151	38.72081456
RU351700	PLS/HAND SET	6	1	1	0	0.016438356	4	1	2	7.076861909	5.374527261
RU351825	PLS/DRAKE PAN	7	1	1	0.75	0.019178082	4	1	2	29.95255825	28.64866057
RU351858	PLS/OSTEOTOMES & MALLET SMALL	17	1	1.25	0.25	0.046575342	4	1	2	27.28576111	21.07008308
RU353326	GEN/BONE PAN	2	1	1	0	0.005479452	2	1	2	2.35895397	2.337236618
RU353334	GEN/BOOKWALTER RETRACT PAN	2	1	1	0.5	0.005479452	2	1	2	16.82052096	17.6173949
RU353342	GEN/BOWEL INSTRUMENTS	1	1	1	1	0.002739726	2	1	2	30.10157926	30.50001623
RU353383	GEN/CLAMP PAN	4	1	1	0.25	0.010958904	2	1	2	11.94920728	11.90577258
RU353532	GEN/PLASTIC PAN	1	1	1	0	0.002739726	4	1	2	1.179476985	1.577913957
RU353581	GEN/BASIC PAN	3	1	1	0	0.008219178	4	1	2	3.538430954	3.096559279
RU353946	ORT/SYN DHS BASIC INST	22	1	1	0.147727273	0.060273973	4	1	2	30.22427757	22.61806503
RU354068	ORT/COBB ELEVATORS & GOUGES	1	1	1	1	0.002739726	2	1	2	30.10157926	30.50001623
RU354076	ORT/CRAIG NEEDLE BIOSPY SET	5	1	1	0.25	0.01369863	2	1	2	13.12894219	11.84676187
RU354183	ORT/ENDER NAIL SET	1	1	1	0	0.002739726	2	1	2	1.179476985	1.577913957
RU354191	ORT/ENDER NAIL INSTRUMENT	1	1	1	0	0.002739726	2	1	2	1.179476985	1.577913957
RU354340	ORT/K WIRE TRAY	9	1	1	0.3125	0.024657534	2	1	2	19.65602907	17.51182275
RU354373	ORT/LAMINECTOMY RETRACT PAN	48	1	1	0.112903226	0.131506849	4	1	2	59.88576857	42.17413491
RU354530	ORT/RUSH ROD PAN	1	1	1	0	0.002739726	4	1	2	1.179476985	1.577913957
RU354878	ORT/ACE 4.5/5 CANN SCREW SET	1	1	1	0	0.002739726	4	1	2	1.179476985	1.577913957
RU354886	ORT/SYN SM EXTERNAL FIXATOR	2	1	1	0.5	0.005479452	4	1	2	16.82052096	16.79880361
RU354894	ORT/SYN LG EXTERNAL FIXATOR	72	1	1	0.469488844	0.197260274	4	1	2	98.53533763	71.55859149
RU355883	EYE/NEWMAN PAN	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU356428	PWR/MESHER	30	1	1	0.4	0.082191781	4	1	2	46.96511816	36.81626233
RU356444	PWR/PADGETT DERMATOME	31	1	1	0.44	0.084931507	4	1	2	49.30312995	38.7341198

RU358002	HANDLE GIGLI SAW/GUIDE	31	1	1	0.588333333	0.084931507	1	2	2	47.74474414	43.0288227
RU358010	KNIFE AMPUTATION	29	1	1	0.492982456	0.079452055	4	1	2	48.47716264	38.74846113
RU358119	CLAMP HEMOSTAT CRILE CRVD	10	1	1	0.666666667	0.02739726	1	2	2	29.19426842	28.51800091
RU358127	CLAMP HEMOSTAT CRILE ST	12	1	1	0.797619048	0.032876712	1	2	2	34.96588366	33.82692612
RU358192	HANDLE KNIFE BEAVER 7IN	5	1	1	0.375	0.01369863	1	2	2	15.80067426	16.2811318
RU358218	CLAMP TONSIL ADULT 8 1/4IN	3	1	1.5	0	0.008219178	1	2	2	2.972003014	2.646903866
RU358440	FORCEP ADSON 5IN W/TEETH	1	1	1	0	0.002739726	1	2	2	0.990667671	2.396505253
RU358515	FORCEPS FERRIS SMITH 6 3/4IN	25	0.882352941	1	0.466911765	0.068493151	1	2	2	36.27938027	34.13588002
RU358549	FORCEPS SINGLEY RING 9IN	1	1	1	0	0.002739726	1	2	2	0.990667671	1.577913957
RU358580	FORCEPS DEBAKEY HEAVY 9 1/2IN	3	1	1.5	0	0.008219178	1	2	2	2.972003014	2.646903866
RU358754	RETRACT ARMY NAVY	4	1	1	1	0.010958904	1	2	2	32.88786806	33.59967061
RU358838	RETRACT BECKMAN ADSON SHRP	2	1	1	0.5	0.005479452	1	2	2	16.44290233	16.79880361
RU358853	RETRACT CEREBELLAR	65	1	1	0.599224806	0.178082192	1	2	2	81.76380582	70.00074532
RU358879	RETRACT WEITLANER SHRP 7 1/2IN	2	1	1	0	0.005479452	1	2	2	1.981335343	2.337236618
RU358903	CUTTER BONE	6	1	1	0.833333333	0.016438356	1	2	2	30.05005667	30.2991692
RU358929	WIRE TWISTER	1	1	1	0	0.002739726	1	2	2	0.990667671	1.577913957
RU359026	RASP	30	1	1	0.312755102	0.082191781	1	2	2	38.77492259	33.47175487
RU359638	PLS/WECK HANDLE & GUARDS	29	1	1	0.552083333	0.079452055	2	1	2	50.18819153	40.45949003
RU360644	FORCEPS DEBAKEY MED 7 3/4IN	33	1	1.052631579	0.25	0.090410959	1	2	2	39.93081232	34.01026942
RU360735	RETRACT ALM 3IN	1	1	1	1	0.002739726	1	2	2	29.91276995	30.50001623
RU361923	PLS/LEAD HAND	128	1	1	0.419163763	0.350684932	4	1	2	163.1510725	115.1014581
RU376004	ORT/DACUS HAND PAN	3	1	1	1	0.008219178	2	1	2	32.46259663	32.83931625
RU376293	ORT/MITEX SUTURE INST	142	1	1	0.541619481	0.389041096	4	1	2	183.229295	128.4789288
RU376343	PEDO/PLASTIC BONE PAN	6	1	1	0	0.016438356	4	1	2	7.076861909	6.193118558

RU376350	PEDO/RETRACT PAN	2	1	1	0.5	0.005479452	4	1	2	16.82052096	17.6173949
RU377135	ORT/MICRO INST	20	1	1	0.333333333	0.054794521	4	1	2	33.23677455	26.47087066
RU377861	ORT/SPINE CLAMP XLONG	1	1	1	1	0.002739726	4	1	2	30.10157926	31.31860753
RU391581	ORT/CURETTES XLARGE	35	1	1	0.597222222	0.095890411	2	1	2	58.57556588	46.32593843
RU402073	FORCEPS DEBAKEY MED 6IN	13	1	1	0.333333333	0.035616438	1	2	2	22.52350728	21.15320474
RU402081	FORCEPS DEBAKEY HEAVY 6IN	19	1	1	0.53125	0.052054795	1	2	2	34.19741821	31.4390456
RU402107	FORCEPS DEBAKEY HEAVY 7 3/4IN	69	1	1	0.391056911	0.189041096	1	2	2	79.69369209	67.00525155
RU402172	NEEDLEHOLDER RYDER 9IN	1	1	1	1	0.002739726	1	2	2	29.91276995	30.50001623
RU402438	ORT/SYN AO ADJUSTMENT KIT	63	1	1	0.339047619	0.17260274	2	1	2	84.13470725	60.12075873
RU402487	ORT/CHAN SPINE PAN	11	0.708333333	1.041666667	0.75	0.030136986	4	1	2	31.88292171	31.49119793
RU423137	ORT/ACE SMALL FRAG SET	1	1	1	1	0.002739726	4	1	2	30.10157926	30.50001623
RU423533	CUP MEDICINE SM 2OZ	3	1	1	0.333333333	0.008219178	4	1	2	13.17981951	13.55653913
RU434944	ORT/DACUS MICRO INST & CLIPS	10	1	1	0.785714286	0.02739726	4	1	2	34.52657436	31.96221372
RU436170	ORT/RICH TRIGEN INST	2	1	1	0	0.005479452	4	1	2	2.35895397	3.155827914
RU437996	PLS/SYN MODULAR HAND	24	1	1	0.541666667	0.065753425	4	1	2	43.98643961	36.35850973
RU452821	ORT/SYN ELASTIC NAIL TIT	1	1	1	1	0.002739726	4	1	2	30.10157926	31.31860753
RU453001	ORT/ZIM MED EXPLANT CUP SYST	2	1	1	0	0.005479452	4	1	2	2.35895397	3.155827914
RU480517	PLS/COLORED JURGAN PIN BALL SET	1	1	1	1	0.002739726	2	1	2	30.10157926	31.31860753
RU482034	ORT/CHHABRAS MICRO INST	47	1	1	0.495	0.128767123	4	1	2	69.77535069	54.12105395
RU482950	ORT/HAND TENDON STRIPPERS	5	1	1	0.8	0.01369863	2	1	2	29.03836818	28.57477915
RU487199	ORT/RICH TRIGEN ADJ/REMOVAL KIT	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU498014	ORT/STRYK HOWM T2 FEM/TIB INST	7	1	1	0.2	0.019178082	4	1	2	14.04199739	12.73809971
RU498048	ORT/DR CHAN COBB ELEVATORS	13	1	1	0.222222222	0.035616438	4	1	2	21.76308584	17.93826222
RU521655	ORT/VASCULAR INST	1	1	1	0	0.002739726	2	1	2	1.179476985	2.396505253

RU521679	ORT/OSCAR II INSTRUMENTS	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU521831	RETRACT WILT GELPI 11IN	63	1	1	0.327564103	0.17260274	1	2	2	71.90685852	59.78789674
RU522495	ORT/SMALL WEDGE	7	1	1	0.428571429	0.019178082	4	1	2	20.65417852	19.35028085
RU523087	FORCEPS RUSSIAN SHT 6IN	11	1	1	0.333333333	0.030136986	1	2	2	20.54148414	19.63387162
RU523119	RETRACT BECKMAN ADSON DULL	2	1	1	0.5	0.005479452	1	2	2	16.44290233	17.6173949
RU523143	RETRACT WEITLANER SHRP 4 1/2IN	92	1	1.392857143	0.566666667	0.252054795	1	2	2	107.5838183	80.36223494
RU600010	SCISSORS JAMISON 8IN	19	1	1	0.241666667	0.052054795	1	2	2	25.8166817	23.05830909
RU600174	KNIFE HANDLE #4	1	1	1	0	0.002739726	1	2	2	0.990667671	2.396505253
RU600210	ORT/CHHABRA TENDON STRIPPERS	15	1	1	0.535714286	0.04109589	4	1	2	33.19387587	28.52874361
RU600768	PEDO/RICH SPATIAL FRAME SYSTEM	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU600769	PEDO/RICH SPATIAL FRAME IMPLANT	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU600783	ORT/SYN CABLE INSTRUMENTS	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU600794	PEDO/RICH JET X/TSF REMOVAL SET	3	1	1	0.333333333	0.008219178	4	1	2	13.17981951	13.55653913
RU600803	HANDLE KNIFE BEAVER 5IN	17	1	1	0.272727273	0.046575342	1	2	2	24.73369845	22.43801586
RU600811	ORT/ARLETS SPINE PAN	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU600812	ORT/ARLET PAN	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU600894	ORT/DEPUY SCREW REMOVAL SET	13	1	1	0.545454545	0.035616438	4	1	2	31.11564589	27.29082227
RU600895	ORT/TRIMLINE MICRO CURETTES	37	1	1	0.101449275	0.101369863	4	1	2	46.5785427	32.67001531
RU603106	ORT/DEPUY SKYLINE INST	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU603107	NSG/SFDNK METRX QUADRANT RET	1	1	1	1	0.002739726	4	1	2	30.10157926	31.31860753
RU603141	TCV/CHERRY TUBING 42IN	1	1	1	0	0.002739726	2	1	2	1.179476985	2.396505253
RU604049	ORT/ HOW GAMMA NAIL 3	6	1	1	0.083333333	0.016438356	4	1	2	9.487466973	8.603723622
RU607093	ORT/CUI TREPHINE TROCAR SET	13	1	1	0.742857143	0.035616438	2	1	2	36.82738792	33.0025643
RU607508	ORT/SYN LARGE FRAGMENT INST	69	1	1	0.60385101	0.189041096	4	1	2	98.8909161	73.17463293

RU607509	ORT/SYN LARGE FRAGMENT PLATE SET	62	1	1	0.635510511	0.169863014	4	1	2	91.54786802	67.95407382
RU607510	ORT/SYN LARGE FRAGMENT SCREW SET	85	1	1	0.497165533	0.232876712	4	1	2	114.6777018	82.23894945
RU607517	ORT/SYN 4.0 CANN SCREW SET	37	1	1	0.290123457	0.101369863	4	1	2	52.04240425	38.95246815
RU607519	ORT/CHHABRAS RADIAL HEAD SYSTEM	5	1	1	0.625	0.01369863	4	1	2	23.97627809	23.51268907
RU607673	OPSC/KAHLERS BONE BIOPSY PAN	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU607697	PLS/TENDON TRAY	30	1	1	0.437681159	0.082191781	2	1	2	48.0560639	37.90720807
RU607776	VEIN RETRACTOR	1	1	1	1	0.002739726	1	2	2	29.91276995	31.31860753
RU607784	ORT/SYN MINI FRAG SET	36	1	1	0.427083333	0.098630137	4	1	2	54.82874105	42.97755057
RU607814	PWR/CORE MICRO DRILL	40	1	1	0.431051587	0.109589041	2	1	2	59.66334139	45.31294232
RU607816	PWR/CORE MICRO OSCILLATING SAW	9	1	1	0.857142857	0.024657534	2	1	2	35.41274075	33.26853443
RU607817	PWR/CORE UNIVERSAL DRIVER TRAY	2	1	1	0.5	0.005479452	2	1	2	16.82052096	17.6173949
RU607824	ORT/SYN 4.5 CANN ANG BLADE PLATE	10	1	1	0.777777778	0.02739726	4	1	2	34.29696018	31.73259953
RU607829	ORT/SYN MEDIUM EXTERNAL FIXATOR	9	1	1	0.375	0.024657534	4	1	2	21.46417631	19.31996999
RU607855	ORT/SYN 3.5MM LCP ELBOW SET	46	1	1	0.488888889	0.126027397	4	1	2	68.41833312	52.3655994
RU607892	ORT/SYN 3.5MM LCP CLAVICLE PLATE	31	1	1	0.380952381	0.084931507	4	1	2	47.5935211	37.02451094
RU607904	ORT/REDUCTION CLAMPS	82	1	1	0.49691358	0.224657534	4	1	2	111.130424	80.77072593
RU607909	ORT/SYN LOCKING CALCANEAL PLATE	35	1	1	0.39520202	0.095890411	4	1	2	52.72563052	39.65741177
RU607916	ORT/SYN RECON INSTRUMENTS	25	1	1	0.424561404	0.068493151	4	1	2	41.77664542	33.72856121
RU607917	ORT/SYN RECON IMPLANTS	22	1	1	0.479166667	0.060273973	4	1	2	39.81738247	33.02976124
RU607922	ORT/SYN RAFN INSTRUMENTS	25	1	1	0.333333333	0.068493151	4	1	2	39.13587897	31.08779476
RU607928	ORT/SYN RAFN IMPLANTS	21	1	1	0.288888889	0.057534247	4	1	2	33.1302516	26.76278468
RU607961	PEDO/RICH SPATIAL RING TRAY	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU607963	ORT/ARLET KERRISON & COBBS PAN	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU607969	PEDO/VERTEBRAL BODY SPREADER	1	1	1	1	0.002739726	4	1	2	30.10157926	31.31860753

RU607985	ORT/DOMSON PITUITARY TRAY	57	1	1	0.502150538	0.156164384	4	1	2	81.78244915	60.28942658
RU608122	ORT/SYN PERC-INSTR FEM NAIL	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU608123	ORT/SYN 7.3 CAN SCREW FTHREAD	13	1	1	0.273809524	0.035616438	4	1	2	23.25573772	19.4309141
RU608182	APPLIER CLIP LG 8" ORANGE WECK	41	1	1	0.719333333	0.112328767	1	2	2	61.45169218	54.42232063
RU608205	ORT/HOUSE ANKLE CURETTES	1	1	1	1	0.002739726	4	1	2	30.10157926	31.31860753
RU608308	OPSC/ORT SHORT CURETTES	6	1	1	0.333333333	0.016438356	4	1	2	16.71928217	15.83553881
RU608319	PLS/BONE REDUCTION FORCEPS	1	1	1	1	0.002739726	4	1	2	30.10157926	31.31860753
RU608321	ORT/SYN SCREW REMOVAL SET	9	1	1	0.333333333	0.024657534	4	1	2	20.25874482	18.1145385
RU608378	ORT/OMNISPAN INST	2	1	1	0.5	0.005479452	4	1	2	16.82052096	17.6173949
RU608392	ORT/WINQUIST NAIL EXTRACTION CS2	6	1	1	0.2	0.016438356	4	1	2	12.86231406	11.97857071
RU608393	ORT/TRACTION TOWER	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU608398	ORT/FROMM TRIANGLE MEDIUM 14IN	2	1	1	0.5	0.005479452	4	1	2	16.82052096	17.6173949
RU608399	ORT/FROMM TRIANGLE LARGE 16IN	3	1	1	0.5	0.008219178	4	1	2	18.00051379	18.37723341
RU608444	ORT/JUGGERKNOT GUIDE	2	1	1	0.5	0.005479452	4	1	2	16.82052096	17.6173949
RU608462	ORT/ACUMED ACUTRAK 2 INST	1	1	1	0	0.002739726	4	1	2	1.179476985	2.396505253
RU608492	ORT/GJOLAJ PAN	24	1	1	0.089285714	0.065753425	4	1	2	30.89189686	23.26396698
RU608502	ORT/KERRISON RONGUER 10IN TRAY	16	1	1	0.523809524	0.043835616	4	1	2	34.02941058	29.76271529
RU608667	ORT/SYN 2.7 LCP MIDFOOT SET	2	1	1	0.5	0.005479452	4	1	2	16.82052096	17.6173949
RU608671	ORT/SYN 6.5 HEADLESS SCREW SET	14	1	1	0.681818182	0.038356164	4	1	2	36.24143758	31.99645964
RU608692	ORT/SYN MEDIUM EXFIX BARS	2	1	1	1	0.005479452	4	1	2	31.28208795	32.07896189
RU615786	OPSC/SYN 4.0 CANN SCREW SET	1	1	1	0	0.002739726	2	1	2	1.179476985	2.396505253
RU617009	OPSC/DACUS KNIFE TENOLYSIS/FREER	1	1	1	0	0.002739726	2	1	2	1.179476985	2.396505253
91363	BOOT UNNAS	2	1	2	0	0.005479452	4	1	1	1.887581205	1.613789266
91519	SPONGE RAYTEC 10 PACK	472	0.999742002	1.503350335	0.01754386	1.293150685	2	1	1	296.8596205	380.8542668

91533	PATTY 1 X 1	84	1	1.243858998	0	0.230136986	2	2	1	67.77914917	67.77914917
91558	TELFA	227	0.97	3.73	0.31	0.621917808	4	1	1	115.7021902	183.1650817
91561	STERI-STRIP 1/2IN	1084	0.919182635	1.427916735	0.135276811	2.969863014	2	2	1	874.6737821	874.6737821
91666	GOWN XLARGE	3625	0.976203658	1.964847033	0.013246067	9.931506849	1	2	1	2006.584991	2924.993044
91937	NEEDLE HYPO 16GA X 1.5IN	2466	0.997533517	1.681308755	0.001692332	6.756164384	1	2	1	1455.133877	1989.802165
92166	COVER LIGHT HANDLE STERIS	1322	0.950041419	2.29431692	0.135141093	3.621917808	4	1	1	702.0364417	1066.714705
92447	SPACE HOOD	1316	0.892490297	2.262535126	0.07362458	3.605479452	1	2	1	678.660047	1061.873337
92627	BLADE #15	1736	0.954688552	2.458900695	0.085571789	4.756164384	1	2	1	893.6881161	1400.769083
92751	GLOVE SURGICAL LATEX UNDER 6.5	1770	0.999036866	1.762819437	0.000236967	4.849315068	2	2	1	1428.2035	1428.2035
92752	GLOVE SURGICAL LATEX UNDER 7	3436	0.996582808	1.984463031	0.001275046	9.41369863	2	2	1	1890.092556	2772.489959
92753	GLOVE SURGICAL LATEX UNDER 7.5	3487	0.996829325	2.084928592	0.001520608	9.553424658	2	2	1	1886.744147	2813.641585
92754	GLOVE SURGICAL LATEX UNDER 8	7146	0.994728956	2.778667367	0.001398038	19.57808219	2	2	1	3471.651997	5766.069047
92755	GLOVE SURGICAL LATEX UNDER 8.5	2946	0.999648151	1.879316941	0.001897533	8.071232877	2	2	1	1658.145624	2377.111589
92758	GLOVE SURGICAL SMOOTH 6.5	895	0.986426442	1.861231782	0.000171999	2.452054795	2	2	1	499.1107144	722.1706965
92759	GLOVE SURGICAL SMOOTH 7	338	1	3.286666667	0	0.926027397	2	2	1	157.4587134	272.7303859
92760	GLOVE SURGICAL SMOOTH 7.5	9	1	3	0	0.024657534	2	2	1	4.954562766	7.262051697
92764	GLOVE SURG FREE UNDER 6.5	832	0.997082166	2.115752968	0.004201681	2.279452055	2	2	1	671.3363346	671.3363346
92765	GLOVE SURG LATEX FREE UNDER 7	853	0.996690757	1.956712256	0.008368201	2.336986301	2	2	1	688.2811219	688.2811219
92767	GLOVE SURG LATEX FREE UNDER 8	589	1	2.492429593	0	1.61369863	2	2	1	300.9334681	475.2609388
92773	GLOVE SURGICAL TEXTURED 7.5	4127	0.998279912	2.460945474	0.001450677	11.30684932	2	2	1	2087.780184	3330.05415
92774	GLOVE SURGICAL TEXTURED 8	3773	0.993229373	2.132186553	0.003573749	10.3369863	2	2	1	2010.836974	3044.41345
92775	GLOVE SURGICAL TEXTURED 8.5	2245	0.943346117	1.512206595	0.034938563	6.150684932	2	2	1	1381.855275	1811.478451
92777	GLOVE SURGICAL MICRO THIN 6.5	4939	0.997515471	2.542621848	0.000286287	13.53150685	2	2	1	2459.387121	3985.252592
92778	GLOVE SURGICAL MICRO THIN 7.0	2747	0.998666667	2.123011465	0.000222222	7.526027397	2	2	1	1470.953428	2216.539557

92779	GLOVE SURGICAL MICRO THIN 7.5	1345	0.999734043	1.719022423	0.000265957	3.684931507	2	2	1	1085.273281	1085.273281
92780	GLOVE SURGICAL MICRO THIN 8	1753	0.998774259	1.977181681	0	4.802739726	2	2	1	977.5361785	1414.486292
92782	GLOVE SURGICAL ORTHOPAEDAEDIC 8.5	1515	0.995285138	1.633364485	0.012697239	4.150684932	2	2	1	1222.445369	1222.445369
92784	GLOVE SURG LATEX FREE OVER 6.5	360	0.997641509	2.661163522	0.002358491	0.98630137	2	2	1	290.4820679	290.4820679
92786	GLOVE SURG LATEX FREE OVER 7.5	379	0.994845361	3.116838488	0.015463918	1.038356164	2	2	1	182.3172697	305.8130659
92787	GLOVE SURG LATEX FREE OVER 8	544	0.995592287	3.230263676	0	1.490410959	2	2	1	256.4631086	438.9506803
92796	GLOVE SURGICAL TEXTURED 7	1405	0.994144144	1.83449351	0.002102102	3.849315068	2	2	1	1133.686959	1133.686959
92798	GLOVE SURGICAL ORTHOPAEDIC 7.5	1671	0.997461158	1.765244144	0.000119613	4.578082192	2	2	1	964.3898918	1348.320932
92799	GLOVE SURGICAL ORTHOPAEDIC 8.0	3272	0.938096005	1.954901068	0.046689501	8.964383562	2	2	1	1802.545727	2640.159239
94697	TOWELS 4PK	1937	0.986437327	1.663998196	0.007340432	5.306849315	4	1	1	1562.954904	1562.954904
GD231670	RELOAD LINEAR CUTTER 75MM 3.5	4	1	4	0	0.010958904	2	1	1	2.506915701	3.227578532
GD232561	ARGON BEAM ANGLED FOOT CONTROL	2	1	2	0	0.005479452	4	1	1	1.887581205	1.613789266
GD233155	DRESSING WOUND 2 X 3IN	1836	0.931656588	1.959902232	0.06133294	5.030136986	2	1	1	1012.951269	1481.458546
GD27441	DRAIN JP 15FR RND	2	1	2	0	0.005479452	2	2	1	1.887581205	1.613789266
GD607599	ORTHOCORD VIOLET W/MO7 TAPER NEEDLE #2	35	1	2.666666667	0	0.095890411	2	2	1	28.24131215	28.24131215
GD608651	CLIP LIGATING MED HORIZON	110	0.96743295	1.861302682	0.157088123	0.301369863	1	2	1	88.75840963	88.75840963
GU607911	WIRE SENSOR ANGLED .035	2	1	2	0	0.005479452	2	2	1	1.887581205	1.613789266
90182	BALLOON LP 14FR X 1CM	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
90268	BOVIE PAD ARGON BEAM CONMED	2	1	1	0	0.005479452	2	2	1	1.981335343	1.613789266
90604	CATHETER FOLEY TEMP PROBE 12FR	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
90662	BOVIE EXTENDER 4IN	71	0.958823529	1	0.007352941	0.194520548	2	2	1	68.55967344	57.28951894
91511	SPONGE STRIPS (PEDS RAYTEC)	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
91574	BOVIE PENCIL LONG EZCLEAN	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
91632	TUBING ENDO SUCTION IRRIGATION	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633

91647	DRAPE LAP INCISE	2	1	1	0	0.005479452	4	1	1	2.35895397	1.613789266
91680	DRAPE CHEST BREAST SHEET	2	1	1	0	0.005479452	4	1	1	2.35895397	1.613789266
91706	CATHETER FOLEY 12FR 5CC	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
91710	CATHETER FOLEY 20FR 5CC	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
91740	Drape Split	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
91757	CATHETER RED RUBBER 10FR	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
91758	CATHETER RED RUBBER 12FR	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
91761	CATHETER RED RUBBER 18FR	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
92465	DRESSING RESTORE 6 X 8IN	1	1	1	0	0.002739726	2	1	1	1.179476985	0.806894633
92472	TUBING IV EXTENSION W/T CONNECTOR	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
92948	BAG URETERAL DRAINAGE	2	1	1	0	0.005479452	4	1	1	2.35895397	1.613789266
93001	BASIN EMESIS KIT DISPOSABLE	1	1	1	0	0.002739726	2	1	1	1.179476985	0.806894633
93184	PLEUROVAC PEDIATRIC DRY	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633
93544	GUIDE WIRE BENTSON TEFLON	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
93548	GUIDE WIRE .035 X 40CM	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
96604	SUMP PERICARDIAL ADULT	2	1	1	0	0.005479452	2	2	1	1.981335343	1.613789266
98214	OMNIPAQUE 180MG 10ML BTL	2	1	1	0	0.005479452	2	2	1	1.981335343	1.613789266
98309	DRAPE LEGGINGS	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633
99233	ENDO NEEDLE PNEUMO 120MM	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
99260	DILATOR URETERAL 06FR COOK	2	1	1	0	0.005479452	2	2	1	1.981335343	1.613789266
99669	PACKING VAGINAL 2 IN.	1	1	1	1	0.002739726	2	2	1	29.91276995	0.806894633
99782	TRU-CUT BIOPSY	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD17665	CATHETER RED RUBBER 28FR	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
GD205708	CATHETER FOGARTY EMBOL 2FR	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633

GD206524	INSTRUMENT WIPE	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
GD208348	RED RUBBER STOPPERS	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
GD225466	PUNCH AORTIC 2.8MM	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
GD228601	TOURNIQUET CUFF 8IN	2	1	1	0	0.005479452	2	2	1	1.981335343	1.613789266
GD230557	CLIP APPLIER ENDO ROTATING MED/LG	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD231662	STAPLER LINEAR CUTTER 75MM 3.5	1	1	1	0	0.002739726	2	1	1	1.179476985	0.806894633
GD232769	TUBING INSUFFLATION	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD233254	BIPOLAR BAYONET WITH CORD	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633
GD362897	ADAPTER URETERAL CATHETER	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD363648	PATTY 1/4 X 1 1/2IN	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD363812	IMMOBILIZER KNEE ADOLESCENT 16IN	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633
GD373241	PATTY 1/4 X 1/4 (LAWS)	2	1	1	0	0.005479452	2	2	1	1.981335343	1.613789266
GD373936	ELECTRODE NIMS	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD375295	CANNULA AORTIC ROOT 18GA PEDIATRIC	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
GD375311	TELFA STRIPS 1/2 X 3	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD388363	ENDO PEANUT	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633
GD388942	GUIDEWIRE AMPLATZ SUPER STIFF .038/145	2	1	1	0	0.005479452	2	2	1	1.981335343	1.613789266
GD389254	CATHETER SILASTIC MALECOT 14FR	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
GD390310	COTTON SQUARE 3X2	2	1	1	0	0.005479452	4	1	1	2.35895397	1.613789266
GD391136	KIT PROCEDURE CLOSURE	2	1	1	0	0.005479452	2	2	1	1.981335343	1.613789266
GD403089	PLEUROVAC PNEUMONECTOMY	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633
GD422162	BAIRHUGGER BLANKET PEDIATRIC	1	1	1	0	0.002739726	2	1	1	1.179476985	0.806894633
GD423665	COVER ULTRASOUND 4515	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633
GD43522	DRAPE PACK PEDS	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633

GD436931	DRAPE ULTRA SOUND PROBE 3688	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633
GD438036	BURR STRAIGHT 1.2 X 6MM C4 8TA11	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD438325	BURR SPIRAL CUTTER 1.8MM CRANIOTOME F28TA23	1	1	1	0	0.002739726	2	1	1	1.179476985	0.806894633
GD438390	BURR CLOWARD 4X10MM OVAL LONG 10OV40L	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD447649	CEMENT BONE WITH TOBRAMYCIN HM	33	0.808333333	1.366666667	0	0.090410959	2	2	1	28.38470548	26.62752289
GD452607	REPEL CUT RESISTANT GLOVE LINER (XLG)	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD455105	MINI BUTTON LP BALLOON KIT 14FR X 1.5CM	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD455311	BAIRHUGGER BLANKET CARDIAC STERILE	1	1	1	0	0.002739726	2	1	1	1.179476985	0.806894633
GD479311	WIRE SENSOR STRAIGHT .035IN X 150CM	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD521719	DRAIN BLAKE 24FR RND	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD522695	KIT PLEURAL CATHETER	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633
GD602198	GUN BIOPSY 16GA X 20CM MONOPTY	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD603100	APPLIER CLIP ENDO 5MM LIGAMAX	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633
GD606098	IMMOBILIZER KNEE YOUTH 18IN	2	1	1	0	0.005479452	4	1	1	2.35895397	1.613789266
GD607106	VASOVIEW ACCESSORY PACK	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633
GD607904	SEPRAFILM 3 X 5 PACK	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
GD608083	SENSOR INVOS ADULT	2	1	2	0	0.005479452	2	2	1	1.981335343	1.613789266
GD608084	SENSOR INVOS PEDS	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD608141	BURR DIAMOND 5MM STRYKER	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
GD608303	BLADE CRESCENTIC 9 X 12MM STRYKER	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
GD608328	TIP APPLICATOR 35CM EVICEL	2	1	1	0	0.005479452	4	1	1	2.35895397	1.613789266
GD608358	BIPOLAR SCOVILLE 1.5MM BAYONET 7 3/4IN	2	1	1	0	0.005479452	2	2	1	1.981335343	1.613789266
GD608496	WEBRIL 2IN	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD608538	OBTURATOR BLADELESS 8MM DAVINCI SI	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633

GD608589	LINER FOR SPLINT FOOT POSTERIOR MED	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633
GD608597	BURR DIAMOND 2MM X 14CM LEGEND	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD608598	BURR DIAMOND 3MM X 14CM LEGEND	2	1	1	0	0.005479452	2	2	1	1.981335343	1.613789266
GD608654	CLIP LIGATING SMALL LNG HORIZON	1	1	1	0	0.002739726	1	2	1	0.990667671	0.806894633
GD608835	PROBE PIERCER 6MM X 8.5CM OSCAR	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD608836	PROBE PIERCER 8MM X 8.5CM OSCAR	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD608837	PROBE PIERCER 10MM X 8.5CM OSCAR	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD608904	BAG RETRIEVAL 10MM APPLIED	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
GD609114	Splint Foot Posterior Med EF	1	1	1	0	0.002739726	4	1	1	1.179476985	0.806894633
GD609115	Liner for Splint Foot Med EF	2	0.5	1	0.5	0.005479452	4	1	1	15.95071122	1.613789266
GD609138	SENSOR NIR INFANT/NEO OXYALERT	1	1	1	0	0.002739726	2	2	1	0.990667671	0.806894633
94158	DRESSING DUODERM 2 X 4IN ULTRA THIN	2	1	2	0	0.005479452	2	1	1	1.887581205	2.35895397
CHR009	ANESTHESIA OR TIME CHARGE	22	1	22	0	0.060273973	2	2	1	8.080926163	21.79468877
GD482489	NEEDLE CORKSCREW	49	1	2.15	0	0.134246575	2	2	1	27.05883831	48.5427159
GD482497	NEEDLE TWISTED PAIR NEEDLES	236	1	9.555555556	0	0.646575342	2	2	1	89.91705257	233.7975705
GD609020	SYSTEM MIXING CEMENT COMPACT ZIM	2	1	2	0	0.005479452	2	2	1	1.887581205	1.981335343
RU607391	OPSC/ACL PAN	12	0.9	1	0.4	0.032876712	4	1	2	22.32243491	24.68333252
RU607627	OPSC/OPUS INSTRUMENTS	2	1	1	0	0.005479452	4	1	2	3.155827914	2.35895397
RU607852	OPSC/LINVATEC AWL SET	11	1	1	0.35	0.030136986	4	1	2	20.1160786	23.10059358
RU614798	OPSC/SHOULDER ACCESSORY PAN	23	1	1	0.425	0.063013699	2	1	2	31.40314364	39.4295105
RU617011	OPSC/S&N BICEPTOR SET	24	1	1	0.651960784	0.065753425	2	1	2	38.73247336	47.17899454
RU617772	OPSC/S&N HLF FLUTED BITS/REAM	5	1	1	0.25	0.01369863	4	1	2	12.66535316	13.12894219
99864	SLING ARM BLUE SMALL	5	1	1	0.2	0.01369863	4	1	1	4.034473165	11.68263074
GD206920	STERIDRAPE APPERTURE #1051	5	1	2.5	0	0.01369863	2	1	1	4.034473165	5.897384924

GD225326	CEMENT CARTRIDGE	4	1	2	0	0.010958904	2	2	1	2.956571114	3.962670686
GD363804	IMMOBILIZER KNEE ADULT SM 20IN	6	1	1	0.166666667	0.016438356	4	1	1	4.841367798	11.89807204
GD422204	CEMENT NOZZLE FLEXIBLE	3	1	1.5	0	0.008219178	2	2	1	2.972003014	2.972003014
GD603635	IMMOBILIZER KNEE ADULT LG 24IN	20	1	1	0	0.054794521	4	1	1	16.13789266	23.5895397
GD607895	BATTERY NAVIGATION STRYKER	3	1	3	0	0.008219178	4	1	1	3.538430954	3.538430954
GD608299	BURR LINDEMAN 2.2MM STRYKER	3	1	1	0	0.008219178	4	1	1	3.538430954	3.538430954
90001	GOWN XXL XLONG	3516	0.813294103	1.357460722	0.161847232	9.632876712	2	1	1	2837.041529	2837.041529
90007	Tray Foley 14FR with Meter	518	0.983108108	1.072648217	0.146246246	1.419178082	1	2	1	417.9714199	417.9714199
90009	IMMOBILIZER KNEE 24IN	1	1	1	0	0.002739726	4	1	1	1.179476985	1.179476985
90066	PACK TOTAL KNEE	2	1	1	0	0.005479452	4	1	1	2.337236618	2.337236618
90151	SALEM SUMP GENTRI 16FR	2	1	2	0	0.005479452	1	2	1	1.887581205	1.613789266
90164	TRAY PNEUMOTHORAX 14FR WAYNE	1	1	1	0	0.002739726	4	1	1	1.179476985	1.179476985
90167	BAIRHUGGER BLANKET LARGE PEDIATRIC UNDERBODY	2	1	1	0	0.005479452	2	1	1	1.613789266	1.613789266
90269	BOVIE EXTENDER 6IN	23	1	1.363636364	0.170454545	0.063013699	2	2	1	18.55857656	18.55857656
90293	DRESSING SACRAL BORDER 7 X 7 (MEPILEX)	26	1	1.136363636	0	0.071232877	2	1	1	20.97926046	20.97926046
90294	DRESSING SACRAL BORDER 9 X 9 (MEPILEX)	20	1	1	0	0.054794521	2	1	1	16.13789266	16.13789266
90581	CATHETER FOLEY TEMP 16 FR	2	1	1	0	0.005479452	1	2	1	1.613789266	1.613789266
90605	CATHETER FOLEY TEMP PROBE 14FR	4	1	1	0	0.010958904	1	2	1	3.227578532	3.227578532
90668	OPSITE/TEGADERM 4 X 10IN	70	1	1.552631579	0	0.191780822	1	2	1	56.48262431	56.48262431
90681	NEEDLE 25GA X 1 1/2IN	398	0.985576138	1.112250599	0.064067085	1.090410959	2	2	1	321.1440639	321.1440639
90899	PREP SKIN CHLORHEXIDINE 26ML	3923	0.836841848	2.070939173	0.264134506	10.74794521	1	2	1	2137.532226	2137.532226
90915	PREP SKIN DURAPREP 26ML	1198	0.846992187	2.570693676	0.323075002	3.282191781	1	2	1	604.189751	604.189751
90916	PAD DEFIB ADULT (FAST PATCH) PHILIPS	11	1	1	0	0.030136986	1	2	1	8.875840963	8.875840963
90920	PREP SKIN DURAPREP 6ML	2	1	2	0	0.005479452	1	2	1	1.613789266	1.613789266

91217	PREP SKIN CHG 10.5 ML CLEAR	159	1	1.576027397	0	0.435616438	2	2	1	128.2962466	128.2962466
91312	OPSITE/TEGADERM 2X3IN	6	1	1.2	0	0.016438356	1	2	1	4.841367798	4.841367798
91332	APPLICATOR COTTON-TIPPED 6IN	11	1	1.571428571	0	0.030136986	1	2	1	8.875840963	8.875840963
91403	DRESSING ABD PAD	484	0.913761701	1.402726903	0.186361126	1.326027397	4	1	1	390.5370024	390.5370024
91417	DRAPE FLUID WARMER ALPHA	14	1	1	0.071428571	0.038356164	4	1	1	11.29652486	11.29652486
91426	COVER CASSETTE	142	0.99537037	1.254497354	0.027777778	0.389041096	1	2	1	114.5790379	114.5790379
91428	STERIDRAPE #1050	12	1	1.714285714	0	0.032876712	4	1	1	9.682735595	9.682735595
91440	GAUZE PLAIN PACKING STRIP 1 IN.	2	1	1	0	0.005479452	1	2	1	1.613789266	1.613789266
91442	GAUZE IODOFORM 1/2 IN.	2	1	1	0	0.005479452	1	2	1	1.613789266	1.613789266
91450	GAUZE XEROFORM 5 IN. X 9 IN.	233	0.996212121	1.28011735	0.015151515	0.638356164	1	2	1	188.0064495	188.0064495
91453	FLUFFS	21	1	1.020833333	0.104166667	0.057534247	4	1	1	16.94478729	16.94478729
91454	BENZOIN	310	0.963878283	1.303890848	0.084545927	0.849315068	2	2	1	250.1373362	250.1373362
91456	KERLIX	265	0.950763541	1.402343457	0.245866994	0.726027397	2	2	1	213.8270777	213.8270777
91500	DRESSING 2 X 2	5	1	1	0	0.01369863	4	1	1	4.034473165	4.034473165
91503	DRESSING 4 X 4 MULTIPACK	1044	0.990109157	1.719320419	0.018485152	2.860273973	2	1	1	842.3979968	842.3979968
91510	DRESSING 4 X 4	14	1	1.166666667	0	0.038356164	4	1	1	11.29652486	11.29652486
91517	WECKCELLS	153	0.96875	3.890625	0.75	0.419178082	1	2	1	95.8756181	95.8756181
91522	SPONGE LAP	1766	0.897751982	1.648582867	0.184645733	4.838356164	2	2	1	1424.975922	1424.975922
91524	PATTY 1 X 3	4	1	1	0	0.010958904	2	2	1	3.227578532	3.227578532
91531	KITTNER/GB	388	0.900822621	1.465286199	0.36043315	1.063013699	2	2	1	313.0751176	254.6971978
91532	PATTY 1/2 X 1/2	86	1	1.343383754	0	0.235616438	4	1	1	69.39293843	69.39293843
91543	BAG-O-JET	24	1	1.095238095	0	0.065753425	2	2	1	19.36547119	19.36547119
91551	STOCKING KNEE LENGTH M REG	1	1	1	0	0.002739726	2	2	1	0.990667671	0.990667671
91565	STERI-STRIP 1/4IN	149	1	1.538151042	0.046875	0.408219178	1	2	1	120.2273003	120.2273003

91578	BOVIE HAND CONTROL	219	0.996503497	1.108391608	0.192074592	0.6	2	2	1	176.7099246	176.7099246
91630	DRAPE CV PERI-GROIN 82X75	5	1	1	0	0.01369863	4	1	1	4.034473165	4.034473165
91637	DRAPE THREE QUARTER SHEET	1023	0.954998292	1.670000273	0.028877422	2.802739726	4	1	1	825.4532095	825.4532095
91638	STERIDRAPE #1000	1430	0.92228384	2.531073196	0.328988592	3.917808219	4	1	1	741.2503642	741.2503642
91642	STERIDRAPE IOBAN	1150	0.921779617	1.215719657	0.084177647	3.150684932	2	1	1	927.9288279	927.9288279
91643	SLEEVE	177	1	1.131498471	0	0.484931507	4	1	1	142.82035	142.82035
91644	Drape Head Bar Sheet 34 X 42	1	1	1	0	0.002739726	2	2	1	0.990667671	0.990667671
91652	DRAPE XLARGE SHEET	152	1	3.130434783	0.458592133	0.416438356	2	1	1	87.14912887	87.14912887
91662	DRAPE UNDER BUTTOCKS	3	1	1	0	0.008219178	2	1	1	2.420683899	2.420683899
91663	DRAPE TABLE COVER	382	0.961199842	1.066925466	0.063224526	1.046575342	4	1	1	308.2337498	308.2337498
91665	GOWN LARGE	1372	0.993667882	1.633259543	0.000598086	3.75890411	4	1	1	1107.059436	1107.059436
91668	GOWN IMPERVIOUS XLARGE	152	0.995519713	1.249103943	0.021505376	0.416438356	2	1	1	122.6479842	122.6479842
91678	PACK CV	1	1	1	0	0.002739726	4	1	1	1.179476985	1.179476985
91684	TOWELS W/ADHESIVE	10	1	1.125	0	0.02739726	4	1	1	8.06894633	8.06894633
91707	CATHETER FOLEY 14FR 5CC	4	1	1	0	0.010958904	1	2	1	3.227578532	3.227578532
91708	CATHETER FOLEY 16FR 5CC	2	1	1	0	0.005479452	1	2	1	1.613789266	1.613789266
91722	FOLEY CATH TRAY 16FR W/URINE METER	6	1	1	0	0.016438356	4	1	1	4.841367798	4.841367798
91735	HOLDER FOLEY STAT LOCK	71	1	1.022727273	0	0.194520548	1	2	1	57.28951894	57.28951894
91759	CATHETER RED RUBBER 14FR	4	1	1	0	0.010958904	1	2	1	3.227578532	3.227578532
91760	CATHETER RED RUBBER 16FR	3	1	1	0	0.008219178	1	2	1	2.420683899	2.420683899
91836	COVER MAYO STAND	531	0.963017476	1.124542675	0.149980082	1.454794521	4	1	1	428.4610501	428.4610501
91858	Catheter Suction 18FR	33	1	1.266666667	0.383333333	0.090410959	1	2	1	26.62752289	26.62752289
91935	NEEDLE 19GA	509	0.989834881	1.567780112	0.027966976	1.394520548	1	2	1	410.7093682	410.7093682
91939	DRAPE BILATERAL LIMB CH	22	1	1	0.078947368	0.060273973	4	1	1	17.75168193	17.75168193

91941	NEEDLE 20GA	94	1	1.310897436	0	0.257534247	1	2	1	75.8480955	75.8480955
91944	NEEDLE 21GA	210	1	1.143120523	0.008849558	0.575342466	1	2	1	169.4478729	169.4478729
91947	NEEDLE 23GA	32	1	1.166666667	0.080808081	0.087671233	2	2	1	25.82062825	25.82062825
91950	NEEDLE 25GA X 5/8IN	40	1	1.166666667	0	0.109589041	2	2	1	32.27578532	32.27578532
92102	ASEPTO	80	1	1.05	0.012631579	0.219178082	1	2	1	64.55157064	64.55157064
92110	SYRINGE 3CC	160	1	1.107608696	0	0.438356164	1	2	1	129.1031413	129.1031413
92111	SYRINGE 5CC	56	0.979166667	1.170833333	0.045833333	0.153424658	1	2	1	45.18609945	45.18609945
92114	SYRINGE 10CC	356	0.973496584	1.298092369	0.043406092	0.975342466	1	2	1	287.2544893	287.2544893
92116	SYRINGE 30CC	1065	0.913110702	1.09630001	0.278212211	2.917808219	1	2	1	859.3427841	859.3427841
92123	SYRINGE 60CC	480	0.966715702	1.102145716	0.110538429	1.315068493	1	2	1	387.3094238	387.3094238
92178	NEEDLE 30GA X 1/2	2	1	2	0	0.005479452	1	2	1	1.613789266	1.613789266
92188	SYRINGE CONTROL	489	0.96157306	1.116393242	0.120167655	1.339726027	1	2	1	394.5714755	394.5714755
92310	CONTAINER URINE STERILE FIELD (OLD)	2759	0.847295623	1.734287125	0.215221999	7.55890411	2	1	1	1618.293896	1618.293896
92311	CONTAINER URINE STERILE FIELD	601	0.855148883	1.69334702	0.384098428	1.646575342	2	1	1	484.9436744	484.9436744
92401	LEUKENS MUCOUS TRAP	6	1	1	0	0.016438356	4	1	1	4.841367798	4.841367798
92412	TUBE FEEDING 8FR	1	1	1	0	0.002739726	2	2	1	0.990667671	0.990667671
92413	TUBE FEEDING 5FR	4	1	1	0	0.010958904	1	2	1	3.227578532	3.227578532
92445	SUCTION TONSIL TIP	387	0.970810313	1.051999198	0.20087477	1.060273973	2	2	1	312.268223	312.268223
92451	CONNECTOR SIMS	6	1	1	0	0.016438356	2	2	1	4.841367798	4.841367798
92519	TUBING SUCTION	527	0.964306152	1.338934742	0.095763178	1.443835616	2	2	1	425.2334716	425.2334716
92530	PACK SPINE COMPLEX	1	1	1	0	0.002739726	4	1	1	1.179476985	1.179476985
92546	DRAIN PENROSE 3/4IN	4	1	1.25	0	0.010958904	2	2	1	3.227578532	3.227578532
92624	BLADE #10	370	0.968994083	1.835927022	0.024714004	1.01369863	1	2	1	298.5510142	298.5510142
92630	BLADE #20	139	0.992045455	1.0875	0.007954545	0.380821918	1	2	1	112.158354	112.158354

92657	STAPLER REMOVER	5	1	1	0	0.01369863	4	1	1	4.034473165	4.034473165
92730	DRAIN JP 19FR RND	11	1	1.375	0.125	0.030136986	2	2	1	8.875840963	8.875840963
92738	DRAIN JP 10MM FLAT	84	0.9875	1.405	0.025	0.230136986	2	2	1	67.77914917	67.77914917
92742	DRAIN JP 10FR RND	4	1	1	0	0.010958904	2	2	1	3.227578532	3.227578532
92750	GLOVE SURGICAL LATEX UNDER 6	649	0.996	1.684438095	0.003333333	1.778082192	2	2	1	523.6746168	523.6746168
92756	GLOVE SURGICAL LATEX UNDER 9	342	1	1.261977797	0	0.936986301	2	2	1	275.9579645	275.9579645
92757	GLOVE SURGICAL SMOOTH 6	8	1	1	0.25	0.021917808	2	2	1	6.455157064	6.455157064
92761	GLOVE SURGICAL SMOOTH 8	14	1	1.75	0	0.038356164	2	2	1	11.29652486	11.29652486
92762	GLOVE SURGICAL SMOOTH 8.5	3	1	1.5	0	0.008219178	2	2	1	2.972003014	2.420683899
92763	GLOVE SURG LATEX FREE UNDER 6	206	0.994565217	1.744565217	0	0.564383562	2	2	1	166.2202944	166.2202944
92766	GLOVE SURG LATEX FREE UNDER 7.5	459	0.995905369	2.015468608	0.000909918	1.257534247	2	2	1	370.3646365	370.3646365
92768	GLOVE SURG LATEX FREE UNDER 8.5	287	0.981609195	1.743103448	0.014655172	0.78630137	2	2	1	231.5787597	231.5787597
92769	GLOVE SURG LATEX FREE UNDER 9	64	0.9875	1.4375	0	0.175342466	2	2	1	51.64125651	51.64125651
92770	GLOVE SURGICAL TEXTURED 5.5	41	1	1.536764706	0	0.112328767	2	2	1	33.08267995	33.08267995
92771	GLOVE SURGICAL TEXTURED 6	192	1	1.462264151	0	0.526027397	2	2	1	154.9237695	154.9237695
92772	GLOVE SURGICAL TEXTURED 6.5	666	1	1.615515709	0	1.824657534	2	2	1	537.3918255	537.3918255
92776	GLOVE SURGICAL MICRO THIN 6	913	0.998928189	1.756239473	0	2.501369863	2	2	1	736.6947999	736.6947999
92781	GLOVE SURGICAL MICRO THIN 8.5	703	0.999056604	1.468636772	0	1.926027397	2	2	1	567.246927	567.246927
92783	GLOVE SURG LATEX FREE OVER 6	187	1	2.141975309	0	0.512328767	2	2	1	150.8892964	150.8892964
92785	GLOVE SURG LATEX FREE OVER 7	285	0.994949495	2.353535354	0	0.780821918	2	2	1	229.9649704	229.9649704
92788	GLOVE SURG LATEX FREE OVER 8.5	358	0.974845679	2.354166667	0.02037037	0.980821918	2	2	1	288.8682786	288.8682786
92789	GLOVE SURG LATEX FREE OVER 9	126	0.99030303	1.500454545	0	0.345205479	2	2	1	101.6687238	101.6687238
92797	GLOVE SURGICAL ORTHOPAEDIC 7.0	379	0.995575221	1.620022602	0.017699115	1.038356164	2	2	1	305.8130659	305.8130659
92804	GLOVE SURGICAL ORTHOPEDIC 6	8	1	1.142857143	0	0.021917808	2	2	1	6.455157064	6.455157064

92805	GLOVE SURGICAL ORTHOPAEDIC 6.5	65	1	1.720588235	0.029411765	0.178082192	2	2	1	52.44815114	52.44815114
92888	NEEDLE COUNTER	34	1	1.086956522	0	0.093150685	1	2	1	27.43441752	27.43441752
92946	URINE METER	9	1	1	0	0.024657534	2	2	1	7.262051697	7.262051697
93020	COVER C-ARM ELASTIC	140	0.984751204	1.213483146	0.063135367	0.383561644	1	2	1	112.9652486	112.9652486
93076	SUCTION FRAZIER TIP 12FR	895	0.929501176	1.078635329	0.136587041	2.452054795	2	2	1	722.1706965	722.1706965
93152	CONNECTOR 5 IN 1	21	1	1	0	0.057534247	2	2	1	16.94478729	16.94478729
93183	DRAIN HEMOVAC SMALL	2	1	1	0	0.005479452	1	2	1	1.613789266	1.613789266
93213	PREP TRAY	647	0.959451219	1.109456808	0.049552771	1.77260274	2	1	1	522.0608275	522.0608275
93215	TRAY FOLEY CATHETER	23	1	1.05	0	0.063013699	2	1	1	18.55857656	18.55857656
93354	LABELS STERILE WITH PEN	5	1	1	0.2	0.01369863	1	2	1	4.034473165	4.034473165
93355	DRESSING WOUND 8 X 4IN	328	0.937006469	1.267166867	0.092745432	0.898630137	2	1	1	264.6614396	264.6614396
93430	TUBE CULTURETTE	106	1	1.297435897	0	0.290410959	2	2	1	85.53083109	85.53083109
93572	VESSEL LOOP MAXI RED	55	0.983333333	1.181666667	0.183333333	0.150684932	1	2	1	44.37920481	44.37920481
93576	LIG-A-BOOT	19	1	1.133333333	0.066666667	0.052054795	2	2	1	15.33099803	15.33099803
93632	SKINMARKER	30	1	1.090909091	0	0.082191781	2	2	1	24.20683899	24.20683899
93654	CONTAINER SPECIMEN STERILE W/S	2	1	2	1	0.005479452	4	1	1	30.81071518	30.81071518
93944	Pouch Fecal One Piece Barrier	1	1	1	0	0.002739726	2	2	1	0.990667671	0.990667671
93995	TUBING TUR	9	1	1.125	0	0.024657534	2	2	1	7.262051697	7.262051697
96326	FILTER STRAW	174	1	1.18048648	0	0.476712329	1	2	1	140.3996661	140.3996661
98048	PACK MAJOR BURN	1	1	1	0	0.002739726	4	1	1	1.179476985	1.179476985
98117	STERI-STRIP 1INCH	13	1	1.8	0	0.035616438	1	2	1	10.48963023	10.48963023
98291	BAIRHUGGER BLANKET UPPER BODY	1081	0.897685243	1.045660645	0.17797947	2.961643836	2	1	1	872.2530982	872.2530982
98330	SCD SLEEVE KNEE LENGTH	40	1	1.029411765	0.019607843	0.109589041	2	2	1	32.27578532	32.27578532
98336	SCD SLEEVE SMALL	71	1	1	0	0.194520548	2	2	1	57.28951894	57.28951894

98338	SCD SLEEVE LARGE	122	0.982510288	1.067901235	0.110288066	0.334246575	2	2	1	98.44114522	98.44114522
99483	DRESSING DUODERM 6X6	1	1	1	0	0.002739726	2	1	1	1.179476985	1.179476985
99507	NEEDLE SPINAL 22GA X 1 1/2IN	3	1	1	0	0.008219178	1	2	1	2.420683899	2.420683899
99508	NEEDLE SPINAL 20GA X 3.5IN	3	1	1	0	0.008219178	1	2	1	2.420683899	2.420683899
99509	NEEDLE SPINAL 22GAX3.5	7	1	1.75	0	0.019178082	1	2	1	5.648262431	5.648262431
99520	WEBRIL 3IN	49	1	1.551724138	0.137931034	0.134246575	1	2	1	39.53783701	39.53783701
99521	WEBRIL 4IN	403	0.93602207	1.412210044	0.09690839	1.104109589	1	2	1	325.1785371	325.1785371
99523	APPLICATOR COTTON-TIPPED 3 IN	4	1	4	0	0.010958904	2	2	1	2.506915701	2.506915701
99623	CATHETER FOLEY COUDE 14FR	9	1	1.142857143	0	0.024657534	1	2	1	7.262051697	7.262051697
99637	CATHETER FOLEY SILICONE 10FR 3CC	2	1	1	0	0.005479452	1	2	1	1.613789266	1.613789266
99701	GOWN BACK	17	1	1	0	0.046575342	4	1	1	13.71720876	13.71720876
99867	IMMOBILIZER SHOULDER SLING XLG	19	1	1.5	0	0.052054795	4	1	1	15.33099803	15.33099803
99905	OPSITE TEGADERM 4 X 4 3/4 IN	128	1	1.47983871	0	0.350684932	1	2	1	103.282513	103.282513
99942	TOTE AAA	1	1	1	0	0.002739726	4	1	1	1.179476985	1.179476985
GD202572	TOWELS WHITE	16	1	1	0	0.043835616	2	1	1	12.91031413	12.91031413
GD204941	BLADE SCAPEL 15C	25	1	1.470588235	0	0.068493151	1	2	1	20.17236582	20.17236582
GD207324	CAUTERY HIGH TEMP FINE TIP CORDLESS	1	1	1	0	0.002739726	2	2	1	0.990667671	0.990667671
GD221143	CORD BIPOLAR	13	1	1.083333333	0	0.035616438	1	2	1	10.48963023	10.48963023
GD221796	STIMULAR NERVE VARISTIM III	1	1	1	0	0.002739726	2	2	1	0.990667671	0.990667671
GD222067	SPONGE TONSIL W/ STRING MED	6	1	2	0.25	0.016438356	4	1	1	11.25737622	11.25737622
GD223586	SPONGE TONSIL W/O STRING MED	27	1	3	0.625	0.073972603	2	2	1	32.13817603	32.13817603
GD223891	C-WIRE .035	72	0.976190476	2.714285714	0.714285714	0.197260274	1	2	1	58.09641357	59.02766616
GD223909	C-WIRE .045	137	0.964285714	4.107142857	0.422619048	0.375342466	1	2	1	77.07300462	77.07300462
GD223917	C-WIRE .062	84	1	3.333333333	0.746031746	0.230136986	1	2	1	63.89560291	63.89560291

GD224790	BOVIE TIP	17	1	1.166666667	0.090909091	0.046575342	1	2	1	13.71720876	13.71720876
GD224816	KEEPERS PEDIATRIC	2	1	2	0	0.005479452	1	2	1	1.887581205	1.613789266
GD224915	STENT URETERAL 6 X 22CM DBLJ PERCUFLEX	1	1	1	0	0.002739726	2	2	1	0.990667671	0.990667671
GD227660	BLADE DERMATOME ZIMMER	2	1	1	0	0.005479452	2	2	1	1.981335343	1.981335343
GD228619	TOURNIQUET CUFF 12IN	13	1	1	0.153846154	0.035616438	2	2	1	10.48963023	10.48963023
GD230102	VESSEL LOOP MAXI SUPER BLUE	1	1	1	0	0.002739726	1	2	1	0.990667671	0.990667671
GD230789	SUCTION POOLE TIP	4	1	1	0.25	0.010958904	2	2	1	3.227578532	3.227578532
GD231860	TOURNIQUET CUFF 42IN	94	0.971794872	1	0.211538462	0.257534247	2	2	1	75.8480955	75.8480955
GD232066	RELOAD 35MM BLUE FOR ATW35	3	1	1.5	0	0.008219178	2	2	1	2.972003014	2.420683899
GD232074	RELOAD WHITE FOR 35MM ENDOCUTTER (ATW35)	3	1	1.5	0	0.008219178	2	1	1	2.420683899	2.420683899
GD233171	DRESSING WOUND 6IN X 3 1/8IN	462	0.988788625	1.458192377	0.004511895	1.265753425	2	1	1	372.7853204	372.7853204
GD233189	DRESSING WOUND 11 3/4IN X 4IN	139	0.992105263	1.284210526	0.069078947	0.380821918	2	1	1	112.158354	112.158354
GD233197	DRESSING WOUND 13.75 X 4.75IN	37	1	1.234848485	0.136363636	0.101369863	2	1	1	29.85510142	29.85510142
GD362939	STOCKINETTE 2IN	2	1	1	0	0.005479452	1	2	1	1.613789266	1.613789266
GD363366	CATHETER FOLEY SILC 12FR	3	1	1	0	0.008219178	1	2	1	2.420683899	2.420683899
GD363374	CATHETER FOLEY SILC 14FR	35	0.967741935	1	0.016129032	0.095890411	1	2	1	28.24131215	28.24131215
GD363382	CATHETER FOLEY SILC 16FR	5	1	1	0	0.01369863	1	2	1	4.034473165	4.034473165
GD363978	FELT SQUARE 1IN	18	1	1.8	0.1	0.049315068	1	2	1	14.52410339	14.52410339
GD372235	RETRIEVER SUTURE SWANSON	1	1	1	0	0.002739726	2	2	1	0.990667671	0.990667671
GD372342	GLOVE LIFELINE LARGE RIGHT	12	1	1.3125	0	0.032876712	2	2	1	9.682735595	9.682735595
GD372359	GLOVE LIFELINE LARGE LEFT	10	1	1.214285714	0	0.02739726	2	2	1	8.06894633	8.06894633
GD372367	GLOVE LIFELINE MEDIUM RIGHT	3	1	1.5	0	0.008219178	2	2	1	2.972003014	2.420683899
GD372375	GLOVE LIFELINE MEDIUM LEFT	3	1	1.5	0	0.008219178	2	2	1	2.972003014	2.420683899
GD372383	GLOVE LIFELINE XLARGE LEFT	5	1	1.25	0	0.01369863	2	2	1	4.034473165	4.034473165

GD372391	GLOVE LIFELINE XLARGE RIGHT	5	1	1.25	0	0.01369863	2	2	1	4.034473165	4.034473165
GD372599	DRAPE BILATERAL LIMB TIBURON	1	1	1	0	0.002739726	2	1	1	1.179476985	1.179476985
GD373845	SPONGE LAP PEDS	5	1	1.666666667	0.333333333	0.01369863	2	2	1	4.034473165	4.034473165
GD374744	KLING 3IN	78	0.981981982	1.427284427	0.099099099	0.21369863	1	2	1	62.93778137	62.93778137
GD375279	OPSITE/TEGADERM 8X12IN	31	1	1.090909091	0.074675325	0.084931507	1	2	1	25.01373362	25.01373362
GD388397	SURGILAV SHORT TIP	25	1	1.052631579	0	0.068493151	4	1	1	20.17236582	20.17236582
GD388702	CATHETER COUNCIL 16FR	1	1	1	0	0.002739726	1	2	1	0.990667671	0.990667671
GD389528	PIN PAUGH DISTRACATION 16 MM.	40	1	2	0.705882353	0.109589041	2	2	1	43.46098443	43.46098443
GD391920	WEBRIL 6 INCH	30	1	1.15	0.175	0.082191781	1	2	1	24.20683899	24.20683899
GD422709	DRAPE CVARTS SPLIT TOP	17	1	1.142857143	0	0.046575342	4	1	1	13.71720876	13.71720876
GD437913	TUBE CULTURE	22	1	1.111111111	0	0.060273973	2	2	1	17.75168193	17.75168193
GD437939	BURR ROUND CUTTER 5MM 10BA50	4	1	1	0	0.010958904	2	1	1	3.227578532	3.227578532
GD438077	BURR ROUND CUTTER 3MM 10BA30	396	1	1.765873016	0.89430104	1.084931507	2	1	1	254.6052747	254.6052747
GD438267	BURR ROUND DIAMOND 4MM 10BA40D	233	1	2.181818182	0.935606061	0.638356164	2	2	1	152.3671028	152.3671028
GD438374	BURR ROUND DIAMOND 3MM 10BA30D	432	0.98427673	1.814971288	0.917996166	1.183561644	2	2	1	348.5784814	274.3106723
GD439661	TEGADERM 2 3/8 IN X2 3/4 IN W/ LABEL	85	1	1.29	0	0.232876712	1	2	1	68.5860438	68.5860438
GD453514	GOWN XLG REUSABLE	118	0.99382716	1.314814815	0	0.323287671	4	1	1	95.21356669	95.21356669
GD470138	SPHERE BRAIN LAB	132	1	7.714285714	0.69047619	0.361643836	1	2	1	71.08929695	71.08929695
GD489971	DRAPE SURGICAL HIP W/ SIDE POCKET & ARM BOARD	1	1	1	0	0.002739726	2	1	1	1.179476985	1.179476985
GD522175	BANDAGE ACE ELASTIC STERILE 4IN	34	1	1.270833333	0.069444444	0.093150685	1	2	1	27.43441752	27.43441752
GD522183	BANDAGE ACE ELASTIC STERILE 6IN	32	1	1.526315789	0.087719298	0.087671233	1	2	1	25.82062825	25.82062825
GD600928	STERILE CAMERA HANDLE COVER	307	0.994055784	1.131127115	0.02354824	0.84109589	2	2	1	247.7166523	247.7166523
GD600959	STOCKINETTE ORTHO IMPERVIOUS	55	0.988888889	1.044444444	0.027777778	0.150684932	2	2	1	44.37920481	44.37920481
GD602120	CLIP MICRO TITANIUM	1	1	1	0	0.002739726	1	2	1	0.990667671	0.990667671

GD602144	GOWN XXXL XLONG	21	1	1.176470588	0.058823529	0.057534247	2	1	1	16.94478729	16.94478729
GD603052	DISTRACTION SCREW STERILE 14MM	123	1	3	0.584383754	0.336986301	2	2	1	75.95587877	75.95587877
GD603137	ENDO PEANUT USS	6	1	2	0	0.016438356	2	2	1	4.844152319	4.844152319
GD607002	TUBING DURASEAL MICROMYST	10	0.916666667	1.055555556	0	0.02739726	2	2	1	8.06894633	8.06894633
GD607004	Y-EXTENSION SET, SMALLBORE	2	1	2	0	0.005479452	1	2	1	1.887581205	1.613789266
GD607059	METRX TUBE RETRACTOR DISPOSABLE 22CM X 8CM	1	1	1	0	0.002739726	2	2	1	0.990667671	0.990667671
GD607332	DRAPE HAND ORTHOPEDIC TIBURON	2	1	1	0	0.005479452	4	1	1	2.35895397	2.35895397
GD607905	DURASEAL 5ML US SURG	18	0.95	1	0	0.049315068	2	2	1	14.52410339	14.52410339
GD608123	BLADE OSCILLATING SAW LARGE 33 X 63 X 0.6MM STRYKER	3	1	1	0.333333333	0.008219178	1	2	1	2.420683899	2.420683899
GD608126	BURR DIAMOND 4MM STRYKER	6	1	1	0	0.016438356	1	2	1	4.841367798	4.841367798
GD608131	BURR ROUND CUTTING 3MM STRYKER	5	1	1	0	0.01369863	1	2	1	4.034473165	4.034473165
GD608140	BURR DIAMOND 2MM STRYKER	1	1	1	0	0.002739726	1	2	1	0.990667671	0.990667671
GD608150	BLADE OSCILLATING SAW LARGE 13 X 90 X 1.19MM STRYKER	4	1	1	0	0.010958904	4	1	1	3.227578532	3.227578532
GD608165	BURR ROUND CUTTING 1.5MM STRYKER	1	1	1	0	0.002739726	1	2	1	0.990667671	0.990667671
GD608210	BLADE RECIP SAW 11 X 77.5 X 1.23MM STRYKER	1	1	1	0	0.002739726	1	2	1	0.990667671	0.990667671
GD608215	BAIRHUGGER BLANKET ADULT UNDERBODY	4	1	1	0	0.010958904	2	1	1	3.227578532	3.227578532
GD608237	OMNIPAQUE 300MG 50ML VIAL	4	1	1.333333333	0	0.010958904	2	2	1	3.227578532	3.227578532
GD608248	SEALANT FIBRIN EVICEL 5ML	6	1	1.2	0	0.016438356	4	1	1	4.841367798	4.841367798
GD608319	CLIP VASCULAR ARTERY MEDIUM SINGLE	1	1	1	0	0.002739726	1	2	1	0.990667671	0.990667671
GD608389	BURR TAPERED 2.3MM STRYKER	11	1	1.25	0	0.030136986	2	2	1	8.875840963	8.875840963
GD608396	BLADE DOUBLE 76 X 13 X 1.19MM RVMJ	1	1	1	0	0.002739726	1	2	1	0.990667671	0.990667671
GD608400	BLADE ACORN 9.0MM SHORT 9AC90	3	1	1.5	0	0.008219178	2	2	1	2.972003014	2.420683899
GD608469	PATTY 1/2 X 1 1/2IN	316	1	2	0.413158971	0.865753425	2	2	1	185.8956499	185.8956499
GD608473	STOCKINETTE IMPERVIOUS MED 9IN	18	1	1	0.055555556	0.049315068	2	2	1	14.52410339	14.52410339

GD608494	CATHETER ECHOTIP 5FR X 70CM OPEN-END URETERAL	2	1	1	0	0.005479452	1	2	1	1.613789266	1.613789266
GD608522	PIN DISTRACTION 12MM	21	1	3	0.714285714	0.057534247	2	2	1	31.14257443	31.14257443
GD608560	KIT CONCENTRATION PLATELET BMT	45	0.952168746	1	0	0.123287671	1	2	1	36.31025848	36.31025848
GD608561	DRAPE PLASTIC U (BLUE)	1848	0.896113886	1.637275924	0.261233286	5.063013699	4	1	1	1491.141282	1120.589829
GD608586	SPLINT FOOT POSTERIOR LG	8	1	1	0	0.021917808	2	1	1	6.455157064	6.455157064
GD608587	SPLINT FOOT POSTERIOR MED	3	1	1	0	0.008219178	2	1	1	2.420683899	2.420683899
GD608620	KIT PIN/DRILL SBI	1	1	1	0	0.002739726	2	2	1	0.990667671	0.990667671
GD608621	BLADE SAW 8MM SYNVASIVE SBI	2	1	1	0	0.005479452	2	2	1	1.981335343	1.981335343
GD608622	BLADE SAW RECIP 8MM SYNVASIVE SBI	2	1	1	0	0.005479452	2	2	1	1.981335343	1.981335343
GD608629	STOCKINETTE IMPERVIOUS 6 X 30IN SMALL	10	1	1.111111111	0	0.02739726	2	2	1	8.06894633	8.06894633
GD608653	CLIP LIGATING MED LONG HORIZON	19	1	1.666666667	0.416666667	0.052054795	1	2	1	24.7055457	24.7055457
GD608655	DRESSING SACRAL BORDER 6 X 6 (MEPILEX)	28	1	1.888888889	0	0.076712329	2	1	1	22.59304972	22.59304972
GD608656	DRESSING SACRAL BORDER 6 X 8 (MEPILEX)	1362	0.88598515	3.762401129	0.381817176	3.731506849	2	1	1	613.312839	613.312839
GD608679	DIFFUSER LUBRICANT MR7	48	0.975	1.007142857	0.035714286	0.131506849	2	2	1	38.73094238	38.73094238
GD608687	SURGICAL KNIFE 160MM SFDK	1	1	1	0	0.002739726	4	1	1	1.179476985	1.179476985
GD608703	KIT PATIENT CARE HANA	29	1	1	0.089285714	0.079452055	4	1	1	23.39994436	25.42385827
GD608779	PACK HIP DISPOSABLE SNEPH	1	1	1	0	0.002739726	1	2	1	0.990667671	0.990667671
GD608832	Probe Scraper 6MM X 18CM Oscar	5	1	1.25	0.25	0.01369863	2	2	1	4.034473165	4.034473165
GD608833	PROBE SCRAPER 8MM X 8.5CM OSCAR	3	1	1	0.333333333	0.008219178	2	2	1	2.420683899	2.420683899
GD608834	PROBE SCRAPER 10MM X 8.5CM OSCAR	4	1	1	0.25	0.010958904	2	2	1	3.227578532	3.227578532
GD608880	DURASEAL 5ML SPINE	6	1	1	0	0.016438356	2	2	1	4.841367798	4.841367798
GD608908	SYRINGE TB 25GA X 5/8IN 1ML	402	0.922245612	1.093715007	0.090551016	1.101369863	1	2	1	324.3716424	324.3716424
GD608927	PACK SINGLE-VIAL SPY ELITE	1	1	1	0	0.002739726	2	2	1	0.990667671	0.990667671
GD609081	SLING ULTRA-II ANTI ROTATION	2	1	1	0	0.005479452	4	1	1	2.35895397	2.35895397

GD612970	PACK DISPOSABLE MCP INTGRA	1	1	1	0	0.002739726	4	1	1	1.179476985	1.179476985
GD617006	ULTRASLING II BLACK X-LARGE	1	1	1	0	0.002739726	4	1	1	1.179476985	1.179476985
GD619858	KIT REPAIR TENDON FLEXOR TOBY	1	1	1	0	0.002739726	4	1	1	1.179476985	1.179476985
GU607583	DILATOR URETHRAL S-CURVE 8-20FR SET	1	1	1	0	0.002739726	2	2	1	0.990667671	0.990667671
RU350082	PEDO/ROMNESS PAN	3	1	1	0	0.008219178	4	1	2	3.538430954	3.538430954
RU350108	ORT/SPINE CHEST RETRACTORS	10	1	1	0.75	0.02739726	4	1	2	30.92894988	30.92894988
RU351148	NSG/LAMINECTOMY SET PART 2	24	1	1	0.138888889	0.065753425	4	1	2	23.88118081	23.88118081
RU351197	NSG/MICRO INST	197	1	1	0.474699732	0.539726027	4	1	2	166.686234	166.686234
RU351288	NSG/MCCULLOCH MICRO DISSECTOMY	127	1	1	0.452747977	0.347945205	4	1	2	111.2244383	111.2244383
RU351791	PLS/LIGHTED BREAST RETRACT	7	1	1	0.714285714	0.019178082	2	1	2	26.79691597	26.79691597
RU353565	GEN/RETRACTOR PAN	40	1	1	0.325569358	0.109589041	4	1	2	41.43933899	41.43933899
RU353896	ORT/DALL MILES TROCHEN CABLE GRIP	217	1	1	0.692866916	0.594520548	4	1	2	187.4223624	187.4223624
RU354118	ORT/DEP AML REVISION INST	30	1	1	0.510869565	0.082191781	4	1	2	39.20756907	39.20756907
RU354142	ORT/SYN DHS IMPLANTS	20	1	1	0.069444444	0.054794521	4	1	2	18.8334764	18.8334764
RU354241	ORT/ZIM FLEXIBLE REAMERS	44	1	1	0.371126228	0.120547945	2	1	2	46.61618599	46.61618599
RU354282	ORT/HIP REVISION INST	240	1	1	0.46153877	0.657534247	4	1	2	198.9742797	198.9742797
RU354290	ORT/TOTAL HIP PAN	517	1	1	0.368652722	1.416438356	4	1	2	407.5212386	407.5212386
RU354449	ORT/PELVIC INSTRUMENTS PAN	65	1	1	0.303736119	0.178082192	4	1	2	59.79789795	59.79789795
RU354563	ORT/SHOULDER BANKHART ACCESSOR	108	1	1	0.517857143	0.295890411	2	1	2	100.315897	100.315897
RU354688	ORT/TOTAL KNEE PAN	594	1	1.000330688	0.244906709	1.62739726	4	1	2	461.4567799	461.4567799
RU354738	ORT/ZIM MILL GALANT KNEE PLATE	308	0.988095238	1.000751328	0.464516755	0.843835616	4	1	2	250.6236967	250.6236967
RU354746	ORT/ZIM FOOTHOLDER	307	0.988095238	1.000751328	0.468768456	0.84109589	4	1	2	249.9885428	249.9885428
RU354852	ORT/STAPLE PAN	37	1	1	0.656162465	0.101369863	4	1	2	48.7340896	48.7340896
RU354985	ORT/REDUCTION INST	56	1	1	0.382597341	0.153424658	4	1	2	56.06507221	56.06507221

RU355222	ORT/GARDNER WELLS SKULL TONGS	65	1	1	0.410947712	0.178082192	2	1	2	63.72435296	63.72435296
RU358994	PROBE DOPPLER	81	1	1.756097561	0.548780488	0.221917808	1	2	2	68.28931286	68.28931286
RU359042	CLIP TOWEL SHRP SM 3 1/2IN	2	1	2	1	0.005479452	1	2	2	31.62930648	31.62930648
RU359844	ORT/KAHLER PAN	74	1	1	0.589852608	0.202739726	2	1	2	75.7498524	75.7498524
RU359984	ORT/CURETTES ANGLED	71	1	1	0.544671782	0.194520548	4	1	2	71.34148009	71.34148009
RU361329	ORT/SYN PELVIC PLATES	59	1	1	0.318937456	0.161643836	4	1	2	55.68064606	55.68064606
RU361543	NSG/SHADOWLINE DISTRACTION PAN	14	1	1	0	0.038356164	4	1	2	12.26769984	12.26769984
RU361725	ORT/PARK PAN	177	1	1	0.407564299	0.484931507	4	1	2	149.5360976	149.5360976
RU361733	ORT/SYN CANN SCREWS 4.5MM	83	1	1	0.560340803	0.22739726	4	1	2	82.55178449	82.55178449
RU361998	ORT/ANTERIOR CERVICAL	11	1	1	0	0.030136986	4	1	2	9.171140566	9.171140566
RU376301	ORT/DIDUCH PAN	23	1	1	0.325396825	0.063013699	4	1	2	28.52014971	28.52014971
RU377820	NSG/KARLIN MICRODISSECT HOOKS	58	1	1	0.421724245	0.15890411	4	1	2	57.89984894	57.89984894
RU377853	NSG/ANTERIOR CERVICAL ACCESS	11	1	1	0	0.030136986	4	1	2	9.171140566	9.171140566
RU377994	ORT/SYN CANN 6.5/7.3MM SCREWS	118	1	1	0.494716904	0.323287671	4	1	2	107.2424087	107.2424087
RU402024	NSG/SHADOWLINE CERVICAL RETR	32	1	1	0.226190476	0.087671233	4	1	2	32.484646	32.484646
RU423145	ORT/ACE PERI REDUCTION INST	72	1	1	0.416015357	0.197260274	4	1	2	69.18951756	69.18951756
RU437897	PWR/MIDASREX MR7 LEGEND DRILL	2	1	1	0.5	0.005479452	4	1	2	16.79880361	16.79880361
RU437905	PWR/MIDASREX MR7 ORTHO DRILL	157	1	1	0.540436016	0.430136986	4	1	2	137.3869579	137.3869579
RU438440	VETS INSTRUMENTATION	198	0.99375	1	0.388547794	0.542465753	4	1	2	166.5740239	166.5740239
RU439059	NSG/JANES MICRO DISSECTORS	20	1	1	0.367647059	0.054794521	2	1	2	27.46396837	27.46396837
RU439307	NSG/KASSELLS MICRO DISSECTORS	4	1	1	0.75	0.010958904	2	1	2	25.54977997	25.54977997
RU452797	NSG/SFDNK METRX MD INST TRAY	13	1	1	0.045454545	0.035616438	4	1	2	12.82358094	12.82358094
RU452805	NSG/SFDNK METRX MD BASE TRAY	13	1	1	0.090909091	0.035616438	4	1	2	14.1387847	14.1387847
RU452839	ORT/ZIM FEMORAL HEAD REAMER SET	40	1	1	0.468500444	0.109589041	4	1	2	45.57895748	45.57895748

RU455634	ORT/BROWN ACETABULA HIP REVISION	18	1	1	0.65	0.049315068	4	1	2	34.11575724	34.11575724
RU470245	PWR/MIDASREX MR7 GOLD TOUCH DRILL	423	1	1	0.340632253	1.15890411	4	1	2	336.9237289	336.9237289
RU479147	ORT/VISE WITH SLAP HAMMER	6	1	1	0.833333333	0.016438356	4	1	2	29.4805779	29.4805779
RU479246	NSG/SFDNK METRX MD MICRO INST	13	1	1	0.045454545	0.035616438	4	1	2	12.82358094	12.82358094
RU479535	PWR/BATTERY	3427	1	2.115184524	0.28828716	9.389041096	4	1	2	1826.127052	1826.127052
RU479600	ORT/ACUFEX ACL GRAFTMASTER II	35	0.954545455	1	0.535650624	0.095890411	2	1	2	43.72440727	43.72440727
RU479618	ORT/ACUF ACL/PCL DRILL GUIDE SYS	37	0.961538462	1	0.564102564	0.101369863	2	1	2	46.06810452	46.06810452
RU479626	ORT/ACUFEX ACL MENISCAL STITCHER	34	1	1	0.599673203	0.093150685	2	1	2	44.81837927	44.81837927
RU482018	ORT/VECTOR VISION INST	19	1	1	0.197916667	0.052054795	2	1	2	21.79215465	21.79215465
RU498113	NSG/RETRACT TRANSLUCENT OMNI	2	1	2	1	0.005479452	4	1	2	31.62930648	31.62930648
RU520071	NSG/JANE KERRISON RONGEURS	164	0.977443609	1.007518797	0.47901095	0.449315068	2	1	2	141.1875145	141.1875145
RU521615	ORT/DEP AML FLEXIBLE OSTEOTOME	219	1	1	0.600554512	0.6	4	1	2	187.0703978	187.0703978
RU521623	ORT/ADULT TRACTION BOW	53	1	1	0.417777778	0.145205479	2	1	2	54.80529961	54.80529961
RU521719	NSG/TRIMLINE CERVICAL CURRETTES	180	1	1	0.419803197	0.493150685	4	1	2	152.9901532	152.9901532
RU522463	ORT/ZIM KAHLERS PELVIC REDUCT	60	1	1	0.470906544	0.164383562	4	1	2	60.84481367	60.84481367
RU522839	RETRACT SENN SHRP 6 7/16IN	8	1	1.333333333	0.111111111	0.021917808	1	2	2	10.02682241	10.02682241
RU522959	CLAMP RIGHT ANGLE 7IN	7	1	1	0.285714286	0.019178082	1	2	2	15.21766764	15.21766764
RU522967	CLAMP RIGHT ANGLE 8IN	7	1	1	0.285714286	0.019178082	1	2	2	15.21766764	15.21766764
RU523127	RETRACT WEITLANER DULL 4 1/2IN	11	1	1.8	0.066666667	0.030136986	1	2	2	9.720244461	9.720244461
RU600013	RETRACT RICHARDSON MED 9 1/2IN	4	1	2	1	0.010958904	1	2	2	32.70035978	32.70035978
RU600023	RETRACT RAKE SHRP 4PRONG	153	1	1.454545455	0.385800474	0.419178082	4	1	2	109.1702442	109.1702442
RU600091	ORT/SHENS PAN PART 2	189	1	1	0.373260366	0.517808219	4	1	2	157.6542199	157.6542199
RU600212	ORT/SYN ANTERIOR INST	10	1	1	0.75	0.02739726	4	1	2	30.92894988	30.92894988
RU600233	NSG/SHAFFREY PIN CUTTER	66	1	1	0.607352941	0.180821918	4	1	2	70.17772273	70.17772273

RU600237	ORT/ACUFEX TENDON STRIPPERS	33	0.958333333	1	0.491013072	0.090410959	2	1	2	40.91217117	40.91217117
RU600785	ORT/SYN SYNFRAME AUXILIARY INS	9	1	1	0.625	0.024657534	4	1	2	26.55255896	26.55255896
RU600786	ORT/SYN SYNFRAME STANDARD INST	9	1	1	0.625	0.024657534	4	1	2	26.55255896	26.55255896
RU600787	ORT/SYN SYNFRAME BONE LEVERS	9	1	1	0.8125	0.024657534	2	1	2	31.97700068	31.97700068
RU600819	ORT/HOW IM REV TRIAL STEM	7	1	1	0.428571429	0.019178082	4	1	2	19.35028085	19.35028085
RU600823	ORT/HOW IM REV EXT GAP	7	1	1	0.285714286	0.019178082	4	1	2	15.21766764	15.21766764
RU600824	ORT/HOW IM REV IM REAMER	7	1	1	0.428571429	0.019178082	4	1	2	19.35028085	19.35028085
RU600826	ORT/HOW IM REV SPACERS	7	1	1	0.285714286	0.019178082	4	1	2	15.21766764	15.21766764
RU600827	ORT/HOW IM REV TIBIAL PREP	7	1	1	0.428571429	0.019178082	4	1	2	19.35028085	19.35028085
RU600835	ORT/SYN LOCKING PERI SCREW&INST	84	1	1	0.436428571	0.230136986	4	1	2	78.89868099	78.89868099
RU600881	ORT/CURETTES STRAIGHT SPINAL	47	1	1	0.401515152	0.128767123	4	1	2	48.95706509	48.95706509
RU600934	ORT/SYN SYNFRAME ANTERIOR INST	9	1	1	0.625	0.024657534	4	1	2	26.55255896	26.55255896
RU600964	ORT/SYN COLLINEAR CLAMPS	18	1	1	0.285714286	0.049315068	2	1	2	23.57345939	23.57345939
RU600968	NSG/BAYONET KNIFE KIT	12	1	1	0.166666667	0.032876712	2	1	2	15.57129635	15.57129635
RU602935	ORT/MILLERS WEBSTER NEEDLEHOLDER	39	1	1	0.588141026	0.106849315	2	1	2	48.28409907	48.28409907
RU603091	ORT/ZIM FEMORAL EXTRACTOR SET	58	1	1	0.431375086	0.15890411	4	1	2	58.17953909	58.17953909
RU603092	ORT/ZIM FLEXIBLE OSTEOTOME SET	56	1	1	0.415113872	0.153424658	4	1	2	56.18877244	56.18877244
RU603112	ORT/LINVATEC SOFT TISSUE SET	35	1	1	0.633986928	0.095890411	4	1	2	46.57194934	46.57194934
RU603157	ORT/HOW TRIALS MIHALKO EXTRAS	7	1	1	0.571428571	0.019178082	4	1	2	23.48289406	23.48289406
RU603216	ORT/DEPUY CEMENT GUN	315	1	1	0.578085283	0.863013699	4	1	2	259.3677177	259.3677177
RU603224	ORT/RETRACTOR SHADOW LINE	12	1	1	0	0.032876712	4	1	2	10.74905452	10.74905452
RU603625	NSG/MIDAS REX METREX ATTACHMENT	17	1	1	0.3	0.046575342	4	1	2	23.22725066	23.22725066
RU604050	ORT/ZIM PRECIMED ACET REAMER	136	1	1	0.253190691	0.37260274	4	1	2	112.2631357	112.2631357
RU606122	ORT/KINAMED CARBOJET LAVAGE	369	1	1	0.514272497	1.010958904	2	1	2	297.7149288	297.7149288

RU607068	ORT/SHENS PAN PART 1	189	1	1	0.358789581	0.517808219	4	1	2	157.2328876	157.2328876
RU607112	NSG/SHAFFREY PLIF OSTEOTOMES	66	1	1	0.416911765	0.180821918	4	1	2	64.65699248	64.65699248
RU607353	ORT/STRYKER HOFFMAN MRI EXFIX	4	1	1	0.5	0.010958904	4	1	2	19.13707192	19.13707192
RU607368	ORT/BROWN GAP BALANCER	112	1	1	0.062459547	0.306849315	4	1	2	88.49493479	88.49493479
RU607458	OPSC/MINI OPEN PAN	3	1	1	0.333333333	0.008219178	4	1	2	13.17981951	13.17981951
RU607460	OPSC/LINVATEC GRAFT TABLE	1	1	1	1	0.002739726	4	1	2	30.10157926	30.10157926
RU607500	ORT/DEPUY MOUNTAIN CT IMPLANT	1	1	1	0	0.002739726	4	1	2	1.179476985	1.179476985
RU607507	ORT/SYN LARGE DISTRACTOR SET	51	1	1	0.5232493	0.139726027	4	1	2	55.52309984	55.52309984
RU607513	ORT/SYN PELVIC INST SET	58	1	1	0.35672819	0.15890411	4	1	2	56.01620418	56.01620418
RU607514	ORT/SYN PELVIC REDUCTION INST	59	1	1	0.471526555	0.161643836	4	1	2	60.10297429	60.10297429
RU607515	ORT/SYN PELVIC RETRACTOR SET	38	1	1	0.367701863	0.104109589	4	1	2	41.14019083	41.14019083
RU607527	ORT/MILLER SCOPE PAN	46	1	1	0.46577381	0.126027397	2	1	2	50.05880697	50.05880697
RU607531	ORT/VICE GRIP SET	183	1	1	0.688884183	0.501369863	2	1	2	161.4651508	161.4651508
RU607617	OPSC/BIRDBEAK GRASPERS	9	1	1	0.45	0.024657534	4	1	2	23.633953	23.633953
RU607674	OPSC/MENISCAL RASPS	5	1	1	0.2	0.01369863	4	1	2	11.68263074	11.68263074
RU607675	OPSC/ZONE SPECIFIC SET	4	1	1	0.5	0.010958904	4	1	2	19.18050663	19.18050663
RU607679	ORT/SYN 4.5 PROXIMAL TIBIA PLATE	40	1	1	0.484126984	0.109589041	4	1	2	46.03153863	46.03153863
RU607695	ORT/ANKLE DISTRACTOR KIT	24	1	1	0.431818182	0.065753425	4	1	2	32.36026272	32.36026272
RU607696	ORT/KNEE DISTRACTION INSTRUMENTS	71	1	1	0.65922619	0.194520548	4	1	2	75.48149871	75.48149871
RU607729	TCV/DOUBLE WIRE TWISTER	30	1	1	0.533333333	0.082191781	1	2	2	39.85794057	39.85794057
RU607745	PWR/BATTERY SAG/OSCILLATING SAW	949	0.99233871	1.000403226	0.335203758	2.6	4	1	2	765.7430067	736.9965827
RU607748	PWR/BATTERY DRILL REAMER/RECIP	1027	1	1.00018997	0.316516155	2.81369863	4	1	2	794.1375621	794.1375621
RU607749	PWR/STRYKER SMALL BATTERY	2050	0.997171946	1.885581381	0.341789666	5.616438356	4	1	2	1173.582435	1173.582435
RU607772	NSG/SFDNK METRX MED INST	13	1	1	0.090909091	0.035616438	4	1	2	14.1387847	14.1387847

RU607773	NSG/SFDNK METRX II FLEX ARM	14	1	1	0.333333333	0.038356164	4	1	2	21.9128713	21.9128713
RU607806	ORT/SYN PELVIC IMP/SCREW SET	57	1	1	0.318937456	0.156164384	4	1	2	54.16134265	54.16134265
RU607811	OPSC/CORE TPS BASE TRAY	1	1	1	0	0.002739726	2	1	2	1.179476985	1.179476985
RU607819	ORT/SYN 3.5 MEDIAL DIST/TIB PLT	30	1	1	0.655982906	0.082191781	4	1	2	43.40889364	43.40889364
RU607820	ORT/SYN 4.5 MEDIAL PROX/TIB PLT	39	1	1	0.439814815	0.106849315	4	1	2	43.98837817	43.98837817
RU607821	ORT/SYN 3.5 ANTEROLATERAL DT PLT	86	1	1	0.621190731	0.235616438	4	1	2	84.95954821	84.95954821
RU607850	ORT/LAMBOTTE OSTEOTOMES SET	290	1	1	0.498942764	0.794520548	2	1	2	238.0571757	238.0571757
RU607851	ORT/SYN LCP 4.5 CONDYLAR PLATE	39	1	1	0.604385965	0.106849315	4	1	2	48.75457374	48.75457374
RU607854	ORT/SYN METAPHYSEAL PLATE SET	8	1	1	1	0.021917808	4	1	2	36.64108805	36.64108805
RU607876	ORT/SYN PERI REDUCTION FORCEPS	195	1	1	0.532196623	0.534246575	4	1	2	169.296822	169.296822
RU607891	ORT/SYN LCP DISTAL FEMUR PLATE	38	1	1	0.607407407	0.104109589	4	1	2	48.08212934	48.08212934
RU607899	ORT/SYN LCP AIMING ARMS	38	1	1	0.47962963	0.104109589	4	1	2	44.38164974	44.38164974
RU607905	ORT/SYN 2.4/3.0 HEADLESS SCREWS	63	1	1	0.580739379	0.17260274	4	1	2	67.12645242	67.12645242
RU607907	ORT/SYN LCP PERIPROSTHETIC SET	2	1	1	0	0.005479452	4	1	2	3.155827914	3.155827914
RU607908	ORT/SYN 2.4 DIST/RAD INST/SCREWS	37	1	1	0.1375	0.101369863	4	1	2	33.71401702	33.71401702
RU607918	ORT/SYN TF NAIL LOCKING SET	60	1	1	0.270703934	0.164383562	4	1	2	55.86093821	55.86093821
RU607919	ORT/SYN TF NAIL INSERTION SET	64	1	1	0.23859127	0.175342466	4	1	2	57.96849301	57.96849301
RU607920	ORT/SYN TIBIAL NAIL IMPLANTS	43	1	1	0.244047619	0.117808219	4	1	2	42.17559342	42.17559342
RU607921	ORT/SYN TIBIAL NAIL INSTRUMENTS	50	1	1	0.285	0.136986301	4	1	2	48.67911375	48.67911375
RU607948	ORT/MALLET 5 LBS	316	1	1	0.645801148	0.865753425	2	1	2	261.2895373	261.2895373
RU607949	ORT/DEPUY LONG DRILL BITS	74	1	1	0.635416667	0.202739726	2	1	2	76.25250109	76.25250109
RU607954	ORT/SHIMER PAN	163	1	1	0.352633478	0.446575342	4	1	2	137.3017979	137.3017979
RU607955	ORT/SHEN CURETTES & KERRISONS	189	1	1	0.367034821	0.517808219	4	1	2	157.4729566	157.4729566
RU607964	ORT/SPINE CHEST CLAMP	10	1	1	0.75	0.02739726	4	1	2	30.92894988	30.92894988

RU607970	ORT/SYN FLEXIBLE REAMERS	128	1	1	0.277478532	0.350684932	4	1	2	109.3478764	109.3478764
RU607972	ORT/DACUS SHOULDER RETRACTOR	12	1	1	0.555555556	0.032876712	4	1	2	26.82319395	26.82319395
RU607976	NSG/BIPOLAR FORCEPS TRAY	179	1	1	0.274604198	0.490410959	4	1	2	148.0042724	148.0042724
RU607982	ORT/DR WEISS INSTRUMENT	310	1	1	0.33787554	0.849315068	4	1	2	250.1813566	250.1813566
RU607996	ORT/BROCKMEIER OPEN SHOULDER	146	1	1	0.379921868	0.4	4	1	2	124.3618564	124.3618564
RU608011	PWR/STRYKER BONE MILL	173	1	1	0.468844237	0.473972603	2	1	2	149.0989352	149.0989352
RU608013	ORT/BROWN KNEE BLOCK RIGHT	43	1	1	0.625	0.117808219	4	1	2	52.39145302	52.39145302
RU608014	ORT/BROWN KNEE BLOCK LEFT	42	1	1	0.45	0.115068493	4	1	2	46.56271521	46.56271521
RU608015	ORT/DEPUY BASE FEMUR& TIBIA	281	1	1	0.418555887	0.769863014	4	1	2	227.2332771	227.2332771
RU608016	ORT/DEPUY FIXED FEMUR REFERENCE	274	1	1	0.41688663	0.750684932	4	1	2	221.8662471	221.8662471
RU608017	ORT/DEPUY SPACER BLOCKS	48	1	1	0.561111111	0.131506849	4	1	2	54.34039145	54.34039145
RU608019	ORT/DEPUY FEMORAL TRIALS	274	1	1	0.433553297	0.750684932	4	1	2	222.3529764	222.3529764
RU608020	ORT/DEPUY PATELLA PLANER	370	1	1	0.352810165	1.01369863	4	1	2	292.9248925	292.9248925
RU608021	ORT/DEPUY INSERTION INSTRUMENTS	274	1	1	0.41688663	0.750684932	4	1	2	221.8662471	221.8662471
RU608022	ORT/DEPUY FB CVD TRIALS	146	1	1	0.484951456	0.4	4	1	2	126.5966536	126.5966536
RU608023	ORT/DEPUY FB TIBIAL PREP	274	1	1	0.421053297	0.750684932	4	1	2	221.9879294	221.9879294
RU608057	ORT/DEPUY FBPS 8-17.5 TRIAL	128	1	1	0.1015625	0.350684932	4	1	2	101.7811915	101.7811915
RU608059	ORT/DEPUY GLOBAL HUMERAL 2	33	1	1	0.025641026	0.090410959	4	1	2	27.43726929	27.43726929
RU608060	ORT/DEPUY GLOBAL HUMERAL 1	33	1	1	0.012820513	0.090410959	4	1	2	27.06604984	27.06604984
RU608061	ORT/DEPUY BIO STOP NEW #4 TRLS	67	1	1	0.287545788	0.183561644	4	1	2	60.84780915	60.84780915
RU608063	ORT/DEPUY DELTA EXT GLENOID	39	1	1	0.236111111	0.106849315	4	1	2	38.0888527	38.0888527
RU608064	ORT/DEPUY DELTEXT HUMERAL TRAY 2	39	1	1	0.236111111	0.106849315	4	1	2	38.0888527	38.0888527
RU608065	ORT/DEPUY DELTEXT HUMERAL TRAY 1	39	1	1	0.236111111	0.106849315	4	1	2	38.0888527	38.0888527
RU608066	ORT/DEPUY GLOBAL APG #1	33	1	1	0.012820513	0.090410959	4	1	2	27.06604984	27.06604984

RU608068	ORT/DEPUY PINNACLE CUP	302	1	1	0.258845946	0.82739726	4	1	2	238.5193774	238.5193774
RU608069	ORT/DEPUY PINN CUP TRIALS 48-66	200	1	1	0.611669108	0.547945205	4	1	2	171.3180518	171.3180518
RU608072	ORT/DEPUY ACETABULAR SCREW INST	302	1	1	0.47904543	0.82739726	4	1	2	244.9563905	244.9563905
RU608077	ORT/DEPUY PINN 36LINER TRLS+4LIP	97	1	1	0.58436214	0.265753425	4	1	2	92.2503393	92.2503393
RU608080	ORT/DEPUY QUICKSET ACET GRATERS	200	1	1	0.422752319	0.547945205	4	1	2	165.815395	165.815395
RU608084	ORT/DEPUY SUMMIT BROACHES	156	1	1	0.121844066	0.42739726	4	1	2	123.6349887	123.6349887
RU608085	ORT/DEPUY SUMMIT CORE	318	1	1	0.340564152	0.871232877	4	1	2	253.063001	253.063001
RU608086	ORT/DEPUY TRI-LOCK BROACHES	133	1	1	0.532687651	0.364383562	4	1	2	118.1060869	118.1060869
RU608090	ORT/DEPUY C-STEM AMT	16	1	1	0.6	0.043835616	4	1	2	31.14889182	31.14889182
RU608091	ORT/DEPUY MOD ENDO/BI-POLAR INST	16	1	1	0.6	0.043835616	4	1	2	31.14889182	31.14889182
RU608092	ORT/DEPUY SUMMIT BASIC	16	1	1	0.633333333	0.043835616	4	1	2	32.11347775	32.11347775
RU608117	ORT/SYN TFN PERC INSTR	30	1	1	0.333333333	0.082191781	4	1	2	34.06753626	34.06753626
RU608118	ORT/SYN 3.5/4.5 LONG SCREWS	39	1	1	0.420833333	0.106849315	4	1	2	43.43864966	43.43864966
RU608120	ORT/SYN 3.5LCP PROX TIB LOWBEND	26	1	1	0.111111111	0.071232877	4	1	2	24.59600452	24.59600452
RU608121	ORT/SYN 3.5LCP DSTL TIBIA LOWBEND	87	1	1	0.609239927	0.238356164	4	1	2	85.37280903	85.37280903
RU608124	ORT/SYN MODULAR FOOT SYSTEM	164	1	1	0.405841064	0.449315068	4	1	2	140.4278986	140.4278986
RU608125	ORT/PELVIC PLATES	36	1	1	0.343478261	0.098630137	4	1	2	38.91931459	38.91931459
RU608126	ORT/SCHANZ PINS	76	1	1	0.503833992	0.208219178	4	1	2	74.77521973	74.77521973
RU608131	NSG/KERRISON RONGUER TRAY	226	1	1	0.32136794	0.619178082	4	1	2	185.0691141	185.0691141
RU608170	ORT/BIOTENODESIS TRAY	108	1	1	0.510952552	0.295890411	2	1	2	100.1154395	100.1154395
RU608184	APPLIER CLIP MED 8" BLUE WECK	28	1	1	0.429971989	0.076712329	1	2	2	35.34588817	35.34588817
RU608187	APPLIER CLIP SM 8" YELLOW WECK	20	1	1	0.602941176	0.054794521	1	2	2	34.2737812	34.2737812
RU608188	ORT/ARTHROSCOPIC ROTATOR CUFF	65	1	1	0.434491979	0.178082192	4	1	2	64.40685724	64.40685724
RU608200	ORT/DAA HIP INSTRUMENTS (HANA)	28	1	1	0.214285714	0.076712329	4	1	2	29.10177956	29.10177956

RU608201	ORT/HANA TABLE RIGHT ACCESSORY	28	1	1	0.321428571	0.076712329	4	1	2	32.20356078	32.20356078
RU608295	ORT/BIOSUTURE TAK INST	28	1	1	0.795833333	0.076712329	4	1	2	45.93755878	45.93755878
RU608328	ORT/DEPUY DELTA XTEND REVISION	36	1	1	0.343333333	0.098630137	4	1	2	38.91511774	38.91511774
RU608329	ORT/HANA TABLE LEFT ACCESSORY	28	1	1	0.25	0.076712329	4	1	2	30.13570663	30.13570663
RU608330	ORT/BIRDBEAK GRASPERS	21	1	1	0.823529412	0.057534247	2	1	2	41.41815303	41.41815303
RU608347	ORT/SPIDER SHOULDER TRAY	148	1	1	0.373919055	0.405479452	4	1	2	125.7067613	125.7067613
RU608379	ORT/EXPRESSEW III INST	39	1	1	0.357620321	0.106849315	4	1	2	41.60791821	41.60791821
RU608380	ORT/MITEK INTRAFIX INST	25	1	1	0.802083333	0.068493151	4	1	2	43.83804552	43.83804552
RU608382	ORT/UNIVERSAL KNEE PAN	563	1	1.000379939	0.289760364	1.542465753	4	1	2	439.2253621	439.2253621
RU608383	ORT/UNIVERSAL HIP PAN	437	1	1	0.286606691	1.197260274	4	1	2	343.5165576	343.5165576
RU608384	ORT/REVISION KNEE OSTETOMES	98	1	1	0.619447219	0.268493151	2	1	2	94.02851023	94.02851023
RU608386	ORT/FRACTURE PAN	230	1	1	0.621893048	0.630136986	4	1	2	196.0519593	196.0519593
RU608387	ORT/WINQUIST NAIL EXTRACTION CS1	54	1	1	0.584859585	0.147945205	4	1	2	59.58795515	59.58795515
RU608389	ORT/BROCKMEIER 4.5/4.75 CORK SWIVEL	35	1	1	0.660457516	0.095890411	4	1	2	47.33846293	47.33846293
RU608390	ORT/BROCKMEIER SUTURE CUTTER	28	1	1	0.661220044	0.076712329	4	1	2	42.04050968	42.04050968
RU608411	ORT/HIP CUP REMOVAL SYS 48-56MM	80	1	1	0.466782365	0.219178082	4	1	2	75.92136749	75.92136749
RU608412	ORT/HIP CUP REMOVAL SYS 58-66MM	81	1	1	0.547935358	0.221917808	4	1	2	79.85357621	79.85357621
RU608416	ORT/DALLMILES EXTRA INSTS	15	1	1	0.514285714	0.04109589	4	1	2	27.90867476	27.90867476
RU608417	ORT/HIP DISLOCATION PAN	19	1	1	0.368421053	0.052054795	4	1	2	26.72666631	26.72666631
RU608418	NSG/MEDT CDHS 5.5/6.0 LONG ROD SET	1	1	1	0	0.002739726	4	1	2	1.179476985	1.179476985
RU608423	NSG/MEDT CDHS 5.5/6.0 MAS 5.5-7.5	1	1	1	0	0.002739726	4	1	2	1.179476985	1.179476985
RU608461	PWR/STRYKER HUDSON ADAPTER	93	1	1	0.413401709	0.254794521	2	1	2	84.24987513	84.24987513
RU608493	NSG/SPINE CLAMP PAN	333	0.979978355	1	0.301004211	0.912328767	4	1	2	267.3933609	267.3933609
RU608494	NSG/SPINE RETRACTOR PAN	332	0.988868275	1.001855288	0.31631628	0.909589041	4	1	2	266.805359	266.805359

RU608495	NSG/ANTERIOR ACCESS PAN	45	1	1	0.154660155	0.123287671	4	1	2	40.2868199	40.2868199
RU608496	NSG/TAYLOR RETRACTOR PAN	218	1	1	0.628473683	0.597260274	4	1	2	187.9427785	187.9427785
RU608497	NSG/BRAUN CERVICAL CURETTES	197	1	1	0.507242912	0.539726027	4	1	2	168.4526231	168.4526231
RU608498	NSG/MYERDING RETRACTORS	244	1	1	0.674428414	0.668493151	4	1	2	209.0426544	209.0426544
RU608499	ORT/SPINE VASCULAR PAN	9	1	1	0.761904762	0.024657534	2	1	2	30.51326244	30.51326244
RU608501	ORT/RONGUERS DISC STRAIGHT (GOLDTIP)	10	1	1	0.523809524	0.02739726	4	1	2	24.38494554	24.38494554
RU608503	ORT/DEPUY ATTUNE TIBIAL PREP IMP	75	1	1	0.186666667	0.205479452	4	1	2	63.99942578	63.99942578
RU608504	ORT/DEPUY ATTUNE SHIMS SPACER BLOCK	75	1	1	0.186666667	0.205479452	4	1	2	63.99942578	63.99942578
RU608505	ORT/DEPUY ATTUNE SIZING & FINISHING	75	1	1	0.186666667	0.205479452	4	1	2	63.99942578	63.99942578
RU608506	ORT/DEPUY ATTUNE PS FEMORAL 6-8	72	1	1	0.263888889	0.197260274	4	1	2	63.95996563	63.95996563
RU608507	ORT/DEPUY ATTUNE PS FEMORAL 3-5	75	1	1	0.226666667	0.205479452	4	1	2	65.1593637	65.1593637
RU608508	ORT/DEPUY ATTUNE PATELLA PREP	75	1	1	0.186666667	0.205479452	4	1	2	63.99942578	63.99942578
RU608509	ORT/DEPUY ATTUNE PRIMARY CUTS	75	1	1	0.186666667	0.205479452	4	1	2	63.99942578	63.99942578
RU608510	ORT/DEPUY ATTUNE CONV CR TRIALS	75	1	1	0.186666667	0.205479452	4	1	2	63.99942578	63.99942578
RU608517	ORT/COMPRESSION PLIERS	17	1	1	0.767857143	0.046575342	4	1	2	36.7663858	36.7663858
RU608549	ORT/MICROAIRE CARPAL TUNNEL SYS	5	1	1	0.416666667	0.01369863	2	1	2	17.48639134	17.48639134
RU608556	ORT/DPY MOUNTAINEER LONG SCREWS	1	1	1	0	0.002739726	4	1	2	1.179476985	1.179476985
RU608670	ORT/SYN 2.7/3.5 LCP ANKLE INST/IMP	9	1	1	1	0.024657534	4	1	2	37.40144241	37.40144241
RU615756	OPSC/SYN 3.5 CLAVICLE PLATE	1	1	1	0	0.002739726	2	1	2	1.179476985	1.179476985
RU617068	ORT/SYN VARIABLE ANG DR SCW	8	1	1	0.4375	0.021917808	4	1	2	20.3683432	20.3683432
RU618155	OPSC/MILAGRO SCREWDRIVER SET	1	1	1	1	0.002739726	4	1	2	30.10157926	30.10157926